AQUATIC TOXICITY AND PESTICIDES IN SURFACE WATERS OF THE CENTRAL VALLEY

FINAL REPORT

Prepared for

California Urban Water Agencies

by

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September 15, 1997

PREFACE

As part of an interest in seeking a comprehensive approach to rectifying the environmental problems of California's Bay-Delta Estuary, the California Urban Water Agencies (CUWA) began a review of the literature on pesticide toxicity in waters of the Central Valley in 1994. Recognizing that significant controversy surrounds the issue of toxicity attributed to both urban and agricultural pesticides, CUWA engaged in an extensive peer review process for this report.

- **Internal Review Draft** - The first draft of this report, entitled "Pesticide Aquatic Toxicity in the Central Valley", was reviewed internally by CUWA member agencies in September and October, 1995.

- **Second Draft Report** - The authors responded to the internal review comments and prepared the second draft report, entitled "Pesticide Aquatic Toxicity in the Central Valley" which was sent to reviewers on November 22, 1995. This draft was distributed to the Interagency Ecological Program (IEP) Contaminant Effects Work Team members and to all agencies and researchers who provided data or reports that were included in the CUWA report.

- **Third Draft Report** - CUWA consultants responded to comments on the second draft report and updated some of the information in the report and produced the third draft, entitled "Aquatic Toxicity and Pesticides in Surface Waters of the Central Valley", dated July 1, 1996. As a courtesy, this draft was sent to the California Rice Industry Association (CRIA) and Northern California Water Association (NCWA) along with a letter requesting their comments.

- **Fourth Draft Report** - CUWA updated information in the report and the revised draft report, entitled "Aquatic Toxicity and Pesticides in Surface Waters of the Central Valley" was sent to CRIA, NCWA, and the California Regional Water Quality Control Board, Central Valley Region (Regional Board) on April 17, 1997.

- **Final Report** - CUWA responded to CRIA's and NCWA's comments and produced the final report, entitled "Aquatic Toxicity and Pesticides in Surface Waters of the Central Valley" on September 15, 1997. This report was not released pending further review and discussion with CRIA, NCWA, and the Department of Pesticide Regulation (DPR). The final report was discussed in a meeting held on September 24, 1988 between CRIA, CUWA, and an independent toxicologist, Dr. Jeff Miller of Aqua-Science.

With release of this report, CUWA hopes that the substantial efforts by the CALFED Bay-Delta Program and the Regional Board to address the problems of aquatic toxicity due to urban and agricultural pesticide discharges continue to move forward expeditiously. While this report documents the widespread extent of aquatic toxicity from pesticides in waters of the Central Valley, there is much yet to be known regarding temporal and areal extent of this toxicity and its ecological significance. CUWA will continue to support extensive efforts by the responsible resource agencies to better understand this issue and aggressively seek control of discharges where they are known to be violating water quality standards or impeding efforts to restore the ecological integrity of the Bay-Delta system.

California Urban Water Agencies
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ACKNOWLEDGMENTS

CUWA distributed drafts of this report to a number of scientists whose studies and data are contained in this document, as well as to numerous other interested parties. Some of these individuals provided CUWA with thoughtful comments, which we have attempted to incorporate in this report. However, we alone take responsibility for any errors that may remain. We thank the following:

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EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

This study on Aquatic Toxicity and Pesticides in Surface Waters of the Central Valley was undertaken by the California Urban Water Agencies ("CUWA") to determine if pesticides could be adversely affecting the biological resources of the Bay-Delta ecosystem. The Central Valley, which forms the watershed for the Bay-Delta, is one of the most extensively farmed areas in the world. The larger rivers in the Central Valley such as the Sacramento, American, Feather, and lower San Joaquin provide major spawning and rearing habitat for fish such as chinook salmon, steelhead trout, striped bass, American shad, and sturgeon. CUWA is concerned that pesticides entering the rivers from a variety of sources could be contributing to the decline in these important fish species as well as other forms of aquatic life. To assess the importance of pesticides, CUWA undertook a detailed review of the data and literature on aquatic toxicity and pesticides in the Sacramento and San Joaquin basins and the Delta.

The primary objective of this study was to summarize the information available on aquatic toxicity and pesticides in the Sacramento and San Joaquin basins and the Delta so that the potential impact that pesticides may have had historically and currently on the biological resources of the Bay-Delta ecosystem could be assessed. An additional objective was to determine if additional work or studies are needed to fully assess the effects of pesticides on the biological resources of the Bay-Delta ecosystem.

Numerous focused toxicity and pesticide studies have been conducted since the 1960s on the Sacramento and San Joaquin rivers and in the Delta. However, there has been no long-term comprehensive study designed to characterize the extent of toxicity, the sources of toxicity throughout the system, and the impacts of toxics on aquatic resources. The majority of the toxicity testing has used the U.S. Environmental Protection Agency ("U.S. EPA") three species freshwater bioassay. These laboratory assays use standard test organisms that are surrogates for trophic levels within the food chain in natural waters and are used as a basis for regulating point source discharges to waterways. A primary producer, the green alga, Selenastrum capricornutum; a primary consumer, the zooplankter, Ceriodaphnia dubia; and a secondary consumer, the fathead minnow, Pimphales promelas are used in the tests to determine if they can survive, grow, and reproduce normally in the water being tested. The genus Selenastrum is common in the study area. Ceriodaphnia dubia is a midwestern species that is believed not to occur in the Bay-Delta ecosystem. However, a closely related species, Ceriodaphnia reticulata, is found in the study area. Pimphales promelas is common in the study area. The relationship between the three species test results and ecosystem impacts is controversial. However, studies by the U.S. EPA and others have found strong qualitative relationships between bioassay results and decreases in both population abundance and number of species in ambient waters. Limited bioassay testing of native species and species of concern including larval striped bass, chinook salmon, and Neomysis mercedis has also been conducted in the Central Valley.[1]

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[1] Throughout this text, Ceriodaphnia dubia will be referred to as Ceriodaphnia and Neomysis mercedis as Neomysis.

KEY FINDINGS

There are numerous factors that may be responsible for the decline in aquatic resources of the Bay-Delta ecosystem. Water diversions and reduced Delta outflow, unscreened agricultural and urban diversions, loss of habitat, channel modifications, introduction of exotic species, commercial fishing, recreational boating, changes in the oceanic environment, and toxic contaminants have all been discussed as potentially playing a role in the decline of aquatic resources. While the effects of water diversions and reduced Delta outflow have been studied by the Interagency Ecological Program ("IEP") and other scientists for several decades, most of the other potential factors have not been extensively investigated.

This study of "Aquatic Toxicity and Pesticides in the Surface Waters of the Central Valley" summarizes what is currently known about the toxicity and pesticide concentrations of waters, sediments, and biota in the Sacramento Basin, the San Joaquin Basin, and the Delta. Fish kills attributed to pesticides became common in the 1950s and were routinely documented by the California Department of Fish and Game ("DFG") starting in 1965. These data are summarized in Table ES1. For example, from 1965 to 1969, 158,000 fish were killed in Central Valley streams and canals in 52 separate episodes that were attributed to pesticides such as DDT, toxaphene, endosulfan, and acrolein, among others. Many of the pesticides that caused these fish kills were banned, phased out, or regulated in the 1970s and 1980s, and new chemicals have taken their place. Today, fish kills, although still sometimes reported, are uncommon. The residues of the persistent chlorinated pesticides remain, and sediments and biota collected from throughout the watershed still contain elevated concentrations of organochlorine pesticides and their breakdown products and ingredients, including PCBs, DDT, DDE, dieldrin, toxaphene, and chlordane.

However, the chemicals that replaced the organochlorine pesticides, such as the organophosphorus insecticides, are chronically toxic to other life stages, such as larval fish, and other organisms, such as invertebrates. Today, laboratory bioassays indicate that surface waters in the Sacramento and San Joaquin basins and the Delta periodically result in mortality to larval fathead minnows, striped bass, Ceriodaphnia and Neomysis. Significantly reduced fathead minnow growth, Ceriodaphnia reproduction, and Selenastrum growth also occur. The toxicity generally occurs throughout the fish rearing period in critical habitat areas for species of concern. Most of the toxicity has not been chemically identified. However, where it has, the toxicity is primarily attributed to organophosphorus and carbamate pesticides, although metals are sometimes responsible, particularly in the upper Sacramento Basin. Although not studied as intensively, there is also evidence that sediments in a number of localized areas are toxic to amphipods, molluscs, and salmonids.

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Table ES-1
Fish Killed by Pesticides as Reported by the California Department of Fish and Game

Year	Number*	
	Sacramento Basin	San Joaquin Basin
1965	4,800	3,027
1966	35,250	11,664
1967	65,277	6,096
1968	9,742	1,450
1969	16,555	3,650
1970	1,550	1,003
1971	12,035	NR
1972	1,108	2,500
1973	2,562	NR
1974	NR	NR
1975	76	NR
1976	13,050	2,000
1977	7,000	1,067
1978	25,400	1,000
1979	325	3,267
1980	12,925	600
1981	5,550	NR
1982	49,850	77,600
1983	100	500
1984	NR	1,050
1985	4,150	NR
1986	1,250	NR
1987	10,080	896
1988	11,095	NR
1989	NR	500
1990	NR	NR
1991	1,130	7,000
1992	NR	NR
1993	NR	NR
1994	56	NR
1995	200	16
1996	200	NR

* Numbers shown are only the sum of quantitative estimates. Actual totals would be higher because many episodes are reported as "many" or "unknown" or greater than a threshold number. NR = None reported.

The pesticide toxicity is believed to be caused primarily by runoff and irrigation return flows from agricultural lands and urban runoff, although acid mine drainage is a major source of metals toxicity in the upper watersheds of several rivers. Municipal and industrial wastewater effluents may also contribute to the toxicity, but were not reviewed in this work. Runoff and drainage from irrigated agricultural land can contribute significantly to streamflow during dry periods. For example, 40 to 45 percent of the flow of the San Joaquin River is agricultural drainage between April and October. These waters often carry pesticides to the rivers. In most of the counties of the Sacramento Valley, 790 to 2,700 pounds of pesticides are applied per square mile annually. In most San Joaquin Valley counties, 815 to 4,300 pounds of pesticides are applied per square mile each year. Although some of these compounds degrade before reaching surface waters, their degradation products may themselves be toxic, while others, such as diazinon and atrazine, have very long half-lives and do not degrade appreciably under ambient conditions.

In urban areas, storm drains convey both storm water runoff and dry weather runoff from lawn over-watering, car washing, construction work, and at times illegal dumping. These flows transport a number of contaminants that may cause toxicity, including pesticides, hydrocarbons, polynuclear aromatic hydrocarbons, and metals. Pesticides used in urban landscaping are washed into receiving waters by storm and dry weather flows.

Sacramento River Basin

The Sacramento River contributes approximately 85 percent of the flow to the Bay-Delta. In addition, the Sacramento River and its tributaries serve as spawning and nursery habitat for migratory species that utilize the Bay-Delta estuary. Adverse effects on larval fish and invertebrates in these upstream waters could reduce forage and the abundance of larval fish, zooplankton, and algae transported downstream to the estuary.

Fish Toxicity. Fish kills caused by pesticides such as DDT, toxaphene and acrolein were common in the 1960s, 1970s, and 1980s in the Sacramento Basin, but have declined substantially in the 1990s. Many of the responsible pesticides, such as DDT and toxaphene were banned, while others, such as the rice pesticides, were regulated. The fish losses led to extensive work, beginning in 1980, to identify the cause of the fish kills and resulted in fairly extensive monitoring of the Sacramento River, the major tributaries, and the agricultural drains for toxicity to aquatic life.

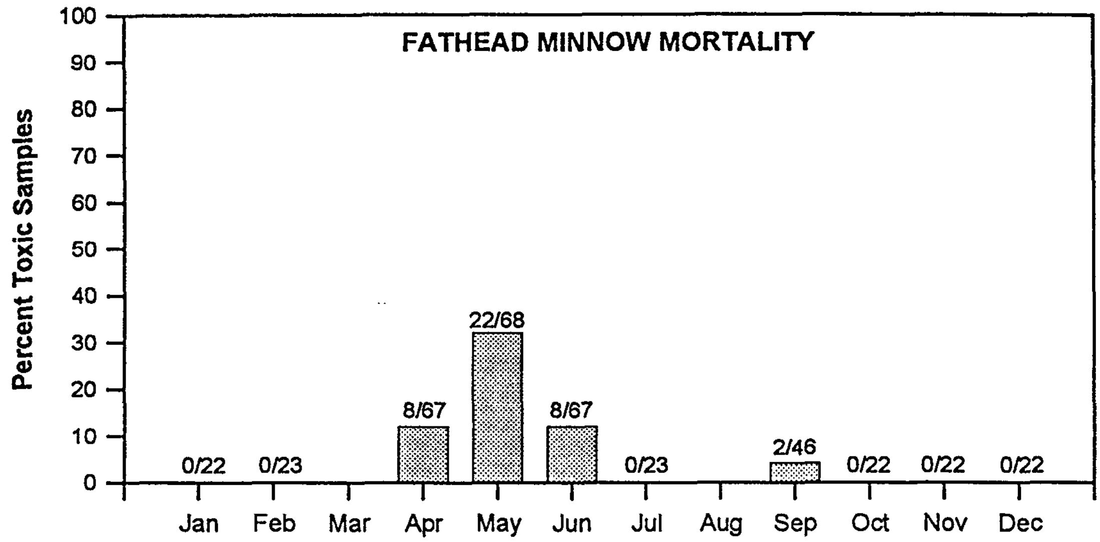
Aquatic toxicity has occurred frequently in water samples collected from the Sacramento River and its major tributaries. Table ES-2 presents a summary of the fathead minnow toxicity test results for the Sacramento River. Toxicity testing has been conducted at 40 locations in the Sacramento River watershed. The number of samples tested at each site varies from 3 to 35 but overall, 15 percent of the samples have been toxic to fathead minnows. The most frequently toxic sites are in the upper watershed and at Freeport Marina. Most of the toxicity, 12 to 32 percent, occurs in the biologically critical period of April to June, when sensitive life stages of a number of fish are present in the river (Figure ES-1). However, most of the samples were collected during this period, biasing the results. Although tested less extensively, Sacramento River waters are also periodically toxic to striped bass. Samples collected from Colusa, above most rice field drainage discharges, and from Walnut Grove and Rio Vista in 1989 and 1990 were toxic to larval striped bass 13 to 50 percent of the time. This indicates that the Sacramento River has periodically been toxic to at least one native species of concern, in addition to fathead minnows.

Table ES-2

Summary of Fathead Minnow Toxicity in the Sacramento Watershed

Station	Monitoring Period	Number of Tests	Number of Toxic Tests	Frequency of Toxicity (%)
Pit River at Highway 299	2/91 - 9/92	3	0	0
Pit River at Bend	2/91 - 9/92	3	1	33
McCloud River at Highway 89	2/91 - 9/92	3	2	67
McCloud River at Gilman Road	2/91 - 9/92	3	0	0
Sacramento River at Dunsmuir	2/91 - 9/92	3	1	33
Sacramento River at Delta	2/91 - 9/92	3	1	33
Shasta Lake	3/88 - 5/90	13	2	15
Shasta Dam	3/88 - 5/90	18	3	17
Whiskeytown Reservoir	3/88 - 9/92	17	2	12
Sacramento River d/s Shasta Dam	2/91 - 5/93	15	3	20
Keswick Dam	3/88 - 5/93	20	1	5
Sacramento River d/s Keswick Dam	2/91 - 9/92	8	0	0
Sacramento River at Redding	3/88 - 5/90	18	2	11
Sacramento River at Red Bluff	3/88 - 5/93	20	4	20
Sacramento River at Hamilton	3/88 - 5/93	20	2	10
Sacramento River at Colusa	3/88 - 5/90	17	2	12
Sacramento River u/s Colusa Basin Drain	3/88 - 5/90	18	5	28
Colusa Basin Drain	3/88 - 5/90	18	0	0
Sacramento River d/s Colusa Basin Drain	3/88 - 5/90	18	4	22
Feather River d/s Thermalito Afterbay	2/91 - 9/92	7	2	29
Feather River near Nicolaus	2/91 - 9/92	5	0	0
Feather River (mouth)	3/88 - 5/90	18	1	6
Yuba River d/s Englebright Reservoir	2/91 - 9/92	7	0	0
Bear River d/s Camp Far West Reservoir	2/91 - 9/92	7	0	0
Sacramento River near Elkhorn	2/91 - 9/92	3	0	0
Sacramento River u/s Sacramento Slough	3/88 - 5/90	18	1	6
Sacramento Slough	3/88 - 5/90	18	1	6
American River d/s Folsom Reservoir	2/91 - 9/92	8	0	0
American River at Discovery Park	2/91 - 9/92	4	0	0
American River (mouth)	3/88 - 5/90	18	3	17
Sacramento River at Village Marina	3/88 - 5/90	18	1	6
Sacramento River at Freeport	3/88 - 5/90	18	1	6
Sacramento River at Freeport Marina	12/90 - 12/96	35	18	51
Sacramento River at Clarksburg	3/88 - 5/90	18	3	17
Sacramento River near Hood	3/91 - 5/94	29	6	21
Sacramento River at Walnut Grove	3/88 - 5/90	18	1	6
Sacramento River at Isleton	3/88 - 5/90	18	2	11
Cache Slough	3/88 - 5/90	7	1	14
Steamboat Slough	3/88 - 5/90	17	3	18
Sacramento River at Rio Vista	3/88 - 5/94	27	5	19
TOTAL		556	84	15

Figure ES-1
Sacramento River Watershed
1988-1990



Conner and Foe 1993

The Sacramento River below Sacramento is toxic to fish and this toxicity could originate from upstream sources. The Sacramento Regional County Sanitation District ("SRCSD") has found that about 50 percent of the samples collected in the Sacramento River at Garcia Bend and the Freeport Marina between December 1990 and December 1996 caused significant mortality to fathead minnows. Concurrent fathead minnow and chinook salmon larval toxicity tests conducted between December 1996 and March 1997 indicate that samples from this site are not acutely or chronically toxic to larval chinook salmon. The Sacramento River Watershed Program is currently monitoring toxicity throughout the Basin and preliminary results, which have not been published, indicate that toxicity persists, even following the major flooding in January 1997. There are plans to continue the toxicity testing at a number of locations in 1997-1998.

Metals from acid mine drainage are believed to be the cause of at least some of the toxicity in the upper watershed (above and in the vicinity of Lake Shasta). The toxicity in the remainder of the watershed is believed to be caused primarily by pesticides in runoff and irrigation return flows from agricultural lands. Historically, rice drainage caused fish losses and a significant amount of the toxicity in agricultural drainage canals of the Sacramento Basin. Rice drainage also may have contributed to toxicity in the Sacramento River below Colusa because toxicity generally increased downstream of the drains. However, the specific toxicant(s) was never identified.

The rice industry has worked diligently with the Department of Pesticide Regulation ("DPR") and the CVRWQCB to adopt on-farm management practices to control rice herbicides. Holding rice waters on the fields has allowed pesticides to degrade, reducing the loading of these chemicals to the Sacramento River. As a result, there have been no major fish kills attributed to rice pesticides since 1983, there has been a substantial decrease in the concentrations of some rice pesticides, and there has been a substantial reduction in both the frequency and amount of toxicity to larval striped bass in rice drainage. In 1989 and 1990, respectively, 81 percent and 100 percent of the samples collected from the Colusa Basin Drain were acutely toxic to larval striped bass. This was reduced to 45 percent in 1991 and 18 percent in 1992. The 1992 study showed that 25 percent of the samples collected from the Colusa Basin Drain, prior to the application of rice pesticides, were toxic. This study suggests that the remaining toxicity to larval striped bass in the Colusa Basin Drain may not be caused by rice drainage. All of the acutely toxic samples in that study were collected early in the rice season, before rice pesticides were detected in the waters, and none of the samples collected directly from rice fields was acutely toxic. The pattern of chronic toxicity suggests that an upstream source may be responsible. One of the two chronically toxic rice field samples was collected at the field inlet and one out of two samples collected from the Glenn-Colusa Canal, the irrigation supply, was also chronically toxic. No follow-up work has been done.

Rice pesticides and their degradation products are still detected in the Sacramento River, and waters in agricultural drains periodically exceed the CVRWQCB performance goals. In 1996, performance goals were exceeded for molinate in 48 percent of the samples, carbofuran in 40 percent, thiobencarb in 31 percent, malathion in 20 percent, and methyl parathion in 10 percent of the samples collected between May and June from the agricultural drains. Further, very little is known about the occurrence and toxicity of degradation products that form when rice waters are held on the fields. Some of these degradation products may be equally or more toxic than the parent compounds or may interact synergistically with the parent compounds, increasing toxicity.

Although rice field drainage has been extensively studied, drainage from other agricultural crops in the Sacramento River Basin has not been extensively tested. Recent toxicity identification evaluations ("TIEs") have shown that ziram, a metallodithiocarbamate which is used extensively on almonds, may be a major cause of fathead minnow toxicity in the Sacramento River at Freeport. Urban runoff from the Sacramento area has been analyzed for pesticides and periodically tested for toxicity since 1986. Run-off dominated streams have also been tested since 1993. Limited testing of urban runoff using fathead minnows has shown no evidence of toxicity to fish.

Tissue Analyses. Organochlorine pesticides and pesticide ingredients have been detected in fish tissues from the Sacramento Basin since 1960. A nationwide study conducted by the U.S. Fish and Wildlife Service ("USFWS") in 1980 and 1981 determined that fish and fish eggs from the Sacramento River had elevated concentrations of PCBs, DDT, toxaphene, and chlordane compared to fish from other rivers. These compounds may cause high mortality of fish eggs and fry. Many organochlorine pesticides are also estrogenic and may impair reproduction, with combinations of pesticides being up to 1600 times more potent than individual compounds. Striped bass from the Sacramento River were compared to striped bass from the Coos River in Oregon in a study conducted by the State Water Resources Control Board ("SWRCB") in 1980-1982. The Sacramento River fish contained higher concentrations of organochlorine compounds, were in poorer health, and displayed varying degrees of stress, including lesions, parasitism, and

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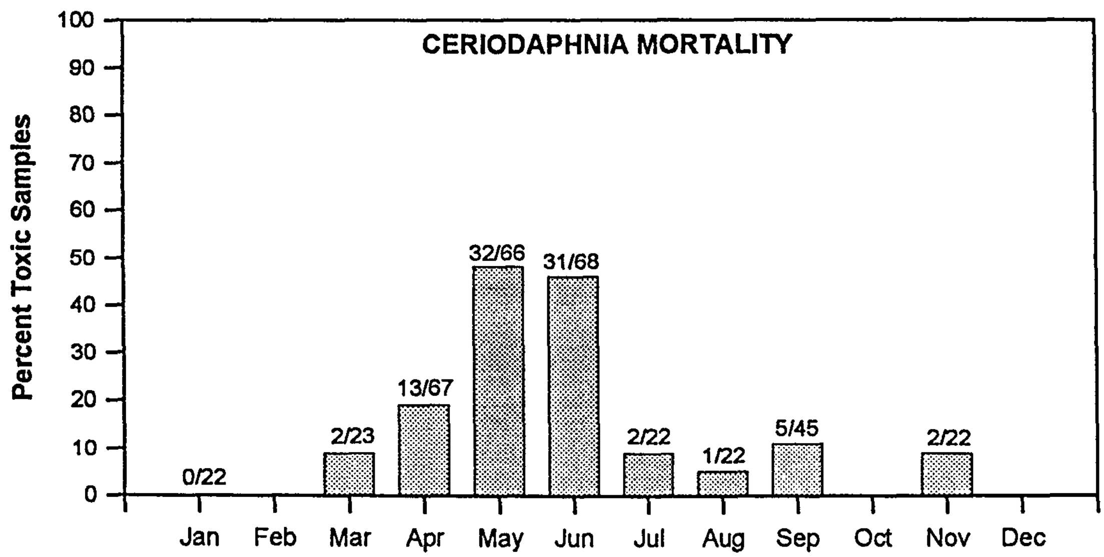
discolored fatty livers. Eggs from these fish had high mortality rates and produced deformed embryos in some cases. Larvae showed skeletal deformities and other abnormalities. More recent monitoring by the DFG, SWRCB, and the U.S. Geological Survey ("USGS") indicate that concentrations of these same organochlorine pesticides have declined, but remain high in fish collected throughout the Basin.

Zooplankton Toxicity. Sacramento River water has historically impaired reproduction and caused mortality of invertebrate species that provide food for fish. Between 1988 and 1994, up to 27 percent of the samples from the major rivers resulted in significant mortality to Ceriodaphnia, primarily in the April to June period when 19 to 46 percent of the samples were toxic (Figure ES-2). Reproduction was also significantly reduced in up to 34 percent of the samples. A TIE conducted on samples collected on June 1, 1988 showed that metals were responsible for the toxicity that occurred throughout the Sacramento River on this date. In 1991-1992, Ceriodaphnia toxicity occurred primarily in the upper watershed and was attributed to metals. Toxicity testing conducted by DPR in 1993 and 1994 showed no toxicity to Ceriodaphnia in the Sacramento River, downstream of the Feather River confluence.

Figure ES-2
Sacramento River Watershed
1988-1990



Conner and Foe 1993

The major agricultural drains that drain the rice farms have been tested periodically for Ceriodaphnia toxicity since 1986. Ceriodaphnia mortality was found in the Colusa Basin Drain, Sacramento Slough, and Butte Slough in the mid-1980s in up to 57 percent of the samples tested. More recent testing of Colusa Basin Drain has shown Ceriodaphnia toxicity occurring in about 13 percent of the samples tested. Significant mortality to Neomysis, a native zooplankter, was

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present in 27 to 78 percent of the samples collected in 1989 from the Colusa Basin Drain. There has been no recent testing using Neomysis.

Other sources of toxicity to Ceriodaphnia include orchards and urban runoff. Drainage from orchards in the winter of 1992 caused Ceriodaphnia mortality in 38 percent of the samples. Urban runoff has also been found to be toxic to Ceriodaphnia in virtually all of the samples tested, primarily due to diazinon and chlorpyrifos. In fact, even rainwater in the Central Valley often contains diazinon at concentrations high enough to cause toxicity to Ceriodaphnia.

Although most of this toxicity has not been adequately explained chemically, where it has, it has been attributed to organophosphorus and carbamate pesticides, including methyl parathion, carbofuran, malathion, chlorpyrifos, and diazinon. Rice drainage toxicity is generally due to the first three compounds, and orchard runoff and urban runoff toxicity to diazinon and chlorpyrifos.

Algal Toxicity. Toxicity studies have also shown that the growth of the alga, Selenastrum, is inhibited in 8 to 22 percent of the samples from the major rivers of the Sacramento Basin. Selenastrum is a surrogate test organism that represents the native species of algae which provide food for the zooplankton. Most of the toxicity to Selenastrum appears to be due to metals rather than pesticides, except in urban runoff where toxicity is sometimes due to the herbicide diuron and unidentified organic(s).

Sediment Toxicity. Although sediment toxicity testing has been much less extensive than water testing, significant toxicity has been found in sediments from several areas in the Sacramento Basin. Sediments collected from Keswick Reservoir downstream of acid-mine drainage discharges are toxic to the amphipod, Hyalella, as well as Ceriodaphnia, larval fathead minnows, chinook salmon fry, and rainbow trout fry. Sediments collected from a sump in Sacramento that receives urban runoff from an industrial area and from Sacramento Slough, which carries predominately rice drainage, were also toxic to Hyalella and Ceriodaphnia.

Pesticide Concentrations. Based on daily sampling of the Sacramento River at Sacramento between May 1991 and April 1994, the most frequently detected pesticides in the river were simazine, diazinon and carbofuran, which were present 42, 38, and 23 percent of the time, respectively. These pesticides do not appreciably degrade under ambient conditions and diazinon concentrations frequently exceeded U.S EPA criteria set to protect freshwater aquatic life. The most frequently detected pesticides were present in distinct pulses, lasting several months. These pulses generally coincide with the time when young striped bass, chinook salmon, green sturgeon, white sturgeon, and delta smelt are present in the river.

San Joaquin River Basin

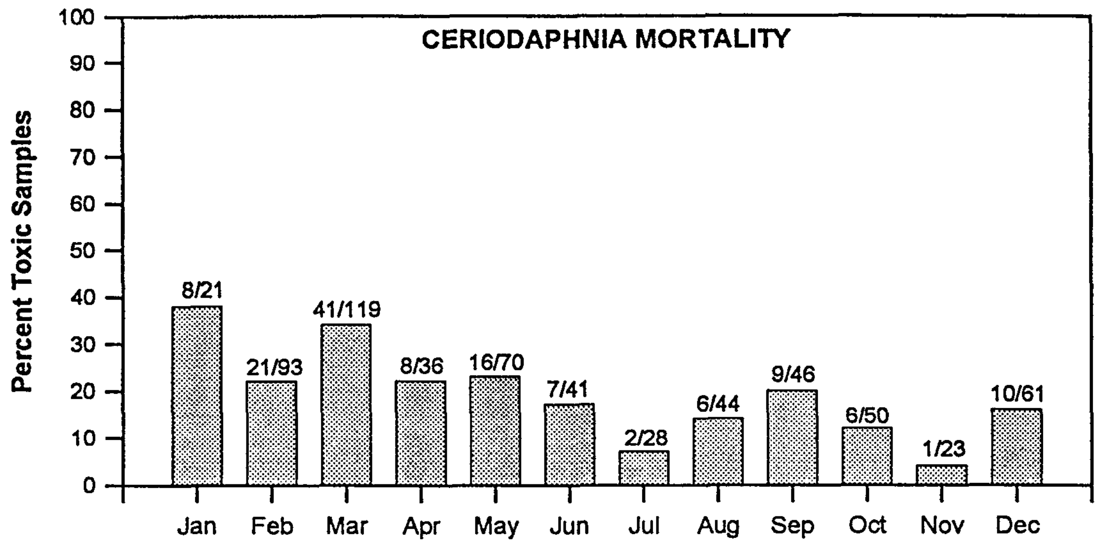
The San Joaquin River contributes approximately 10 percent of the flow to the Bay-Delta. It is the only conduit leading to the spawning habitat in the major rivers of the San Joaquin Basin. Portions of the San Joaquin River consist largely of irrigation runoff all summer long. This runoff often carries pesticides to the rivers. High concentrations of pesticides also occur throughout the area. While their levels are generally believed to be too low to kill fish outright, they are high enough to adversely affect their food supplies by causing direct mortality and inhibiting reproduction.

Fish Toxicity. Fish kills caused by pesticides such as DDT, endosulfan, and acrolein were common in the 1960s, 1970s, and 1980s throughout the basin, but have declined substantially in the 1990s. However, aquatic toxicity still occurs frequently in water samples collected from the San Joaquin River and its major tributaries. Limited data have been collected on fathead minnow toxicity in the San Joaquin Basin. Based on one study conducted from February 1988 to June 1990, significant mortality to fathead minnows occurred in up to 5 percent of the samples from the major rivers. Some mortality was noted in all months. Fathead minnow toxicity occurred in about 18 percent of the samples from the major creeks that are dominated by agricultural drainage. In a USFWS study, subsurface agricultural drainage was toxic to chinook salmon and striped bass, resulting in 77 percent mortality in 28 days to salmon and 100 percent mortality in 23 days to striped bass. The toxicity was attributed to high concentrations of major ions (e.g. sodium, sulfate, chloride, boron) present in atypical ratios. The USFWS did not measure pesticides in their study.

Tissue Analyses. Organochlorine pesticides, including three that are banned in California- DDT, toxaphene and chlordane - are present in fish tissues throughout the basin at levels that exceed National Academy of Sciences guidelines to protect fish and Department of Food and Agriculture guidelines to protect public health. These compounds may cause high mortality of fish eggs and fry. Some are also estrogenic and may impair fish reproduction. Elevated concentrations of organochlorine pesticides are also present in freshwater clams and crayfish from the San Joaquin Basin. The highest concentrations were found in clams from the westside streams that are dominated by agricultural drainage.

Zooplankton Toxicity. There is evidence that pesticides in the San Joaquin River and its major tributaries are impairing reproduction and causing mortality of invertebrate species that provide food for fish. From 9 to 22 percent of the samples from the major rivers resulted in significant mortality to Ceriodaphnia in studies conducted between 1988 and 1993. In agriculturally dominated streams, Ceriodaphnia mortality was observed in 33 to 38 percent of the samples. In February 1993, 100 percent mortality to Ceriodaphnia was observed for 12 consecutive days in the San Joaquin River at Vernalis. Most of the toxicity (23 to 38 percent), occurs in the January to May period (Figure ES-3). Neomysis mortality was observed in 7 percent of the samples from the major rivers and 21 percent of the samples from agriculturally dominated streams. Mortality was believed to be due primarily to runoff and irrigation return flows from row and orchard crops. No TIEs have been conducted on San Joaquin Basin samples but concentrations of diazinon and chlorpyrifos often exceed criteria to protect freshwater aquatic life. Pesticides have been measured in rainfall in the San Joaquin Valley at concentrations high enough to be acutely toxic to Ceriodaphnia. The most commonly detected pesticides in rainfall were diazinon, parathion, malathion, and chlorpyrifos.

Figure ES-3
San Joaquin Watershed
1988-1992



Foe and Conner 1991
Foe 1995

Algal Toxicity. Only one study has been conducted in which water from the major rivers and agriculturally dominated streams was tested for Selenastrum toxicity. Algal production was lower in the Mendota Pool than elsewhere in the basin during both irrigation and non-irrigation seasons. No cause was apparent.

Sediment Toxicity. Organochlorine pesticides and pesticide ingredients, including DDT, DDD, DDE, dieldrin and PCBs are present at elevated concentrations in bottom sediments throughout the basin, with the highest concentrations found in the westside agriculturally dominated streams. The San Joaquin River has among the highest sediment pesticide concentrations among major rivers of the United States. Significant sediment toxicity was also detected at three agriculturally dominated sites. Sediments from Turlock Irrigation District ("TID") Lateral #5 and Orestimba Creek were toxic to Hyalella. Sediment samples from Orestimba Creek and Mud Slough were also toxic to Ceriodaphnia.

Pesticide Concentrations. Based on daily sampling of the San Joaquin River at Vernalis between January 1991 and April 1994, the most frequently detected pesticides in the San Joaquin River were simazine and diazinon, which were present 70 and 80 percent of the time, respectively. As in the Sacramento River, diazinon concentrations frequently exceeded criteria set to protect freshwater aquatic life. The concentrations of other organophosphorus pesticides, including ethyl parathion (no longer registered for use in California) and chlorpyrifos, have frequently exceeded criteria to protect freshwater aquatic life by several orders of magnitude. Concentrations of these pesticides also frequently exceeded those known to be toxic to organisms at the base of the foodchain, primarily midges and Neomysis. The most frequently detected pesticides were present in distinct pulses, lasting several months. These pulses generally coincide with the time when young striped bass, chinook salmon, green sturgeon, white sturgeon, and delta smelt are present in the river.

Delta

The Delta, the confluence of the Sacramento and San Joaquin rivers, has an area of about 1000 square miles and is interlaced by a network of about 1,100 miles of waterways. The Delta is an important spawning and nursery ground for many species of concern.

Fish Toxicity and Tissue Analysis. Toxicity testing conducted on Delta waterways shows that there is infrequent toxicity to fathead minnows. A study conducted in 1987 during the rice drainage season resulted in 30 percent of the samples being toxic to fathead minnows and growth was reduced in all of the samples. In 1988, 8 percent of the samples were acutely toxic and subsequent testing from 1991 to 1995 has shown no acute toxicity and minimal chronic toxicity to fathead minnows.

There is other evidence that fish have been adversely affected by pesticides. From 15 to 30 percent of the striped bass larvae collected within the Delta from 1988 to 1990 had liver alterations that are consistent with exposure to pesticides. Organochlorine pesticides and pesticide ingredients, including DDT, PCBs, toxaphene, and chlordane, are periodically detected in fish from throughout the Delta. Historically, concentrations were high enough in striped bass to reduce egg hatchability and cause high mortality among larvae and fry.

Zooplankton Toxicity. Delta waters have impaired reproduction and caused mortality of invertebrate species that provide food for fish. Significant mortality to Neomysis occurred in about 10 percent of the samples collected from the lower Sacramento River in 1990. Ceriodaphnia mortality occurred in 2 to 20 percent of the samples and reproduction was impaired in up to 15 percent of the samples collected from the lower Sacramento River in 1987 to 1992. During 1994-1995, Ceriodaphnia mortality occurred in 2 to 9 percent of the samples. The mortality was attributed to organophosphorus and carbamate pesticides, including diazinon, chlorpyrifos, and carbofuran. Most of the toxicity to Ceriodaphnia is found in back sloughs and small upland drainages. During rainfall events, Delta waterways are frequently toxic to Ceriodaphnia.

Algal Toxicity. Toxicity studies have shown that algal growth is impaired in 2 to 11 percent of the samples. The impairment has been attributed to nonpolar organic compounds which include pesticides. As with Ceriodaphnia, the Selenastrum toxicity is found in back sloughs and small upland drainages. The USGS is currently conducting a study to determine whether herbicides may reduce primary productivity in the Delta.

Sediment Toxicity. Sediment toxicity has been detected at ten different sites in the Delta by the CVRWQCB, most of which were selected because they were known to be contaminated. Sediments from the Sacramento River at Green 25 (a buoy in the lower Sacramento River) as well as from Duck Slough, Smith Canal, Port of Stockton, Old Mormon Slough, Rough and

Ready Island, and Stockton Turning Basin were toxic to Hyalella and Ceriodaphnia. Sediments collected from the Sacramento River near Collinsville and the San Joaquin River near Antioch by the San Francisco Estuary Project Regional Monitoring Program were toxic to an estuarine amphipod, larval mussels, and larval oysters.

CONCLUSIONS AND RECOMMENDATIONS

This literature review indicates that pesticides and aquatic toxicity are ubiquitous in surface waters of the Sacramento and San Joaquin basins and the Delta. Pesticides are found in waters, sediments, and tissues collected throughout the area. Rainfall, urban runoff, agricultural drainage, agriculturally dominated streams, and sediments and water of the Sacramento and San Joaquin rivers and their tributaries are periodically toxic. Toxicity testing has provided evidence that pesticides are killing and/or impairing growth and reproduction in fish, zooplankton, and algae – all levels of the aquatic foodchain. There has been fairly limited testing of native species. However, sediments and receiving waters in the Sacramento and San Joaquin basins and the Delta have been shown to be toxic to Neomysis and salmonids, in addition to the non-native but commercially important striped bass.

This literature review suggests that significant work is needed to determine if there is toxicity to species of concern, to identify the sources and chemicals responsible for toxicity, and to determine if there is evidence that toxicity has resulted in population level effects on species of concern. A comprehensive long-term monitoring program is needed to answer these questions and research should be conducted on best management practices to control pesticides in urban runoff and agricultural drainage.

C-030759

SECTION ONE
INTRODUCTION

C-030760

1.0 INTRODUCTION

There are numerous factors that may be responsible for the decline in aquatic resources of the Bay-Delta ecosystem. Water diversions and reduced Delta outflow, unscreened agricultural and urban diversions, loss of habitat, channel modifications, introduction of exotic species, commercial fishing, recreational boating, changes in oceanic environment, and toxic contaminants have all been discussed as potentially playing a role in the decline of aquatic resources. While the effects of water diversions and reduced Delta outflow have been studied by the Interagency Ecological Program ("IEP") and other scientists for several decades, most of the other potential factors have not been extensively investigated. This study on "Aquatic Toxicity and Pesticides in Surface Waters of the Central Valley" was undertaken by the California Urban Water Agencies ("CUWA") to determine if pesticides could be adversely affecting aquatic organisms in the Bay-Delta ecosystem. The larger rivers in the Central Valley such as the Sacramento, American, Feather, and lower San Joaquin provide major spawning and rearing habitat for fish such as salmon, steelhead trout, striped bass, shad, and sturgeon. CUWA was concerned that pesticides entering the rivers from a variety of sources could be contributing to the decline in these important fish species as well as other forms of aquatic life. To assess the importance of pesticides, CUWA undertook a detailed review of the data and literature on pesticides and aquatic toxicity in the Sacramento and San Joaquin basins and the Delta.

1.1 STUDY OBJECTIVES

The objectives of this study were:

1. Summarize the information available on aquatic toxicity and pesticides in the Sacramento and San Joaquin basins and the Delta.

2. Assess the potential impact that pesticides may have had historically and currently on the biological resources of the Bay-Delta ecosystem.

3. Determine additional work or studies needed to fully assess the effects of pesticides on the biological resources of the Bay-Delta ecosystem.

1.2 CONDUCT OF THE STUDY

This study was conducted for CUWA primarily by J. Phyllis Fox with assistance from CUWA's Bay-Delta Program Manager, Elaine Archibald of Archibald & Wallberg Consultants. The consultants were advised by a Project Advisory Committee ("PAC") consisting of staff from member agencies of CUWA. This report has been reviewed by many of the scientists whose work is discussed herein, as well as by a large number of water agency engineers and biologists. A complete list of peer reviewers is presented at the beginning of the report.

1.3 STUDY APPROACH

The status of research related to pesticide monitoring programs of waters, soils, and biota through 1970 was comprehensively reviewed by the State Water Resources Control Board ("SWRCB") in 1971.[1] This report covers the period from 1971 through the present, emphasizing more recent work completed in the last decade. This report focuses on more recent work because many of the pesticides that were formerly a concern have been banned or severely restricted. Further, analytical methods have been refined and detection limits have substantially improved in the last decade.

CUWA reviewed numerous reports on pesticides and aquatic toxicity in the Sacramento and San Joaquin basins and the Delta. The multitude of studies are summarized in this report according to the geographic area in which they were conducted. A large number of toxicity studies have been conducted since 1986 on the Sacramento and San Joaquin rivers and in the Delta.

The majority of the toxicity testing, primarily that conducted by the Central Valley Regional Water Quality Control Board ("CVRWQCB"), has used the U.S. Environmental Protection Agency ("U.S. EPA") three species freshwater bioassay.[2] Others have used the American Society of Testing and Materials ("ASTM") 96-hr static bioassay procedures. The U.S. EPA test uses standard test organisms from three trophic levels -- a primary producer, the green alga, Selenastrum capricornutum; a primary consumer, the zooplankter, Ceriodaphnia dubia; and a secondary consumer, the fathead minnow, Pimephales promelas. The test assays 7-day fathead minnow survival and growth, 7-day Ceriodaphnia survival and reproduction, and 4-day Selenastrum growth. The genus Selenastrum is common in the study area. Ceriodaphnia dubia is a midwestern species that is believed not to occur in the study area. However, Ceriodaphnia reticulata, a related species, is found in the study area. Pimephales promelas is common in the study area. The relationship between the three-species test results and ecosystem impacts is controversial. However, a number of studies has demonstrated strong qualitative relationships between bioassay results and decreases in both population abundance and number of species in

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1 SWRCB, A Review of Pesticide Monitoring Programs in California, February 1971.

2 U.S. EPA, Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms, Second Edition, Report EPA/600/4-89-001, March 1989 and Third Edition, Report EPA-600-4-91-002, July 1994.

ambient waters.[3] Limited testing of native species such as larval striped bass, chinook salmon, and Neomysis also has been conducted in the Central Valley.

1.4 REPORT ORGANIZATION

This report is organized in five sections:

Section 1: An introduction to the study.

Section 2: A summary of the Sacramento Basin studies.

Section 3: A summary of the Sacramento-San Joaquin Delta studies.

Section 4: A summary of the San Joaquin Basin studies.

Section 5: A discussion of the conclusions and recommendations.

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[3] V. DeVlaming, Are the Results of Single Species Toxicity Tests Reliable Predictors of Aquatic Ecosystem Community Response? A Review, State Water Resources Control Board, 1997; U.S. EPA, Technical Support Document for Water Quality Based Toxics Control, Report EPA/505/2-90/001, 1991; K.W. Eagleson, D.L. Lenat, L. Ausley, and F. Winborne, Comparison of Measured Instream Biological Responses with Responses Predicted by Ceriodaphnia Chronic Toxicity Tests, Environmental Toxicology and Chemistry, v. 9, 1990, pp. 1019-1028; and W.J. Birge, J.A. Black, T.M. Shortand, and A.G. Waterman, A Comparative Ecological and Toxicological Investigation of a Secondary Wastewater Treatment Plant Effluent and Its Receiving Water, Environmental Toxicology and Chemistry, v. 8, 1989, pp. 437-450.

C-030763

SECTION TWO
SACRAMENTO BASIN

C-030764

2.0 SACRAMENTO BASIN

The Sacramento Basin, drained by the Sacramento River, covers an area of approximately 26,000 square miles. The major east-side tributaries to the Sacramento River are the Pit, Feather, Yuba, and American Rivers. Smaller west-side tributaries include Clear, Cottonwood, Thomes, Stoney, Putah, and Cache Creeks (Figure 1). The latter two creeks actually drain into the Yolo Bypass, which drains into the Delta.

Toxicity and pesticide concentrations have been periodically monitored in waters, sediments, and biota since the 1960s by the CVRWQCB, the Department of Pesticide Regulation ("DPR"), the Department of Fish and Game ("DFG"), the U.S. Geological Survey ("USGS"), the U.S. Fish and Wildlife Service ("USFWS"), the National Marine Fisheries Service ("NMFS"), and the SWRCB. The results of this work are summarized for major rivers in Section 2.1 and for potential sources in Section 2.2.

2.1 MAJOR RIVERS

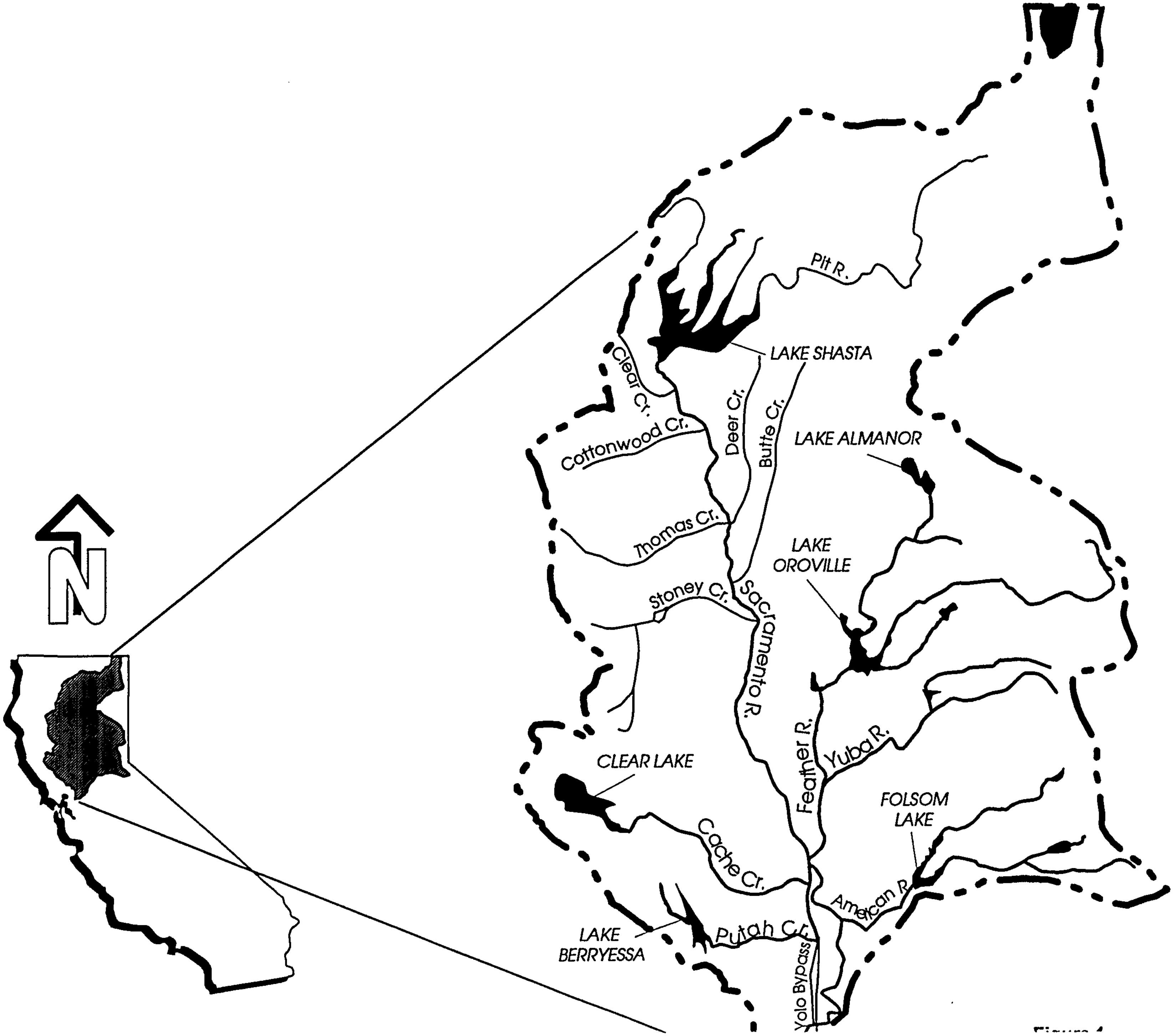
Toxicity and pesticide concentrations have been monitored in waters (Sec. 2.1.1), sediments (Sec. 2.1.2), and biota (Sec. 2.1.3). The principal conclusions from this work are as follows:

- Between 1988 and 1994, significant mortality to larval fathead minnows occurred in 3 to 11 percent of the samples from the major rivers, primarily in the April to June period, when 12 to 32 percent of the samples were toxic. Growth was also significantly reduced in up to 13 percent of the samples. In limited testing, samples from the Sacramento River were also toxic to larval striped bass. Since 1990, 50 percent of the samples from the Sacramento River at Freeport have been toxic to larval fathead minnows.

- Between 1988 and 1994, significant mortality to Ceriodaphnia occurred in up to 27 percent of the samples from the major rivers, primarily in the April to June period. Reproduction was also significantly reduced in up to 34 percent of the samples.

- Between 1988 and 1993, significant algal growth impairment occurred in 8 to 22 percent of the samples from the major rivers. Most of the toxicity occurred in the upper Sacramento River above Redding. The growth impairment was generally believed to be due to metals from acid mine drainage.

- Sediments from Keswick Reservoir, downstream from discharge of acid mine drainage, are frequently toxic to amphipods, Ceriodaphnia, rainbow trout fry, chinook salmon fry, and larval fathead minnows. Metals,


N
Pit R.
LAKE SHASTA
Clear Cr.
Deer Cr.
Butte Cr.
Cottonwood Cr.
LAKE ALMANOR
Thomas Cr.
LAKE OROVILLE
Stoney Cr.
Sacramento R.
Feather R.
Yuba R.
CLEAR LAKE
FOLSOM LAKE
Cache Cr.
American R.
LAKE BERRYESSA
Putah Cr.
Yolo Bypass

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particularly zinc and cadmium, are believed to be the cause. Sediments from an urban runoff site and an agricultural drain were also toxic to amphipods and Ceriodaphnia.

- The most frequently detected pesticides are simazine, diazinon and carbofuran, which are present at Sacramento 42, 38, and 23 percent of the time, respectively. These pesticides are present in the river during the April to May period when young striped bass and salmon are present. Diazinon concentrations frequently exceed criteria set to protect freshwater aquatic life.

- Organochlorine pesticides and pesticide ingredients, including DDT, PCBs, toxaphene and chlordane, are periodically detected in fish tissues throughout the basin. These compounds may cause high mortality in fry and impair reproduction.

2.1.1 Waters

2.1.1.1 CVRWQCB 1988-90 Bioassay Study

Between March 1988 and May 1990, the CVRWQCB conducted a two and one-half year bioassay study to assess the toxicity of surface waters in the Sacramento River system. Samples were collected on 18 separate dates before, during, and after the rice season from 16 sites between Shasta Lake and Sacramento. Additional samples were collected in the Delta and are discussed in Section 3.1.1.4. The U.S. EPA three-species bioassay was used to monitor fathead minnow growth and mortality, Ceriodaphnia reproduction and mortality, and Selenastrum growth at all sites. A modification of the ASTM 96-hr static bioassay was used to monitor larval striped bass mortality at select sites. The fathead minnow mortality data are summarized in Table 1, the Ceriodaphnia mortality data are summarized in Table 2, and the Selenastrum growth data are summarized in Table 3.[4]

In the Sacramento Basin, significant mortality to fathead minnows was found in 30 out of 272 samples, or in about 11 percent of the total (Table 1). Among these toxic samples, 26 or 90 percent of the total occurred in the April to June period. An additional six samples showed significant fathead minnow growth impairment. On a single date, May 15, 1989, almost the entire Sacramento River system was toxic to fathead minnows, from Shasta Lake to below Rio Vista, except Redding and the Colusa Basin Drain (Table 1). Although the cause of the toxicity was not determined, these results suggest that rice drainage was probably not responsible.

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[4] Valerie Connor, Linda Deanovic, and Christopher Foe, Sacramento River Basin Biotoxicity Survey Results: 1988 - 1990, CVRWQCB Staff Report, December 1993.

Table 1. Fathead Minnow Mortality (%) in Water Samples Collected from the Sacramento River Watershed, 1988-1990.[1]

Sampling Site[2]	1988									1989							1990	
	3/9	4/20	5/15	6/1	6/13	7/20	9/14	10/24	12/13	4/13	4/26	5/24	6/2	6/22	9/27	11/29	1/10	5/14
Sacramento Basin																		
Shasta Lake	-	-	40	-	-	-	0	7	11	13	10	20	10	10	3	0	0	0
Shasta Dam	0	7	47	30	25	0	20	4	33	43	13	17	13	3	10	10	0	0
**Whiskeytown Res.	-	-	-	-	-	-	-	-	-	33	3	17	27	20	3	7	0	3
Keswick Dam	7	7	45	27	20	3	13	0	15	23	3	17	10	0	7	7	0	0
Redding	13	7	23	35	25	10	0	4	22	23	10	17	13	7	10	23	0	17
Red Bluff	13	30	70	43	10	0	27	11	11	13	0	3	15	5	30	30	0	23
Hamilton	13	20	63	47	0	0	3	18	33	13	13	0	40	17	0	23	0	40
Colusa	7	27	-	30	0	13	20	11	44	30	3	0	17	7	13	27	0	37
u/s CBD	7	23	60	43	0	7	7	4	26	33	13	7	27	7	0	0	0	0
**Colusa Basin Drain	7	3	13	20	5	7	0	4	7	7	7	3	20	0	3	10	3	3
d/s CBD	7	3	47	33	5	0	0	11	18	20	7	3	37	17	100	0	7	7
u/s Sac. Slough	7	3	70	10	5	0	0	11	18	17	0	5	-	10	3	17	0	3
**Sacramento Slough	27	3	40	20	5	3	7	11	7	7	0	7	40	27	3	7	30	0
**Feather River	13	7	67	30	10	0	13	4	11	13	13	5	13	7	0	20	0	3
Village Marina	20	0	43	7	10	0	13	11	18	10	0	10	20	3	0	7	0	17
**American River	10	87	70	27	0	0	17	7	18	30	13	20	33	7	0	17	0	3
Delta																		
Freeport	0	17	70	23	5	7	3	11	7	10	3	10	33	3	0	10	0	0
Clarksburg	7	23	53	43	0	3	3	15	7	23	0	7	50	10	3	20	7	3
Walnut Grove	13	17	57	30	5	0	10	4	11	23	13	7	20	13	0	0	0	3
Isleton	17	17	57	10	10	0	13	7	11	27	7	15	17	7	0	13	3	3
Steamboat Slough	7	7	50	23	0	0	3	15	0	47	3	7	33	0	0	13	0	-
**Cache Slough	17	7	47	10	0	0	3	-	-	-	-	-	-	-	-	-	-	-
Rio Vista	3	27	53	20	20	3	3	11	22	20	7	13	17	0	0	17	0	0
Green 25	13	0	63	13	0	7	0	7	26	-	-	-	-	-	-	-	-	-
Green 7	7	0	3	7	20	0	3	-	-	-	-	-	-	-	-	-	-	-
Lab Control	0	0	3	3	0	0	0	7	7	0	3	3	10	10	0	17	7	3

1 Conner, Deanovic and Foe 1993, Tables 5 and 6.

2 All sites are located on the Sacramento River, except the tributaries which are indicated by a double asterisk (**); u/s=upstream; d/s=downstream; CBD=Colusa Basin Drain.

[shaded] Significant mortality is defined as any sample exhibiting a 30% higher mortality than the lab control.

[boxed] Significant growth impairment.

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Table 2. *Ceriodaphnia* Mortality (%) in Water Samples Collected from the Sacramento River Watershed, 1988-1990.[1]

Sampling Site[2]	1988							1989							1990	
	3/9	4/20	5/15	6/1	6/13	8/17	9/14	4/13	4/26	5/24	6/2	7/6	9/27	11/29	1/10	5/14
Sacramento Basin																
Shasta Lake	-	-	30	-	-	20	0	30	40	10	50	0	20	0	0	0
Shasta Dam	70	20	20	100	20	10	10	40	20	60	50	30	30	10	10	0
**Whiskeytown Res.	-	-	-	-	-	-	-	10	40	40	70	0	30	10	0	10
Keswick Dam	10	60	10	100	40	20	10	50	20	30	0	20	0	0	0	0
Redding	10	0	40	100	30	0	20	20	50	30	20	0	0	11	0	10
Red Bluff	10	20	20	100	0	0	0	0	10	0	0	0	30	40	10	30
Hamilton	20	0	30	10	10	0	10	10	40	0	10	0	20	10	0	50
Colusa	10	0	-	100	0	10	10	10	10	10	0	0	10	20	0	40
u/s CBD	10	30	40	100	20	0	20	60	40	10	60	0	10	0	0	30
**Colusa Basin Drain	10	40	100	100	0	50	20	10	50	100	100	0	0	10	10	100
d/s CBD	0	10	40	100	10	0	10	40	0	60	80	0	10	0	0	0
u/s Sac. Slough	0	30	10	100	0	0	60	40	20	40	-	0	20	0	0	20
**Sacramento Slough	20	20	0	100	0	20	10	50	40	90	10	0	10	0	10	0
**Feather River	0	20	0	90	40	0	40	0	20	10	60	0	10	20	0	10
Village Marina	10	0	0	100	0	0	10	0	20	50	50	40	0	33	0	10
**American River	0	60	30	60	40	10	10	10	10	10	40	0	20	11	0	20
Delta																
Freeport	0	0	10	100	0	-	20	10	0	60	10	0	20	0	0	0
Clarksburg	10	20	20	100	0	-	20	30	20	60	10	20	10	0	10	10
Walnut Grove	0	10	50	100	20	0	0	20	40	40	30	0	10	0	0	40
Isleton	10	0	10	90	10	0	0	10	0	50	30	0	0	10	20	0
Steamboat Slough	20	10	90	60	0	10	60	0	10	60	30	0	20	10	20	-
**Cache Slough	0	10	30	20	10	10	30	-	-	-	-	-	-	-	-	-
Rio Vista	0	0	40	20	10	0	30	0	10	60	20	10	20	10	0	10
Green 25	0	0	50	30	0	0	10	-	-	-	-	-	-	-	-	-
Green 7	60	10	80	20	30	20	-	-	-	-	-	-	-	-	-	-
Lab Control	0	0	0	0	10	0	0	10	20	10	10	0	20	0	10	0

1 Conner, Deanovic and Foe 1993, Table 8.

2 All sites are located on the Sacramento River, except the tributaries which are indicated by a double asterisk (**); u/s=upstream; d/s=downstream; CBD=Colusa Basin Drain.

(shaded) Significant mortality is defined as any sample exhibiting 30% higher mortality than the laboratory control.

(boxed) Significant reproductive impairment.

Table 3. Average *Selenastrum* Chlorophyll Concentration (cells x 10^4/mL) in Water Samples Collected from the Sacramento River Watershed, 1988-1990.[1]

Sampling Site[2]	1988							1989						1990	
	6/1	6/13	7/20	8/17	9/14	10/24	12/13	4/13	4/26	5/24	6/2	9/27	11/29	1/10	5/14
Sacramento Basin															
Shasta Lake	-	-	-	-	11	5	97	53	86	148	68	25	4	0	60
Shasta Dam	26	16	4	61	5	1	113	87	71	92	88	44	9	0.2	65
**Whiskeytown Res.	-	-	-	-	-	-	-	49	55	94	53	75	11	1	55
Keswick Dam	19	12	4	83	3	1	102	63	95	154	58	59	4	1	60
Redding	23	12	4	93	13	2	93	58	64	143	66	23	7	2	55
Red Bluff	34	10	9	90	7	1	103	74	98	141	75	39	25	8	72
Hamilton	34	11	7	69	21	3	60	83	130	145	103	69	14	8	70
Colusa	28	19	14	101	8	5	96	33	100	181	105	55	18	6	74
u/s CBD	26	20	10	35	17	3	55	84	78	163	95	38	12	8	56
**Colusa Basin Drain	46	46	22	88	54	3	151	222	146	154	192	121	58	5	50
d/s CBD	34	20	9	105	26	3	107	93	115	144	118	87	15	11	62
u/s Sac. Slough	31	15	9	106	10	4	94	103	120	163	-	76	20	13	67
**Sacramento Slough	57	40	16	139	54	6	169	152	149	135	163	108	20	17	68
**Feather River	28	19	8	120	8	3	54	47	59	158	52	48	16	4	59
Village Marina	30	26	8	92	26	4	115	68	106	149	118	63	12	5	45
**American River	24	21	5	68	22	5	67	45	89	104	45	48	19	0.2	44
Delta															
Freeport	28	18	13	62		4	102	82	127	154	107	28	14	6	60
Clarksburg	39	22	17	117	27	4	129	82	151	162	149	20	14	1	81
Walnut Grove	51	24	14	120	33	5	126	105	144	147	108	10	31	5	69
Isleton	38	14	11	115	30	3	108	92	158	106	113	108	26	9	63
Steamboat Slough	25	20	13	101	23	3	109	69	86	77	117	21	27	11	-
**Cache Slough	32	21	12	94	22	-	-	-	-	-	-	-	-	-	-
Rio Vista	23	17	10	105	25	4	113	75	85	140	115	27	39	5	56
Green 25	23	17	10	84	19	5	112	-	-	-	-	-	-	-	-
Green 7	22	14	14	63	-	-	-	-	-	-	-	-	-	-	-
Lab Control	14	5	2	18	9	4	13	12	25	17	43	14	3	10	18

1 Conner, Deanovic and Foe 1993, Tables 11 and 12.

2 All sites are located on the Sacramento River, except the tributaries which are indicated by a double asterisk (**); u/s=upstream; d/s=downstream; CBD=Colusa Basin Drain.

(shaded) Algal impairment is defined as any sample exhibiting both a statistical and a 30% reduction in chlorophyll concentration relative to Colusa.

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Several samples from the Sacramento River were also assayed with larval striped bass. In preliminary work, one sample was collected at each of Rio Vista (5/88), Shasta Dam (6/88), and Isleton (6/88) and tested in 24-hour and 96-hour static non-renewal bioassays with 4 to 5 days old larval striped bass. Test samples and controls were adjusted to a mean salinity of 2.5 to 3 parts per thousand ("ppt") to minimize mortality due to osmotic stress. Statistically significant mortality (50 percent) compared to the control (0 percent) was observed at Rio Vista. No significant mortality was observed at the other two test sites.[5]

Four additional samples were collected from the Sacramento River at Colusa in June 1989 and tested in 96-hour static non-renewal bioassays with 1 to 2 days old striped bass larvae. Samples were tested at ambient conductivities. Of these, two exhibited significantly increased mortality of 88 percent. Four samples collected from the river in May and June 1989 downstream from the Colusa Basin Drain were similarly tested. Of these, two were toxic to larval striped bass and resulted in 95 and 100 percent mortality. The results for Colusa, which is above the point at which most rice drainage enters the river, suggests that at least some of the striped bass mortality is not due to rice drainage.[6]

Larval striped bass bioassays are difficult to interpret because the larvae are very sensitive to salinity. Studies indicate that mortalities of 1 to 2 day old larvae range from 1 to 15 percent for conductivities greater of 500 µmhos/cm and above and are 44 percent or greater at lower conductivities.[7] Further, different progenies exhibit considerable variation in their ability to tolerate low conductivity. Normally, this is addressed in striped bass bioassays by adjusting the conductivity of the test solution to 2000 to 4000 µmhos/cm by the addition of a small quantity of seawater to increase survival. This procedure was used in the preliminary 1988 striped bass bioassays described above. However, chemical interactions between the toxicant(s) and the added salts can mask toxic effects.

The 1989 larval striped bass bioassay studies discussed above were conducted at ambient conductivities (110 to 160 µmhos/cm) to evaluate the conditions to which larval bass would actually be exposed in the river and to avoid masking toxic effects. University of California at Davis ("UCD") well water with a conductivity of 200 to 250 µmhos/cm was apparently used as the control. The water quality data in the appendix of the report suggests that the authors did not

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5 Howard C. Bailey, Response of Larval Striped Bass to Agricultural Drainage and Sacramento River Waters, August 12, 1988.

6 H.C. Bailey, C.A. Alexander, and S.I. Doroshov, Toxicity of Water Samples from Colusa Basin Drain and the Sacramento River to Larval Striped Bass and Opossum Shrimp, University of California, Davis, Department of Animal Science, 1989, Table 1.

7 Bailey et al., 1989, p. 137; Howard C. Bailey and Sergei I. Doroshov, The Effect of Low Salinity, Tri-iodothyronine, and Female Size on the Survival of Larval Striped Bass (Morone saxatilis), Draft Manuscript, 1997.

adjust the controls to the same conductivities as the river samples, although water quality data are not reported for all tests and the authors are silent on this important point. The authors concluded that the toxic effects they observed, which were significantly higher than the controls, were probably not due to the low conductivities of the test solutions because no toxicity was observed in other tests with identical conductivities. However, the possibility that the mortality was due to the low salinity of the test solutions cannot be ruled out. The controls were well waters with potentially higher conductivities and different ionic composition than the river samples.

Significant mortality to Ceriodaphnia was found in 65 out of 244 samples, or in about 27 percent of the total. Among these toxic samples, 57 or 88 percent of the total occurred in the April to June period. An additional 18 samples showed significant Ceriodaphnia reproductive impairment. On a single date, June 1, 1988, mortality to Ceriodaphnia was observed throughout the Sacramento River system, from Shasta Dam to Steamboat Slough, except at Hamilton (Table 2).[8] Two samples from Colusa and one from Walnut Grove were also tested with Neomysis, and no evidence of acute toxicity was found.[9] A toxicity identification evaluation ("TIE") conducted on samples collected below Shasta Dam on August 17, 1988 suggested that metals were responsible for growth impairment at that site. Acid mine drainage with high concentrations of copper, zinc, and cadmium enter the river above this point.[10]

Significant growth impairment to Selenastrum was found in 50 out of 227 samples, or 22 percent of the total. Most of the impaired samples were from the upper Sacramento River above Redding -- Shasta Lake, downstream of Shasta Dam, Whiskeytown Reservoir, and below Keswick Dam. Since many of the impaired samples were not from agricultural areas, pesticides are probably not the primary cause of their toxicity. Impairment was found periodically at most sites and in all months (Table 3).

2.1.1.2 CVRWQCB 1991-92 Bioassay Study

Between February 1991 and September 1992, the CVRWQCB evaluated the toxicity of surface waters above and below major reservoirs in the Sacramento Basin and the Delta. The U.S. EPA three-species bioassay was used to monitor fathead minnow growth and mortality, Ceriodaphnia reproduction and mortality, and Selenastrum growth from 3 to 12 times at 18 sites.

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[8] Connor et al., 1993, Table 19.

[9] Bailey et al., 1989, Table 2.

[10] B.J. Finlayson and D.C. Wilson, Evaluation of Lethal Levels, Release Criteria, and Water Quality Objectives for an Acid-Mine Waste, ASTM Special Technical Publication 1007, 1989, pp. 189-203; D. Wilson, B. Finlayson, and N. Morgan, Copper, Zinc, and Cadmium Concentrations of Resident Trout Related to Acid-Mine Wastes, California Fish and Game, v. 67, no. 3, 1980, pp. 176-186; Jon Goetzl and Mark Stephenson, Metals Implementation Plan Project: Metals Monitoring of Central Valley Reservoir Releases: 1991-1992, June 1993.

Two sites in the Delta are discussed in Section 3.1.1.6. Metals were also monitored, and metal TIEs were performed to determine if metals were responsible for noted effects. The data are summarized in Table 4.

In the Sacramento Basin, significant toxicity to fathead minnows was found in ten out of 79 samples, or about 13 percent of the total. Of the toxic samples, two caused significant mortality and ten significantly reduced growth. Significant toxicity to Ceriodaphnia was found in 12 out of 88 samples, or 14 percent of the total. Of the toxic samples, two caused significant mortality and 12 significantly reduced reproduction. Significant reduction in growth of Selenastrum was found in 16 out of 103 samples, or 16 percent of the time. Most of the toxicity occurred upstream of Shasta Dam and immediately downstream of Shasta Dam (36 percent of the samples) and Keswick Dam (75 percent of the samples).

Metals were removed using ion exchange columns or EDTA chelation, and the samples were retested. This treatment significantly increased the growth of Selenastrum in 13 of the samples, particularly those downstream of Keswick Dam. It also significantly increased the growth of fathead minnows in three samples and enhanced Ceriodaphnia reproduction in another seven samples. These results suggest that some of the toxicity in the upper watershed is due to metals. Water quality objectives for cadmium, copper, iron, and zinc were frequently exceeded downstream of Keswick Dam and periodically exceeded elsewhere including the American River downstream from Folsom Dam, the American River at Discovery Park, and the Sacramento River near Elkhorn.[11]

2.1.1.3 North Valley Bioassay

The purpose of this study was to follow up on toxicity noted in the upper river in previous CVRWQCB bioassay studies. Samples were collected on seven dates between April and July 1993 from four sites in the upper Sacramento River -- below Shasta Dam, below Keswick Dam, at Red Bluff, and at Hamilton City -- and assayed for fathead minnow growth and mortality, Ceriodaphnia reproduction and mortality, and Selenastrum growth using the U.S. EPA three-species bioassay. Samples were also analyzed for total and dissolved zinc, copper, and cadmium.

For fathead minnows, significant mortality was noted in 8 percent of the samples and growth was significantly reduced in 4 percent of the samples. For Ceriodaphnia, significant mortality was noted in 25 percent of the samples, and reproduction was significantly reduced in 10 percent of the samples. For Selenastrum, growth was reduced in 8 percent of the samples.

On July 26, 1993, 100 percent mortality occurred in Ceriodaphnia at all four sites. The acute mortality in these samples was associated with the presence of protozoans and bacteria,

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[11] Valerie Connor and Linda Deanovic, Central Valley Regional Water Quality Control Board Basin Plan Metal Implementation Plan Development Project, Bioassay Results: 1991 - 1992, Draft, December 1994.

Table 4. Summary of Fathead Minnow, *Ceriodaphnia*, and *Selenastrum* Toxicity in the Sacramento River and Delta, 1991-1992.[1]

LOCATION	FATHEAD MINNOWS Number of Tests	Number of Toxic Tests	Frequency of Toxicity	CERIODAPHNIA Number of Tests	Number of Toxic Tests	Frequency of Toxicity	SELENASTRUM Number of Tests	Number of Toxic Tests	Frequency of Toxicity
Sacramento Basin									
Pit River at Bend	3	1	33	4	0	0	4	1	25
Pit River at Highway 299	3	0	0	4	0	0	4	0	0
McCloud River at Gilman Road	3	0	0	4	2	50	4	0	0
McCloud River at Highway 89	3	2	67	4	0	0	4	0	0
Sacramento River at Dunsmuir	3	1	33	4	2	50	4	1	25
Sacramento River at Delta	3	1	33	4	2	50	4	0	0
Whiskeytown Reservoir	8	1	12	7	0	0	8	2	25
Sacramento River d/s Shasta Dam	12	2	17	10	3	30	11	4	36
Sacramento River d/s Keswick Dam	8	0	0	7	0	0	8	6	75
Feather River d/s Thermalito Afterbay	7	2	28	6	1	17	9	0	0
Feather River near Nicolaus	5	0	0	4	0	0	7	0	0
Yuba River d/s Englebright Reservoir	7	0	0	6	0	0	9	0	0
Bear River d/s Camp Far West Reservoir	7	0	0	7	1	14	9	0	0
Sacramento River near Elkhorn	3	0	0	3	0	0	3	0	0
American River d/s Folsom Reservoir	8	0	0	8	0	0	9	1	11
American River at Discovery Park	4	0	0	6	0	0	6	1	17
Delta									
Sacramento River near Hood	7	0	0	8	1	13	8	0	0
Mokelumne River d/s Camanche Reservoir	8	4	50	9	1	11	8	0	0

1 Connor and Deanovic, 1994.

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including an Aeromonas species, a Pseudomonas species, and an unidentified species. The authors speculated that chronic zinc stress may have made the daphnids more susceptible to microorganism mortality.[12]

Thirteen rainbow trout from the river reach under study were examined. Thirty-eight percent exhibited varying degrees of compromised health, including frayed and eroded fins, clubbing of gill lamellae, necrotic lesions on the gills, and poor condition factors.[13] TIEs and metal analyses indicated that chronic zinc toxicity was present in some samples.

2.1.1.4 Four River Study

The DPR in cooperation with the DFG monitored pesticides and toxicity for one year in four rivers in California -- the Merced, Sacramento, Russian, and Salinas Rivers. The Sacramento River monitoring site is located 2.5 miles downstream from the confluence of the Sacramento and Feather Rivers. Three-day composite samples were collected weekly from November 12, 1993 to November 7, 1994. The samples were analyzed for organophosphorus, carbamate, and endosulfan pesticides, and acute toxicity determined in 96-hr bioassays with fathead minnows and Ceriodaphnia.

The only compound that was detected was diazinon in the January 28-31 sample (0.11 μg/L) and in the February 11-14 sample (0.07 μg/L).[14] Both concentrations exceed the 4-day average criterion established by the DFG (0.04 μg/L)[15] and the maximum concentration recommended by the National Academy of Sciences ("NAS") (0.009 μg/L)[16] to protect freshwater aquatic life. The NAS criterion was established in 1973 by dividing the lowest LC50 known at the time, 0.9 μg/L, by a factor of safety of 100 and is generally believed to be overprotective.

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[12] Emilie Reyes, Howard Bailey, David Hinton, and Valerie Connor, The Role of Microorganisms and Zinc in the Ceriodaphnia Mortality Observed in Sacramento River Bioassays, no date.

[13] Howard C. Bailey, Valerie Connor, Linda Deanovic, and David E. Hinton, Master Contract, North Valley Study, Quarterly Report, March 25, 1994.

[14] Craig Nordmark, Preliminary Results of the Four River Monitoring Study, Sacramento River; November 1993- November 1994, DPR Memorandum to Roger Sava, June 22, 1995.

[15] Mary Menconi and Cara Cox, Hazard Assessment of the Insecticide Diazinon to Aquatic Organisms in the Sacramento-San Joaquin River System, DFG Administrative Report 94-2, 1994, p. ii.

[16] National Academy of Sciences - National Academy of Engineering, Water Quality Criteria 1972, U.S. Environmental Protection Agency, Ecological Research Series (Blue Book), 1973, p. 186.

Significant mortality to larval fathead minnows occurred in two out of 31 samples or 6 percent of the total. The sample collected on November 19, 1993 resulted in 95 percent mortality and the sample collected on July 28, 1994 in 85 percent mortality. No significant mortality to Ceriodaphnia was observed.[17]

2.1.1.5 USGS Pesticide Monitoring

Pesticides were monitored on the Sacramento River at Sacramento between May 1991 and April 1994. Samples were collected daily and typically 2-day composites prepared and analyzed for up to 21 pesticides. Summary statistics are presented in Table 5. The most frequently detected pesticides were simazine and diazinon, which were present 42 and 38 percent of the time, respectively. The only other pesticides that were detected are atrazine (13 percent),[18] carbofuran (23 percent), methidathion (13 percent), molinate[19] (13 percent), and thiobencarb (8 percent). None of these pesticides except diazinon is known to be toxic at the concentrations that were measured. However, water quality standards and toxicity testing data for sensitive life stages of species of concern do not exist for most of these pesticides. Diazinon concentrations frequently exceeded the DFG 4-day (0.04 μg/L) and 1-hr average criteria (0.08 μg/L),[20] the NAS maximum criterion (0.009 μg/L)[21] set to protect freshwater aquatic life, and the LC50 of the midge (0.030 μg/L),[22] an insect which is eaten by young salmon.

The half lives of all of the detected pesticides except molinate have been measured in the Sacramento River, San Joaquin River, and Suisun Bay by the USGS. Their half lives generally vary with temperature and pH and are: 3 days to stable for carbofuran, 16 days to stable for methidathion, 6 days to stable for thiobencarb, 7 to 133 days for diazinon, and stable for simazine and atrazine under all conditions tested. The measurements were made for three separate conditions at temperatures ranging from 10.4 to 25°C and pHs from 7.3 to 8.1. These results are generally consistent with a Lagrangian study of the river, which found that molinate decreased

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[17] Robert Fujimura, DFG Aquatic Toxicology Lab Report No. P-1717, July 25, 1995.

[18] Percent of time detected.

[19] Ordram is the trade name for molinate.

[20] Menconi and Cox, 1994, p. ii.

[21] NAS, 1973, p. 186.

[22] Robert Sheipline, Background Information on Nine Selected Pesticides, CVRWQCB Staff Report, 1993, p. 72. Some researchers have questioned the reported LC50 for the midge because it conflicts with more recent microcosm studies (Adames et al., 1996, pp. 37-38).

Table 5. Summary of USGS Pesticide Data for the Sacramento River, 1991-1994.[1]

Pesticide	Number of Analyses	Number of Detects	Maximum Detected Value (ng/L)	Median Detected Value (ng/L)	Percentile of Median Detected Value[2]
Alachlor	351	0	-	-	-
Atrazine	563	75	238	16	93%
Butylate	351	0	-	-	-
Carbaryl	563	0	-	-	-
Carbofuran	603	139	109	7	89%
Chlorpyrifos	563	0	-	-	-
Cyanazine	351	0	-	-	-
Dacthal	351	0	-	-	-
Diazinon	563	214	393	24	81%
Eptam	351	0	-	-	-
Fonofos	563	0	-	-	-
Malathion	563	0	-	-	-
Methidathion	563	72	212	20	94%
Metolachlor	351	0	-	-	-
Molinate	603	79	1,553	213	94%
Napropamide	351	0	-	-	-
Pebulate	351	0	-	-	-
Simazine	563	236	522	75	79%
Thiobencarb	603	51	697	7	96%
Trifluralin	563	0	-	-	-

1 MacCoy et al., 1995.

2 P = (1-[((x-1)/2)/(x+y-1)])*100, where x=number of detects, y=number of nondetects.

slightly with time, but carbofuran and thiobencarb concentrations were constant throughout a 45-mile reach of the Sacramento River for up to 96 hours (Sec. 2.2.1.1.6).[23]

The most frequently detected pesticides were present in distinct pulses, which lasted several months. A diazinon pulse was present between January and March in 1992 and 1993 (Figure 2). A simazine pulse was present between November and May of 1992, 1993, and 1994 (Figure 3). A carbofuran pulse was present between April and July in 1991 and 1993 and at lower levels during other periods (Figure 4).[24] These pulses generally coincide with the time when young striped bass, chinook salmon, green sturgeon, white sturgeon, and delta smelt are present in the river. These types of pesticides are not known to be toxic to fish at concentrations measured in these pulses. However, we did not find any data on the toxicity of these pesticides to sensitive life stages of any fish except carbofuran. Carbofuran is not toxic to striped bass or chinook salmon at the measured concentrations.[25]

A Lagrangian study by the USGS, which is discussed in Section 2.2.1.1.6, measured degradation products of molinate, carbofuran, and methyl parathion from downstream of the Colusa Basin Drain to Steamboat Slough in the Delta over a 96-hr period. Methyl parathion was not detected, but its microbial or hydrolysis degradation product, para-nitrophenol, was detected throughout the lower Sacramento River. In addition, two photolysis degradation products of molinate, 2-keto molinate and 4-keto molinate, and the hydrolysis or microbial degradation product of carbofuran, carbofuran phenol, were also detected throughout the lower river.[26]

2.1.1.6 SRWTP Sacramento River Monitoring

Ambient Testing. The Sacramento Regional County Sanitation District's Sacramento Regional Wastewater Treatment Plant ("SRWTP") has been monitoring the toxicity of the Sacramento River below Sacramento since September 1988 using the U.S. EPA three-species

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[23] B.E. Jennings, K.M. Kuivila, and W. Meyers, Pesticides in San Francisco Bay-Estuary, California: II. Total Degradation Rate Estimates of Select Pesticides, Poster Session, 3rd Biennial State of the Estuary Conference, October 1996.

[24] These figures were prepared from a Lotus file supplied by Kathy Kuivila, USGS. The data are also published in: Dorene MacCoy, Kathryn L. Crepeau, and Kathryn M. Kuivila, Dissolved Pesticide Data for the San Joaquin River at Vernalis and the Sacramento River at Sacramento, California, 1991-94, USGS Open-File Report 95-110, 1995.

[25] Alan J. Heath, Joseph J. Cech, Joseph G. Zinkl, Brian Finlayson, and Robert Fujimura, Sublethal Effects of Methyl Parathion, Carbofuran, and Molinate on Larval Striped Bass, American Fisheries Society Symposium, 14:17-28, 1993.

[26] Joseph L. Domagalski and Kathryn M. Kuivila, Transport and Transformation of Dissolved Rice Pesticides in the Sacramento River Delta, California, USGS Open-File Report 91-227, 1991.

Figure 2
Diazinon Concentrations in Water Samples from the Sacramento River at Sacramento

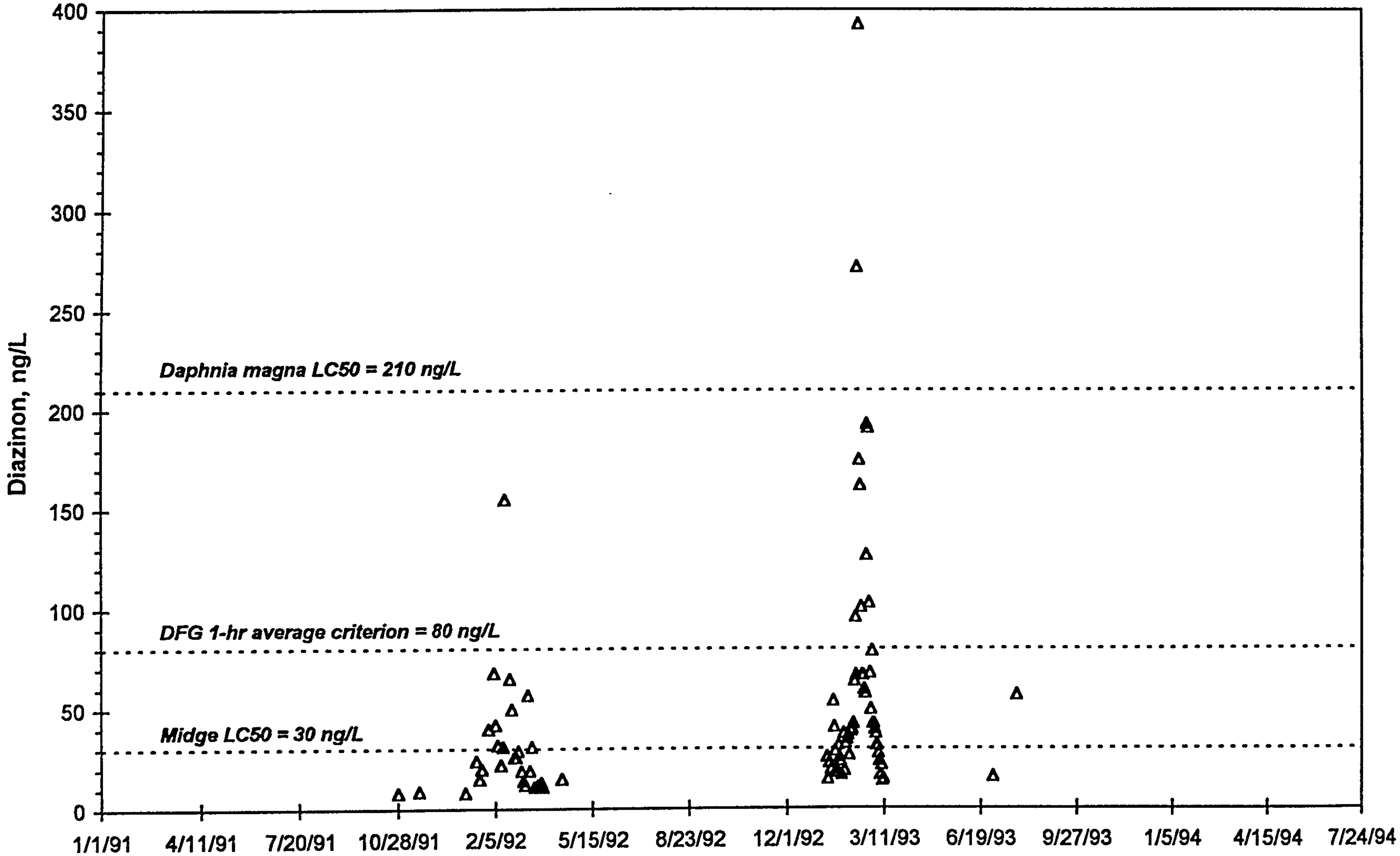

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Figure 3
Simazine Concentrations in Water Samples from the Sacramento River at Sacramento

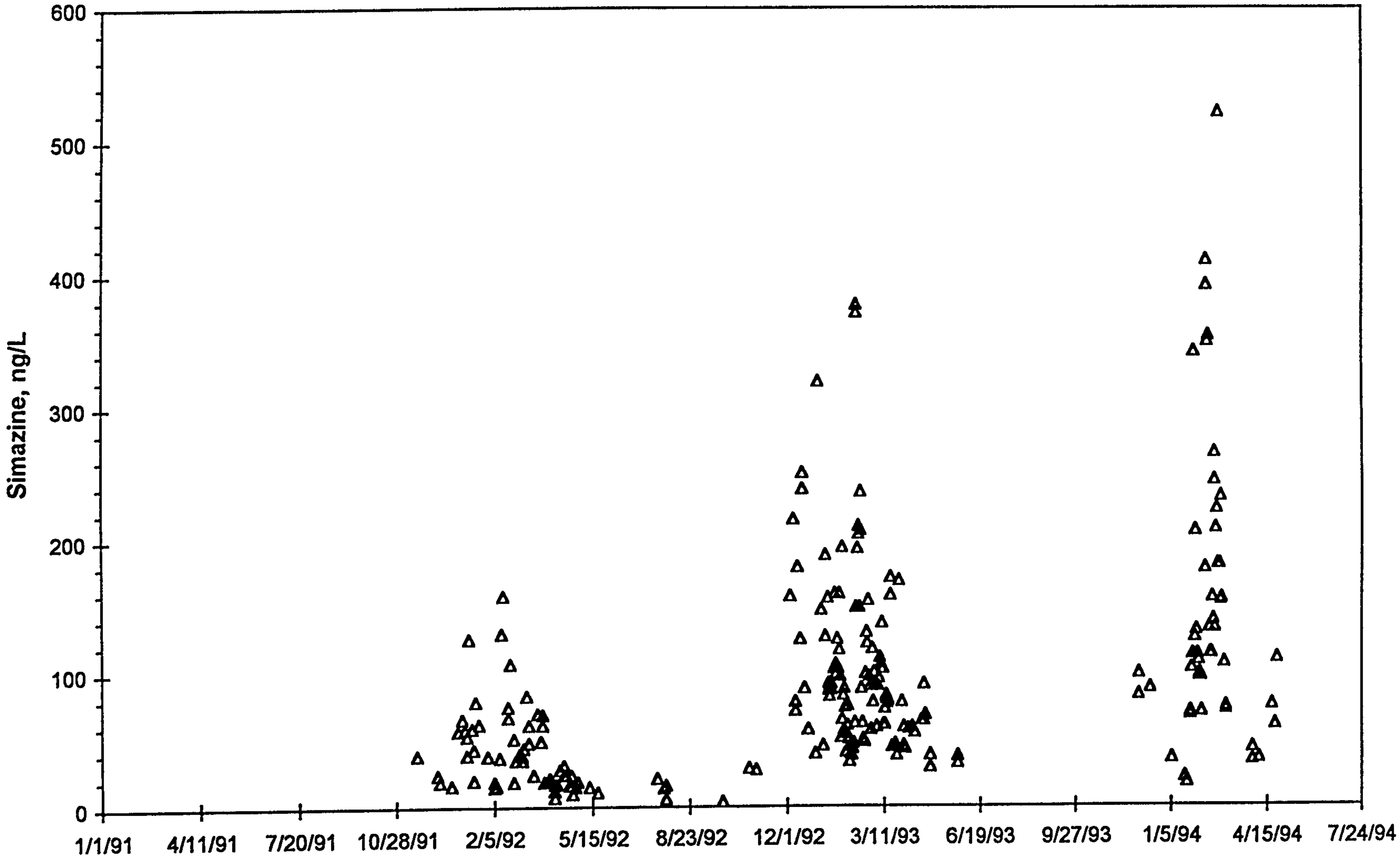
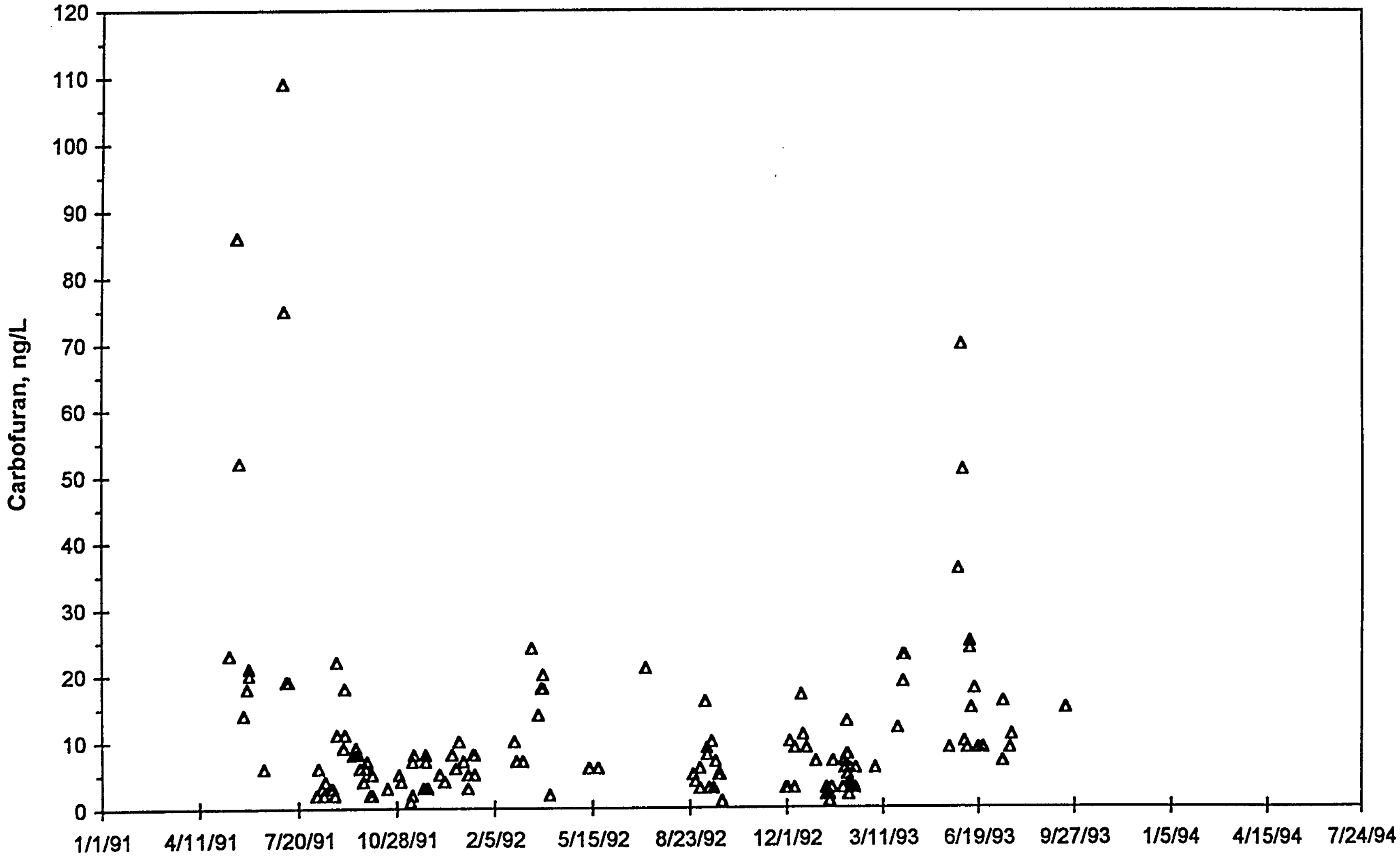


Figure 4
Carbofuran Concentrations in Water Samples from the Sacramento River at Sacramento



freshwater bioassay. The sampling locations are upstream of the SRWTP discharge, but downstream of the combined wastewater and most stormwater discharge points for the Sacramento urban area. The SRWTP testing has occurred in three distinct phases. No toxicity was found in Phase I, but toxicity occurred in Phases II and III. The fathead minnow mortality data from Phases II and III are summarized in Table 6.

In Phase I, 16 samples were collected roughly monthly from the Sacramento River at Garcia Bend (river mile 52) from September 1988 through September 1989 and tested for fathead minnow mortality and growth and Selenastrum growth. The growth data have not been statistically analyzed to determine if the samples differ from the controls. However, no significant mortality to fathead minnows was found in any of these samples.[27] The CVRWQCB also monitored fathead minnow mortality both above and below Garcia Bend throughout this period (Table 1 and Sec. 2.2.1.1.3) and only found a single toxic sample in May 1988. This suggests that the fathead minnow mortality problem noted in Phases II and III of this program started after September 1989.

In Phase II, 16 samples were collected roughly bimonthly from the Sacramento River at Garcia Bend from December 1990 through November 1992. The sampling point was moved to the Freeport Marina (river mile 46) in 1992. These samples were tested for fathead minnow mortality and growth, Ceriodaphnia mortality and reproduction, and Selenastrum growth.[28] Significant mortality to larval fathead minnows was found in seven of these 16 samples or 44 percent of the total. The statistically significant 7-day mortalities ranged from 20 to 86 percent. These data are plotted in Figure 5, which shows that significant mortality occurred in February, May, June, and August to October. Only one sample showed a significant reduction in growth. Significant mortality to Ceriodaphnia occurred in one of these 16 samples, or 6 percent of the total, and reproduction was significantly reduced in two samples or 13 percent of the total. Selenastrum cell growth was significantly reduced in only one sample.

In Phase III, which is continuing, 19 samples have been collected from the Sacramento River at the Freeport Marina from November 1993 through February 1997 and tested for fathead

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27 Aqua Terra Technologies, Effluent Toxicity Characterization, Sacramento Regional Wastewater Treatment Plant, December 1989.

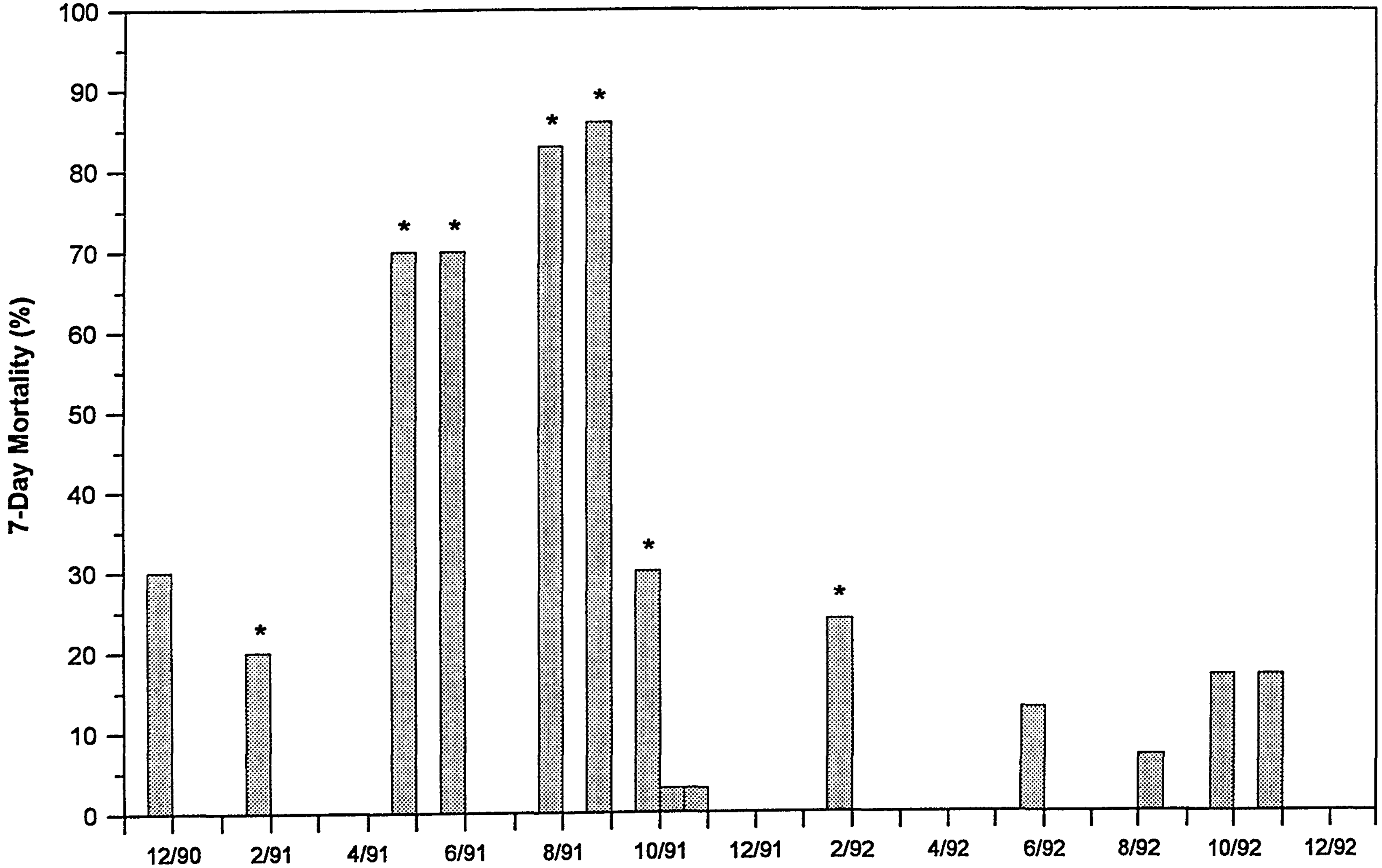
28 AQUA-Science, Phase II Effluent Variability Study, Report 1 (Dec-90 and Feb-91), March 14, 1991; AQUA-Science, Phase II Effluent Variability Study, Report 2 (May-91 and June-91), July 7, 1991; AQUA-Science, Phase II Effluent Variability Study, Report 3 (Aug-91 to Oct-91), November 26, 1991; AQUA-Science, Phase II Effluent Variability Study, Report 4 (Nov-91 and Feb-92), March 18, 1992; AQUA-Science, Phase II Effluent Variability Study, Report 5 (May-92 and June-92), July 22, 1992; AQUA-Science, Phase II Effluent Variability Study, Report 6 (Aug-92 to Nov-92), December 17, 1992; and AQUA-Science, Phase II Effluent Variability Study, Summary Report, April 12, 1993.

Table 6. Phase II and III SRWTP Ambient Toxicity to Larval Fathead Minnows

Sample Date	Cumulative Number Dead Out of 30 Animals							7-Day Mortality[1] (%)	Control Mortality (%)
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7		
12/12/90	0	0	1	1	1	1	9	**30**	10
2/5/91	0	0	0	2	3	5	6	**20**	0
5/9/91	1	1	1	1	1	8	21	**70**	7
6/14/91	0	0	0	10	17	20	21	**70**	3
8/29/91	0	0	19	20	22	24	25	**83**	3
9/25/91	0	0	0	10	22	24	25	**86**	17
10/16/91	0	0	0	0	1	4	9	**30**	0
11/19/91	0	0	0	0	0	0	1	3	3
2/11/92	0	0	5	5	7	7	7	**24**	0
5/12/92	0	0	0	0	0	0	0	0	0
6/17/92	0	0	0	1	4	4	4	13	7
8/11/92	0	0	0	0	0	0	0	0	10
8/28/92	1	1	1	2	2	2	2	7	40
10/14/92	1	1	2	2	4	4	5	17	3
11/17/92	0	0	2	2	2	2	2	7	3
11/16/93	0	0	0	0	1	2	2	7	6
2/16/94	2	2	3	9	18	29	29	**97**	7
3/25/94	0	0	7	13	14	14	14	**47**	17
5/25/94	0	0	2	9	14	15	18	**60**	7
8/17/94	0	1	1	3	3	3	3	10	2
10/19/94								3	10
2/15/95	0	0	4	9	13	14	14	**47**	5
5/23/95	0	0	2	5	5	6	6	20	9
8/15/95	0	0	0	0	0	0	0	0	22
11/14/95	0	0	0	0	0	1	1	3	7
11/28/95	0	0	2	3	3	7	9	30	9
1/16/96	0	1	4	7	11	17	17	**57**	1
2/21/96	0	0	4	11	15	17	17	**57**	1
5/21/96	0	0	0	1	3	3	7	**23**	5
6/19/96	0	0	1	1	1	2	2	7	2
8/21/96	0	3	9	14	16	20	20	**67**	8
10/16/96	0	0	1	1	1	1	1	3	2
12/11/96	0	0	0	5	23	25	25	**83**	5
2/18/97	0	0	6	12	12	15	16	**53**	5

1 7-day mortality is calculated by dividing the number of dead fish on day 7 by the number of exposed fish. Thirty fish were exposed, except for the 9/25/91 and 2/11/92 samples for which 29 fish were exposed. Bold indicates that the 7-day mortality is significantly greater than the control ($p<0.05$).

Figure 5. SRWTP Phase II -
Toxicity of Sacramento River Water to Fathead Minnows



* *Seven-day mortality significantly greater than control (p<0.05)*

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minnow mortality and growth.[29] Samples are collected quarterly during four seasons -- wet weather (December to February), low river flows (October to December), agricultural runoff (April to June), and tomato processing (July to September). Significant mortality to larval fathead minnows was found in ten of these 19 samples or 53 percent of the total. The statistically significant 7-day mortalities ranged from 20 to 97 percent. Two samples collected in January and February 1997 resulted in 47 percent and 53 percent mortality, respectively.[30] These data are plotted in Figure 6, which shows that significant mortality has occurred in January through March, May, September, and December.

All of the Phase II and III SRWTP data are summarized on Figure 7, which shows that significant mortality has occurred in all months, except April and July when no samples were collected, and in November, when none of the five samples displayed significant mortality. In contrast, both samples collected in January and all six of the samples collected in February resulted in significant mortality of larval fathead minnows.

The fathead minnow mortality data in Table 6 were analyzed to determine whether there is any correlation between river flow and toxicity. The 7-day mortality data were correlated with Sacramento River flow at Freeport (from Dayflow). The results of this analysis are shown in Figure 8. This figure shows that there is no relationship ($r^2 = 0.02$, p=0.49) between river flow and toxicity. Although most of the samples are clustered around a river flow of about 10,000 cfs, significant mortality was also present in two samples collected at flows over 40,000 cfs, suggesting that high flows do not dilute the toxicity.

The fathead minnow mortality data were also analyzed to determine whether there is any correlation between average larval fathead minnow mortality in May and June and striped bass abundance as measured by the fall midwater trawl index and the 38 mm index. Striped bass was selected for this analysis because previous toxicity testing had demonstrated that the Sacramento River is periodically toxic to striped bass, and it is the only species of concern that failed to respond to increased flows in 1995. This analysis indicates that there is no statistically significant relationship between either the midwater trawl index (r^2=0.13, p=0.55) or the 38 mm index (r^2=0.04, p=0.76) and the average May/June larval fathead minnow mortality from the SRWTP testing. This is not surprising because the SRWTP data are periodic grab samples and do not represent average mortality over the May-June period. Much more intensive sampling would have to be conducted to estimate average monthly toxicity.[31]

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29 AQUA-Science, Reports for test dates: November 16, 1993; February 16, 1994; March 25, 1994; May 25, 1994; August 17, 1994; October 19, 1994; February 15, 1995; May 23, 1995; November 14, 1995; November 28, 1995; January 16, 1996; and February 21, 1996.

30 Jeff Miller, AQUA-Science, Personal communication, March 1, 1997.

31 Phyllis Fox and Jeff Miller, Fathead Minnow Mortality in the Sacramento River, IEP Newsletter, v. 9, no. 3, Summer 1996, pp. 26-28.

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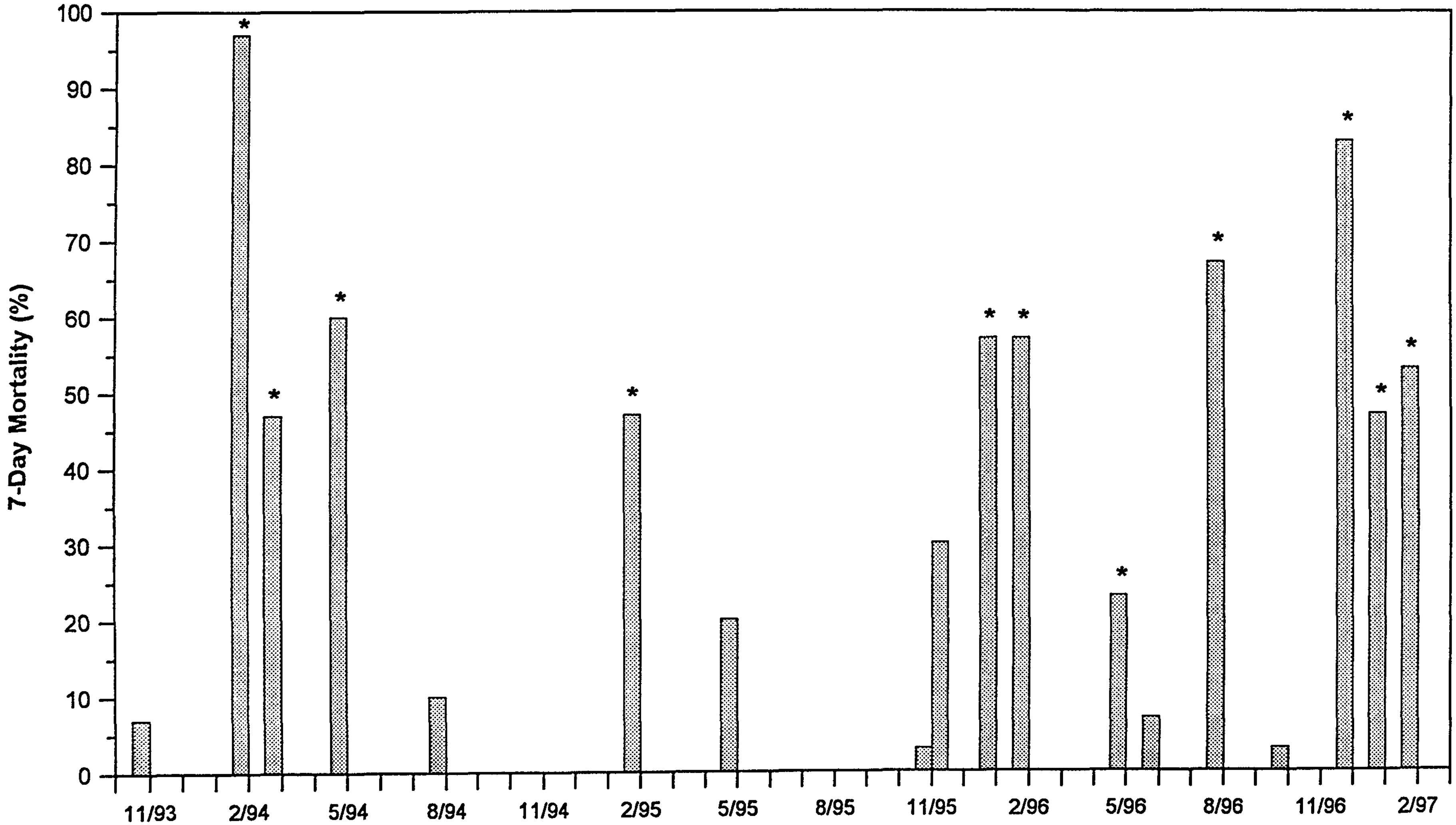
Figure 6. SRWTP Phase III - Toxicity of Sacramento River Water to Fathead Minnows



* *Seven-day mortality significantly greater than control (p<0.05)*

Figure 7. Fathead Minnow Mortality, December 1990 - February 1997

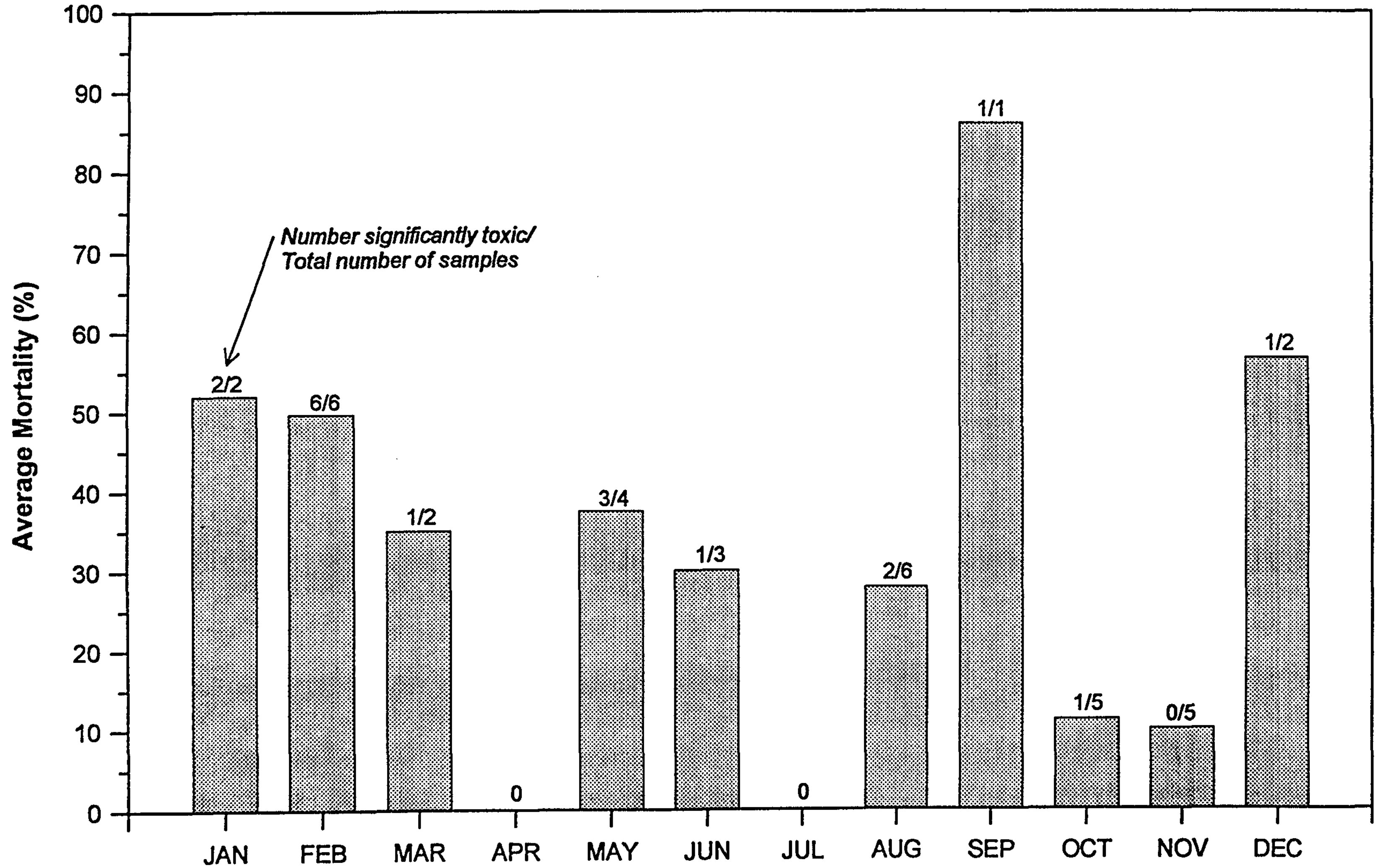
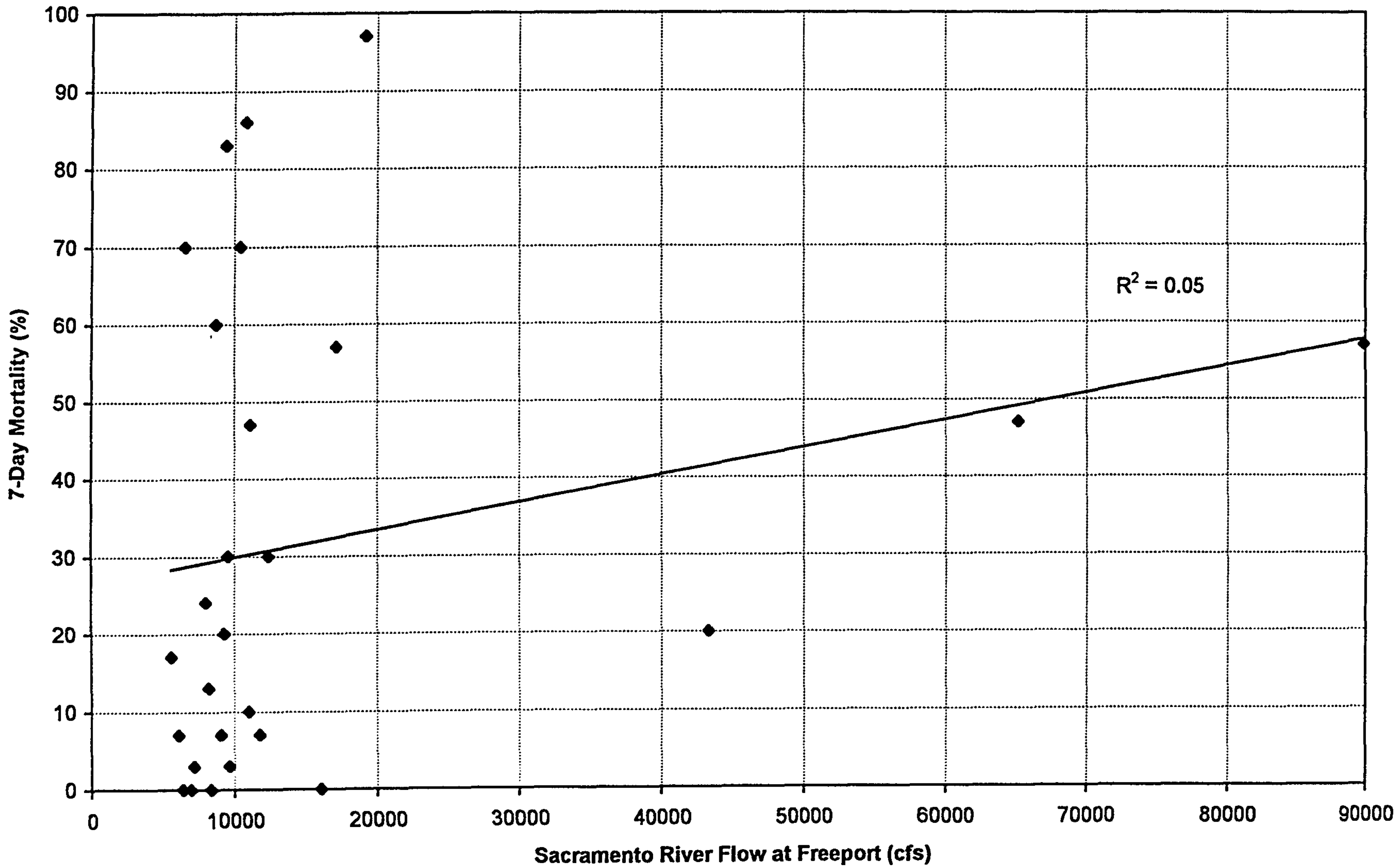


Figure 8
SRWTP Phases II and III, 12/20/90-2/21/96



Toxicity Identification Evaluation. A TIE was conducted on the February 1996 sample in an attempt to identify the toxicant. The TIE is summarized in Figure 9.[32] The sample was first treated with 3 and 8 mg/L of EDTA, a chelating agent that removes cationic metals. The higher treatment removed 100 percent of the toxicity, suggesting that a cationic metal is responsible for the toxicity. Cationic metals include positively charged metals such as cadmium, chromium, copper, nickel, and zinc. The sample was next treated with 50 and 100 µg/L of piperonyl butoxide ("PBO"),[33] which binds with metabolically activated pesticides such as the organophosphorus pesticides, preventing the formation of the toxic oxons. The 50 µg/L PBO treatment reduced the mortality from 58 percent to about 5 percent, suggesting that a metabolically activated pesticide may contribute to the toxicity. However, the higher treatment (100 µg/L) increased the toxicity compared to the lower treatment (50 µg/L). Finally, the sample was passed through an 8-carbon packed column (C-8 SPE), which removes nonpolar organics. This treatment also reduced the mortality from 58 percent to about 5 percent, suggesting that a nonpolar organic may contribute to the toxicity. The column was then eluted with methanol and the toxicity of the methanol extract tested (2x addback). The mortality following the C-8 SPE and 2x addback treatments are the same, indicating that the methanol was not able to remove the toxicant from the C-8 SPE column. Since carbaryl, diazinon, chlorpyrifos, malathion, and methidathion are eluted with methanol, these pesticides are probably not the toxin.[34]

These TIE results suggested that either all of these classes of toxicants (cationic metals, nonpolar organics, organophosphorus insecticides) were contributing to the toxicity or a single chemical with these properties was involved. It was postulated that the metallodithiocarbamate fungicides, which contain both cationic metals and organic moieties and are applied from February to mid-April when most of the toxicity has been observed, may be responsible for the toxicity, at least during that season. These include ziram, maneb, and mancozeb.

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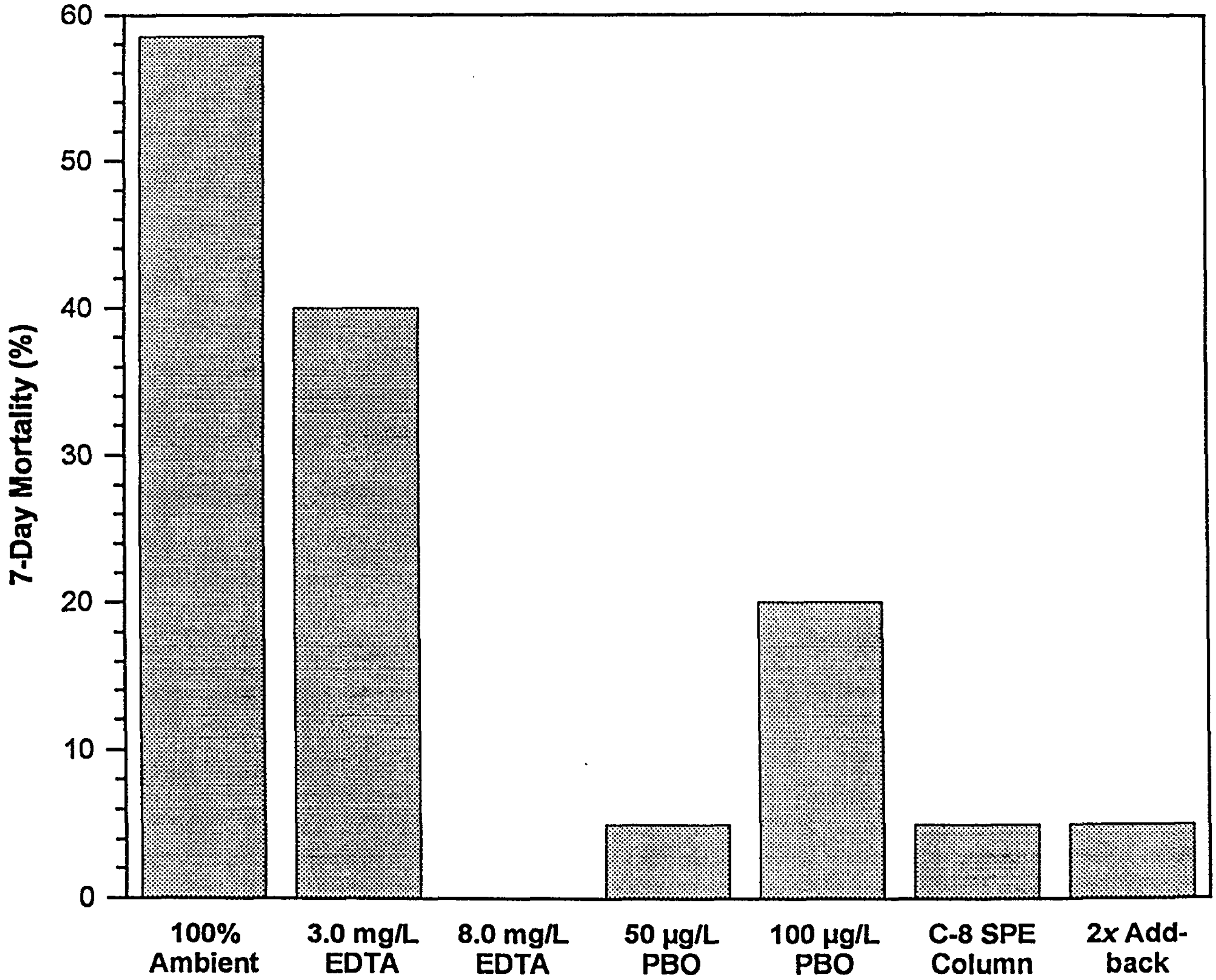
[32] Jeff Miller, AQUA-Science, Personal communication, June 5, 1996.

[33] Organophosphorus pesticides like diazinon and chlorpyrifos are not toxic until they are metabolically oxidized to their oxygen analogues or oxons. Piperonyl butoxide ("PBO") binds with organophosphorus pesticides, preventing the formation of oxons. If a water sample is toxic because of the presence of metabolically activated organophosphorus pesticides, the addition of PBO should reduce or eliminate the toxicity.

[34] K.L. Crepeau, K.M. Kuivila, and C. Foe, Modifications to the EPA Method for Aquatic Toxicity Identification Evaluations for Target Insecticides, Presentation, Northern California Society of Environmental Toxicology and Chemistry, 6th Annual Meeting, June 24-25, 1996; and Howard C. Bailey, Carol DiGiorgio, Kevin Kroll, Jeffrey L. Miller, David E. Hinton, and Gwen Starrott, Development of Procedures for Identifying Pesticide Toxicity in Ambient Waters: Carbofuran, Diazinon, Chlorpyrifos, Environmental Toxicology and Chemistry, v. 15, no. 6, 1996, pp. 837-845.

Figure 9. TIE on 2/21/96 Ambient Sample



C-030790

DPR Pesticide Use Reports indicate that approximately 1.6 million lbs. of ziram were applied in California in 1995.[35] About 74 percent was applied to almonds, which are grown extensively in Northern California. Ziram is applied to almond orchards along the Upper Sacramento River and its tributaries, the lower Feather River and along the west side of the valley in the lower basin (Figure 10). Two other metallodithiocarbamate fungicides are also used in the Central Valley, maneb (1.3 million lbs) and mancozeb (0.7 million lbs). Maneb is primarily used on almonds, lettuce, and walnuts, while mancozeb is used on potatoes, grapes, tomatoes and onions, among others. These three compounds contain either zinc (Ziram) or manganese (maneb, mancozeb).

Two follow-up Phase I TIEs were conducted using ziram at concentrations of 12.5 and 25 mg/L. Ziram is the major metallodithiocarbamate fungicide used in the Sacramento watershed. Ziram at 12.5 mg/L was treated with 3 and 8 mg/L of EDTA, 10 and 25 mg/L of sodium thiosulfate, 100 and 200 μg/L of piperonyl butoxide, and a C-8 SPE column with 2X methanol add-back. The 8 mg/L treatment with EDTA removed 100 percent of the toxicity, analogous to the February 1996 ambient sample. The 10 mg/L sodium thiosulfate treatment reduced the toxicity from 95 percent to 33 percent and the 25 mg/L treatment to 10 percent. The 100 mg/L of PBO did not reduce toxicity, comparable to the ambient sample, but the 200 mg/L treatment reduced it from 95 percent to 50 percent. A 200 mg/L dose was not tested on the ambient sample. Finally, the C-8 SPE column removed 100 percent of the toxicity, analogous to the ambient sample. However, unlike the ambient sample, the 2X methanol add-back removed 100 percent of the toxicity. This apparent discrepancy is probably due to ziram's very steep dose-response curve. These results indicate that ziram produces the same pattern of toxicity demonstrated by the river water sample.

Two 7-day larval fathead minnow chronic bioassays were completed for ziram. These studies indicate that the LC50 for survival ranges from 3.3 to 7.0 μg/L and for growth from 3.2 to 7.8 μg/L. The NOEC for survival ranges from 1 to 5.6 μg/L and for growth is 1 μg/L.[36] Toxicity data from the U.S. EPA AQUIRE database suggest that fathead minnows are one of the more sensitive species to ziram. Ziram LC50s reported in that database are: common carp - 2.28 mg/L; rainbow trout - 0.27 - 1.7 mg/L; guppy - 0.75 mg/L; channel catfish - 0.50 mg/L; fathead minnows - 0.008 - 0.25 mg/L; and bluegill - 0.0097 μg/L.

Additional TIEs were conducted for CUWA on two samples collected from the Freeport Marina in February 1997, one sample collected from Red Bluff, and one sample collected from the American River at Discovery Park. The results were similar to those described above for the

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35 DPR, Pesticide Use Report, Annual 1995, Indexed by Chemical, December 1996.

36 Jeff Miller, Glenn Miller, and Phyllis Fox, Identification of the Causes of Fathead Minnow, Toxicity in the Sacramento River Watershed - Role of Metallodithiocarbamate Fungicides, Proposal Submitted to the IEP Contaminant Project Work Team, January 1997 and presentation to Contaminant PWT on February 4, 1997.

C-030791

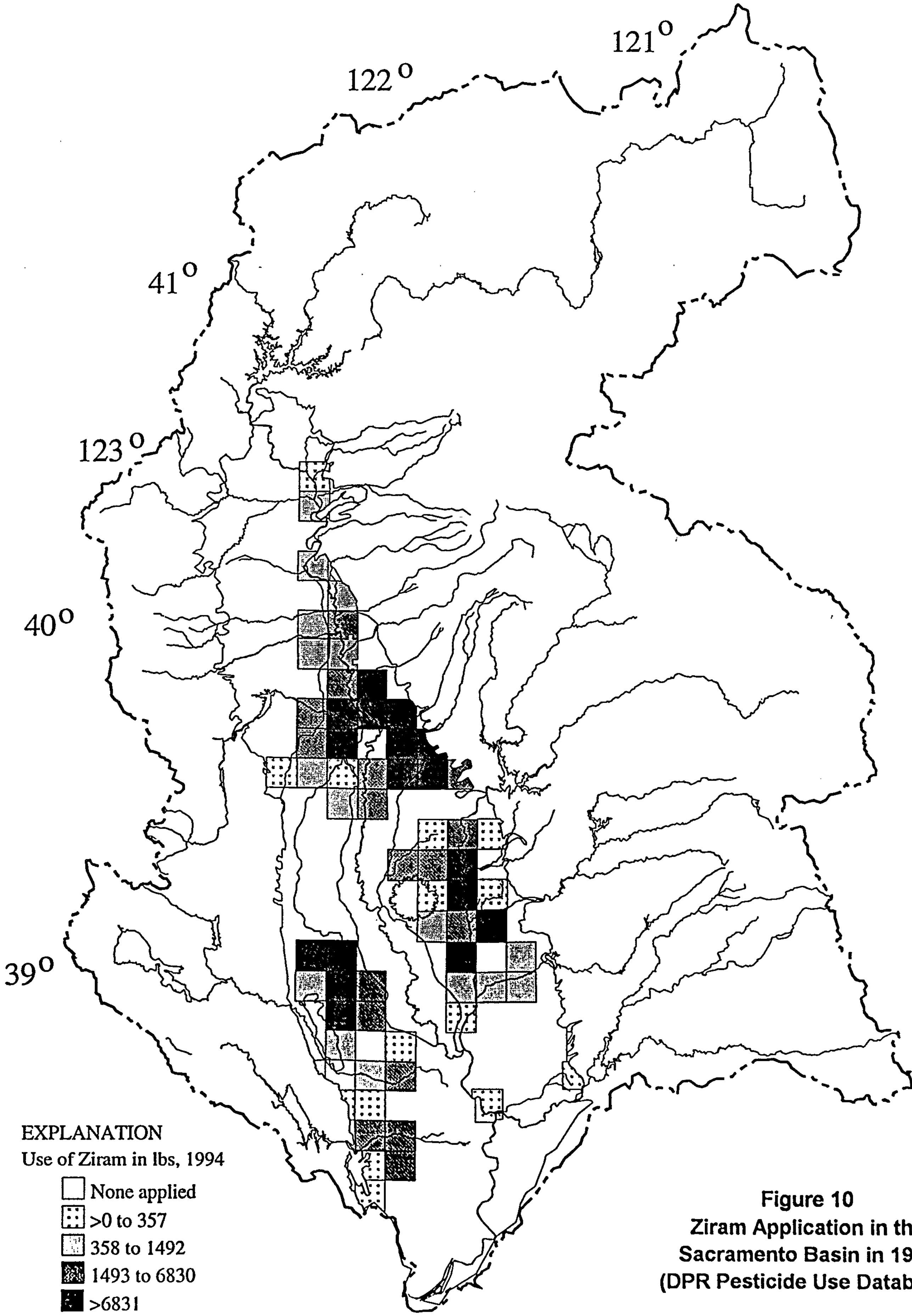

Figure 10
Ziram Application in the Sacramento Basin in 1994
(DPR Pesticide Use Database)

C-030792

SRWTP Freeport Marina samples and suggest that the toxicity was due to non-polar organics possibly in combination with cationic metals, or alternatively, to one or more toxicants with both cationic and organic properties,[37] such as the metallodithiocarbamate fungicides.

Salmon Toxicity. In additional work funded by CUWA, ambient samples from the Sacramento River at the Freeport Marina were tested in parallel bioassays using larval fathead minnows and swim-up fry (Tests 1-3, 5) or sac-fry (Test 4) chinook salmon from the Mokelumne River (Test 1) or Nimbus (Tests 2-5) Hatcheries. Tests were 7-day, 24-hr renewal (except Test 1 for salmon, which was 48 hr) survival and growth bioassays using standard U.S. EPA protocols. This study indicates that salmon are less sensitive to the toxicant than fathead minnows. Statistically significant fathead minnow mortality (31-83 percent) and reduced growth were observed in the December, January, and one February test. Reduced fathead minnow growth was also observed in a second February test. No salmon mortality or reduced growth was found in any of the tests (Table 7). This is consistent with the hypothesis that ziram is the toxicant because salmonids are far less sensitive to ziram than fathead minnows based on the AQUIRE data reported above. However, it is also possible that the study design, including timing of sample collection, duration of exposure and end points, may not have been appropriate to detect toxic effects in salmon. Salmon, for example, have a much longer life span than fathead minnows and may require a longer exposure to produce detectable effects. The authors concluded that "additional studies, using more rigorous study designs, will be needed before it can be concluded that toxicants in the river water samples which affected fathead minnow survival do not cause adverse effects to salmon."[38]

In sum, since 1990, 51 percent of the samples from the Sacramento River below Sacramento have been toxic to larval fathead minnows. Eighteen out of 35 samples collected between December 1990 and February 1997 caused significant fathead minnow mortality, killing from 20 to 97 percent of the exposed fish. Based on tabulations of LC50s, most other fish appear to be more sensitive to chemicals than fathead minnows. However, fathead minnows are more sensitive to ziram, the possible toxicant. Further studies are needed to definitively identify the toxicant(s).

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[37] Memorandum from J.L. Miller, AQUA-Science, to Elaine Archibald, CUWA, Re: TIE update, July 19, 1997.

[38] AQUA-Science, Comparative 7-Day Toxicity of Sacramento River Water to Larval Fathead Minnows and Larval Chinook Salmon, Draft Report, April 1, 1997.

Table 7. Summary of Swim-up Chinook Salmon and Larval Fathead Minnow Bioassays with Sacramento River at Freeport Marina Samples[1]

Test Date	Larval Fathead Mortality (%) (mean weight of fish (mg))		Chinook Salmon Mortality (%) (mean weight of fish (mg))	
	Control	River	Control	River
12/11/96	10 0.363±0.025	83* 0.047±0.050	0 NT	0 NT
1/22/97	0 0.355±0.013	48* 0.143±0.032	0 348.5±16.2	0 332.6±10.9
2/20/97	3 0.332±0.018	31* 0.243±0.043	0 NT	3 NT
2/27/97	0 0.359±0.013	7 0.306±0.024*	0 NT	0 NT
3/6/97	3 0.325±0.022	25 0.254±0.075	0 NT	0 NT

1 AQUA-Science, 1997.
* Significantly different from controls
NT = Not tested

2.1.2 Sediments

2.1.2.1 DFG Rice Pesticide Studies

The DFG monitored molinate concentrations in sediments collected from the Colusa Basin Drain on June 18 and September 9, 1980. On June 18, molinate ranged from 170 to 2,040 μg/kg in sediments and on September 9, molinate was not detected.[39]

2.1.2.2 Toxicity Studies

Two reconnaissance studies of sediment toxicity have been conducted in the Sacramento Basin. In 1992, the DFG assayed sediment toxicity at two locations using the ASTM 10-day Hyalella azteca bulk sediment test. They found 0 to 12 percent mortality at three sites in Whiskeytown Reservoir and 5 percent mortality at one site in Keswick Reservoir that was unaffected by Iron Mountain Mine and Spring Creek discharges. Mortalities were not significantly different from controls, which had no mortality.[40] As discussed below, the DFG subsequently conducted a detailed study of sites in Keswick Reservoir that were affected by acid-mine drainage.

Pacific Eco-Risk Laboratories and the CVRWQCB measured sediment toxicity at five sites in the Sacramento Basin. Toxicity was assayed using the Hyalella test for bulk sediments and the three-brood Ceriodaphnia test for sediment elutriates and site water. Elutriates were prepared from site water, and when site water was toxic, with control water (well water). The sites tested are Cache Creek (affected by agricultural and mine drainage), Sacramento Sump 111 (urban runoff from a light industrial area), Folsom Reservoir (designated a "pristine" control site by the authors), Colusa Basin Drain (rice drainage), and Sacramento Slough (rice drainage). Samples were collected in June and July 1995.

Sediment toxicity was significantly different from controls only in samples collected from Sacramento Sump 111 and Sacramento Slough. In eight replicate Hyalella tests of bulk sediments from Sacramento Sump 111, 72 percent mortality was found. The overlying site water resulted in 100 Ceriodaphnia mortality, while the sediment elutriate prepared with control water resulted in only 15 percent mortality. The CVRWQCB also reported that stormwater runoff from Sump 111 was toxic to Ceriodaphnia and concluded based on TIEs that the toxicity was due to diazinon (Sec. 2.2.2). Eight sediment samples collected from Sacramento Slough resulted in 20 percent mortality in the bulk Hyalella test. No Ceriodaphnia mortality occurred in the elutriate and overlying water from Sacramento Slough. However, Ceriodaphnia reproduction was significantly

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[39] B.J. Finlayson, J.L. Nelson, and T.L. Lew, Colusa Basin Drain and Reclamation Slough Monitoring Studies, 1980 and 1981, DFG Administrative Report 82-3, 1982, Table 2.

[40] Bob Fujimura, Freshwater Sediment Toxicity, Presentation to the IEP Contaminant PWT, November 1, 1996.

reduced in both elutriate and overlying water compared to controls. Colusa Basin Drain overlying site water also significantly reduced the reproduction of Ceriodaphnia, but not the sediment elutriate.[41]

Keswick Reservoir receives metal-laden acid-mine drainage from abandoned mines in the Spring Creek watershed. Metal-rich precipitates have accumulated as sediment in the Spring Creek Arm of the Reservoir. These sediments are suspended during reservoir and powerplant operations, potentially impacting aquatic resources within the Reservoir and downstream along the upper Sacramento River.

Bulk sediments were collected from 16 sites in 1993 and four sites in 1994. Sediment samples were analyzed for metals (Fe, Al, Cu, Zn, Cd) and tested for toxicity using 10-day tests with the amphipod Hyalella azteca. Elutriate waters, prepared by mixing 50 to 80 g of the upper 18 inches of each sediment core with 200 to 320 g of spring water, were tested in 96-hr static bioassays for acute toxicity to Ceriodaphnia and swim-up fry rainbow trout; in 48-hr bioassays for acute toxicity to swim-up fry chinook salmon (static), larval fathead minnows (static renewal), and Ceriodaphnia (range tests to check LC50s from 96-hr tests); and in 7-day static renewal tests for chronic toxicity to Ceriodaphnia and larval fathead minnow.

The toxicity tests on bulk sediments showed that all of the sites in the Spring Creek Arm of Keswick Reservoir (11 sites) had significant toxicity to Hyalella with a mean mortality of 58 percent. Some toxicity (77 percent mean mortality) was also observed downstream of the Spring Creek Arm (3 sites, 2 toxic), but little toxicity (26 percent mean mortality) was associated with sediments collected upstream (2 sites, 1 toxic).

Sediment elutriate waters from all of the sites in the Spring Creek Arm resulted in 100 percent mortality to Ceriodaphnia in the 96-hr acute tests. The LC50 for the elutriate waters varied from 2.2 to 39 percent. Less mortality was observed in downstream elutriates (63 percent; 3 sites, 1 toxic) and upstream elutriates (62 percent, 2 sites, 1 toxic). Ceriodaphnia survival and reproduction were significantly reduced compared to controls at two sites in the Spring Creek Arm (#524, 505) and reproduction only was significantly reduced at a third site (#519).

A similar pattern of acute toxicity was observed for rainbow trout fry in the 96-hr acute tests. Sediment elutriate waters from all sites except one in the Spring Creek Arm resulted in 100 percent mortality. The LC50 values ranged from 6.9 to >50 percent. Less mortality was observed in downstream elutriates (62 percent; 3 sites, 1 toxic) and upstream elutriates (50 percent; 2 sites, 1 toxic). Significant acute toxicity to chinook salmon fry and larval fathead minnows was also found in the 48-hr acute tests. Larval fathead minnow survival, but not growth, was significantly reduced at the only site tested (#524).

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[41] Scott Ogle, Jeffrey Costifas, Christopher Foe, Valerie Connor, Linda Deanovic, Tom Kimball, and Emilie Reyes, A Preliminary Survey of Sediment Toxicity in California's Central Valley, Draft Pacific Eco-Risk Laboratories Report, August 1996.

Trace metal concentrations in sediment were generally high, with levels ranging up to 400,000 µg/g for iron, 87,500 µg/g for aluminum, 4,800 µg/g for copper, 1,600 µg/g for zinc, and 11 µg/g for cadmium. Toxicity of the undiluted elutriate waters from Spring Creek Arm sediments appeared to be associated with one or more of the metals. Dissolved zinc concentrations in elutriate waters greatly exceeded the 96-hr LC50 values for rainbow trout and Ceriodaphnia and approached or exceeded the 96-hr LC50 values for cadmium to rainbow trout.[42]

2.1.3 Biota

2.1.3.1 DFG Fish Kill Reports

Since 1965, the DFG has inventoried fish and wildlife losses due to pesticides throughout the State. Normally, fish kills are reported by members of the public to local game wardens, who conduct field investigations to determine the cause of the incidents. At the end of each year, these are compiled by region at the Fish and Wildlife Water Pollution Control Laboratory in Rancho Cordova and reported to the DPR. These reports typically contain the county and location (name of water body) where the kill occurred, the date of the kill, the name of the responsible pesticide, and the number and species of fish (or wildlife) that was killed. Some of the reports also contain information on other causes of kills (e.g., low dissolved oxygen, ammonia, chlorine, sewage, fuel spills).[43]

These reports indicate that in the 1960s through the 1980s, thousands of fish were typically killed annually from the application of pesticides in the Sacramento Basin, ranging from 100 fish in 1983 to 65,277 in 1967. Those who report and compile these reports generally believe that they are underestimates, because many fish kills are not reported, and among those that are, the game warden frequently arrives after the evidence has been removed by scavengers and it is not possible to inventory the damage. The most commonly reported pesticides causing fish kills are DDT, toxaphene, chlordane, acrolein (magnacide), endosulfan (thiodan), and copper compounds.

Most of these pesticides have been banned (DDT, toxaphene, chlordane) or restricted (acrolein, endosulfan). Acrolein, which is an herbicide and algicide injected directly into water to control submerged and floating weeds in irrigation ditches and canals, can only be used in canals which end at the field and thus would normally not support fish life. Endosulfan, an insecticide

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[42] Robert W. Fujimura, Charlie Huang, and Brian Finlayson, Chemical and Toxicological Characterization of Keswick Reservoir Sediments, Final Report to State Water Resources Control Board, March 31, 1995.

[43] DFG, Fish and Wildlife Losses Due to Pesticides and Pollution, 1970 - 1980; DFG, Fish and Wildlife Losses in California, 1981 - 1988; DFG, Pollution-Caused Fish and Wildlife Losses in California, 1989 - 1990; DFG, Fish and Wildlife Losses Due to Pesticides, 1991 - 1993; Report of Fish and Wildlife Incidents Involving Pesticides, 1994 - 1996.

used for vegetable crops, is currently restricted to use only in the Imperial Valley. As a result of these bans and restrictions, the number of fish kills reported in the 1990s has generally declined and currently number in the hundreds (Table 8).

2.1.3.2 SWRCB Toxic Substances Monitoring Program

Since 1978, the SWRCB has monitored pesticides, pesticide ingredients, and pesticide byproducts in fish from up to 44 stations in the Sacramento Basin, including four on the American River, eight on the Feather River, two on the Sacramento River, one on the Yuba River, eight on agricultural drains, and two on urban drains. The analyses were performed on either muscle tissue (filet), or when only very small fish were available, on a whole body composite. Over 50 percent of the samples were four species -- carp, channel catfish, white catfish, and largemouth bass. The minimum and maximum detected values are summarized in Table 9.[44]

Pesticides were detected in fish from 32 of the 44 stations. However, they were generally detected less frequently and concentrations were lower than in the San Joaquin Basin (Sec. 4.1.3). The most frequently detected pesticides and pesticide ingredients were DDT (5 - 1,358 µg/kg), dieldrin (5.1 - 40 µg/kg), PCBs (50 - 7,700 µg/kg), chlordane (5 - 184.6 µg/kg), toxaphene (100 - 890 µg/kg), and endosulfan (6.3 - 266 µg/kg). All of these compounds are no longer registered for general use in California. PCBs were used as pesticide ingredients until 1970. The concentrations of the most frequently detected pesticides were plotted against time and the graphs visually inspected to determine if there were any trends in the data. Generally, the concentrations of DDT, PCBs, toxaphene, and dieldrin have declined since 1978, endosulfan has increased, and chlordane has not changed.

Other pesticides and pesticide breakdown products that were detected include aldrin (in one sample), chlorpyrifos (in one sample), dacthal[45] (in seven samples), dicofol (in one sample), dichlorobenzophenone ("DBP") (in one sample), hexachlorocyclohexane ("HCH") (in seven samples), hexachlorobenzene (in four samples), and methyl parathion (in one sample). DBP is a breakdown product of dicofol. Aldrin, dieldrin, HCH, and hexachlorobenzene are no longer registered for use in California.

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[44] The data were obtained from the SWRCB electronic bulletin board (916-657-9722) in a file called TSM.LOTUS.ZIP. The data have also been published as follows: SWRCB, Toxic Substances Monitoring Program. Ten Year Summary Report 1978-1987, Report 90-1WQ, August 1990; SWRCB, Toxic Substances Monitoring Program 1988-89, Report 91-1 WQ, June 1991; SWRCB, Toxic Substances Monitoring Program. 1990 Data Report, Report 92-1 WQ, May 1992; and SWRCB, Toxic Substances Monitoring Program 1991 Data Report, Report 93-1WQ, June 1993.

[45] Dacthal and DCPA are synonymous.

Table 8. Fish Kills by Pesticides in the Sacramento Basin, 1965-1996

Year	No. of Fish Killed	Fish Species Killed	Responsible Pesticide	County
1965	250	Black bass	Unknown	Sutter
1965	250	Bluegill	Herbicide	Butte
1965	250	Brown trout	Herbicide	El Dorado
1965	1,000+	Carp	Herbicide	Butte
1965	1,000+	Carp	Unknown	Glenn
1965	25	Catfish	Herbicide	Butte
1965	25	Catfish	Unknown	Glenn
1965	250	Channel catfish	Unknown	Sutter
1965	1,000+	Hitch	Herbicide	Butte
1965	750	Rainbow trout	Herbicide	El Dorado
1966	1,500	Bluegill	Chlorazine	El Dorado
1966	5,000+	Carp, bass, perch, crappie	Unknown	Sacramento
1966	250	Hardheads	Xylene (herbicide)	Solano
1966	25-30,000	Minnows	Dibron	Butte
1966	250	Minnows	Xylene (herbicide)	Solano
1966	750	Suckers	Xylene (herbicide)	Solano
1966	unknown	Trout	Chlorazine	El Dorado
1967	10,000+	Asstd. striped cyprinids	DDT	Colusa-Yolo
1967	10,000+	Black bass	DDT	Colusa-Yolo
1967	250	Black bass	Toxaphene, DDT	Sutter
1967	10,000+	Bluegill	DDT	Colusa-Yolo
1967	25	Bluegill	DDT	Glenn
1967	25	Bullhead	DDT	Glenn
1967	10,000+	Carp	DDT	Colusa-Yolo
1967	1,000+	Carp	DDT	Glenn
1967	25	Crappie	DDT	Glenn
1967	500	Largemouth bass	DDT	Colusa-Yolo
1967	450	Largemouth bass	Toxaphene, DDT	Sutter
1967	1,000+	Non-game	Toxaphene, DDT	Sutter
1967	2	Striped bass	Chlorinated hydrocarbons	Sacramento
1967	1,000+	Sunfish	DDT	Colusa-Yolo
1967	1,000+	Sunfish	Toxaphene, DDT	Sutter
1967	20,000	Trash fish	Toxaphene, DDT	Sutter
1967	unknown	Warmwater game fish	Unknown (aerial spray)	Tehama
1968	75+	Bass	Parathion	Butte
1968	75+	Bluegill	Herbicide	Yolo
1968	1,150+	Brown trout	Copper sulfate	Nevada
1968	unknown	Carp	Herbicide	Solano
1968	1,000+	Carp	Herbicide	Yolo
1968	500	Carp	Unknown	Yolo
1968	2,000	Carp	Unknown	Solano
1968	1,000+	Catfish	Herbicide	Yolo
1968	1	Catfish	Parathion	Butte
1968	18	Catfish	Unknown	Yolo
1968	50	Catfish	Unknown	Solano
1968	250+	Fingerlings	Parathion	Butte

Table 8. Fish Kills by Pesticides in the Sacramento Basin, 1965-1996

Year	No. of Fish Killed	Fish Species Killed	Responsible Pesticide	County
1968	17	Green sunfish	Unknown	Yolo
1968	1,000+	Hardhead	Herbicide	Yolo
1968	unknown	Hitch minnows	Herbicide	Solano
1968	25+	Minnows	Parathion	Butte
1968	unknown	Mosquito fish	Herbicide	Solano
1968	1,000+	Suckers	Herbicide	Yolo
1968	500	Suckers	Unknown	Solano
1968	unknown	Sunfish	Herbicide	Solano
1968	6	Sunfish	Parathion	Butte
1968	75+	Trout	Unknown	El Dorado
1968	1,000+	Unknown	Unknown	Colusa
1969	250	Bass	Toxaphene, DDT	Tehama
1969	400	Black bass	Toxaphene, DDT	Butte
1969	300	Bluegill	Toxaphene, DDT	Butte
1969	250	Bluegill	Toxaphene, DDT, Disyston	Glenn
1969	250	Bluegill	Weed killer	El Dorado
1969	1,000+	Carp	Toxaphene, DDT	Butte
1969	10,000+	Carp	Toxaphene, DDT, Disyston	Glenn
1969	unknown	Carp	Weed oil herbicide	Solano
1969	750	Carp	Xylene (herbicide)	Solano
1969	250	Catfish	Toxaphene, DDT, Disyston	Glenn
1969	250	Catfish	Weed killer	El Dorado
1969	1,000+	Chub	Toxaphene, DDT	Butte
1969	25	Crayfish	Xylene (herbicide)	Solano
1969	750	Hitch	Xylene (herbicide)	Solano
1969	unknown	Hitch minnows	Weed oil herbicide	Solano
1969	300	Perch	Toxaphene, DDT	Butte
1969	250	Perch	Toxaphene, DDT, Disyston	Glenn
1969	250	Rough fish	Toxaphene, DDT	Tehama
1969	55	Salmonids	Aqualin (acrolein)	Shasta
1969	200	Steelhead trout	Aqualin (acrolein)	Shasta
1969	25	Sunfish	Toxaphene, DDT	Tehama
1969	unknown	Sunfish & Mosquito fish	Weed oil herbicide	Solano
1970	100	Bass	Unknown - polyram	Lassen
1970	50	Black bass	Unknown pesticide	Tehama
1970	50	Carp	Unknown pesticide	Tehama
1970	50	Catfish	Unknown pesticide	Tehama
1970	100	Perch	Unknown - polyram	Lassen
1970	1,000	Shad	Unknown pesticide	Tehama
1970	200	Suckers	Unknown - polyram	Lassen
1971	50	Black bass	Unknown pesticide	Yolo-Colusa
1971	500	Bluegill	Hydrothal	Butte
1971	5,000	Bluegill	Parathion, 7-4D	Glenn
1971	25	Bluegill	Thiodan (aerial drift)	Yolo
1971	50	Bluegill	Toxaphene	Yolo
1971	1,000	Carp	Hydrothal	Butte

Table 8. Fish Kills by Pesticides in the Sacramento Basin, 1965-1996

Year	No. of Fish Killed	Fish Species Killed	Responsible Pesticide	County
1971	50	Carp	Socal w/ #3501	Butte
1971	2,000	Carp	Thiodan (aerial drift)	Yolo
1971	500	Carp	Toxaphene	Yolo
1971	1,000	Carp	Unknown pesticide	Yolo-Colusa
1971	500	Carp	Unknown pesticide	Solano
1971	100	Catfish	Hydrothal	Butte
1971	100+	Catfish	Parathion, 7-4D	Glenn
1971	50	Catfish	Socal w/ #3501	Butte
1971	10	Catfish	Thiodan (aerial drift)	Yolo
1971	50	Catfish	Unknown pesticide	Yolo-Colusa
1971	50	Crappie	Unknown pesticide	Yolo-Colusa
1971	1,000	Crayfish	Socal w/ #3501	Butte
1972	50	Bluegill	Unknown	Butte
1972	6	Carp	Magnacide H	Yolo
1972	1,000	Carp	Unknown	Butte
1972	2	Catfish	Magnacide H	Yolo
1972	50	Catfish	Unknown	Butte
1973	50	Bluegill	Chlorodane, Dibromo	Napa
1973	50	Carp	Chlorodane, Dibromo	Napa
1973	1,000	Carp	Toxaphene, Thiodan, Dylox	Glenn
1973	12	Carp & Squawfish	Chlorodane, Dibromo	Napa
1973	unknown	Catfish	Toxaphene, Thiodan, Dylox	Glenn
1973	50	Green sunfish	Chlorodane, Dibromo	Napa
1973	1,000	Shiners	Chlorodane, Dibromo	Napa
1973	100	Squawfish	Chlorodane, Dibromo	Napa
1973	50	Steelhead	Chlorodane, Dibromo	Napa
1973	100	Sunfish	Toxaphene, Thiodan, Dylox	Glenn
1973	100	Tadpoles & crayfish	Chlorodane, Dibromo	Napa
1973	50	Trout or steelhead	Unknown	Shasta
1974	NR	-	-	-
1975	6	Catfish	Xylene B pesticide	Solano
1975	70	Sacramento pike, Carp, Suckers	Xylene B pesticide	Solano
1976	100	Bluegill	Lanate	Yolo
1976	50	Bluegill	Magnacide H (acrolein)	Tehama
1976	100	Brown bullhead	Magnacide H	Siskiyou
1976	50	Brown bullhead	Magnacide H (acrolein)	Tehama
1976	400	Carp	Lanate	Yolo
1976	200	Channel catfish	Lanate	Yolo
1976	50	Green sunfish	Magnacide H	Siskiyou
1976	50	Japanese smelt	Magnacide H	Siskiyou
1976	1,000	King salmon	Magnacide H (acrolein)	Tehama
1976	1,000	Steelhead	Magnacide H	Siskiyou
1976	10,000	Stickleback	Magnacide H (acrolein)	Tehama
1976	50	Suckers	Magnacide H	Siskiyou
1977	875	Black bass	BiBrom-Toxaphene	Sacramento
1977	1,750	Carp	BiBrom-Toxaphene	Sacramento

Table 8. Fish Kills by Pesticides in the Sacramento Basin, 1965-1996

Year	No. of Fish Killed	Fish Species Killed	Responsible Pesticide	County
1977	875	Catfish	BiBrom-Toxaphene	Sacramento
1977	875	Crappie	BiBrom-Toxaphene	Sacramento
1977	2,625	Sunfish	BiBrom-Toxaphene	Sacramento
1978	101-500	Carp	Unknown	Solano
1978	20-30,000	Carp	Unknown pesticide	Yolo
1978	1-50	Crayfish	Unknown	Solano
1978	50	Hardhead	Unknown pesticide	Yolo
1978	1-50	Perch	Unknown	Solano
1979	1-50	Steelhead	Guthion & "Supreme Oil"	Solano
1979	101-500	Suckers	Guthion & "Supreme Oil"	Solano
1980	1-50	"Other"	Herbicide or pesticide	Sutter
1980	1-50	Black bass	Herbicide or pesticide	Sutter
1980	1-50	Bluegill/perch	Unknown herbicide	Yuba
1980	51-100	Carp	Herbicide or pesticide	Sutter
1980	10,000+	Carp	Unknown pesticide	Sutter
1980	501-1,000	Crayfish	Unknown herbicide	Yuba
1980	1-50	Dace	Herbicide or pesticide	Sutter
1980	1,000+	Goldfish	Unknown pesticide	Sutter
1980	1,000+	Miscellaneous fish	Unknown pesticide	Sutter
1981	<50	Bluegill	Magnacide H (acrolein)	Colusa
1981	1,000+	Carp	Magnacide H (acrolein)	Colusa
1981	1,500	Carp	Manzate or Thiodan	Sutter
1981	<500	Catfish	Magnacide H (acrolein)	Colusa
1981	1,500	Catfish	Manzate or Thiodan	Sutter
1981	1,000	Crappie	Manzate or Thiodan	Sutter
1982	<50	Brown trout	Diazinon & Malathion	Siskiyou
1982	<500	Brown trout	Magnacide H (acrolein)	Shasta
1982	<500	Brown trout	Unknown pesticide	Butte
1982	13,200	Carp	Molinate	Yolo-Colusa
1982	<500	Carp	Thiodan	Yolo
1982	1,000+	Catfish	Thiodan	Yolo
1982	1,000	Channel catfish	Molinate	Yolo-Colusa
1982	27,500	King salmon	Magnacide H (acrolein)	Tehama
1982	1,000+	Non-game fish	Magnacide H (acrolein)	Shasta
1982	1,000+	Non-game fish	Magnacide H (acrolein)	Shasta
1982	<500	Rainbow trout	Magnacide H (acrolein)	Shasta
1982	<500	Rainbow trout	Unknown pesticide	Butte
1982	1,000+	Squawfish	Magnacide H (acrolein)	Shasta
1982	100	Steelhead	Magnacide H (acrolein)	Tehama
1982	<500	Striped bass	Thiodan	Yolo
1982	1,000+	Tui chub	Magnacide H (acrolein)	Shasta
1983	20	Black bass	Copper sulfate	Sacramento
1983	30	Brown bullhead	Copper sulfate	Sacramento
1983	50	Carp	Copper sulfate	Sacramento
1984	NR	-	-	-
1985	50	Bluegill	Magnacide H (acrolein)	Shasta

Table 8. Fish Kills by Pesticides in the Sacramento Basin, 1965-1996

Year	No. of Fish Killed	Fish Species Killed	Responsible Pesticide	County
1985	250	Carp & Suckers	Copper sulfate	Glenn
1985	2,350	Rainbow trout	Magnacide H (acrolein)	Shasta
1985	1,000	Sacramento sucker	Magnacide H (acrolein)	Shasta
1985	500	Squawfish/Hardhead	Magnacide H (acrolein)	Shasta
1986	100+	Carp	Unknown pesticide	Stanislaus
1986	100+	Catfish	Unknown pesticide	Stanislaus
1986	1000+	Shad	Unknown pesticide	Stanislaus
1986	50+	Striped bass	Unknown pesticide	Stanislaus
1987	10	Lamprey	Magnacide H (acrolein)	Tehama
1987	10	Lamprey	Magnacide H (acrolein)	Tehama
1987	10,000+	Sculpin	Magnacide H (acrolein)	Tehama
1987	10+	Sculpin	Magnacide H (acrolein)	Tehama
1987	20	Squawfish	Magnacide H (acrolein)	Tehama
1987	20	Squawfish/Hardhead	Magnacide H (acrolein)	Tehama
1987	5	Tule perch	Magnacide H (acrolein)	Tehama
1987	5	Tule perch	Magnacide H (acrolein)	Tehama
1988	75	Bullhead/Catfish/Bluegill	Magnacide H (acrolein)	Tehama
1988	8,000	Chinook salmon	Magnacide H (acrolein)	Tehama
1988	28	Rainbow trout	Magnacide H (acrolein)	Tehama
1988	3,000	Squawfish/Sticklebacks	Magnacide H (acrolein)	Tehama
1989	NR	-	-	-
1990	NR	-	-	-
1991	30+	Catfish	Copper	Solano
1991	numerous	Mosquito fish	Copper	Solano
1991	1,000+	Trout, Sucker, Squawfish, Sculpin	Metam-sodium	Siskiyou/Shasta
1992	NR	-	-	-
1993	NR	-	-	-
1994	6	Catfish	Acrolein	Nevada
1994	unknown	Largemouth Bass	Acrolein	Nevada
1994	50	Sunfish	Acrolein	Nevada
1995	100+	Catfish	Chlorine	Sacramento
1995	100	Rainbow trout	Copper	Nevada
1996	200	Rainbow trout	Endosulfan	Placer

JR = None Reported

Table 9. Pesticides, Pesticide Ingredients, and their Byproducts in Fish (µg/Kg wet weight) from the Sacramento Basin, 1978-1993.[1]

STATION	Aldrin		Total Chlordane		Chlorpyrifos		Dacthal		Total DDT	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
American River/d/s Highway 160 Bridge	nd	nd	47.7	188	nd	nd	nd	nd	102	500
American River/d/s Watt Avenue Bridge	nd	nd	5.8	185	nd	nd	nd	nd	6	312
American River/So Fork/Highway 49	nd	nd	nd	nd	nd	nd	nd	nd	10	10
Arcade Creek/u/s Marysville Blvd	nd	nd	7.8	7.8	nd	nd	nd	nd	7.2	7.2
Bounde Creek/Norman-Princeton Road	nd	nd	nd	nd	nd	nd	nd	nd	98	100
Bullards Bar Res/Willow Cr	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Butte Creek/Colusa Highway	nd	nd	nd	nd	nd	nd	nd	nd	34	34
Cache Creek	nd	nd	nd	nd	nd	nd	nd	nd	13	48
Central Drain/Norman-Princeton Road	nd	nd	nd	nd	nd	nd	nd	nd	107	107
Clear Lake/Rattlesnake Isle	nd	nd	nd	nd	nd	nd	nd	nd	26	26
Colusa Drain/Abel Road	nd	nd	12	36	nd	nd	6	36	96	623
Colusa Drain/Knights Landing	15	15	5.7	40.9	nd	nd	8	8	39	895
Colusa Drain/Yolo-Colusa County Line	nd	nd	nd	nd	nd	nd	nd	nd	212	212
Fall River	nd	nd	nd	nd	nd	nd	nd	nd	8.9	8.9
Feather River/d/s Highway 99 Bridge	nd	nd	30.5	66.4	nd	nd	nd	nd	11	865
Feather River/Gridley	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Feather River/So Fork/Forbestown	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Feather River/So Fork/Woodleaf	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Folsom Lake	nd	nd	nd	nd	nd	nd	nd	nd	5	5
Logan Creek/Norman-Princeton Road	nd	nd	nd	nd	nd	nd	nd	nd	214	214
Natomas E Main Drain/d/s W El Camino Ave	nd	nd	29	72	nd	nd	14	19	35	126
Natomas East Main Drain/Arcade Creek	nd	nd	nd	nd	nd	nd	nd	nd	9.3	9.3
Pit River/Pit 7 Powerhouse	nd	nd	nd	nd	nd	nd	nd	nd	56	56
Putah Creek	nd	nd	nd	nd	nd	nd	nd	nd	8	11
Reclamation Slough	nd	nd	8	49	nd	nd	nd	nd	63	1,358
Sacramento River/Hamilton City	nd	nd	5	5	nd	nd	nd	nd	69	69
Sacramento River/Keswick	nd	nd	nd	nd	nd	nd	5.9	5.9	9	33
Sutter Bypass	nd	nd	6.3	50	nd	nd	nd	nd	79	784
Sycamore Slough/Knight's Landing	nd	nd	nd	nd	nd	nd	nd	nd	162	162
Sycamore Slough/Yolo-Colusa County Line	nd	nd	nd	nd	nd	nd	nd	nd	84	84
Willow Creek/Norman-Princeton Road	nd	nd	nd	nd	nd	nd	nd	nd	213	213
Yuba River/Marysville	nd	nd	nd	nd	13	13	nd	nd	7	111

in Fish (µg/Kg wet weight) from the Sacramento Basin, 1978-1993.[1]

STATION	Dicofol		Dichlorobenzo-phenone		Dieldrin		Total Endosulfan		Total HCH	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
American River/d/s Highway 160 Bridge	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
American River/d/s Watt Avenue Bridge	nd	nd	nd	nd	6.7	6.7	nd	nd	2	4
American River/So Fork/Highway 49	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Arcade Creek/u/s Marysville Blvd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Bounde Creek/Norman-Princeton Road	nd	nd	nd	nd	5.9	6.9	nd	nd	nd	nd
Bullards Bar Res/Willow Cr	nd	nd	nd	nd	nd	nd	nd	nd	3.5	3.5
Butte Creek/Colusa Highway	nd	nd	nd	nd	nd	nd	nd	nd	2	2
Cache Creek	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Central Drain/Norman-Princeton Road	nd	nd	nd	nd	7	7	nd	nd	nd	nd
Clear Lake/Rattlesnake Isle	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Colusa Drain/Abel Road	nd	nd	nd	nd	7	13	140	140	2	2
Colusa Drain/Knights Landing	nd	nd	nd	nd	5.4	25	7.7	14	nd	nd
Colusa Drain/Yolo-Colusa County Line	nd	nd	nd	nd	nd	nd	120	120	nd	nd
Fall River	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Feather River/d/s Highway 99 Bridge	nd	nd	nd	nd	5.1	13	7.8	7.8	4.6	4.6
Feather River/Gridley	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Feather River/So Fork/Forbestown	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Feather River/So Fork/Woodleaf	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Folsom Lake	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Logan Creek/Norman-Princeton Road	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Natomas E Main Drain/d/s W El Camino Ave	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Natomas East Main Drain/Arcade Creek	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pit River/Pit 7 Powerhouse	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Putah Creek	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Reclamation Slough	nd	nd	nd	nd	5	40	6.3	22	nd	nd
Sacramento River/Hamilton City	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Sacramento River/Keswick	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Sutter Bypass	190	190	37	37	5	15	8.3	26	nd	nd
Sycamore Slough/Knight's Landing	nd	nd	nd	nd	7.9	7.9	130	130	nd	nd
Sycamore Slough/Yolo-Colusa County Line	nd	nd	nd	nd	8.8	8.8	266	266	nd	nd
Willow Creek/Norman-Princeton Road	nd	nd	nd	nd	12	12	75	75	nd	nd
Yuba River/Marysville	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

Table 10. Pesticides, Pesticide Ingredients, and their Byproducts in Fish (µg/Kg wet weight) from the Sacramento Basin, 1978-1993.[1]

STATION	Heptachlor epoxide		Hexachlorobenzene		Methyl parathion		Total PCB		Toxaphene	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
American River/d/s Highway 160 Bridge	nd	nd	nd	nd	nd	nd	140	180	nd	nd
American River/d/s Watt Avenue Bridge	nd	nd	2	7.2	nd	nd	50	225	nd	nd
American River/So Fork/Highway 49	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Arcade Creek/u/s Marysville Blvd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Bounde Creek/Norman-Princeton Road	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Bullards Bar Res/Willow Cr	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Butte Creek/Colusa Highway	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cache Creek	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Central Drain/Norman-Princeton Road	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Clear Lake/Rattlesnake Isle	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Colusa Drain/Abel Road	nd	nd	nd	nd	nd	nd	330	350	100	200
Colusa Drain/Knights Landing	nd	nd	nd	nd	nd	nd	134	192	450	450
Colusa Drain/Yolo-Colusa County Line	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Fall River	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Feather River/d/s Highway 99 Bridge	nd	nd	2.8	2.8	nd	nd	60	696	380	380
Feather River/Gridley	nd	nd	nd	nd	nd	nd	80	80	nd	nd
Feather River/So Fork/Forbestown	nd	nd	nd	nd	nd	nd	140	7,700	nd	nd
Feather River/So Fork/Woodleaf	nd	nd	nd	nd	nd	nd	140	140	nd	nd
Folsom Lake	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Logan Creek/Norman-Princeton Road	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Natomas E Main Drain/d/s W El Camino Ave	nd	nd	nd	nd	nd	nd	290	500	nd	nd
Natomas East Main Drain/Arcade Creek	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Pit River/Pit 7 Powerhouse	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Putah Creek	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Reclamation Slough	nd	nd	3	3	nd	nd	180	350	300	400
Sacramento River/Hamilton City	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Sacramento River/Keswick	nd	nd	nd	nd	nd	nd	52	52	nd	nd
Sutter Bypass	nd	nd	nd	nd	nd	nd	64	110	250	890
Sycamore Slough/Knight's Landing	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Sycamore Slough/Yolo-Colusa County Line	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Willow Creek/Norman-Princeton Road	nd	nd	nd	nd	10	10	nd	nd	nd	nd
Yuba River/Marysville	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

1 SWRCB data, from file TSMLOTUS.ZIP

C-030806

The biological significance of these compounds is uncertain. Although fish may survive relatively high residue concentrations in their body fats, residues concentrated in the eggs of mature fish may be lethal to developing fry. It is well known that organochlorine pesticides accumulate in eggs and that up to 100 percent loss of fry occurs when eggs contain significant quantities.[46] One study, for example, indicates that mortality of lake trout fry occurs when the DDT concentration in an ether extract of the eggs exceeds 2.9 mg/kg.[47] Many of these organochlorine compounds, including PCBs, endosulfan, dieldrin, and toxaphene, act like natural estrogens and are suspected to disrupt normal reproductive functions of exposed organisms. Recent research indicates that these types of compounds result in abnormal sexual development in reptiles[48] and birds,[49] feminized responses in male fish,[50] and reduced concentrations of estrogen and testosterone in both male and female fish.[51] A recent study using juvenile channel catfish found estrogenic responses (increased vitellogenic levels) when methoxychlor was administered by intraperitoneal injection, but none for four other organochlorine pesticides (o,p'-DDT, beta-

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[46] NAS, 1973, p. 184.

[47] G.E. Burdick, E.J. Harris, H.J. Dean, T.M. Walker, Jack Skea, and David Colby, The Accumulation of DDT in Lake Trout and the Effect on Reproduction, Transactions of the American Fisheries Society, v. 93, no. 2, 1964, pp. 127-136.

[48] Louis J. Guillette, Jr., Timothy Gross, Greg R. Masson, John M. Matter, H. Franklin Percival, and Allan R. Woodward, Developmental Abnormalities of the Gonad and Abnormal Sex Hormone Concentrations in Juvenile Alligators from Contaminated and Control Lakes in Florida, Environmental Health Perspectives, v. 102, 1994, p. 680, and Louis J. Guillette, Jr., Timothy S. Gross, Denise A. Gross, Andrew A. Rooney, and H. Franklin Percival, Gonadal Steroidogenesis *in Vitro* from Juvenile Alligators Obtained from Contaminated or Control Lakes, Environmental Health Perspectives, v. 103 (Suppl. 4), 1994, p. 31.

[49] D. Michael Fry, Reproductive Effects in Birds Exposed to Pesticides and Industrial Chemicals, Environmental Health Perspectives, v. 103 (Suppl. 7), 1995, p. 165.

[50] R. White, S. Jobling, S.A. Hoare, J.P. Sumpter, M.G. Parker, Environmentally Persistent Alkylphenolic Compounds are Estrogenic, Endocrinology, v.135, 1994, p. 175; S. Jobling and J.P. Sumpter, Detergent Components in Sewage Effluent are Weakly Oestrogenic to Fish: An In vitro Study Using Rainbow Trout (Oncorhynchus mykiss) Hepatocytes, Aquatic Toxicology, v. 27, 1993, p. 361; Susan Jobling, Tracey Reynolds, Roger White, Malcolm G. Parker, John P. Sumpter, A Variety of Environmentally Persistent Chemicals, Including Some Phthalate Plasticizers, are Weakly Estrogenic, Environmental Health Perspectives, v. 103, 1995, p. 582.

[51] D.L. Maclatchy and G.J. Van Der Kraak, The Phytoestrogen beta-Sitosterol Alters The Reproductive Endocrine Status of Goldfish, Toxicology and Applied Pharmacology v. 134, no. 2, 1995, p. 305.

HCH, lindane, and chlordecone).[52] Although one study suggested that combinations of two organochlorine compounds are 160 to 1600 times more potent than the individual compounds, the authors recently withdrew the study because the results could not be replicated.[53]

Several samples collected in the basin exceeded levels established by the National Academy of Sciences ("NAS") to protect predators and the U.S. Food and Drug Administration ("FDA") to protect public health. Most of the exceedances occurred in agricultural drains. DDT, banned since 1972, was found at almost every location, but exceeded the NAS criterion of 1,000 µg/kg in only one sample from Reclamation Slough. However, a recent risk assessment[54] indicates that DDT concentrations are high enough in many samples (>0.21 mg/kg wet weight) that mothers who frequently consume the fish could have breast milk DDT concentrations high enough to expose infants to unsafe levels. Endosulfan exceeded the NAS criterion of 100 µg/kg in two samples from Colusa Basin Drain and two samples from Sycamore Slough. Toxaphene, banned since 1986, exceeded the NAS criterion of 100 µg/kg in three samples from Colusa Basin Drain, two samples from Reclamation Slough, three samples from Sutter Bypass, and one sample from the Feather River. Chlordane, formerly widely used to control ants and termites in urban areas, exceeded the NAS criterion of 100 µg/kg in three samples from the American River. PCBs, formerly used as pesticide ingredients, exceeded the NAS criterion of 500 µg/kg in four samples from the Feather River and one sample from the Natomas Drain. One of these PCB samples also exceeded the FDA action level of 2,000 µg/kg (Table 10). PCBs may have originated from transformer spills rather than agricultural use.

2.1.3.3 USFWS National Pesticide Monitoring Program

The USFWS National Pesticide Monitoring Program has periodically monitored organochlorine pesticides in fish from up to 112 stations in major drainages throughout the United States since the mid-1960s. Two of these stations are located in California -- the Sacramento River at Sacramento (Station 39) and the San Joaquin River at Los Banos (Station 40). The results of these studies have been reported in journal articles including those by Henderson et al.

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[52] W.H. Benson and A.C. Nimrod, Estrogenic Responses to Xenobiotics in Channel Catfish, Presentation, Northern California Society of Environmental Toxicology and Chemistry, 6th Annual Meeting, June 24-25, 1996.

[53] Steven F. Arnold, Diane M. Klotz, Bridgette M. Collins, Peter M. Vonier, Louis J. Guillette, Jr., and John A. McLachlan, Synergistic Activation of Estrogen Receptors with Combinations of Environmental Chemicals, Science, v. 272, June 7, 1996, pp. 1489-1492. (Reported to be withdrawn in Env. Sci. Tech., v. 31, no. 9, 1997, p. 408A.)

[54] Koenraad Marien and Denise M. Laflamme, Determination of a Tolerable Daily Intake of DDT for Consumers of DDT-Contaminated Fish from the Lower Yakima River, Washington, Risk Analysis, v. 15, no. 6, 1995, pp. 709-717.

Table 10. Pesticides in Fish Exceeding National Academy of Sciences Recommended Guidelines.[1]

STATION	Chlordane 100 µg/Kg[2]	DDT 1000 µg/Kg	Endosulfan 100 µg/Kg	PCB 500 µg/Kg	Toxaphene 100 µg/Kg
Sacramento Basin					
American River/d/s Highway 160 Bridge	1/2[3]	-	-	-	-
American River/d/s Watt Avenue Bridge	2/16	-	-	-	-
Colusa Drain/Abel Road	-	-	1/6	-	2/6
Colusa Drain/Knights Landing	-	-	-	-	1/8
Colusa Drain/Yolo-Colusa County Line	-	-	1/1	-	-
Feather River/d/s Highway 99 Bridge	-	-	-	1/16	1/16
Feather River/So Fork/Forbestown	-	-	-	3/6	-
Natomas E Main Drain/d/s W El Camino Ave	-	-	-	1/2	-
Reclamation Slough	-	1/5	-	-	2/5
Sutter Bypass	-	-	-	-	3/6
Sycamore Slough/Knights Landing	-	-	1/1	-	-
Sycamore Slough/Yolo-Colusa County Line	-	-	1/1	-	-
Delta					
Beach Lake	1/5	1/5	-	1/5	-
Paradise Cut/Tracy	4/7	4/7	1/7	-	5/7
Sacramento River/Hood	3/25	3/25	-	-	5/25
San Joaquin River/Twitchell Island	1/2	1/2	-	1/2	1/2
San Joaquin Basin					
Mendota Pool	-	-	1/2	-	-
Merced River/East Side Drain	-	-	-	-	1/1
Merced River/Hagaman County Park	-	1/12	-	-	6/12
Merced River/Hatfield St Recreation Area	-	-	-	-	1/2
Mud Slough	-	-	-	-	1/3
Salt Slough	-	-	-	-	4/5
San Joaquin River/Fremont Ford	-	-	-	-	1/1
San Joaquin River/Highway 152 Bridge	-	-	-	-	1/1
San Joaquin River/Newman	-	-	-	-	1/1
San Joaquin River/Orestimba Creek	-	1/2	-	-	1/2
San Joaquin River/Vernalis	6/25	15/25	2/25	-	21/25
Stanislaus River	2/13	2/13	-	-	5/13
Tuolumne River/San Joaquin River	1/12	1/12	1/12	-	5/12

1 National Academy of Sciences, National Academy of Engineering, *Water Quality Criteria 1972* (Blue Book), U.S. EPA, 1972, p. 186.
2 NAS recommended guideline.
3 Number of exceedances/total number of samples.

1969,[55] Henderson et al. 1971,[56] Schmitt et al. 1981,[57] Schmitt et al. 1983,[58] Schmitt et al. 1985,[59] and Schmitt et al. 1990.[60] The fish commonly caught at the Sacramento station include carp, largemouth bass, white catfish, and white crappie. The most commonly detected compounds were DDE, DDD, DDT, PCBs, and dieldrin.

2.1.3.4 DFG Rice Pesticide Monitoring Program

The rice herbicides molinate and thiobencarb have also been monitored in fish from agricultural drains between 1980 and 1990. Most of the samples were collected of white catfish and channel catfish from the Colusa Basin Drain. This work shows that concentrations of molinate and thiobencarb have decreased significantly since 1983, probably due to the implementation of on-farm management practices. The concentrations of molinate in white catfish from the Colusa Basin Drain decreased from 0.60 to 1.8 μg/g in 1983 to 0.17μg/g in 1990. The concentrations of thiobencarb in white catfish from the Colusa Basin Drain decreased from 0.50 to 3.4 μg/g in 1983 to <0.05 μg/g in 1990. In channel catfish, the concentrations of molinate in the Colusa Basin Drain decreased from 1.4 to 1.6 μg/g in 1983 to 0.23 to 0.48 μg/g in 1990. The concentrations of thiobencarb in channel catfish from the Colusa Basin Drain decreased from 2.9 to 4.6 μg/g in 1983 to <0.05 to 0.06 μg/g in 1990.[61]

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55 C. Henderson, W. L. Johnson, and A. Inglis, Organochlorine Insecticide Residues in Fish, Pesticide Monitoring Journal, v. 3, 1969, pp. 145-171.

56 C. Henderson, A. Inglis, and W.L. Johnson, Organochlorine Insecticide Residues in Fish, Pesticide Monitoring Journal, v. 5, 1971, pp. 1-11.

57 Christopher J. Schmitt, J. Larry Ludke, and David F. Walsh, Organochlorine Residues in Fish: National Pesticide Monitoring Program, 1970-74, Pesticide Monitoring Journal, v. 14, no. 4, 1981, pp. 136-206.

58 Christopher J. Schmitt, J. Larry Ludke, and T.W. May, Organochlorine Residues in Freshwater Fish, 1976-1979: National Pesticide Monitoring Program, USFWS Resource Publication 152, 1983.

59 Christopher J. Schmitt, Jim L. Zajicek, and M.A. Ribick, National Pesticide Monitoring Program: Residues of Organochlorine Chemicals in Freshwater Fish, 1980-81, Archives of Environmental Contamination and Toxicology, v. 14, 1985, pp. 225-260.

60 Christopher J. Schmitt, Jim L. Zajicek, and Paul H. Peterman, National Contaminant Biomonitoring Program: Residues of Organochlorine Chemicals in U.S. Freshwater Fish, 1976-1984, Archives of Environmental Contamination and Toxicology, v. 19, 1990, pp. 748-781.

61 J.M. Harrington and T.S. Lew, Rice Pesticide Concentrations in the Sacramento River and Associated Agricultural Drains, 1989 - 1990, Department of Fish and Game Administrative Report 92-2, Table 5.

2.1.3.5 NMFS Salmon Program

In May and June 1992, the National Marine Fisheries Service ("NMFS") collected 689 juvenile chinook salmon, including 300 from hatcheries (Nimbus Dam and Feather River), 80 from Chipps Island, and 259 from San Francisco Bay. Tissues and fluids of the salmon were analyzed for chemical and biochemical parameters including: (1) the liver for chlorinated organics; (2) the liver for cytochrome p-450 activity; (3) bile for fluorescent aromatic contaminants; and (4) stomach contents for polycyclic aromatic hydrocarbons ("PAHs") and chlorinated hydrocarbons (PCBs and chlorinated pesticides).

The concentrations of PCBs (330 - 350 ng/g) and chlorinated pesticides (170 - 240 ng/g) were elevated in stomach contents of salmon from the hatcheries and Chipps Island compared to San Francisco Bay. However, there was no statistically significant difference between the hatcheries and Chipps Island. The livers of juvenile salmon from Chipps Island had significantly higher concentrations of PCBs (320 ng/g) and chlorinated pesticides (190 ng/g) than salmon from the hatcheries, which had 90 ng/g of total PCBs and 67 ng/g of other chlorinated hydrocarbons. The livers of salmon from San Francisco Bay also had elevated concentrations of PCBs (450 ng/g) and chlorinated pesticides (180 ng/g). These results indicate that salmon in the Sacramento River are being exposed to elevated concentrations of bioavailable PCBs and chlorinated pesticides.[62]

Comparable levels of PCBs and organochlorine pesticides have also been found in salmonids from high altitude, pristine eastern Sierra lakes. Lake trout from Lake Tahoe had 548 ng/g of PCBs, 335 ng/g of DDT, 307 ng/g of toxaphene, and 140 ng/g of chlordane. Rainbow trout from Huntington Lake had 121 ng/g of PCBs, 28 ng/g of DDT, 69 ng/g of toxaphene and 19 ng/g of chlordane. The source was attributed to atmospheric pollution.[63]

2.1.3.6 USFWS Striped Bass Study

The Columbia National Fisheries Research Laboratory in Columbia, Missouri conducted a comprehensive survey of contaminants in striped bass adults, eggs, and young-of-year in 1980 and 1981. Adult striped bass were collected from the Sacramento River in 1980 and a number of east coast rivers in 1980 and 1981 including the Choptank River, Cooper River, Hudson River, Potomac River, Roanoke River, Elk River, Nanticoke River, James River, Santee River, and St. Johns River. The adults were artificially spawned and organochlorine pesticides, dioxins, furans,

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[62] Usha Varanasi, Ed Casillas, and John Stein, Contaminant Levels and Associated Biochemical Effects in Outmigrating Juvenile Chinook Salmon in San Francisco Bay, Final Report - Year 1, NMFS Report, April 1993.

[63] K. Ohyama and F. Matsumura, The Pattern of Distribution of Organochlorine Residues Among High Altitude Lakes in Sierra Nevada, Poster, Northern California Society of Environmental Toxicology and Chemistry, 6th Annual Meeting, June 24-25, 1996.

PCBs, and metals were measured in adults, eggs, young-of-year, and 60-day old bass. The results for the Sacramento River fish are summarized in Table 11.

This study found elevated concentrations of PCBs, DDT, toxaphene, and chlordane in adult fish and unfertilized eggs from most of the sites that were tested. Concentrations were substantially lower in the young-of-year and 60-day-old fish, although these life stages were not analyzed for Sacramento River fish. The concentrations of toxaphene (1.44 µg/g), chlordane (2.1 µg/g), p,p'-DDE (5.17 µg/g), p,p'-DDD (1.11 µg/g), p,p'-DDT (0.53 µg/g), PCB 1254 (4.6 µg/g) and PCB 1260 (6.11 µg/g) were substantially higher in unfertilized eggs from the Sacramento River fish than in eggs from fish from other areas. Organochlorine compounds in eggs from Sacramento River fish were also uniquely elevated compared to adult Sacramento River fish, while this was not true for fish from other areas. The concentrations of cadmium (0.36 µg/g), copper (5.9 µg/g), and selenium (2.4 µg/g) were also substantially elevated in eggs from Sacramento River fish compared to eggs from fish from other areas and also compared to Sacramento River adults. All concentration are wet weight. It is unclear why Sacramento River eggs appear to concentrate metals and organochlorine compounds, while fish from other areas do not appear to do so.[64]

2.1.3.7 DFG Pesticide Investigation Study

The DFG measured DDT and its metabolites annually in flesh and ova of trout, largemouth bass, striped bass, chinook salmon, and sturgeon between 1964 and 1976. PCBs were also measured in 1972 and 1976. It is unknown where the samples were collected. A comprehensive report has never been published on this work. However, some of the analyses have been published in journal articles and internal reports. These results show that elevated concentrations of total DDT were present in the flesh and ova of all fish that were tested.[65] Total DDT in striped bass increased from 0.62 mg/kg in seven flesh samples collected in 1964 to a peak of 1.80 mg/kg in 22 samples collected in 1972, the year DDT was banned, and declined thereafter

[64] Paul Mehrle and Larry Ludke, Impacts of Contaminants on Early Life Stages of Striped Bass, Progress Report 1980-1983, Columbia National Fisheries Research Laboratory, Columbia, Missouri, 1983.

[65] Eldridge G. Hunt and J.D. Linn, Fish Kills by Pesticides, In: Proceedings of the Symposium on the Biological Impact of Pesticides in the Environment, J.W. Gillette, Ed., Oregon State University, Corvallis, 1969, pp. 44-59.

Table 11. Contaminants in Striped Bass Collected from the Sacramento River in 1980 and Artificially Spawned[1]
(whole body wet weight concentrations)

Contaminant	Adults	Unfertilized Eggs
ORGANOCHLORINE PESTICIDES (µg/g)		
p,p'-DDE	0.72	5.17
p,p'-DDD	0.07	1.11
p,p'-DDT	0.06	0.53
o,p'-DDE	ND	NA
o,p'-DDD	ND	NA
o,p'-DDT	0.07	NA
Toxaphene	0.5	1.44
Dieldrin[2]	0.03	0.1
Endrin	0.03	T
alpha-BHC	ND	ND
Lindane	ND	T
Hexachlorobenzene	ND	0.02
Heptachlor epoxide[3]	0.04	0.04
Chlordane[4]	0.32	2.1
Mirex	NA	NA
Dacthal	0.03	0.04
DIOXINS (ppt)		
Tetrachlorodioxins	ND	6*
Pentachlorodioxins	ND	ND
Hexachlorodioxins	ND	ND
Heptachlorodioxins	ND	ND
Octachlorodioxins	ND	ND
Nonachlorodioxins	ND	NA
FURANS (ppt)		
Tetrachlorofurans	10	30*
Pentachlorofurans	9	4
Hexachlorofurans	T	ND
Heptachlorofurans	2	ND
Octachlorofurans	4.5	ND
Nonachlorofurans	26	NA
PCBs (µg/g)		
PCB 1248	ND	0.03
PCB 1254	0.8	4.6
PCB 1260	1.7	6.11
Total PCBs	2.5	10.74

Table 11. Contaminants in Striped Bass Collected from the Sacramento River in 1980 and Artificially Spawned[1]

(whole body wet weight concentrations)

Contaminant	Adults	Unfertilized Eggs
PCBs[5] (ppt)		
non-o-tetrachloro-PCBs	NA	100
non-o-pentachloro-PCBs	ND	96
non-o-hexachloro-PCBs	42	125
Total non-o-chloro-PCBs	42	NA
METALS (ppm)		
Arsenic	0.38	0.25
Boron	NA	0.4
Cadmium	0.015	0.36
Chromium	0.84	NA
Copper	1.46	5.9
Lead	0.19	0.01
Manganese	2.09	NA
Mercury	0.27	NA
Nickel	0.26	NA
Selenium	0.48	2.4
Strontium	17.48	0.63
Vanadium	0.55	NA

1 Merle and Ludke, 1983, Tables 3, 5, and 9.
2 Dieldrin residues expressed as sum of aldrin + dieldrin.
3 Heptachlor epoxide residues expressed as sum of heptachlor + heptachlor expoxide.
4 Chlordane residues expressed as sum of cis- and trans-chlordane + cis- and trans-nonachlor + oxychlordane.
5 Non-ortho-substituted.
* Chlorine substituents in the 2,3,7,8 portions of the aromatic ring.
ND = Not detected
NA = Not analyzed
T = Trace

to 0.12 mg/kg in nine samples collected in 1976.[66] DDT concentrations in ova were typically substantially higher than in flesh.[67]

2.1.3.8 SWRCB Cooperative Striped Bass Study

In 1978-79, the National Marine Fisheries Services ("NMFS") examined nearly 300 striped bass from the Bay-Delta. They found that many pre-spawning adults suffered from parasite infections and lesions. Livers, reproductive organs, and eggs were damaged or appeared abnormal. Some fish had healed scars or sores on the body. Elevated concentrations of contaminants, including chlorinated organics, aromatic hydrocarbons and metals, were present in vital organs. They hypothesized that the poor reproductive fitness of pre-spawning adult fish was due to water pollution and had contributed to the decline in striped bass.

As a result, the Cooperative Striped Bass Study ("COSB") was launched to extend the NMFS studies and determine to what extent water pollution may have contributed to the poor health and population decline of striped bass. The COSB was a collaborative study jointly funded and performed by the NMFS, SWRCB, DFG, University of California at Santa Cruz and Davis, and San Francisco State University. The three-year study collected and analyzed over 500 striped bass between 1978 and 1980 from the Bay-Delta and comparison sites at Coos Bay (Oregon), Lake Mead (Nevada), and the Hudson River (New York) for 325 different variables. This comprehensive study has been summarized by Jung and others.[68] This report reviews the results of the pesticide investigations.

Pre-spawning adult striped bass were collected from the Sacramento and San Joaquin Rivers in 1978, 1980, and 1981 and organochlorine compounds analyzed in ovaries, gonads, liver, and muscle. The most frequently detected compounds were DDT and its metabolites, PCBs, and toxaphene. Concentrations of these compounds were elevated in all tissues tested and substantially higher than in striped bass collected from Coos River, Oregon.[69]

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[66] Donald E. Stevens, Factors Affecting the Striped Bass Fisheries of the West Coast, In: Marine Recreational Fisheries, H. Clepper, Ed., Sport Fishing Institute, Washington, D.C., 1980, pp. 15-28.

[67] Paul Hubbell, Program to Evaluate Unexplained Fish Mortalities in the San Francisco Bay-Delta Region, January 7, 1971.

[68] Marvin Jung, Jeannette A. Whipple, and L. Michael Moser, Summary Report of the Cooperative Striped Bass Study (COSB), December 1984, In: SWRCB, Cooperative Striped Bass Study, Technical Supplement II, January 1986.

[69] Jeannette A. Whipple, Donald G. Crosby, and Marvin Jung, Cooperative Striped Bass Study, Third Progress Report, SWRCB, February 1983, Tables 19-25.

In another COSB study, live adult female striped bass were collected from the Sacramento River at Knight's Landing during the spawning season using electroshock. Nine fish were spawned at the Elk Grove Fish Hatchery, the eggs fertilized with milt from previously caught males, and the larvae reared to yolk-sac absorption or oil globule absorption. Organochlorine compounds were measured in the muscle, ovary, and liver tissue of the adult females and in developing eggs, larvae, and fry.

The Sacramento River fish were in poor health compared to the Oregon striped bass and showed varying degrees of stress, including subcutaneous lesions, parasitism, and discolored fatty livers with occasional fibrous erosion. Eggs from three of the seven families (10,14,19) had low mortality at gastrulation and about 80 percent hatch. Eggs from four families (2,5,8,20) had desynchronous cleavage, deformed embryos, and some oil globule dispersion, and 44 to 80 percent mortalities at gastrulation, resulting in 20 to 33 percent hatch.

The larvae from several families displayed developmental abnormalities. Larvae from three families (8,10,19) displayed scoliosis and other skeletal deformities, poor yolk-sac utilization, and delayed initiation of feeding. Larvae from family 19 also had underdeveloped mouths and guts, blunt noses, and ineffectively fed while 20 to 30 percent had distended guts and failed to feed at all. Larvae from family 5 were gaunt and underdeveloped even though food density was high and also displayed swim-bladder inflation. No abnormalities were observed in family 14 larvae.[70] These types of abnormalities are characteristics of fish exposed to pollutants[71] and as discussed below, are associated with elevated concentrations of total DDT, PCBs, and toxaphene.

Organochlorine compounds detected in tissues from 11 adult striped bass from the Sacramento River were substantially higher than in Oregon fish. The most frequently detected compounds (concentrations are wet weight for lateral muscle, ovary, and liver extract, respectively) were DDT (0.9, 1.33, 0.53 mg/kg), Aroclor 1260 (1.36, 1.70, 1.03 mg/kg), Aroclor 1254 (1.18, 1.84, 1.03 mg/kg), toxaphene (0.18, 0.35, 0.12 mg/kg), and several cyclodienes. Other compounds that were detected include heptachlor (2.0, 3.8, 2.8 mg/kg), heptachlor epoxide (6.4, 5.8, 3.7 mg/kg), hexachlorobenzene (4.2, 6.9, 4.6 mg/kg), endrin (2.3, 7.0, 4.4 mg/kg), aldrin (2.6, 3.9, 2.4 mg/kg), alpha-BHC (3.5, 4.2, 2.0 mg/kg), gamma-BHC (2.5, 3.5, 1.0 mg/kg), cis-nonachlor (5.0, 14.1, 10.8 mg/kg), trans-nonachlor (99, 140, 76 mg/kg), cis-chlordane (35, 84, 37 mg/kg), trans-chlordane (15, 30, 8.8 mg/kg), and oxychlordane (17, 20, 9.1 mg/kg).

Organochlorine compounds were also analyzed in eggs and larvae from four of the families discussed above. The same compounds that were elevated in the mothers were similarly

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[70] Donald G. Crosby, Kathryn Hogan, Gerald W. Bowes, and Gregory L. Foster, <u>The Potential Impact of Chlorinated Hydrocarbon Residues on California Striped Bass</u>, December 1984, In: SWRCB, <u>Cooperative Striped Bass Study</u>, Technical Supplement 1, January 1986.

[71] Alan G. Heath, <u>Water Pollution and Fish Physiology</u>, 2nd Edition, Lewis Publishers, 1995.

elevated in the eggs, larvae, and fry, although concentrations in fry declined compared to ovary, egg, and larval concentrations, probably due to excretion or dilution from increased body size (Table 11). The highest mortalities, observed in families 10 and 19, corresponded to the highest concentrations of total DDT plus toxaphene. Skeletal deformities in families 8, 10, and 19 and distension of the gut and swim bladder and poor yolk sac utilization in families 10 and 19 are consistent with elevated concentrations of DDT and toxaphene. The concentrations of total DDT, PCBs, and toxaphene in the eggs exceeded those reported in the literature from that era to cause reduced egg hatchability and high mortality among surviving larvae and fry of other fish species (Table 12).[72] Studies conducted since then have confirmed that the concentrations of PCBs and DDT measured individually and in combination with other contaminants in the COSB studies were high enough to significantly reduce the survival of striped bass larvae.[73]

Subsequent statistical analyses of the COSB data found significant correlations between certain toxic chemicals and reduced reproductive capacity, fecundity, and egg viability. The presence of DDT, but not the metabolites DDD and DDE, in liver and gonads was correlated with abnormal egg development and necrosis of eggs in pre-spawning adult striped bass. Delayed maturation rates of eggs were correlated with PCB concentrations in ovaries. High concentrations of benzene were correlated with blood cell destruction, abnormal blood cell development, and other blood parameters. Aromatic hydrocarbons were correlated with the presence of lesion scars (toluene and ethylbenzene), egg condition in pre-spawning striped bass (ethylbenzene and 1,2-dimethylcyclohexane), and egg resorption and abnormal reproduction.[74]

2.1.3.9 DFG Striped Bass Health Index Monitoring

The COSB study demonstrated strong associations between some pollutants and poor striped bass condition. Therefore, the DFG continued some of the measurements pioneered by the COSB. Mature female striped bass were collected annually during the spawning season between 1984 and 1988 from the San Joaquin River near Antioch and on the Sacramento River near Clarksburg. External and internal examinations were conducted and parasite damage catalogued. Liver tissues were analyzed for organochlorine compounds, aromatic hydrocarbons,

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[72] Crosby et al., 1984.

[73] Deborah T. Westin, Charles E. Olney, and Bruce A. Rogers, Effects of Parental and Dietary Organochlorines on Survival and Body Burdens of Striped Bass Larvae, Transactions of the American Fisheries Society, v. 114, 1985, pp. 125-136 and Lenwood W. Hall, Jr., Larry O. Horseman, and Scott Zeger, Effects of Organic and Inorganic Chemical Contaminants on Fertilization, Hatching Success, and Prolarval Survival of Striped Bass, Archives of Environmental Contamination and Toxicology, v. 13, 1984, pp. 723-729.

[74] David C. Carlson, Cooperative Striped Bass Study: Executive Summary and Update of Actions to Implement Study Recommendations, SWRCB Report, September 1987.

Table 12. Organochlorine Concentrations (mg/Kg) in Whole Tissue (wet weight) and Lipid of Striped Bass Ovaries, Eggs, Larvae, and Fry Collected in 1981[a]

Compound	Family:	8		10		14		19	
		LW*	WW	LW	WW	LW	WW	LW	WW
Total PCB:	Ovary	12.42	2.11	16.16	1.78	22.46	4.27	15.41	3.86
	Eggs	11.18	4.92	15.06	4.67	12.11	4.72	9.57	2.58[b]
	Larvae	22.72	3.93	19.56	3.48	13.22	2.47	6.45	0.99
	Fry	17.48	0.70	11.52	0.86	11.70	0.83	[51.49][c]	3.66
Toxaphene:	Ovary	1.34	0.23	2.80	0.31	1.97	0.37	1.40	0.35
	Eggs	0.59	0.26	0.68	0.21	0.91	0.35	1.78	0.48[b]
	Larvae	1.50	0.26	2.35	0.42	1.85	0.35	1.23	0.19
	Fry	1.34	0.05	2.15	0.16	1.47	0.10	2.06	0.15
Total DDT:	Ovary	5.16	0.88	8.10	0.89	9.56	1.82	8.36	2.09
	Eggs	2.15	0.95	4.24	1.32	2.56	1.00	3.23	0.87[b]
	Larvae	2.52	0.44	5.76	1.03	3.73	0.70	2.44	0.37
	Fry	3.77	0.15	3.34	0.25	2.59	0.18	4.50	0.32
Total Organo- chlorine Pesticides:	Ovary	21.81	4.57	29.44	3.24	37.42	7.11	26.95	6.74
	Eggs	14.62	6.43	22.82	7.08	16.36	6.38	15.21	4.10[b]
	Larvae	28.25	4.89	28.80	5.13	19.68	3.68	10.68	1.63
	Fry	23.60	0.94	17.73	1.33	16.33	1.16	[60.41][c]	4.29

* LW = lipid weight; WW = wet weight
a Crosby et al. 1984
b 20-30% loss during analysis
c Figure questionable

and metals. All 11 years of data, from 1978 to 1988, were statistically analyzed at the end of the study.

The most frequently detected organochlorine compounds were DDT and its metabolites, PCB 1260, cis-chlordane, cis-nonachlor, and trans-nonachlor, similar to results of the COSB study discussed above. Figure 11 shows the time history of total DDT and Figure 12 of Aroclor 1260 in striped bass livers from the Sacramento and San Joaquin Rivers.[75] These figures suggest that concentrations have not declined appreciably since 1981, except for the 1992 sample. This sample was analyzed in a USGS study (discussed below) that used different analytical methods, which may account for the apparent decline in concentrations.

Statistical analyses, primarily nonparametric correlation analysis, of all 11 years of data did not find many strong, consistent relationships among variables, conflicting with the results of the COSB study (Sec. 2.1.3.8). However, only two pollutant variables, monocyclic aromatic hydrocarbons and alicyclic hexanes, were monitored consistently in fish throughout all 11 years of the study. These analyses concluded that parasite loads had increased over the study period while concentrations of aromatic hydrocarbons and benzene had declined. Fecundity was inversely related to egg resorption, and egg resorption declined as concentrations of monocyclic aromatic hydrocarbons in the liver decreased. The concentration of mercury, zinc, selenium, and roundworm larva infestations generally increased with fish age. Skeletal abnormalities were positively associated with the mercury concentration in liver tissue. The authors concluded that "[a]lthough there has been improvement in some measures of health, striped bass still do not appear to be 'healthy'."[76]

2.1.3.10 USGS Striped Bass Study

In mid-May 1992, five male and two female striped bass were captured by electrofishing from the Sacramento River at Knights Landing and from the San Joaquin River by the DFG. In addition, five fish, which were offspring of adults from the Delta, were reared in captivity at the Bodega Marine Laboratories and used as control fish. The fish were dissected, liver and other tissues removed and frozen, and the livers were analyzed for organochlorine pesticides. Sediments were also collected from 17 sites in San Francisco Bay and analyzed for organochlorine pesticides. The sediment data are not discussed here because the sampling sites

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[75] David W. Kohlhorst and Roger E. Johnson, Striped Bass Health Index Monitoring, 1984 Final Report; Diane L. Knudsen and David W. Kohlhorst, Striped Bass Health Index Monitoring, 1985 Final Report; Kevan A. F. Urquhart and Diane L. Knudsen, Striped Bass Health Index Monitoring, 1986 Final Report; Kevan A. F. Urquhart and Diane L. Knudsen, Striped Bass Health Monitoring, 1987 Final Report; Diane L. Knudsen and Kevan A.F. Urquhart, Striped Bass Health Monitoring, 1988 Final Report.

[76] Knudsen and Urquhart, 1988.

Figure 11. Concentrations of Total DDT in Striped Bass Livers Collected in the Delta

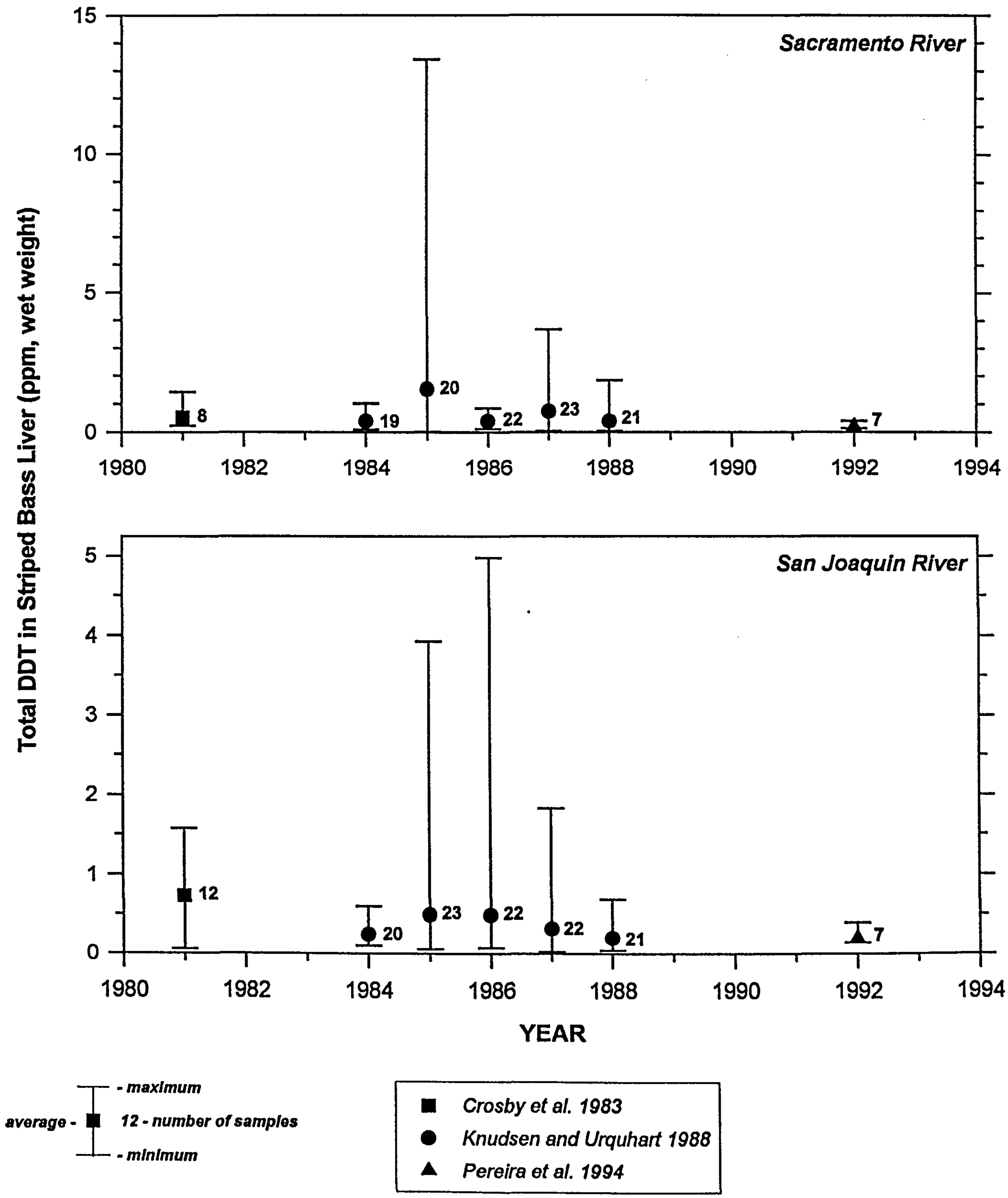
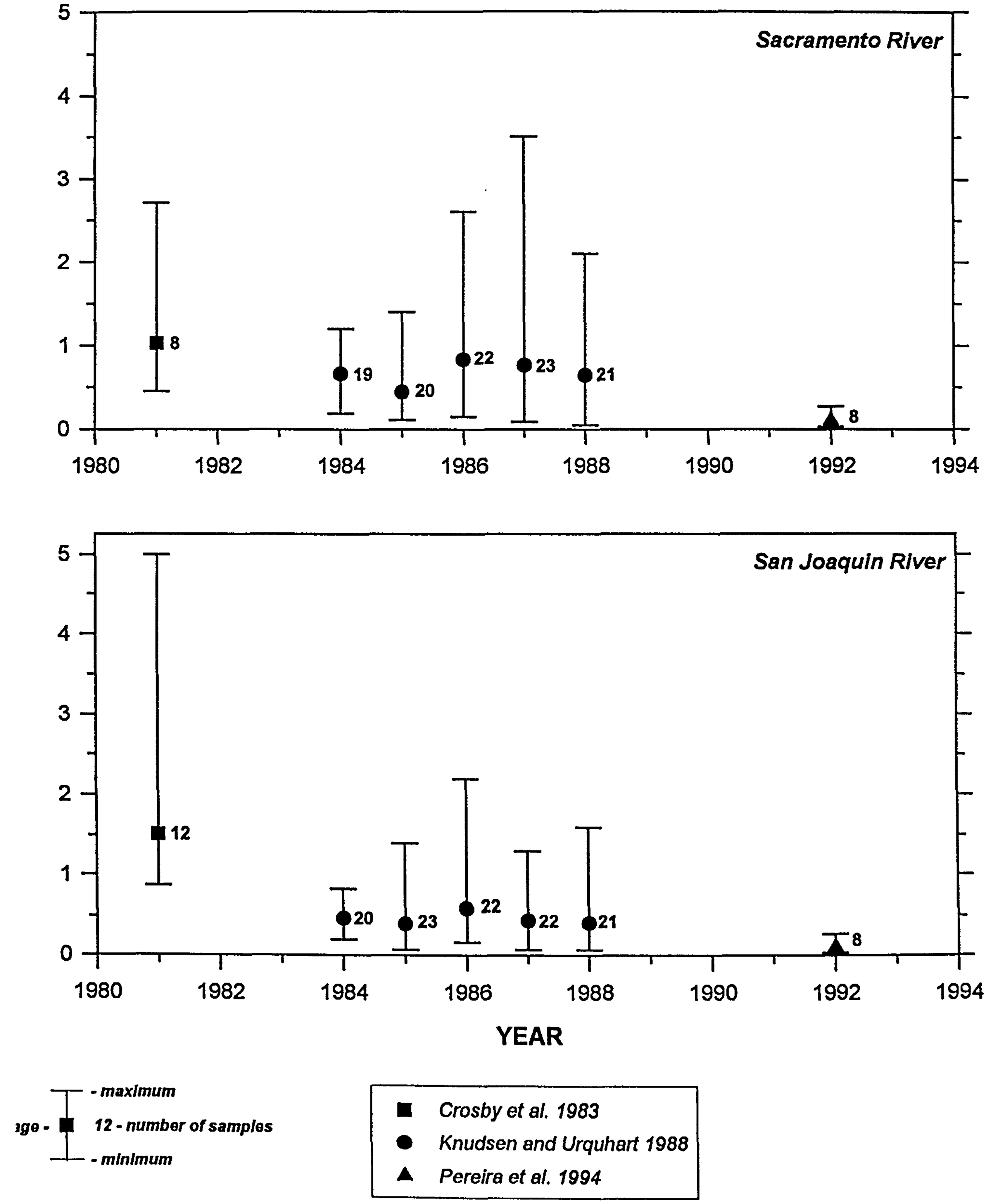


Figure 12. Concentrations of PCBs (Aroclor 1260) in Striped Bass Livers Collected in the Delta



are outside of the Central Valley. The concentrations of organochlorine pesticides in livers of the seven striped bass and controls are summarized in Table 13.

This study found concentrations of total DDT that were comparable to those measured in earlier studies (Figure 11), but much lower concentrations of PCBs (Figure 12), total chlordane (13-42 μg/kg), and dacthal (<0.1-8.7 μg/kg). Chlordane (<0.1 μg/kg), PCBs (<0.1 μg/kg), and dacthal (<0.1 μg/kg) were not detected in the controls. Very low concentrations of DDT and its degradation products (total DDT: <0.1-5.7 μg/kg) were found in some of the controls, possibly due to transfer of DDT from Delta mothers to offspring via the egg-yolk lipid. All concentrations are wet weight. Livers from the female striped bass generally contained lower levels of DDT, chlordane, and PCBs than livers from the male fish.

Generally, concentrations of DDT compounds were in the order DDE>DDD>DDT, consistent with sediments from the San Joaquin Valley (Sec. 4.1.2). This distribution results because DDT is degraded under aerobic conditions by microorganisms in agricultural soils to DDE and under anaerobic conditions to DDD. Likewise, concentrations of cis-chlordane were greater than those of trans-chlordane because the former is environmentally more stable. The ratios of the PCB isomers lie within the range of those found in the bottom sediments from San Francisco Bay, suggesting the PCBs originated from sediments.[77]

2.1.3.11 NAREL Putah Creek Study

The National Air and Radiation Environmental Laboratory ("NAREL") monitored contaminants at four sites along Putah Creek, above and below the former University of California at Davis Laboratory for Energy-Related Health Research that was located there from 1958 to 1988. U.S. EPA Region 9 collected fish, sediment, and water samples from August 27, 1996 to September 12, 1996 from one upstream and three downstream locations. Samples were analyzed for radionuclides, pesticides, PCBs, and metals. Fish that were collected include black crappie, bluegill, large mouth bass, white catfish, carp, green sunfish, and crayfish.

No pesticides or PCBs were detected at any site in waters, sediments or tissues. The pesticides that were measured are chlordane, 4,4'-DDT, dicofol, dieldrin, endosulfan I, endosulfan II, endrin, heptachlor epoxide, hexachlorobenzene, lindane, and toxaphene. Radionuclide and metal concentrations in tissues, waters, and sediments were not appreciably elevated compared to background or relevant standards and guidelines, except Hg-203, mercury, and lead in tissue samples collected at the downstream sites. It was concluded that concentrations of mercury (0.13

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[77] Wilfred E. Pereira, Frances D. Hostettler, John R. Cashman, and Richard S. Nishioka, 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, v. 28, no. 7, 1994, pp. 434-441.

Table 13. Concentrations of Organochlorine Pesticides in Livers of Striped Bass (*Morone saxatilis*) in 1992 (µg/Kg wet weight)[1]

Compound	Sample No.							Control No.				
	4	5	6	7	8	9	10	12	13	14	15	16
DDE	103	131	297	172	137	104	62	3.4	< 0.1	1	< 0.1	1.7
DDD	35	47	86	40	39	32	34	1.5	0.2	< 0.1	< 0.1	< 0.1
DDT	8.8	11	13	13	11	6.1	7.3	0.8	0.2	< 0.1	< 0.1	< 0.1
Total DDT	**147**	**189**	**396**	**225**	**187**	**142**	**103**	**5.7**	**0.4**	**1**	**< 0.1**	**1.7**
γ-Chlordane	4.4	5.6	6.1	5.1	1.3	3.4	5.3	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
α-Chlordane	5.7	9.4	7.4	7.1	2.1	5	6.2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Trans-nonachlor	10	18	11	15	6.2	6.3	7.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Cis-nonachlor	4.8	9.2	4.5	7.4	3.1	3	1.4	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Total Chlordane	**25**	**42**	**29**	**35**	**13**	**18**	**20**	**< 0.1**	**< 0.1**	**< 0.1**	**< 0.1**	**< 0.1**
Tetrachloro PCB	13	1.9	7.4	9.3	2.9	5	24	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Pentachloro PCB	50	113	18	56	19	13	35	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Hexachloro PCB	77	155	11	84	22	17	8	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Total PCB	**140**	**270**	**36**	**149**	**44**	**35**	**67**	**< 0.1**	**< 0.1**	**< 0.1**	**< 0.1**	**< 0.1**
DCPA[2]	1.9	< 0.1	8.7	5.8	0.7	3.1	2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1

1 Pereira et al. 1994.
2 Also known as dacthal and chlorthal.

to 0.69 mg/kg wet weight) and lead (<0.08 to 1.06 mg/kg wet weight) in fish were high enough to present a possible health hazard to those consuming the fish.[78]

2.2 SOURCES

The toxicity and pesticides detected in the major rivers probably originate primarily from urban and agricultural use of pesticides. Secondary sources of toxicity include metals from urban runoff and acid mine drainage. The following sections explore potential sources, including agriculture (Sec. 2.2.1), urban runoff (Sec. 2.2.2), and precipitation (Sec. 2.2.3). Municipal effluents, particularly from the Sacramento urban area, may also contribute to toxicity, but were not reviewed in this work. The principal conclusions from the work reviewed below are as follows:

- Pesticides and toxicity have not been measured extensively in agricultural runoff and irrigation return flows except rice drainage. Rice drainage that enters the rivers in the April to June period has historically been periodically toxic to both fish and invertebrates, but increased rice water holding times have substantially reduced this toxicity. This drainage is present during the times and at locations where young striped bass, salmon, and other fish are present. Pre-harvest drainage, which enters the rivers in September, is generally not toxic.

- Between 1988 and 1990, samples from the Colusa Basin Drain were acutely toxic to larval striped bass 67 to 100 percent of the time and average annual mortality ranged from 68 to 79 percent. Implementation of on-farm rice management practices resulted in a decline in both the severity and the frequency of toxicity of Colusa Basin Drain water to larval striped bass. The severity of mortality declined from 79 percent in 1990 to 40 percent in 1991 to 12 percent in 1992, and the frequency from 100 percent in 1990 to 45 percent in 1991 to 18 percent in 1992. No studies using larval striped bass have been done since 1992.

- Between 1988 and 1991, rice drainage caused significant mortality to Ceriodaphnia in 50 to 57 percent of the samples and to Neomysis in 27 to 78 percent of the samples. Toxicity in some samples was due to organophosphorus and carbamate pesticides, including methyl parathion, carbofuran, and malathion. Since these studies were done, concentrations

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[78] Clinton Cox, Concentrations of Selected Radionuclides and Chemicals in Fish, Sediment, and Water Collected from the Putah Creek Near the Former Laboratory for Energy-Related Health Research, Davis, CA, Report Prepared for Agency for Toxic Substances and Disease Registry, Atlanta, GA by USEPA-NAREL, Montgomery, AL, March 31, 1997.

of rice pesticides have declined due to the implementation of on-farm management practices.

- Runoff from orchards caused significant mortality to Ceriodaphnia in 38 percent of the samples. Toxicity was attributed to diazinon.

- Urban runoff caused significant mortality to Ceriodaphnia in virtually all of the samples tested. It is also frequently toxic to Selenastrum. The Ceriodaphnia toxicity was primarily due to diazinon and chlorpyrifos, and the Selenastrum toxicity to diuron. Although not measured as frequently, chlorpyrifos and metals were present at toxic concentrations in some samples.

- Diazinon was present in rainfall throughout the Basin at concentrations high enough to cause toxicity to Ceriodaphnia.

2.2.1 Agriculture

In most counties of the Sacramento Basin, 790 to 2,700 pounds of pesticides are applied per square mile annually.[79] Rice is the major crop grown in the Basin, accounting for about 40 percent of the total agricultural acreage. Over 90 percent of California's rice crop is grown in Butte, Colusa, Glenn, Placer, Sacramento, Sutter, Yolo, and Yuba counties. Orchards, field crops, and some truck crops and grapes are also grown.

There are 17 major agricultural drains that discharge into surface water of the Sacramento Valley. About 80 percent of the surface runoff is contributed by five drains -- Colusa Basin Drain, Sacramento Slough, Reclamation District 1000, Reclamation District 108, and Toe Drain. Colusa Basin Drain carries most of the surface runoff from irrigated areas above Knight's Landing, west of the Sacramento River, and Sacramento Slough carries a good portion of the runoff from acreage above Knight's Landing, east of the River.[80]

2.2.1.1 Rice Drainage

Rice, a semi-aquatic plant, is cultivated using the continuous flood method of irrigation. The rice is kept partially submerged and receives continuous irrigation during much of the growing season. The major sources of irrigation water are the Tehama-Colusa Canal and the Glenn-Colusa Canal, which import water from the Upper Sacramento River. Rice fields are treated with pesticides to prevent the growth of water-grasses, broadleaf plants, algae, and other

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[79] Brown and Caldwell Consultants, Sanitary Survey of the State Water Project, Final Report, October 1990. Figure 4-15.

[80] Ibid., p. 4-53.

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organisms that reduce rice yields. Pesticide residues are discharged into surface waters when the flooded fields are drained.

Currently, most rice fields are flooded with irrigation water in late April to early May. The fields are then seeded, and one to two weeks later herbicides are applied, including molinate, thiobencarb, methyl parathion, and bensulfuron methyl. Carbofuran is applied before flooding. After a mandatory holding period of about 28 days to allow pesticides to dissipate, water is released from the fields for salinity control and weed control. Some growers also use the pin point flood method, in which fields are flooded, seeded, drained, and reflooded. In September, the fields are drained and the rice is harvested. However, historically, mandatory holding periods and water conservation were not required, and large amounts of pesticide-laden rice drainage entered the rivers in the mid-April to mid-July period.[81,82]

Rice return water principally enters the Sacramento River in May and June through five drains: Butte Slough, Reclamation District 108, Colusa Basin Drain, Sacramento Slough, and Jack Slough. Colusa Basin Drain and Sacramento Slough contribute the majority of the rice drainage. Historically, the 90-km section of the Sacramento River from Colusa downstream to Sacramento received up to 33 percent of the total rice drainage and the Sacramento River downstream of Sacramento up to 24 percent. This section of river and the downstream estuary serve as spawning and nursery habitats from May through June for striped bass, American shad, and white sturgeon. Downstream migrant chinook salmon smolts and steelhead trout also occupy this area when rice drainage is present. In recent years, however, comparatively less rice drainage is present in this river reach during the May to June period due to stringent water management requirements.

In the early 1980's, the rice herbicides molinate and thiobencarb caused large fish kills in agricultural drains, and thiobencarb caused taste and odor problems in the City of Sacramento's drinking water. In the late 1980's, it was established that three rice insecticides, carbofuran, malathion and methyl parathion, were present in the drains at concentrations that pose a threat to aquatic resources.

These problems led to an extensive amount of work on rice drainage. This work identified a number of management practices that reduced the off-field movement of rice herbicides. Beginning in 1984, the DPR set up the Rice Herbicide Program to reduce and control the discharge of pesticides from rice fields. This program has been reviewed annually by the CVRWQCB. In 1990, the Basin Plan was amended to contain a prohibition on the discharge of

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[81] John W. Cornacchia, David B. Cohen, Gerald W. Bowles, Rudy J. Schnagl, and Barry L. Montoya, Rice Herbicides: Molinate and Thiobencarb, SWRCB Special Projects Report No. 84, April 1984, p. 5.

[82] Valerie Connor, Biotoxicity Monitoring of Pre-Harvest Drainage from Rice Fields: September 1987-1989, CVRWQCB Memorandum to Jerry Bruns and Rudy Schnagl, March 13, 1990.

irrigation return flows containing the pesticides carbofuran, malathion, methyl parathion, molinate, and thiobencarb. The prohibition is waived if the discharger is following a management practice approved by the CVRWQCB. To receive approval, the management practices must be expected to meet specified performance goals.[83] This program has been effective in reducing rice pesticide residues. For example, the mass transport of molinate in the Sacramento River has been reduced from over 40,000 pounds in 1982 to 239 pounds in 1994 and of thiobencarb from about 1,400 pounds in 1982 to none in 1994.[84] However, as discussed in Section 2.2.1.1.6, degradation products form when rice waters are held on the fields. Degradation products of molinate, carbofuran, and methyl parathion have been detected in the Sacramento River downstream from the Colusa Basin Drain to Steamboat Slough in the Delta. These degradation products are not routinely monitored under the rice pesticide regulatory program and very little is known about their toxicity.

The following sections review the numerous studies that have been conducted on rice drainage. Some of this work has been recently summarized by the DWR[85] and the California Rice Industry Association.[86] The DWR study concluded that waters in the Colusa Basin Drain were generally warmer and more alkaline than the Sacramento River and thus increased both the temperature and pH of the river below the discharge point at Knights Landing. They also concluded that copper, selenium, and lead were periodically elevated in waters and copper and lead in fish from the Drain. Pesticides, particularly organochlorine compounds such as toxaphene and DDT, were also elevated in fish. However, they concluded that fish kills and taste problems formerly associated with rice herbicides were "under control."

Likewise, the California Rice Industry Association concluded that "rice pesticides have impacted aquatic species. Molinate poisoned carp and, to a lesser extent, other fish species in drains. Methyl parathion and carbofuran have been measured at levels in drains and in the river that are toxic to microinvertebrates in laboratory bioassays. Higher aquatic organisms may have been impacted by a depletion of the aquatic food chain. The widespread use of the highly toxic bufencarb in the late 1970s most likely had an impact on aquatic species in the drains, and quite likely, in the River and Delta as well. Bufencarb, methyl parathion, carbofuran, malathion, and carbaryl were all in use in the late 1970s and early 1980s. They would have acted additively when

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[83] The performance goals are 0.4 μg/L for carbofuran, 0.1 μg/L for malathion, 10.0 μg/L for molinate, 0.13 μg/L for methyl parathion, and 1.5 μg/L for thiobencarb.

[84] Rudy Schnagl, Review of Department of Pesticide Regulation's 1995 Management Practices for Rice Pesticides, CVRWQCB Staff Report, January 1995.

[85] Stephen M. Turek, Colusa Basin Drain Water Quality Literature Review, Memorandum Report, DWR Northern District, April 1990.

[86] James L. Byard, The Impact of Rice Pesticides on the Aquatic Ecosystems of the Sacramento River and Delta, Prepared for the California Rice Industry Association, October 1996.

present in the same body of water. Bufencarb is gone, and relatively small amounts of malathion and carbaryl are used on rice today. The rice pesticide management program has reduced the releases of these chemicals to a level that has no measurable impact on aquatic species in the River or Delta."

2.2.1.1.1 DFG Rice Herbicide Study

Fish losses had occurred annually since 1976 between May and June in the agricultural drains of the Sacramento Valley. The primary fish affected was carp, Cyprinus carpio, and losses were estimated at 30,000 in 1980, 10,000 in 1981, 13,000 in 1982, and 7,000 in 1983. In 1980, the DFG initiated studies on agricultural drains to determine the cause of the fish kills. This work led to the implementation of on-farm management practices, which substantially decreased the peak concentration of molinate and thiobencarb (Tables 14, 15) and eliminated the fish kills. Peak concentrations of rice pesticides in agricultural drains currently do not exceed levels that are known to be toxic to fish.[87] However, they still periodically cause toxicity to Ceriodaphnia in 96-hr bioassays and exceed the 42-day no observable effect concentration ("NOEC") for Neomysis of 26 µg/L molinate and 6.2 µg/L thiobencarb.[88] They also periodically exceed the performance goals established by the CVRWQCB to protect aquatic life. The results of this work are summarized below.

1980 and 1981 Studies. Field investigations were conducted between June and October 1980 and April and September 1981 to determine the cause of the seasonal fish losses which occurred in agricultural drains. Rice herbicides were monitored at eight sites in two agricultural drains as well as in fish and sediment, and in-situ fish toxicity tests were conducted. The drainage from two rice fields was monitored before and after aerial applications of molinate and ethyl parathion. Molinate, methyl parathion, and thiobencarb were present in pulses over the drainage season at most stations. Prior to the implementation of water management practices, fields were freely drained into waterways shortly after pesticides were applied. The study concluded that molinate was responsible for fish losses, which coincided with peak molinate concentrations. Dead fish collected during the losses contained residues of molinate.[89]

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[87] G.A. Faggella and B.J. Finlayson, Hazard Assessment of Rice Herbicides Molinate and Thiobencarb to Larval and Juvenile Striped Bass, DFG Administrative Report 87-2, 1987 and B.J. Finlayson and G.A. Faggella, Comparison of Laboratory and Field Observations of Fish Exposed to the Herbicides Molinate and Thiobencarb, Transactions of the American Fisheries Society, v. 115, 1986, pp. 882-890.

[88] James M. Harrington, Hazard Assessment of the Rice Herbicides Molinate and Thiobencarb to Aquatic Organisms in the Sacramento River System, DFG Administrative Report 90-1, 1990, p. ii.

[89] B.J. Finlayson, J.L. Nelson, and T.L. Lew, Colusa Basin Drain and Reclamation Slough Monitoring Studies, 1980 and 1981, DFG Administrative Report 82-3, 1982.

Table 14. Peak Molinate Concentrations at Monitoring Sites in the Sacramento Basin, 1981-1994.[1]

Year	CONCENTRATION (µg/L)				
	Colusa Basin Drain near Knight's Landing	Colusa Basin Drain near Highway 20	Sacramento Slough	Butte Slough	Sacramento River at Village Marina
1981	340	357			
1982	204	697		187	27
1983	211	228	68		7
1984	110	120	44		21
1985	95	100	49		16
1986	77	88	30		11
1987	43	53	22	44	7.6
1988	67	89	30	52	8.0
1989	51	60	30	43	6.0
1990	51	59	40	36	8.9
1991	18	17	9.6	26	1.3
1992	6.2	24	15	26	< 1
1993	69.1	96.1	31.2	39.2	2.59
1994	21	57	9.8	18.3	
1995		25		8.5	ND[2]
1996		44		15.7	0.95

1 Gorder et al., December 31, 1996.
2 Not detected. Detection limits were less than or equal to 1.0 µg/L.

Table 15. Peak Thiobencarb Concentrations at Monitoring Sites in the Sacramento Basin, 1981-1994.[1]

Year	CONCENTRATION (µg/L)				
	Colusa Basin Drain near Knight's Landing	Colusa Basin Drain near Highway 20	Sacramento Slough	Butte Slough	Sacramento River at Village Marina
1981	21	23			
1982	57	170		10	6
1983	11.3	9.0	4.9		0.8
1984	7.5	14.0	7.8		1.0
1985	19	18	11		4.1
1986	7.4	6.9	3.8		1.1
1987	3.7	1.5	0.6	ND[2]	ND
1988	4.5	0.6	ND	1.0	ND
1989	1.34	0.55	ND	0.98	ND
1990	ND	ND	ND	2.0	ND
1991	ND	ND	ND	ND	ND
1992	5.7	6.7	2.0	9.7	ND
1993	4.87	3.68	ND	ND	ND
1994	15.8	37.4	ND	0.53	
1995		3.5		1.3	ND
1996		16.2		2.0	ND

1 Gorder et al., December 31, 1996.
2 Not detected. Detection limits were less than or equal to 1.0 µg/L.

1982 Study. Field investigations were conducted between May and July 1982. Molinate and thiobencarb were monitored in water samples from nine sites and in fish. Molinate and thiobencarb were detected in agricultural drain waters between the second week of May and the first week of July at concentrations up to 697 µg/L and 170 µg/L, respectively. They were also detected in the Sacramento River at Village Marina between mid-May and late June at concentrations up to 27 µg/L and 6 µg/L, respectively. Fish losses, primarily carp, occurred in the Colusa Basin Drain and Sutter Bypass in early June and coincided with peak molinate and thiobencarb concentrations. Dead fish had higher residues of both herbicides than live fish. Molinate and thiobencarb residues in fish ranged from <100 to 2,400 µg/kg and <100 to 3,800 µg/kg, respectively.[90]

1983 Study. Field investigations were conducted between November 1982 and July 1983. Molinate and thiobencarb were monitored in water samples from five sites, including three sites along the Sacramento River, and in fish from one site. Blood hemoglobin and hematocrit levels and acetylcholinesterase activity of brain tissue of carp and white catfish were also measured. Molinate and thiobencarb were detected in agricultural drains between the third week of May and the second week of July at concentrations up to 228 µg/L and 11.3 µg/L, respectively. Concentrations of both herbicides were substantially reduced in Colusa Basin Drain, Sutter Bypass, and Sacramento River in 1983 compared to 1981 and 1982. Fish losses, primarily carp, occurred in the Colusa Basin Drain in early June and coincided with peak molinate and thiobencarb concentrations. Live carp collected from the drain during this period showed signs of anemia, and there was strong field evidence that molinate was responsible for the death of carp in the Colusa Basin Drain. Detectable residues of both molinate and thiobencarb in Colusa Basin Drain fish ranged from <100 to 2,200 µg/kg and <100 to 2,300 µg/kg, respectively, and were present for up to 60 days.[91]

1984 Study. Field investigations were conducted between April and June 1984. Molinate and thiobencarb were monitored in water samples from six sites and in fish from two sites. Molinate and thiobencarb were detected in agricultural drains between April 25 and June 27 at concentrations up to 120 µg/L and 14.0 µg/L, respectively. Concentrations were slightly lower than in 1983, but dramatically lower than in 1981 and 1982. No fish losses were observed in 1984. Detectable residues of molinate and thiobencarb in fish ranged from <100 to 270 µg/kg and <100 to 280 µg/kg, respectively, and were much lower than in previous years.[92]

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[90] B.J. Finlayson and T.L. Lew, Rice Herbicide Concentrations in Sacramento River and Associated Agricultural Drains, 1982, DFG Administrative Report 83-5, 1983.

[91] B.J. Finlayson and T.S. Lew, Rice Herbicide Concentrations in Sacramento River and Associated Agricultural Drains, 1983, DFG Administrative Report 83-7, 1983.

[92] B.J. Finlayson and T.S. Lew, Rice Herbicide Concentrations in the Sacramento River and Associated Agricultural Drains, 1984, DFG Administrative Report 84-4, 1984.

1985 Study. Field investigations were conducted between April and June 1985. Molinate and thiobencarb were monitored in water samples from seven sites and in fish from two sites. Molinate and thiobencarb were detected in agricultural drains between April 26 and June 26 at concentrations up to 100 µg/L and 19.0 µg/L, respectively. Molinate concentrations were slightly lower than in 1984, but thiobencarb concentrations were two to three times higher than 1984 levels. No fish losses were observed in the agricultural drains in 1985. Molinate residues in fish from agricultural drains were slightly less than in 1984, <50 to 200 µg/kg, but thiobencarb residues were higher than in previous years, 50 to 3,200 µg/kg.[93]

1986 Study. Field investigations were conducted between April and June 1986. Molinate and thiobencarb were monitored in water samples from five sites and in fish from one site. Molinate was detected in agricultural drains between May 5 and June 30 at concentrations up to 88 µg/L and thiobencarb between May 19 and June 30 at concentrations up to 7.4 µg/L. Concentrations continued to decline due to the implementation of on-farm management practices. No fish losses were observed for the third consecutive year. Molinate and thiobencarb residues in fish from the Colusa Basin Drain ranged from 110 to 820 µg/kg and from 340 to 3,800 µg/kg, respectively.[94]

1987-1988 Study. Field investigations were conducted between May and June 1987 and April and September 1988. Molinate, thiobencarb, and carbofuran were monitored in water samples from six locations in 1987 and eight locations in 1988 and in fish from one site. Select water samples were also analyzed for bentazon, propanil, and carbaryl. Molinate was detected from early May to late June, thiobencarb from late May to mid-June, and carbofuran from late April through May in agricultural drains in 1987 and 1988. Maximum concentrations of molinate, thiobencarb, and carbofuran were 53, 3.7 and 13 µg/L in 1987 and 89, 4.5, and 4.4 µg/L in 1988, respectively. Maximum concentrations in the Sacramento River were 7.6, <1.0, and 2.1 µg/L in 1987 and 8.0, <1.0, and <1.0 in 1988, respectively. Bentazon was detected in 1988 from early June to late September in the agricultural drains at a maximum concentration of 5.5 µg/L. Propanil was detected once, and carbaryl was not detected. No fish losses occurred for the fourth (1987) and fifth (1988) consecutive years. Molinate and thiobencarb residues in fish from the Colusa Basin Drain ranged from 270 to 560 µg/kg and from <50 to 370 µg/kg in 1987 and from <50 to 90 µg/kg and from <50 to 80 µg/kg in 1988, respectively. No carbofuran was detected in fish.[95]

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[93] B.J. Finlayson and T.S. Lew, Rice Herbicide Concentrations in the Sacramento River and Associated Agricultural Drains, 1985, DFG Administrative Report 85-2, 1985.

[94] B.J. Finlayson and T.S. Lew, Rice Herbicide Concentrations in the Sacramento River and Associated Agricultural Drains, 1986, DFG Administrative Report 86-2, 1986.

[95] J.M. Harrington and T.S. Lew, Rice Pesticide Concentrations in the Sacramento River and Associated Agricultural Drains, 1987-1988, DFG Administrative Report 89-1, 1988.

1989-1990 Study. Field investigations were conducted between April and June 1989 and 1990. Molinate, thiobencarb, and carbofuran were monitored in water samples from nine locations in 1989 and from seven locations in 1990. Molinate was detected in agricultural drains from early May through June, and carbofuran was detected from late April through May. Thiobencarb was not detected in 1989 and was barely detected during a one-week period in late May 1990. Maximum concentrations of molinate, thiobencarb, and carbofuran in the Colusa Basin Drain were 60, <1.0, and 1.5 µg/L in 1989 and 59, 1.3, and 2.6 µg/L in 1990, respectively. Maximum concentrations of molinate, thiobencarb, and carbofuran in the Sacramento River were 6.0, <1.0, and <1.0 µg/L in 1989 and 8.9, <1.0, and 0.6 µg/L in 1990, respectively. Water quality criteria recommended by the DFG to protect freshwater aquatic life for molinate of 13 µg/L (in the presence of thiobencarb) and 26 µg/L (in the absence of thiobencarb) were exceeded during 1989 and 1990 in the agricultural drains. Molinate and thiobencarb residues in fish from the Colusa Basin Drain ranged from 190 to 380 µg/kg and <50 to 70 µg/kg in 1989 and from 170 to 480 µg/kg and <50 to 60 µg/kg in 1990, respectively.[96]

1991 Study. Field investigations were conducted between May and July 1991. Molinate, thiobencarb, bensulfuron methyl, carbofuran, methyl parathion, and malathion were monitored in water samples from up to eight sites. Molinate was detected in agricultural drains from mid-May through early July when sampling terminated at concentrations up to 18 µg/L. Thiobencarb was not detected in agricultural drains in 1991. Carbofuran was detected on April 18 and from early May through mid-June, when sampling was terminated at concentrations up to 0.6 µg/L. Bensulfuron methyl was detected in agricultural drains in four samples collected between May 30 and June 10 at concentrations up to 0.825 µg/L. Methyl parathion was detected in agricultural drains in May and June in three samples at concentrations up to 0.30 µg/L and malathion in two samples at concentrations up to 0.30 µg/L. All of these peak concentrations, except bensulfuron methyl, exceed performance goals established by the CVRWQCB. Elevated concentrations of methyl parathion were attributed to aerial drift. No thiobencarb, methyl parathion, or malathion were detected in the Sacramento River, but molinate was present in two samples at concentrations up to 1.3 µg/L.[97]

1992 Study. Field investigations were conducted between May and August 1992 Molinate, thiobencarb, carbofuran, bensulfuron methyl, methyl parathion, and malathion were monitored in water samples from up to eight sites. Molinate was detected in agricultural drains from mid-May through mid-July at concentrations up to 26 µg/L. Thiobencarb was detected in agricultural drains from early June through early August when sampling terminated at concentrations up to 9.7 µg/L. Carbofuran was detected in agricultural drains from early May to

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[96] J.M. Harrington and T.S. Lew, Rice Pesticide Concentrations in the Sacramento River and Associated Agricultural Drains, 1989-1990, DFG Administrative Report 92-2, 1992.

[97] Marshall Lee and Nancy Gorder, Information on Rice Pesticides Submitted to the Central Valley Regional Water Quality Control Board, Department of Pesticide Regulation, January 10, 1992.

mid-July at concentrations up to 0.7 μg/L. Bensulfuron methyl was detected in agricultural drains from late May through early June at concentrations up to 1.88 μg/L. Methyl parathion was detected in agricultural drains in five samples at concentrations up to 0.4 μg/L and malathion in one sample at 0.1 μg/L. All of these peak concentrations except malathion and bensulfuron methyl exceed performance goals established by the CVRWQCB. No molinate or thiobencarb were detected in the Sacramento River, but carbofuran was present in two samples at a maximum concentration of 0.3 μg/L.[98] Drought conditions, which reduced surface water flows, contributed to elevated concentrations in 1992.

1993 Study. Field investigations were conducted from early May until mid-July 1993. Molinate, thiobencarb, carbofuran, bensulfuron methyl, methyl parathion, and malathion were monitored in water samples from up to six sites. Molinate and thiobencarb were detected in agricultural drains from mid-May until mid-July at concentrations up to 96.1 μg/L and 4.87 μg/L, respectively. Carbofuran was detected in agricultural drains from late April through mid-July at concentrations up to 1.9 μg/L. Bensulfuron methyl was detected from late May through mid-June when sampling terminated at concentrations up to 1.82 μg/L. Methyl parathion was detected from mid-May to mid-June in the Colusa Basin Drain at concentrations up to 1.1 μg/L and periodically elsewhere. Malathion was detected in seven samples from agricultural drains at concentrations up to 0.17 μg/L. All of these peak concentrations, except bensulfuron methyl, exceed performance goals established by the CVRWQCB. No thiobencarb or carbofuran were detected in the Sacramento River, but molinate was present in three samples at a maximum concentration of 2.59 μg/L.[99] Rainy weather in late May and early June resulted in 178 emergency release variances, which contributed to elevated concentrations in 1993.

1994 Study. Field investigations were conducted from early May through early July 1994. Molinate, thiobencarb, carbofuran, methyl parathion, and malathion were monitored in water samples from up to six sites. Molinate was present in agricultural drains from early May to early July at concentrations up to 57 μg/L and exceeded the performance goal of 10 μg/L in 42 percent of the samples. Thiobencarb was detected in agricultural drains from mid-May through late June at concentrations up to 37.4 μg/L and exceeded the performance goal of 1.5 μg/L in 10 percent of the samples. Carbofuran was detected in agricultural drains from early May through mid-June at concentrations up to 2.3 μg/L and exceeded the performance goal of 0.4 μg/L in 29 percent of the samples. Methyl parathion was detected in four samples from agricultural drains at concentrations up to 2.1 μg/L and exceeded the performance goal of 0.13 μg/L in 4 percent of the samples. Malathion was detected in six samples at concentrations up to 0.12 μg/L and exceeded

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[98] Marshall Lee and Nancy Gorder, Information on Rice Pesticides Submitted to the Central Valley Regional Water Quality Control Board, Department of Pesticide Regulation, January 29, 1993.

[99] DPR, Information on Rice Pesticides Submitted to the Central Valley Regional Water Quality Control Board, March 8, 1994.

the performance goal of 0.1 µg/L in 8 percent of the samples.[100] The elevated concentrations of thiobencarb and methyl parathion were attributed to aerial drift. No thiobencarb was detected in the Sacramento River, but molinate was present in four samples at a maximum concentration of 0.42 µg/L. Unusually high concentrations of rice pesticides in 1994 may have been caused by low flows due to the drought.

Water samples were also collected weekly from the Colusa Basin Drain and Butte Slough from May 5 to June 13 and 96-hr Ceriodaphnia bioassays were conducted. No statistically significant mortality was found. The maximum mortality of 20 percent on June 13, 1994 coincided with a carbofuran concentration of 2.3 µg/L, which approached the 48-hr LC50 value of 2.6 µg/L.[101]

1995 Study. Field investigations were conducted from mid-April through mid-July. Molinate, thiobencarb, carbofuran, methyl parathion, and malathion were monitored in water samples from up to four sites. Molinate was present in agricultural drains from mid-May through mid-July at concentrations up to 25 µg/L and exceeded the performance goal of 10 µg/L in 24 percent of the samples. Thiobencarb was detected in agricultural drains from mid-May through early July at concentrations up to 3.5 µg/L and exceeded the performance goal of 1.5 µg/L in 11 percent of the samples. Carbofuran was detected in the drain from mid-May through mid-June at concentrations up to 0.7 µg/L and exceeded the performance goal of 0.4 µg/L in 18 percent of the samples. Methyl parathion was detected in only four out of 38 samples from agricultural drains at concentrations up to 0.19 µg/L and exceeded the performance goal of 0.13 µg/L in only one of these. Malathion was detected in only three out of 38 samples from the agricultural drains at concentrations up to 1.03 µg/L and exceeded the performance goal of 0.1 µg/L in all of them. The elevated concentrations were attributed to aerial drift and low flows in the Colusa Basin Drain during the peak concentration period.

None of these pesticides was detected in the Sacramento River at the Village Marina. Thiobencarb was also not detected in 13 samples collected from the Sacramento River at the intake to the City of Sacramento water treatment facility. However, molinate was detected in two of these samples at concentrations of 0.12 and 0.16 µg/L.[102]

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[100] J. Marshall Lee and Nancy N. Gorder, Information on Rice Pesticides Submitted to the Central Valley Regional Water Quality Control Board, Department of Pesticide Regulation, December 28, 1994.

[101] Robert Fujimura, DFG Aquatic Toxicology Lab Report No. P-1688, August 8, 1994.

[102] Nancy K.N. Gorder and J. Marshall Lee, Information on Rice Pesticides Submitted to the California Regional Water Quality Control Board, Central Valley Region, Department of Pesticide Regulation, December 28, 1995.

Eight samples were collected weekly from the Colusa Basin Drain from April 14 to June 27, 1995 and 96-hr Ceriodaphnia bioassays were conducted. Statistically significant mortality was found in a single sample (45 percent) collected on May 30, 1995. Concentrations of thiobencarb, molinate, malathion, methyl parathion, and carbofuran were less than 5 percent of their respective LC50 values, suggesting these rice pesticides were not the cause of the mortality.[103]

1996 Study. Field investigations were conducted from early April through the end of June. Molinate, thiobencarb, carbofuran, methyl parathion, and malathion were monitored in water samples from three sites, the Colusa Basin Drain, Butte Slough, and the Sacramento River at the Village Marina.

Molinate was detected from early May through the end of June in 74 percent of the samples collected in agricultural drains at concentrations up to 44 µg/L. It exceeded the performance goal of 10 µg/L in 20 out of 42 samples or 48 percent of the total. Thiobencarb was detected during the same period in 55 percent of the samples collected from the drains at concentrations up to 16.2 µg/L and exceeded the performance goal of 1.5 µg/L in 13 out of 42 samples or 31 percent of the total. Carbofuran was detected in 40 percent of the samples collected from the drains at concentrations up to 2.97 µg/L and exceeded the performance goal of 0.4 µg/L in all the samples in which it was detected, or 17 out of 42. Methyl parathion was detected in only four out of 38 samples collected from the drains or 10 percent of the total at concentrations up to 0.12 µg/L and did not exceed the performance goal of 0.13 µg/L in any of them. Malathion was detected in eight out of 38 samples collected from the drains or 21 percent of the total at concentrations up to 3.27 µg/L and exceeded the performance goal of 0.1 µg/L in all samples in which it was detected. Carbofuran and malathion were both detected in the drains before these chemicals were used on rice, suggesting other sources.

Among these four pesticides, only molinate was detected in the Sacramento River. Molinate was detected in two samples collected from the Sacramento River at a concentration of 0.95 µg/L. The City of Sacramento also detected molinate at its water intake on one day in May and three days in June at concentrations up to 0.14 µg/L.[104]

Eight samples were collected between April 1 and May 4, 1996 from the Colusa Basin Drain and 96-hr Ceriodaphnia bioassays were conducted. Statistically significant mortality (100 percent) was found in a single sample collected on May 28. The concentrations of all rice pesticides were less than their LC50s except malathion, which was present at four to five times its

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[103] Robert Fujimura, DFG Aquatic Toxicology Lab Report No. P-1751, August 1, 1995.

[104] Nancy K.N. Gorder, J. Marshall Lee, and KayLynn Newhart, Information on Rice Pesticides Submitted to the California Regional Water Quality Control Board, Central Valley Region, December 31, 1996.

acute LC50, suggesting it caused the toxicity. The concentrations of carbofuran exceeded the Ceriodaphnia LC50 of 2.6 μg/L in two samples that were not tested for toxicity.[105]

2.2.1.1.2 DPR Pesticide Studies

The DPR has conducted studies to develop methods to control the off-target movement of pesticides from rice fields.

Bensulfuron Methyl Study. Bensulfuron methyl ("BSM") is a rice herbicide. The dissipation of BSM was studied in three commercial rice fields located in Colusa and Glenn Counties. Samples were collected of irrigation supply and paddy water one day prior to application and 0, 1, 3, and 8 days after application. Samples were also collected from the Colusa Basin Drain, the Sacramento Slough, and the Sacramento River at Village Marina. BSM declined exponentially in paddy water of the three fields and half lives ranged from one to four days. Applications of BSM were made from May 1 to July 18, 1990. Residues of BSM were detected from late May through June in the Colusa Basin Drain at concentrations up to 2 μg/L and in the first half of June in Sacramento Slough at concentrations less than 1 μg/L. No BSM was detected in the Sacramento River.[106]

Carbofuran Study. Carbofuran is a rice insecticide used to control the rice water weevil. The concentrations of carbofuran in runoff water and paddy soil and water were studied in three commercial rice fields located in Colusa and Glenn Counties. Runoff samples were collected at the outlet of each field and analyzed for carbofuran during a 12-week period from mid-April to early July. Dissipation of carbofuran from soil and water was examined by sampling treated areas in the bottom paddies of each field. A total of 1.72, 5.40, and 11.03 percent of the carbofuran applied was discharged in runoff water from the three fields during a 54- to 80-day period after flooding. Soil half-lives ranged from 43 to 58 days and water half-lives from 18 to 26 days. Most of the carbofuran mass applied to the fields remained in paddy soil and, on average, no more than 27 percent of the applied mass was found in paddy water on any single day.[107]

Methyl Parathion Study. Methyl parathion is a rice insecticide. Concentrations in the Colusa Basin Drain in 1990 (up to 0.66 μg/L) exceeded target levels (0.26 μg/L) established by the CVRWQCB to protect aquatic life. Water from agricultural drainage ditches adjacent to four

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[105] Charlie Huang, Aquatic Toxicology Lab Report No. P-1790, October 1, 1996.

[106] Susan Nicosia, Chris Collison, and Paul Lee, Bensulfuron Methyl Dissipation in California Rice Fields, and Residue Levels in Agricultural Drains and the Sacramento River, Bulletin of Environmental Contamination and Toxicology, v. 47, 1991, pp. 131-137.

[107] S. Nicosia, N. Carr, D.A. Gonzales, and M.K. Orr, Off-Field Movement and Dissipation of Soil-Incorporated Carbofuran from Three Commercial Rice Fields, Journal of Environmental Quality, v. 20, no. 3, 1991, pp. 532-539.

rice fields in Colusa County was analyzed for methyl parathion during and following the aerial application period. Maximum concentrations of methyl parathion at the four sites were 5.3, 16.7, 2.8, and 4.7 μg/L. Mean deposition on the drains ranged from 1.2 to 11.1 mg/m², which is equivalent to 1.7 to 15.9 percent of the amount applied. Increased offsite deposition occurred when the flight pattern was parallel to the drain.[108]

2.2.1.1.3 CVRWQCB/SWRCB Bioassay Studies

Beginning in 1986, the CVRWQCB conducted a series of bioassay studies to assess the toxicity of rice drainage waters in the Sacramento Basin and their impact on the Sacramento River. Most of the work focused on the drainage waters released in the April to June period and used Ceriodaphnia and fathead minnows as the test organisms. In 1990, the work was continued by the SWRCB and used larval striped bass and Neomysis as test organisms. This work found that April-June drainage was frequently toxic to Neomysis, larval striped bass, and larval fathead minnows and periodically toxic to Ceriodaphnia. However, the frequency and severity of toxicity decreased substantially between 1989 and 1992, when the monitoring program was discontinued. The average larval striped bass mortality declined from 79 percent in 1990 to 41 percent in 1991 to 12 percent in 1992. Similarly, the average Neomysis toxicity declined from 68 percent in 1989 to 18 percent in 1991, the only two years in which Neomysis was tested. The pattern of toxicity also shifted over this period from primarily occurring late in the rice growing season (after mid-May) to early in the season (prior to mid-May). The decline in toxicity was attributed to changes in management practices implemented over this period, primarily increases in on-field holding times. Pre-harvest drainage, which is released in September, was generally not toxic.

The results of this work are summarized below. Most of the laboratory work described below was performed at the University of California at Davis.

1986 Bioassay Study. Samples were collected on two dates during the rice drainage season from the section of the Sacramento River that receives rice drainage, namely, Butte Slough, Colusa Basin Drain, Sacramento Slough, the Feather River and upstream and downstream of their junction with the Sacramento as well as at Natomas Drain outfall. The samples were assayed for Selenastrum growth and Ceriodaphnia mortality and reproduction and analyzed for metals and select pesticides. Some of the data are summarized in Table 16.

On May 29, 1986, Selenastrum growth was inhibited at all sites compared to the control. Discharges from Butte Slough and Sacramento Slough significantly reduced Selenastrum growth in the Sacramento River below the discharge point compared to the upstream sample. Butte Slough, Colusa Basin Drain, and Sacramento Slough were also toxic to Ceriodaphnia and discharges from Butte Slough increased Ceriodaphnia mortality compared to the upstream sample

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[108] J.A. Pino, R.L. Rasmussen, and J. White, Estimation of the Contribution from Offsite Aerial Deposition to Methyl Parathion Residues in Agricultural Drains in the Sacramento Valley, DPR Environmental Hazards Assessment Report, May 1992.

Table 16. Summary of *Selenastrum* Chlorophyll Concentrations and *Ceriodaphnia* Mortality in Samples Collected from the Sacramento River Watershed, 1986.[1]

STATION	May 29, 1986 *Selenastrum* Growth (Cells x 10^4/mL)	May 29, 1986 *Ceriodaphnia* Mortality (%)	June 24, 1986 *Selenastrum* Growth (Cells x 10^4/mL)	June 24, 1986 *Ceriodaphnia* Mortality (%)
Sacramento River u/s Butte Slough	189	0	364	-
Butte Slough	-	80	451	40
Sacramento River d/s Butte Slough	43	10	363	10
Sacramento River u/s Colusa Basin Drain	135	10	425	10
Colusa Basin Drain	156	100	445	30
Sacramento River d/s Colusa Basin Drain	128	10	454	10
Sacramento River u/s Sacramento Slough	212	10	458	10
Sacramento Slough	58	30	628	30
Sacramento River d/s Sacramento Slough (Upstream Feather River)	97	0	492	20
Feather River	127	0	-	20
Sacramento River d/s Feather River	-	-	230	20
Sacramento River at Natomas	96	0	216	0
Control	295	0	571	0

1 Shaner, 1986; Foe, February 6, 1987.

(shaded) Significant algal impairment is defined as any sample exhibiting a statistically significant reduction in growth compared to the control. Significant mortality is defined as any sample exhibiting 30 percent higher mortality than the control.

(Table 16). The concentration of chlorpyrifos (1.3 µg/L) in the sample from the Colusa Basin Drain exceeded the Ceriodaphnia LC50 (0.11 µg/L)[109] by an order of magnitude and was high enough to account for the toxicity (100 percent mortality). Methyl parathion was also elevated in this sample (0.7 µg/L).

On June 24, 1986, Selenastrum growth was inhibited at all sites except Sacramento Slough compared to the control. Butte Slough, Colusa Basin Drain, and Sacramento Slough were again toxic to Ceriodaphnia, but did not increase the toxicity of the Sacramento River below the point of discharge (Table 16). The Colusa Basin Drain sample also significantly impaired Ceriodaphnia reproduction.[110]

Based on these results, sampling was extended outside of the rice drainage season, and a more intensive sampling program was conducted to better characterize the toxicity of the drains and also several tributaries of the Sacramento River, which receive a mixture of agricultural and urban runoff. Selenastrum growth and Ceriodaphnia reproduction and mortality were measured at 15 sites on November 11 and December 16, 1986. Some of the data are summarized in Table 17.

Water from the agricultural drains was not toxic to either organism. However, American River water suppressed Ceriodaphnia reproduction on both dates and caused about a 50 percent decrease in reproduction up to 15 miles downstream on the Sacramento River. The Natomas East Main Drain and the Sacramento River at Miller Park inhibited Selenastrum growth in December.[111]

1987 Bioassay Study. The rice drainage monitoring program began in 1986 was continued in 1987. Samples were collected on six dates before and during the rice drainage season from 12 sites in the Sacramento Basin, including three agricultural drains and points upstream and downstream of them on the Sacramento River. Fathead minnow tissue growth and mortality, Ceriodaphnia reproduction and mortality, and Selenastrum growth were monitored. The fathead minnow and Ceriodaphnia mortality data are summarized in Table 18.[112]

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[109] Robert Fujimura, DFG Aquatic Toxicology Laboratory Report No. P-1534, March 22, 1993, Attachment A.

[110] Stephen W. Shaner, Ambient Water Toxicity Testing, May-June 1986, CVRWQCB Memorandum to Jerry Bruns and John Norton, August 25, 1986.

[111] Christopher Foe, Sacramento River Agricultural Drain Ambient Toxicity Test Results for the Months of November and December 1986, CVRWQCB Memorandum to Jerry Bruns, February 6, 1987.

[112] Christopher Foe, Results of the 1986-87 Lower Sacramento River Toxicity Survey, CVRWQCB Memorandum to Jerry Bruns, January 19, 1988.

Table 17. Summary of *Selenastrum* Chlorophyll Concentrations and *Ceriodaphnia* Mortality in Samples Collected from the Sacramento River Watershed, 1986.[1]

LOCATION	November 11, 1986		December 16, 1986	
	Selenastrum Growth (µg/L)	*Ceriodaphnia* Mortality (%)	*Selenastrum* Growth (µg/L)	*Ceriodaphnia* Mortality (%)
Sacramento River at Colusa	339	10	88	0
RD108 Drain	232	0	-	-
Sacramento River u/s Colusa Basin Drain	257	0	98	0
Colusa Basin Drain	367	0	116	10
Sacramento River d/s Colusa Basin Drain	159	0	73	0
Sacramento River u/s Sacramento Slough	337	10	98	0
Sacramento Slough	471	0	55	10
Sacramento River d/s Sacramento Slough	349	0	92	0
Feather River	274	0	110	0
Sacramento River d/s Feather River	296	0	146	0
Sacramento River at Village Marina	321	0	134	0
East Natomas Main Drain	361	0	49	0
American River	266	0	116	10
Sacramento River at Miller Park	332	10	-	-
Sacramento River at Freeport	-	-	61	10

1 Foe, February 6, 1987.

(shaded) Significant algal impairment is defined as any sample exhibiting significant reduction in growth compared to Colusa. Significant mortality is defined as any sample exhibiting 30 percent higher mortality than Colusa.

Table 18. Summary of Fathead Minnow and *Ceriodaphnia* Mortality (%) in Water Samples Collected from the Sacramento River Watershed, 1987.[1]

SAMPLING SITE[2]	FATHEAD MINNOW				CERIODAPHNIA					
	5/27	6/5	6/16	9/15	1/6	4/23	5/27	6/5	6/16	9/15
Sacramento Basin										
Colusa (RM 145)	17	13	8.7	10	0	10	20	0	0	0
u/s CBD (RM 90.5)	13	20	9.7	0.0	10	10	0	10	20	20
**Colusa Basin Drain	68	13	10	0.0	0	10	100	10	0	0
d/s CBD (RM 88.0)	47	33	9.7	0.0	0	0	40	30	0	10
u/s Sacramento Slough (RM 81.0)	3.0	20	9.3	10	0	10	0	20	0	20
**Sacramento Slough	50	13	9.3	7.0	0	0	0	10	0	0
d/s Sacramento Slough (RM 80.0)	3.0	10	9.3	13	0	0	0	10	0	0
**Feather River	17	60	6.7	20	0	20	50	30	0	20
d/s Feather River (RM 77.0)	27	13	8.5	10	0	0	10	30	0	10
Village Marina (RM 61.0)	20	20	9.5	13	0	0	0	10	10	10
E. Natomas Main Drain	30	20	10	-	10	20	0	10	0	-
American River	40	47	9.3	-	10	30	40	20	10	-
Delta										
Freeport (RM 46.5)	13	17	-	-	0	10	0	0	-	-
Clarksburg (RM 42)	7.0	17	-	-	-	0	0	0	-	-
Walnut Grove (RM 27)	17	33	-	-	-	10	10	0	-	-
Isleton (RM 17.5)	50	17	-	-	-	0	0	0	-	-
Cache Slough	7.0	23	-	-	-	10	20	20	-	-
Steamboat Slough	17	30	-	-	-	0	0	0	-	-
Above Rio Vista (RM 12.5)	27	20	-	-	-	-	20	0	-	-
Below Rio Vista (RM 11.5)	47	43	-	-	-	10	10	0	-	-
Collinsville (RM 1.0)	10	35	-	-	-	10	20	0	-	-
Chipps Island	7	43	-	-	-	10	30	100	-	-
Control	0	3.0	10	3.0						

1 Foe, January 19, 1988.
2 All sites are located on the Sacramento River, except the tributaries which are indicated by a double asterisk (**); u/s=upstream, d/s=downstream, CBD=Colusa Basin Drain, RM=river mile.
[shaded] Significant fathead minnow mortality is defined as any sample exhibiting 30% higher mortality than the control. Significant *Ceriodaphnia* mortality is defined as any sample exhibiting 30% higher mortality than the sample at Freeport.

Significant mortality to fathead minnows was found in eight out of 46 samples, or 17 percent of the total. All of the toxic samples were collected in a two week period between the last week of May and the first week of June when rice drainage was present. However, several of the toxic samples were clearly not due to rice drainage (samples from Feather River, American River, and East Natomas Main Drain). Fathead minnow growth was also lower than the control at all sites. Significant mortality was found in both agricultural drains on May 27, but not on the other three sampling dates. The discharge from the Colusa Basin Drain (66 percent mortality) on May 27 significantly increased the mortality of fathead minnows below the discharge point (47 percent) compared to the upstream sample (13 percent). No toxicity was found during the pre-harvest drainage season in September.

Significant mortality to Ceriodaphnia was found in eight out of 70 samples, or in about 11 percent of the total. All of the toxic samples were collected in the April to June rice drainage period. An additional seven samples showed significant Ceriodaphnia reproductive impairment. The discharge from the Colusa Basin Drain (100 percent mortality) on May 27 significantly increased the mortality of Ceriodaphnia below the discharge point (40 percent) compared to the upstream sample (0 percent). No Ceriodaphnia toxicity was observed in Sacramento Slough. No toxicity was found during the pre-harvest drainage season in September.

1988 Colusa Basin Drain Study. In 1988, fathead minnow and Ceriodaphnia tests were run on grab water samples collected almost daily from May 3 through June 20 from the Colusa Basin Drain. Samples were collected at the intersection of Road 99E and the Colusa Basin Drain, about 1.5 miles upstream from its confluence with the Sacramento River. Three samples were also tested for toxicity to larval striped bass, using 96-hr static non-renewal bioassays and 4 to 12 day old larvae. Salinities were adjusted to 2.5 to 3 ppt to minimize osmotic stress (Sec. 2.1.1.1).

No significant fathead minnow toxicity was observed. However, 25 out of 44 or 57 percent of the samples were toxic to Ceriodaphnia.[113] Two out of three samples tested were acutely toxic to larval striped bass.[114] TIEs conducted by the U.S. EPA on two samples (May 17 and June 1, 1988) identified methyl parathion and carbofuran as possible toxicants responsible for the Ceriodaphnia toxicity.[115]

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[113] Christopher G. Foe, Preliminary 1988 Colusa Basin Drain Rice Season Biotoxicity Results, CVRWQCB Memorandum to Jerry Bruns, August 26, 1988.

[114] Howard C. Bailey, Response of Larval Striped Bass to Agricultural Drainage and Sacramento River Waters, August 12, 1988.

[115] Teresa J. Norberg-King, Elizabeth J. Durhan, and Gerald T. Ankley, Application of Toxicity Identification Evaluation Procedures to the Ambient Waters of the Colusa Basin Drain, California, Environmental Toxicology and Chemistry, v. 10, 1991, pp. 891-900.

1989 Colusa Basin Drain Study. In 1989, fathead minnow and Ceriodaphnia tests were again run on grab water samples collected almost daily from April 23 through June 18 from the same Colusa Basin Drain location. Samples collected between May 15 and June 14 from the Colusa Basin Drain and from the Sacramento River both above (Colusa) and below (Walnut Grove) rice inputs were also tested for toxicity to larval striped bass and Neomysis. Static 96-hr bioassays were conducted with 1-2 day old striped bass and 1-3 day old Neomysis. Striped bass bioassays were conducted at ambient salinities and Neomysis bioassays were adjusted to 2500 µmhos/cm.

No significant fathead minnow toxicity was observed. However, 13 out of 16 or 81 percent of the samples collected from Colusa Basin Drain were acutely toxic to larval striped bass. Mortality to striped bass averaged 68 percent and ranged from 8.5 to 100 percent. Control mortality ranged from 5.1 to 32.5 percent. The average mortality to striped bass was 88 percent in two out of four samples collected at Colusa, above rice drainage inputs, and 98 percent in two out of four samples collected at Walnut Grove, below rice drainage inputs. All of the larval striped bass bioassays were conducted at ambient salinities, which averaged about 500 µmhos/cm for the Colusa Basin Drain samples and 110 to 160 µmhos/cm for the river samples.[116] As discussed in Section 2.1.1.1, mortality is high at low salinities. The possibility that the mortality was due to the low salinity of the test solutions cannot be ruled out. The controls were well water adjusted to ambient salinities and thus may have had different ionic composition than the test samples.

Fifteen out of 19 samples were acutely toxic to Neomysis. Mortality averaged 70 percent and ranged from 0 to 100 percent. Control mortality ranged from 0 to 20 percent. No toxicity was found in two samples from Colusa and one from Walnut Grove.[117] Similar results were obtained by DFG for Neomysis.[118] Likewise, 21 out of 42 or 50 percent of the samples were toxic to Ceriodaphnia, consistent with the 1988 results.[119] TIEs conducted by the U.S. EPA on five samples collected from Colusa Basin Drain suggested that methyl parathion, carbofuran, and malathion were responsible for the Ceriodaphnia toxicity.[120] Pesticide analyses on the most toxic

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[116] Bailey et al., 1989, Table 1.

[117] Bailey et al., 1989, Table 2.

[118] Brian Finlayson, Acute Toxicity Tests on Juvenile Neomysis mercedis, DFG Memorandum to Christopher Foe, August 11, 1989.

[119] Christopher Foe and Valerie Connor, 1989 Rice Season Toxicity Monitoring Results, CVRWQCB Staff Report, July 1991a.

[120] Teresa J. Norberg-King and Elizabeth J. Durhan, 1989 Colusa Basin Drain Toxicity Identification Evaluation, Sacramento, California, U.S. EPA Report 09-89, November 1989.

samples indicated that carbofuran was present in all samples (0.16 - 1.5 µg/L) and methyl parathion (<0.4 - 6.4 µg/L) and malathion (<0.2 - 14 µg/L) were present in most samples.

1989 Pre-Harvest Rice Drainage Study. Pre-harvest drainage from rice fields was monitored for fathead minnow growth and mortality and Ceriodaphnia reproduction and mortality on September 15, 1989 at 13 sites, including 11 agricultural drains and two upstream sites. The results, summarized in Table 19, indicate that no toxicity to fathead minnows was detected at any site. Significant Ceriodaphnia mortality was found at three sites, Stone Corral GCID (40 percent), Colusa Basin Drain at Highway 45 (30 percent), and the Maxwell Irrigation District (40 percent). The CVRWQCB concluded that toxicity was low and that the release of pre-harvest rice drainage does not cause a water quality problem.[121]

1990 Colusa Basin Drain Study. In 1990, 16 grab samples were collected about three times a week from the same Colusa Basin Drain site between April 16 and May 23. Static 96-hr bioassays were conducted with 1-day old striped bass larvae. Control water was UCD well water supplemented as necessary with seawater to match the conductivity of drain water. All of the samples were acutely toxic to larval striped bass, and mortality ranged from 26 to 100 percent and averaged 79 percent. Control mortality was either 0 percent or 9.6 percent.

The Bailey et al. (1992) larval striped bass results differ from similar work conducted by DFG. In 96-hour static bioassays using 1 to 2 day old larvae conducted by the DFG on samples collected during the same time period (Sec. 2.2.1.1.4), only one out of five samples from the Colusa Basin Drain was toxic to larval striped bass. In the DFG work, the salinities of the samples and NTL well water controls were adjusted to 2 ppt with artificial seasalt, which substantially reduced mortality due to osmotic stress and also could have masked toxic effects. The Bailey et al. (1992) work, on the other hand, was conducted at ambient salinities. As discussed in Section 2.1.1.1, some of the mortality in the Bailey et al. study could have been due to low salinity of the test solutions or differences in the ionic composition of test solutions and controls. Likewise, the low mortalities reported by DFG could have been due, in part, to reductions in toxicity due to chemical interactions between the added salts and the toxicant(s).

A single sample was passed through a C_{18} column and tested with Neomysis. No toxicity was found in the column eluent, indicating that the toxic fraction was removed and suggesting that the toxicity resides in the organic fraction. The settled and sediment-containing samples produced equivalent responses, suggesting that the toxicity is not associated with the particulate fraction of the sample.[122]

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[121] Valerie Connor, Biotoxicity Monitoring of Pre-Harvest Drainage from Rice Fields: September 1987 - 1989, CVRWQCB Memorandum to Jerry Bruns and Rudy Schnagl, March 13, 1990.

[122] Howard C. Bailey, David J. Ostrach, and David E. Hinton, Effect of Rice Irrigation Water in Colusa Basin Drain on Fertilization Success and Embryonic Development in Striped Bass. Submitted to SWRCB, June 11, 1992.

Table 19. Toxicity of Pre-Harvest Drainage to *Ceriodaphnia* and Fathead Minnows, September 15, 1989.

STATION	CERIODAPHNIA		FATHEAD MINNOW	
	9-Day Reproduction	Mortality (%)	Growth (mg)	Mortality (%)
Glenn-Colusa Irrigation District (GCID); Hunter Creek at Four Mile Rd	63.0	0	20.3	0
Provident Irrigation District and GCID; Willow Creek at Norman Rd	64.6	0	20.0	0
Sutter Butte area; Butte Slough Outfall, at outfall gates on Sacramento River	63.8	10	19.0	13
Princeton area of GCID; drain at Clark and Dodge Rds	65.6	10	18.9	10
GCID; Stone Corral Creek at Four Mile Rd	42.6	40	20.5	10
GCID; Kuhl Weir on Two Mile Rd	51.9	0	20.1	0
GCID; San Jose Creek at San Jose Rd	52.4	20	20.3	10
Colusa Basin Drain at Highway 45	56.2	30	20.2	7
Colusa Basin Drain at Rd 99	59.3	0	19.6	10
Sacramento Slough at Karnack Pumping Plant; drains eastern side rice fields	43	0	20.0	13
Maxwell Irrigation District Drain	33.0	40	20.1	10
Sacramento River at Colusa; upstream of rice inputs	60.8	0	20.6	26
Glenn-Colusa Canal; Highway 62 east of Willows (before rice inputs)	47.5	0	20.3	17
Lab Control	16.9	0	20.9	7

1 Connor, March 13, 1990.

(shaded) Significant mortality is defined as any sample exhibiting a 30% difference in mortality relative to the lab control.

In 1990, select samples were also evaluated for toxicity to striped bass embryos. At the end of the 120 hr exposure period, which included about 72 hr of post-hatch exposure, control mortality was 23 percent while mortality in the treatment groups ranged from 73 to 100 percent. At least two of the three samples tested produced significantly higher mortality than the controls within 48 hrs, indicating a failure to complete the normal embryo development and hatching process.[123]

1991 Colusa Basin Drain Study. In 1991, 20 grab samples were collected between April 18 and June 6 from the same Colusa Basin Drain site. A sample was also collected from the Sacramento River at Garcia Bend, downstream from the discharge of the Colusa Basin Drain into the Sacramento River. Static 96-hr bioassays were conducted with ≤1-day old posthatch striped bass larvae. Control water was Sierra spring water to which salts were added to adjust the conductivity to 500 µmhos/cm.

Nine out of the 20 samples collected from the Colusa Basin Drain were acutely toxic to striped bass larvae. Mortality averaged 40 percent and ranged from 4 to 100 percent. Control mortality averaged 12.5 percent and ranged from 2 to 37 percent. In contrast, a DFG study found that only one out of seven samples was toxic to larval striped bass (Sec. 2.2.1.1.4). The difference is probably due to differences in the salinity of the test solutions. As discussed in Section 2.1.1.1, some of the striped bass mortality found by Bailey et al. (1992) could have been due to the low salinity test waters.

A May 8 sample collected at Garcia Bend resulted in significant mortality to both striped bass (70 percent) and fathead minnows. Although the mortality for the fathead minnow bioassay was not reported, a sample collected the next day (May 9) by others resulted in 70 percent mortality of larval fathead minnows (Table 6). Previous work[124] indicated that rice drainage was not toxic to fathead minnows, suggesting that the Garcia Bend toxicity is not due to rice drainage. Other work suggests that ziram may cause the toxicity at Garcia Bend (Sec. 2.1.1.6).

Limited TIEs were conducted on five of the toxic samples collected in May. In these TIEs, the samples were treated with EDTA and C_{18} columns and the treated samples were tested with larval striped bass. Three separate aliquots of each sample at pH 3, pH 9, and the initial sample pH were passed through the C_{18} columns and the eluent tested. In all cases, mortality was substantially reduced or eliminated in samples passed through C_{18} columns, which preferentially remove nonpolar organic materials. In some cases, mortality may have been reduced by treatment with EDTA, but this effect was small compared to that observed with the C_{18} columns.

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[123] H.C. Bailey, C. Alexander, C. Digiorgio, M. Miller, S.I. Doroshov, and D.E. Hinton, The Effect of Agricultural Discharge on Striped Bass (Morone saxatilis) in California's Sacramento-San Joaquin Drainage, Ecotoxicology, v. 3, 1994, pp. 123-142.

[124] Foe and Connor, July 1991a.

Surviving larvae from these toxicity tests were fixed in Bouin's fixative, sectioned in paraffin, stained with hematoxylin and eosin, and examined for morphological characteristics. The results, summarized in Table 20, indicate that exposure to Colusa Basin Drain water resulted in alterations of the skeletal muscle and necrotic lesions of varying intensity located primarily in undifferentiated cells of the brain and upper spinal cord of the central nervous system. Although some of these conditions were seen in the controls, the control frequency was much lower than for exposed fish.

In 1991, 24 grab samples, mostly the same as those evaluated for striped bass toxicity, were also assayed for toxicity to Neomysis mercedis in 48-hr static bioassays. Only two of the samples resulted in statistically significant mortality compared to the controls. Mortality averaged 20 percent and ranged from 0 to 100 percent, while control mortality ranged from 0 to 30 percent. Survival was 100 percent in 58 percent of the samples.[125]

1992 Colusa Basin Drain Study. In 1992, 17 grab samples were collected between April 12 and June 5 from the same Colusa Basin Drain site. Ten samples were also collected from a rice field in eastern Sutter County and two samples were collected from the Glenn-Colusa Canal, a source of rice field water. Static 4-day and 10-day bioassays were conducted with ≤1-day old posthatch striped bass larvae. The exposure period was extended for an additional six days in this work to monitor latent effects on survival. Test solutions were diluted to 10 percent by the addition of control water after 4 days to simulate travel downstream to the estuary. Control water was Institute of Ecology well water, which normally has a conductivity of 500 to 550 µmhos/cm. Organophosphate, carbamate, and thiocarbamate pesticides were measured in eight of the Drain samples and six of the rice field samples.

After exposure for 4 days, three out of the 17 Drain samples or 18 percent of the total resulted in statistically significant mortality to striped bass larvae compared to the controls. Mortality averaged 12 percent and ranged from 0 to 58 percent. Control mortality averaged 10 percent and ranged from 2 to 18 percent. After exposure for 10 days, 4 out of 16 samples were toxic to larval striped bass. Mortality averaged 44 percent and ranged from 18 to 81 percent. Control mortality averaged 31 percent and ranged from 17 to 53 percent. Thus, statistically significant mortality was generally identified within the first 96 hours of exposure. Only one sample exhibited increased mortality at the end of 10 days without showing any effects at the end of 4 days. As discussed in Section 2.1.1.1, some of the mortality could have been due to the low salinity of test waters.

All of the toxic samples were collected early in the rice season, prior to mid-May, while in previous years, especially 1989 and 1990, most of the toxic samples were collected after mid-May. No rice pesticides were detected in any of the toxic samples, although 2.8 µg/L of propham was detected in one of them. Monitoring conducted by DPR in 1992 (Sec. 2.2.1.1.1) confirms

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[125] Howard C. Bailey, David Ostrach, and David E. Hinton, Colusa Basin Drain Toxicity Testing, Progress Report through January 31, 1992, December 1993.

Table 20. Histopathologic Studies of Larval Striped Bass (*Morone saxatilis*) Exposed for 96 hours to Colusa Basin Drain (CBD) Waters or Sacramento River Water (Garcia Bend) in 1991[1]

Sample Date	Number of Individuals	Central Nervous System			Skeletal Muscle	
		Midbrain (Mesencephalon)	Hindbrain (Rhombencephalon)	Spinal Cord	Pallor and Vacuolation of Fibers	Necrosis of Fibers
4/29	CBD N=5	3/4 (2)*	3/4 (2)*	1/5 (1)	5/5 (2)	1/5 (1)
5/1	CBD N=2	2/2 (2)	2/2 (3)	1/2 (3)	2/2 (2)	0/2
	Control N=5	0/5	0/5	0/5	0/5	0/5
5/15	CBD N=6	5/6 (2)	6/6 (2+)	2/6 (2+)	6/6 (2)	4/6 (1.5)
5/21	Sac River N=6	2/6 (2)	0/6	0/6	4/6 (2)	0/6
	Control N=6	1/6 (1)	0/6	0/6	3/6 (1)	0/6

1 Bailey et al. 1993.
* Portion of organ not present in tissue sections of 1 fish.
Numerator in fractions = number of individuals showing that alteration
Denominator in fractions = number of individuals exposed or analyzed
Numbers in parentheses indicate subjective severity of alteration.
(1 = present but rare; 2 = moderate; 3 = severe)

that the major rice pesticides were either not detected in Drain water or were present at very low concentrations (methyl parathion = 0.4 µg/L) during the period when toxic samples were found.[126]

A TIE was conducted on one of these toxic samples (April 26). The C_{18} column removed 100 percent of the toxicity after exposure for 4 days and 64 percent after 10 days, suggesting that nonpolar organics may have caused the toxicity. Concentrations of organophosphate, carbamate, and thiocarbamate pesticides measured in these samples were not individually or cumulatively high enough to explain the toxicity.

None of the samples collected from the rice fields or from the Glenn-Colusa Canal resulted in statistically significant mortality to larval striped bass after exposure for 4 days even though rice pesticides were detected at elevated concentrations in several of them. Rice field mortality ranged from 0 to 16 percent and averaged 3.9 percent and no mortality was found in either Canal sample. Control mortality ranged from 5 to 18 percent. However, after exposure for 10 days, statistically significant mortality compared to the controls was found in two samples from the rice fields and one of the Canal samples. Both of the toxic rice field samples were collected prior to mid-May before rice pesticides were detected in the waters. One of the toxic rice field samples (mortality = 66 percent) was collected at the inlet to the field. Rice field mortality ranged from 16 to 66 percent and averaged 34 percent. Canal mortality in the single toxic sample was 50 percent. Controls ranged from 14 to 32 percent.

Both of the toxic rice field samples were collected in early May before molinate or carbofuran were detected in field water. Further, two samples that were not toxic had high concentrations of molinate (91 µg/L and 417 µg/L) and one of these had a high concentration of carbofuran (139 µg/L). The 96-hr larval striped bass LC50 for molinate is 9,400 µg/L and for carbofuran is 170 to 280 µg/L.[127]

Surviving larvae from these toxicity tests were fixed in 10 percent neutral buffered formalin, sectioned in paraffin, stained with hematoxylin and eosin, and examined for morphological characteristics. Central nervous system and skeletal muscle lesions and/or vacuolation similar to that reported in 1991 (Table 20) were observed in larval striped bass exposed to water collected from the Colusa Basin Drain, rice fields, and the Glenn-Colusa Canal.

Striped bass larvae were also exposed to known concentrations of thiobencarb, carbofuran, bufencarb (no longer registered for use), methyl parathion, molinate, and diazinon (not used on rice) and surviving fish were morphologically examined. Structural responses to individual pesticides varied considerably depending upon the pesticide used and its concentration.

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[126] Lee and Groder, January 29, 1993.

[127] Robert Fujimura, Brain Finlayson, and Gary Chapman, Evaluation of Acute and Chronic Toxicity Tests with Larval Striped Bass, In: Aquatic Toxicology and Risk Assessment, Volume 14, ASTM STP 1124, 1991, pp. 193-211.

These tests did demonstrate that some of these chemicals produced some of the types of lesions (brain necrosis and vacuolation) observed in the ambient samples. However, except for carbofuran and thiobencarb, necrosis of the brain was uncommon. Further spinal column lesions, one of the defining features of exposed Colusa Basin Drain fish, were not observed. Diazinon (1.2 μg/L) and bufencarb (0.4 μg/L) were the most toxic chemicals tested, producing necrosis and vacuolation at the lowest concentrations tested (indicated in parentheses). For both molinate and thiobencarb, the incidence and severity of morphological alterations were higher at lower concentrations than higher ones. Striped bass exposed as embryos generally exhibited more histological effects than when exposed as larvae.

In 1992, two samples collected by the USGS in June were tested with Neomysis after 48 and 96 hours. The June 22 sample resulted in statistically significant mortality of 80 percent after 48 hours compared to 0 percent in the control. Mortality did not increase after 96 hours. The June 18 sample resulted in 13 percent mortality after 48 hours and statistically significant mortality of 60 percent after 96 hours compared to 20 percent in the controls. Concurrent 7-day tests with Ceriodaphnia on these same samples did not result in any mortality, but reproduction was 25 percent lower in the June 18 sample than in the control.[128]

These results collectively suggest that the toxicity found in Colusa Basin Drain water in 1992 was not due to parent compounds of the principle rice herbicides (i.e., molinate, carbofuran, thiobencarb, methyl parathion, malathion). The fact that parent compounds were not detected in toxic samples implicate either a non-rice source, a rice pesticide degradation product, or a rice pesticide that was not measured. A major rice pesticide degradation product is probably not involved because all of the toxic samples were collected early in the rice season, before mid-May. The toxicity found at the inlet to a rice field and in irrigation water from the Glenn-Colusa Canal and morphological alterations of fish exposed to Canal water suggest that at least some of the toxicity originates in the water supply to the fields and is not associated with rice farming practices.

2.2.1.1.4 DFG Bioassay Study

Samples were collected three times a week between April 16 and June 25, 1990 from three sites -- the Colusa Basin Drain, the Sacramento River near Colusa, and the Sacramento River at Rio Vista. The samples were analyzed for three pesticides (carbofuran, malathion, methyl parathion) and three metals (cadmium, copper, zinc) and assayed for toxicity to young Neomysis and larval striped bass using the ASTM static 96-hr bioassay. The pesticide data are summarized in Table 21 and the mortality data in Table 22.

In the Colusa Basin Drain, significant mortality to Neomysis was found in 13 out of 28 samples, or in about 46 percent of the total. The toxicity was attributed to methyl parathion between May 12 and 28, when concentrations were equal to or greater than the 96-hr LC50 for

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[128] Bailey et al., 1993.

Table 21. Concentrations (µg/L) of Carbofuran, Malathion, and Methyl Parathion in Water Samples Collected from the Sacramento River in 1990.[1]

Collection Date	Sacramento River above Colusa			Colusa Basin Drain			Sacramento River at Rio Vista		
	Carbofuran	Malathion	Methyl parathion	Carbofuran	Malathion	Methyl parathion	Carbofuran	Malathion	Methyl parathion
April 16	< 0.05	< 0.10	< 0.10	< 0.05	< 0.10	< 0.10	< 0.05	< 0.10	< 0.10
April 19	< 0.05	< 0.10	< 0.10	0.21	< 0.10	< 0.10	< 0.05	< 0.10	< 0.10
April 21	0.24	< 0.10	< 0.10	0.30	< 0.10	< 0.10	< 0.05	< 0.10	< 0.10
April 23	< 0.10	< 0.10	< 0.10	0.58	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
April 26	< 0.05	< 0.10	< 0.10	1.2	< 0.10	< 0.10	< 0.05	< 0.10	< 0.10
April 28	< 0.10	< 0.10	< 0.10	1.3	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
April 30	< 0.05	< 0.10	< 0.10	1.0	< 0.10	< 0.10	< 0.05	< 0.10	< 0.10
May 3	< 0.10	< 0.10	< 0.10	0.90	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
May 5	< 0.10	< 0.10	< 0.10	0.46	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
May 8	< 0.10	< 0.10	< 0.10	0.12	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
May 12	< 0.05	< 0.10	< 0.10	0.60	< 0.10	0.41	< 0.05	< 0.10	< 0.10
May 14	< 0.05	< 0.10	< 0.10	0.49	< 0.10	0.61	< 0.05	< 0.10	< 0.10
May 17	< 0.05	< 0.10	< 0.10	0.78	< 0.10	0.66	< 0.05	< 0.10	< 0.10
May 19	< 0.05	< 0.10	< 0.10	0.80	< 0.10	0.42	< 0.05	< 0.10	< 0.10
May 21	< 0.05	< 0.10	< 0.10	0.27	< 0.10	0.54	< 0.05	< 0.10	< 0.10
May 24	< 0.05	< 0.10	< 0.10	0.64	0.59	0.22	< 0.05	< 0.10	< 0.10
May 26	< 0.05	< 0.10	< 0.10	0.64	< 0.10	0.21	< 0.05	< 0.10	< 0.10
May 28	< 0.05	< 0.10	< 0.10	0.42	< 0.10	0.21	< 0.10	< 0.10	< 0.10
May 31	< 0.05	< 0.10	< 0.10	0.48	< 0.10	0.12	< 0.10	< 0.10	< 0.10
June 2	< 0.05	< 0.10	< 0.10	0.43	0.12	0.20	0.15	< 0.10	< 0.10
June 4	< 0.05	< 0.10	< 0.10	0.42	0.15	0.12	0.20	< 0.10	< 0.10
June 7	< 0.05	< 0.10	< 0.10	0.36	< 0.10	0.18	0.14	< 0.10	< 0.10
June 9	< 0.05	< 0.10	< 0.10	0.37	< 0.10	< 0.10	0.13	< 0.10	< 0.10
June 11	< 0.05	< 0.10	< 0.10	0.29	< 0.10	0.13	0.10	< 0.10	< 0.10
June 14	< 0.05	< 0.10	< 0.10	0.46	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
June 16	< 0.05	< 0.10	< 0.10	0.47	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
June 18	< 0.05	< 0.10	< 0.10	0.35	< 0.10	< 0.10	< 0.05	< 0.10	< 0.10
June 21	< 0.05	< 0.10	< 0.10	0.28	< 0.10	< 0.10	< 0.05	< 0.10	< 0.10
June 23	< 0.05	< 0.10	< 0.10	0.26	< 0.10	< 0.10	< 0.05	< 0.10	< 0.10
June 25	< 0.10	< 0.10	< 0.10	0.27	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10

1 Finlayson et al., 1990.

Table 22. *Neomysis* and Striped Bass Mortality (%) in Water from the Sacramento River at Colusa (SRC), Colusa Basin Drain (CBD), and Rio Vista (SR4) in 1990.[1]

DATE	*Neomysis* Mortality			Striped Bass Mortality	
	SRC	CBD	SR4	CBD	SR4
April 16	16	20	11	-	26
April 19	25	15	25	-	47
April 21	0	-	-	-	45
April 23	-	-	-	-	11
April 26	5	0	0	-	20
April 28	10	5	11	-	5
April 30	0	35	5	-	11
May 3	0	35	15	-	10
May 5	5	21	0	-	5
May 8	10	11	0	-	10
May 12	28	100	25	11	25
May 14	42	100	21	-	15
May 17	25	100	45	10	50
May 19	35	100	0	30	50
May 21	5	100	10	26	11
May 24	12	100	6	-	10
May 26	17	100	5	-	11
May 28	10	55	11	25	5
May 31	5	32	0	-	5
June 2	15	8	6	-	5
June 4	7	9	44	-	15
June 7	38	17	21	-	55
June 9	56	13	6	-	20
June 11	17	14	0	-	25
June 14	5	44	0	-	0
June 16	10	10	5	-	26
June 18	15	11	10	-	19
June 21	11	10	15	-	-
June 23	40	14	32	-	-
June 25	24	15	6	-	-

1 Finlayson et al., 1991.

(shaded) Significant mortality is defined as any sample in which the mortality was significantly greater than the laboratory control ($p < 0.05$).

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Neomysis (0.20 µg/L). Significant mortality (30 percent) to larval striped bass was also found in one out of five or 20 percent of the samples collected between May 12 and May 28, 1990. In contrast, Bailey et al.[129] reported that all of the samples collected in the Colusa Basin Drain between April 16 and May 23, 1990 were acutely toxic (average mortality 79 percent) to larval striped bass.

The DFG repeated the striped bass portion of this work in 1991. Seven samples were collected between May 2 and June 13, 1991 from the Colusa Basin Drain. One of the seven samples resulted in significant mortality (19 percent) to larval striped bass. In contrast, nine out of 20 samples collected between April 18 and June 6, 1991 and tested by Bailey et al.[130] resulted in an average mortality of 40 percent.[131]

The difference between the DFG and Bailey et al. (1993) work is probably due to differences in the salinity of the test solutions. As discussed above, the Bailey et al. work was conducted at ambient conductivities of 500 to 550 µmhos/cm while the DFG increased ambient salinities to 2,000 ppt using artificial seasalt to minimize osmotic stress. The former treatment may increase mortality from osmotic stress while the latter may reduce toxicity due to interactions between the added salts and the toxicant(s).

In contrast, only about 10 percent of the samples from each of the two Sacramento River sites were toxic to Neomysis and striped bass. The Sacramento River near Colusa, upstream of rice drainage, was toxic to Neomysis more frequently than at Rio Vista, below rice inputs, suggesting that rice drainage is not the cause of the toxicity. Carbofuran was detected in two toxic Sacramento River samples at concentrations (0.10, 0.24 µg/L) well below the 96-hr LC50 for striped bass (210 µg/L) and Neomysis (3.7 µg/L).

Trace metal concentrations were consistent among the three sites and well below toxicity and water quality criteria levels. Cadmium concentrations were typically less than the detection limit (0.1µg/L) except for a few hits at 0.2 to 0.7 µg/L. Copper concentrations ranged from 1 to 27 µg/L and zinc concentrations from <1 to 31 µg/L.[132]

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[129] Bailey et al., 1992.

[130] Bailey et al., 1993.

[131] Robert Fujimura, Aquatic Toxicology Lab Report No. P-1439, June 10, 1992.

[132] B.J. Finlayson, J.M. Harrington, R. Fujimura, and G. Isaac, Toxicity of Colusa Basin Drain Water to Young Mysids and Striped Bass, CDFG Administrative Report 91-2, 1991 and B.J. Finlayson, J.A. Harrington, R. Fujimura and G. Isaac, Identification of Methyl Parathion Toxicity in Colusa Basin Drain Water, Environmental Toxicology and Chemistry, v. 12, 1993, pp. 291-303.

Bioassays were also conducted to determine the LC50s of several pesticides, including carbofuran, thiobencarb, molinate, endosulfan, malathion, and methyl parathion to larval striped bass and chinook salmon fry. This work demonstrated that striped bass larvae were more sensitive to several pesticides than chinook salmon fry. Lower LC50s were obtained for striped bass larvae compared to chinook salmon fry for carbofuran (210 versus 610 μg/L), thiobencarb (730 versus 760 μg/L), molinate (9,400 versus 13,000 μg/L), endosulfan (0.31 versus 0.74 μg/L), and malathion (47 versus 101 μg/L). Striped bass and salmon were equally sensitive to methyl parathion. Mixtures of the insecticides methyl parathion, malathion, and carbofuran produced additive toxicity to striped bass and Neomysis.[133]

2.2.1.1.5 USDOI Study

During March 1994, the U.S. Department of the Interior ("USDOI") measured eleven pesticides,[134] five halogenated organic compounds,[135] and 21 metals in water from 26 rice fields in Butte, Colusa, and Sutter counties as well as the Colusa Basin Drain at Knight's Landing, the Sacramento River near Corning, and the Colusa, Delevan, and Sutter National Wildlife Refuges. No organic compounds were detected. However, detection limits were high, ranging from 3 to 5 μg/L for the pesticides and 0.5 μg/L for the halogenated organics. Metals were less than concentrations posing hazards to fish and wildlife, with the possible exception of silver, which was present at up to 20 μg/L.[136]

2.2.1.1.6 USGS Study

The USGS also monitored three rice pesticides, molinate, carbofuran and thiobencarb, during May, June, and July of 1990 to 1992 at the Colusa Basin Drain, the Sacramento River at Sacramento and Rio Vista, and at Chipps Island. The highest concentrations were measured in the Colusa Basin Drain. Concentrations progressively decreased downstream due to dilution and degradation. For example, the maximum concentration of molinate in 1991 decreased from 14.9 μg/L at Colusa Basin Drain to 1.17 μg/L at Sacramento, to 0.347 μg/L at Rio Vista.

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[133] DFG, Standardized Testing Program, 1990 Progress Report, December 1991, and Fujimura, et al., 1991.

[134] The pesticides that were monitored are aldicarb sulfoxide, aldicarb sulfone, oxamyl, methomyl, 3-OH-carbofuran, aldicarb, propoxur, carbofuran, carbaryl, methiocarb, and thiobencarb.

[135] The compounds that were monitored are bromodichloromethane, bromoform, chloroform, dibromochloromethane, and total trihalomethanes.

[136] Glenn Wylie, Analytical Results of Water Chemistry from Rice Fields and Related Aquatic Systems, USDOI, National Biological Survey Memorandum to Chairman, CVHJV Research Committee, April 29, 1994.

The maximum concentration of molinate in the Colusa Basin Drain decreased from 51 µg/L in 1990 to 14.9 µg/L in 1991, when the holding period for rice field water was 19 days, to 4.10 µg/L in 1992, when the holding period was 28 days, roughly a factor of three each year. Carbofuran concentrations decreased by a factor of four from 1990 to 1991, but decreased only slightly from 1991 to 1992. The decreases were probably due in part to the implementation of on-farm management practices, which resulted in progressively longer holding times for rice field water.[137] However, since the decreases were not proportional to increases in holding times, other factors likely contributed. Thiobencarb was not detected in 1990, and the maximum concentration increased from 0.162 µg/L in 1991 to 0.200 µg/L in 1992.

The transport and transformation of rice pesticides were studied in a Lagrangian study of a 45-mile reach of the Sacramento River downstream of the Colusa Basin Drain. Sampling began on June 3, 1990 at 1800 hours. The parcel of water was followed using a drogue, and samples were collected every six hours for a total of 96 hours. Samples were analyzed for molinate, carbofuran, methyl parathion, thiobencarb, carbofuran phenol, and para-nitrophenol. Molinate, thiobencarb, and carbofuran were detected at all sites. Molinate decreased slightly with time, but carbofuran and thiobencarb concentrations were constant. In addition, two photolysis degradation products of molinate, 2-keto molinate and 4-keto molinate, and the hydrolysis or microbial degradation product of carbofuran, carbofuran phenol, were detected. The U.S. EPA has also detected carbofuran phenol in a sample collected from the Colusa Basin Drain in May 1988 that was toxic to Ceriodaphnia.[138] Methyl parathion was not detected, but its hydrolysis or microbial degradation product, para-nitrophenol, was detected. These results indicate that rice herbicides and their degradation products were being transported into the Delta from upstream sources.[139] This study demonstrates the potential for other unidentified pesticides to enter the Delta from agricultural practices in the Central Valley.

Thus, while holding rice water on the fields allows the parent compounds to degrade, other compounds are formed through photolysis, hydrolysis, and microbial degradation. Many other degradation products of these rice herbicides have been reported in the literature (Table 23), but were not measured in this USGS study nor have they been measured in surface waters downstream from rice growing areas. The only known exception is 3-hydroxycarbofuran which was monitored in the USDOI study (Sec. 2.2.1.1.5) in March 1994 before the parent compound is normally applied. Very little work has been done on the presence and potential toxicity of rice herbicide degradation products on aquatic resources in the Sacramento watershed.

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137 Kathryn L. Crepeau, Kathryn M. Kuivila, and Joseph L. Domagalski, Concentrations of Dissolved Rice Pesticides in the Colusa Basin Drain and Sacramento River, California, 1990-92, In: USGS Water Resources Investigations Report 94-4015, 1994.

138 Norberg-King, 1991, p. 896.

139 Joseph L. Domagalski and Kathryn M. Kuivila, Transport and Transformation of Dissolved Rice Pesticides in the Sacramento River Delta, California, USGS Open-File Report 91-227, 1991.

Table 23. Rice Pesticide Degradation Products.[1]

MOLINATE

- 2-keto molinate (P)*
- 4-keto molinate (P)*
- ethyl mercaptan (H)
- dialkylamine (H)
- molinate sulfoxide (H,O)
- carboxymethyl molinate (H,O)
- hexahydroazepine-1-carbothioate (H,O)

CARBOFURAN

- 2,3-dihydro-2,2-dimethylbenzofuran-4,7-diol (P)
- 2,3-dihydro-3-keto-2,2-dimethylbenzofuran-7-methylcarbamate (P)
- carbofuran phenol (H,B)*
- 3-hydroxycarbofuran (B)
- 3-ketocarbofuran (B)
- 3-hydroxycarbofuran phenol (B)

METHYL PARATHION

- methyl paraoxon (P)
- p-nitrophenol (H,B)*
- dimethylphosphorothioate (H)

MALATHION

- malathion monoacid (P)
- O,O-diethyl phosphorothioic acid (P)
- diethyl fumarate (B)
- phosphorodithioic acid (B)

THIOBENCARB

- thiobencarb S-oxide (P)
- N-monoethylthiobencarb (P)
- 2-hydroxythiobencarb (P)
- 3-hydroxythiobencarb (P)
- 4-chlorobenzyl mercaptan (P)

P = photolysis, H = hydrolysis, B = biological degradation, O = oxidation

1 Summarized from Howard 1991 and Gever et al. 1996.

* Detected in the Sacramento River and Colusa Basin Drain by Domagalski and Kuivila (1991).

Some of these degradation products may be equally or more toxic than the parent compounds or may interact synergistically with the parent compounds, increasing toxicity. For example, malathion, which is used on rice, undergoes hydrolysis to diethyl fumarate in aqueous solutions. Diethyl fumarate is not only more toxic to fathead minnows than malathion, but also interacts synergistically with malathion and other degradation products to enhance the toxicity of the mixture.[140] Similarly, degradation products of diflubenzuron, which has been proposed as a replacement for carbofuran in California rice culture to control rice water weevil, are equally toxic to Daphnia magna as the parent compound.[141]

However, some pesticide degradation products may be less toxic or degrade more rapidly than their parent compounds. Carbofuran phenol, a degradation product of carbofuran detected in the Sacramento River, is an order of magnitude less toxic than its parent compound. The 48-hr LC50 is 2.6 µg/L for carbofuran and greater than 20 µg/L for carbofuran phenol. The concentrations of carbofuran phenol in a toxic sample of Colusa Basin Drain water were less than the LC50 and did not contribute to its toxicity. Likewise, concentrations of carbofuran phenol measured by the USGS in the Sacramento River are substantially less than LC50s.[142]

2.2.1.1.7 UC Davis Regression Study

Striped bass spawn in the same area where rice drainage is discharged into the Sacramento River. Thus, linear regression and principle component analysis were used to explore the relationship between rice pesticides and striped bass recruitment in the period 1970 to 1988. The estimated in-stream concentrations (the ratio of total pounds of each pesticide applied to rice divided by the flow in the Sacramento River in May at Grimes) of carbaryl (r^2=0.23, p=0.05), carbofuran (r^2=0.28, p=0.02), methyl parathion (r^2=0.35, p=0.01), MCPA (r^2=0.34, p=0.01), molinate (r^2=0.63, p<0.01), and bufencarb (r^2=0.52, p=0.03) were regressed against the 38 mm striped bass index. The EIC accounted for 23 to 63 percent of the variability in annual recruitment of larval striped bass during the period when each pesticide was used. The six chemicals used in these analyses were selected because they were used in at least five years and their EICs were significantly correlated with the difference between the actual and predicted 38 mm index in exploratory analyses.

Principal component analyses suggested that bufencarb explained variability in recruitment not well-explained by any of the other chemicals. Multiple linear regressions of the EICs of

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[140] Michael E. Bender, The Toxicity of the Hydrolysis and Breakdown Products of Malathion to the Fathead Minnow (Pimephales Promelas, Rafinesque), Water Research, v. 3, 1969, pp. 571-582.

[141] Scott A. Mabury and Donald G. Crosby, Fate and Disposition of Diflubenzuron in Rice Fields, Environmental Toxicology and Chemistry, v. 15, no. 11, 1996, pp. 1908-1913.

[142] Norberg-King et al., 1991.

bufencarb plus molinate (r^2=0.89, p<0.01), MCPA (r^2=0.90, p<0.01), and carbofuran (r^2=0.94, p<0.01) accounted for 89 to 94 percent of the variability in recruitment.[143]

CUWA repeated Bailey et al.'s regression analyses and was unable to confirm some of their results. There were significant differences in the data set, particularly for bufencarb and molinate. When the most recent DPR data were used in regressions between the 38 mm striped bass index and the EIC, bufencarb accounted for only 10 percent of the variability (r^2=0.10, p=0.31) in the index compared to 52 percent reported by Bailey and molinate accounted for only 50 percent (r^2=0.50, p=0.001) compared to 63 percent reported by Bailey. Good agreement was obtained for the other compounds, including carbaryl, carbofuran, methyl parathion, and MCPA. The time trends in the data were removed using first differencing and the regressions were repeated. None of these relationships was statistically significant and all of the r^2s were very low. Therefore, Bailey's regression results may be due solely to strong time trends in both time series.

If these regressions were valid, one would expect striped bass recruitment to increase as pesticide concentrations in the Sacramento River decreased. However, the substantial reduction in concentrations of all monitored rice pesticides in the Sacramento River since 1981 (Tables 14, 15) did not result in a concomitant increase in striped bass recruitment. Several explanations are plausible. First, rice pesticide degradation products, which are not monitored under the current rice regulatory program, have been detected in the Sacramento River and may be a source of toxicity (Sec. 2.2.1.1.6). Second, recent work at the University of California at Davis indicates that concentrations of rice pesticides in the surface microlayer of rice fields are 10,000 to 100,000 times higher than in underlying waters which are routinely monitored (Sec. 2.2.1.1.8). If these microlayers also exist in the river, striped bass eggs and larvae could be exposed to high pesticide concentrations. Finally, other sources of toxicity are possible. For example, between December 1990 and February 1997, the Sacramento River below Sacramento was toxic to fathead minnows 51 percent of the time (Sec. 2.1.1.6). Similarly, elevated concentrations of organochlorine pesticides are present in striped bass collected in the Sacramento River (Sec. 2.1.3). Alternatively, other factors besides toxics, including predation, adverse oceanic conditions, harvest or water development, may singularly or in combination be responsible for the striped bass decline.

2.2.1.1.8 UC Davis Microlayer Study

The thin organic film or surface microlayer found on natural waters can concentrate hydrophobic pollutants, including many pesticides. Organisms that frequent or reside in the surface layer, such as striped bass and other fish eggs and larvae, may be exposed to elevated concentrations of pollutants. Pollutants presents in these microlayers are not normally sampled in ambient monitoring programs because water samples are typically collected at depth.

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[143] Bailey et al., 1994, pp. 136-137.

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Samples of water and the microlayers from flooded rice fields were collected in June 1993 following the application of carbofuran (3.27 kg/ha) and a mixture of carbofuran (3.12 kg/ha) and thiobencarb (3.04 kg/ha). The log of enrichment factors (microlayer:underlying water) were 3.88 to 4.18 for carbofuran and 4.77 to 5.15 for thiobencarb. Thus, concentrations of these compounds were about 10,000 to 100,000 times greater in the surface film than in the underlying water. Similar results were obtained for experimental plots at Davis. Degradation rates appeared to be more rapid with the microlayer than without it.

Thus, while holding rice waters on the fields has substantially decreased concentrations of parent compounds, elevated concentrations may still be present in the surface microlayers.[144] The fate of these microlayers when flooded fields are drained into the Sacramento River is unknown. Further, it is unknown whether similar microlayers also exist in ambient receiving waters. If they are present, surface-dwelling aquatic organisms and fish eggs may be particularly vulnerable to pesticide exposures from these microlayers.

The surface microlayer is critically important to a number of organisms, some of whom dwell there. The surface microlayer is important for the reproduction and feeding of many fish, insects, shellfish, phytoplankton, and zooplankton, whose eggs and larval stages often concentrate in and depend upon it. These organisms, dubbed "neustonic" organisms, colonize surface films by physical attachment to the film, tactic movements, secretions of mucilaginous extracellular buoyant material, and bubble flotation. Many bacteria, yeasts, and molds are concentrated up to 10^4 fold in this layer. Most of the water column productivity is concentrated in this layer, which is inhabited by large numbers of microalgae. These algae float on the surface, sometimes causing blooms by their profuse growth. These would be continuously in contact with the microlayer. Many zooplankton have diurnal migration patterns and feed in the surface microlayer. Aquatic emergent insects reside in this layer. Many larval and juvenile stages of fish inhabit the upper centimeter of the surface. Chinook salmon feed in this layer, taking in water along with the insects. Many young fish also penetrate this layer to take in atmospheric oxygen when inflating their swim bladder. Finally, eggs of striped bass and other fish are broadcast spawned on the surface.[145]

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[144] Joel R. Gever, Scott A. Mabury, and Donald G. Crosby, Rice Field Surface Microlayers: Collection, Composition and Pesticide Enrichment, Environmental Toxicology and Chemistry, v. 15, no. 10, 1996, pp. 1676-1682.

[145] J.T. Hardy, The Sea Surface Microlayer: Biology, Chemistry, and Anthropogenic Enrichment, Prog. Oceanog., v. 11, 1982, pp. 307-328.

C-030860

2.2.1.1.9 DFG Rotifer Study

Rotifers in the Sacramento River at both Hood and Sherman Island have declined in spring, summer, and fall since 1973. The DFG used linear regression and ANOVAs to investigate the influence of food supply (chlorophyll a concentrations) and rice pesticides on this decline.[146]

They reported that there was a significant linear relationship between the log of rotifer abundance and both the log of pounds of molinate applied and the log of the chlorophyll a concentration at Hood for the period 1973 to 1992. A multiple linear regression including the log of both chlorophyll a and total pounds of rice pesticides applied accounted for 84 percent of the variability in the log of rotifer abundance and all fitted constants were statistically significant.[147]

However, an ANOVA using log rotifer abundance and log chlorophyll a at Hood and log pounds of molinate transported past Sacramento in May and June for 1982 to 1991 (the years for which molinate mass loading data were available) showed that chlorophyll a was significant but molinate was not. Further, molinate also did not appear to have any effect on abundance when two low flow years with different molinate application rates were directly compared (1977, 1984). Finally, the rotifer population did not respond to changes in rice field management practices implemented in the mid-1980s. Thus, the author concluded that the long-term downward trend in rotifer abundance was more likely due to lower concentrations of phytoplankton in the Sacramento River and upstream reservoirs than rice herbicides. The CVRWQCB has recently proposed to conduct a survey to determine the potential role of toxicity in the decline of rotifers.[148]

2.2.1.2 Other Agricultural Drainage

2.2.1.2.1 CVRWQCB Orchard Bioassay Study

A bioassay study was conducted by the CVRWQCB in the winter of 1992 to assess the toxicity of orchard runoff in the Sacramento Basin and the Delta. The Delta portion of the study is discussed in Section 3.2.1.3. In the Sacramento Basin, six stations were located on water courses draining small watersheds with more than 10 percent of their acreage in orchard and five were located on major rivers. Ceriodaphnia toxicity was assayed in all samples and organophosphorus and carbamate pesticides were determined in toxic samples. The data are

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[146] James J. Orsi, An Investigation of Rotifer Abundance in the Sacrament River from 1973 to 1993, DFG, Bay-Delta Division, June 14, 1996.

[147] Jim Orsi, Presentation to Contaminant PWT, September 27, 1996.

[148] Val Connor, Personal Communication, January 31, 1997.

summarized in Table 24.[149] A more intensive study was conducted in 1994-95 by the CVRWQCB and the SWRCB, but the results have not been published yet.

Among samples collected in the Sacramento Basin, significant mortality to Ceriodaphnia was found in nine out of 24 samples, or 38 percent of the total. All of the toxic samples were from agriculturally dominated sites. Most of the toxicity occurred February 4-20, 1990 during a period of precipitation. During this time, there was 100 percent mortality in the agriculturally dominated streams. The Feather River showed 50 percent mortality on February 10, 1992, but there was no mortality in the Sacramento River.

Five pesticides were detected in the toxic samples -- diazinon (0.51 - 6.84 μg/L), diuron (0.10 - 30.6 μg/L), methidathion (0.15 - 15.1 μg/L), propham (3.6 - 19.9 μg/L), and fluometron (3.0 μg/L). Propham (106 lbs used statewide in 1992) and fluometron (331 lbs used statewide in 1992) are minor use herbicides that are not common in the Sacramento Basin. Concentrations were high enough to explain partial or complete toxicity in all but one of the samples. The maximum concentration of methidathion exceeded the 96-hr LC50s for bluegills (9μg/L) and rainbow trout (14 μg/L).[150] The authors concluded that the toxicity was largely due to pesticides, primarily diazinon, that had been applied to orchards and were transported offsite in runoff.[151]

2.2.2 Urban Runoff

The CVRWQCB monitored sump 104 in the City of Sacramento during a storm event on December 5, 1986. Sump 104 drains a 4,000 acre watershed, which is predominately residential, but also includes a small amount of commercial and light industrial property. Water samples were collected 40 minutes before the storm and after 40, 90, and 300 minutes of discharge. Ceriodaphnia reproduction and mortality and Selenastrum growth were measured on the pre-event sample and on dilutions of the post-event samples. There was no difference in the growth of Selenastrum cultured in pre-event, full strength post event, and Sacramento River water collected at Village Marina. However, the pre-event, and 100, 50, and 25 percent post-event samples were acutely toxic to Ceriodaphnia. Average Ceriodaphnia reproduction in the 10, 5, and 0 percent post-event samples was approximately half the normal rate.[152]

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[149] Christopher Foe and Robert Sheipline, Pesticides in Surface Water from Applications on Orchards and Alfalfa During the Winter and Spring of 1991-92, CVRWQCB Staff Report, February 1993.

[150] U.S. EPA, AQUIRE database, March 28, 1996.

[151] Foe and Sheipline, 1993, Table 3.

[152] Christopher Foe, Memorandum on the Results of the December 5th, 1986 Urban Run-Off Toxicity Tests, CVRWQCB Memorandum to Jerry Bruns, December 15, 1986.

Table 24. Orchard Study of *Ceriodaphnia* Toxicity in the Sacramento Basin and the Delta, 1992.

STATION	Percent Mortality[3]						
	1/13/92	1/20/92	1/27/92	2/3/92	2/10/92	2/17/92	2/24/92
Sacramento Basin							
Feather R at Lee Rd[1]	0	0	0	0	50	0	30
Sacramento R at Meridian[1]	0	0	0	10	0	0	0
Clark's Ditch at White Rd[2]	no flow				100*	100*	100*
Gilsizer S1 at Washington Rd[2]	0	0	100*	100*	100*	100*	100*
Delta							
Mokelumne R at New Hope[1]	0	0	70*	100	0	0	0
French Camp S1 at Manthey[1]	100	0	100*	100*	100*	0	0
Old R at Cohen Rd[1]	20	0	0	0	20	100*	0
San Joaquin R at Bowman Rd[1]	0	0	10	0	0	100*	100*
Ledgewood Ck at Portsmouth[2]	0	0	0	0	100*	0	0
Lone Tree Ck at Austin Rd[2]	10	60*	100*	100*	100*	100*	0
Marsh Ck at Cypress Rd[2]	-	0	0	0	30*	0	0
Laboratory Control	0	0	0	0	0	0	20

1 Seven-day bioassay test.
2 Four-day bioassay test.
3 Foe and Sheipline 1993, Table 2.
* Pesticide concentrations high enough to explain partial or complete toxicity.
[shaded] Significant mortality is defined as any sample with 30 percent more deaths than the laboratory control.

The CVRWQCB monitored three urban runoff sumps in Sacramento during a storm event on January 27-28, 1987. Sump 99 drains a residential area, sump 104 a mixed residential and commercial area, and sump 111 a light industrial area. Fathead minnow larval growth and survival, Ceriodaphnia reproduction and survival, and Selenastrum growth were assayed in serial dilutions of urban runoff. The impact of the storm on the American River was also evaluated by comparing the toxicity at Nimbus at the beginning of the storm with that at the mouth of the river 5, 9, 13, and 26 hours later.

Undiluted water from all three sumps was acutely toxic to Ceriodaphnia and resulted in 100 percent mortality in 24 hours. None of the three samples was toxic to fathead minnow larvae. Toxicity to Selenastrum varied. Undiluted sump 99 water was not toxic, and undiluted sump 104 and undiluted sump 111 waters were toxic to Selenastrum. The storm apparently caused toxicity in the American River. The samples collected from the mouth of the river 9 and 13 hours after the start of the storm had fathead minnow mortalities of 100 percent and a 50 percent decrease in Ceriodaphnia reproduction while earlier and later samples were not toxic.[153]

The CVRWQCB is currently investigating the aquatic toxicity of urban runoff. During the 1993-94 rainfall season, fathead minnow, Ceriodaphnia, and Selenastrum toxicity were monitored in urban runoff from a residential area (sump 104), an industrial area (sump 111), and a runoff-dominated stream in Sacramento. The results are summarized in Table 25. Toxicity was detected in all three species, and all samples caused 100 percent mortality to Ceriodaphnia. TIEs on toxic samples indicated that diazinon was the primary toxicant. Toxicity to fathead minnows and Selenastrum was also detected, although the responsible chemicals were not identified.[154]

In a follow-up survey, toxicity tests were performed on urban runoff collected in January 1994 from nine sumps and runoff-dominated streams in the Sacramento area. The results are summarized in Table 26. In all samples but one, 100 percent Ceriodaphnia mortality was observed. No toxicity was observed at the RD 1000 drain, which was not runoff dominated and contained rice field drainage.[155]

The addition of PBO reduced the toxicity at most sites, suggesting that organophosphorus pesticides are the likely toxicants. Diazinon concentrations (0.16 - 1.1 µg/L), which exceeded the

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[153] Christopher Foe, American River Urban Runoff Toxicity Test Results for the January 27-28th, 1987, Precipitation Event, CVRWQCB Memorandum to Jerry Bruns, March 19, 1987.

[154] Valerie Connor, Status of Urban Storm Runoff Projects, CVRWQCB Memorandum to Jerry Bruns, January 30, 1995.

[155] Valerie Connor, Pesticide Toxicity in Urban Storm Runoff, Presentation at CVRWQCB, May 10, 1995.

Table 25. Summary of Toxicity Tests Conducted in Sacramento During the 1993-94 Storm Season.

	Residential Area			Industrial Area			Runoff-Dominated Stream	
	Nov	Dec	Jan	Nov	Dec	Jan	Nov	Jan
Ceriodaphnia	**X**	**X**	**X**	X	X	**X**	**X**	**X**
Fathead Minnow					X	X		
Selenastrum				X			X	X

X Toxicity detected
Diazinon toxicity

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Table 26. Bioassay Results and Diazinon Concentrations for Sacramento and Stockton Stormwater Runoff.[1]

Site (date)	Diazinon[2] (µg/L)	*Ceriodaphnia* % Mortality[3,4] 96-hour results - PBO	+ PBO
Sacramento			
Sump 104 (1/23/95)	>0.5, 1.050	100*	0
Sump 111 (1/23/95)	0.500, 0.450	100*	0
Strong Ranch Slough (1/23/95)	0.410	100*	7
Chicken Ranch Slough (1/23/95)	0.625	100*	33
Morrison Creek (1/23/95)	>0.5, 0.340	100*	0
Elder Creek (1/23/95)	>0.5, 1.100	100*	0
Arcade Creek (1/23/95)	0.400	100*	0
RD 1000 Drain (1/23/95)	0.160	0	0
Natomas East Main Drain (1/23/95)	0.260	100	7
Lab Control		7	0
Stockton			
Mosher Slough (2/6/94)	0.900	100*	20
Mosher Slough (2/7/94)	0.630	100*	0
5 Mile Creek (2/6/94)	1.000	100	20
5 Mile Creek (2/7/94)	>1.000	100*	80
Calaveras River (2/6/94)	0.380	100	20
Calaveras River (2/7/94)	0.450	100	0
Mormon Slough (2/6/94)	0.320	10	0
Mormon Slough (2/7/94)	0.900	100*	100
Lake McLeod (2/6/94)	0.200	0	0
Lake McLeod (2/7/94)	0.500	100	0
Turning Basin (2/6/94)	0.190	0	0
Turning Basin (2/7/94)	0.600	100*	20
Lab Control Water #1		0	0
Lab Control Water #2		0	0

1 Connor, May 10, 1995.
2 Diazinon concentrations were determined using a Millepore™ ELISA (Enzyme-linked immunosorbent assay) analysis system with a detection limit of 0.030 µg/L.
3 Bioassays were conducted using two replicates of five organisms for untreated waters and a single replicate of five organisms for the piperonyl butoxide (PBO) treatments. PBO concentration was 200 µg/L.
4 Treatments indicated with an asterisk (*) exhibited 100% mortality in 24 hours.

Ceriodaphnia 96-hr LC50 (0.47 - 0.51 μg/L)[156] in most of the samples, were high enough to explain most of the toxicity. However, the addition of PBO failed to reduce or eliminate the toxicity in several samples including those from Strong Ranch Slough, Chicken Ranch Slough, and Natomas East Main Drain,[157] suggesting that contaminants other than organophosphorus pesticides were responsible, or that not enough PBO was added.

Similar results were obtained during the 1994-1995 rainfall season. Sacramento urban runoff collected from Arcade, Elder, and Strong Ranch Creeks following precipitation events all exhibited acute toxicity to Ceriodaphnia. The toxicity was removed by treatment with PBO, suggesting that organophosphorus pesticides were responsible. Toxic levels of diazinon, chlorpyrifos, and metals were found at some sites.[158] TIEs confirmed that both diazinon and chlorpyrifos contributed to the observed toxicity.[159] Diazinon is present in urban runoff throughout the rainfall season (Table 27), but peaks during the orchard dormant spray season (Figure 13).

Algal bioassays were conducted on runoff from the second storm of the 1994-95 season, and toxic samples were passed through a resin column to remove pesticides. The results are summarized in Table 28. All samples exhibited algal toxicity as evidenced by reduced cell numbers in the samples compared to the control. The resin column treatment generally reduced toxicity, suggesting that nonpolar organics, such as pesticides, were responsible for the toxicity. Diuron and simazine were detected in all toxic samples at concentrations that potentially could cause Selenastrum toxicity.[160] Recent work indicates that about 40 percent of the algal toxicity is due to diuron.[161]

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[156] Menconi and Cox, 1994, Table B-1.

[157] Valerie Connor, Toxicity and Diazinon Levels Associated with Urban Storm Runoff, CVRWQCB memorandum to Jerry Bruns, February 15, 1994.

[158] Valerie Connor, Status of Urban Storm Runoff Projects, CVRWQCB memorandum to Jerry Bruns, January 30, 1995.

[159] Valerie Connor, Chlorpyrifos in Urban Stream Runoff, CVRWQCB memorandum to Jerry Bruns and Christopher Foe, January 8, 1996.

[160] Valerie Connor, Algal Toxicity and Herbicide Levels Associated with Urban Storm Runoff, CVRWQCB memorandum to Jerry Bruns, January 19, 1995.

[161] S.L. Clark, L.A. Deanovic, H.C. Bailey, J.L. Miller, M.J. Miller, V.M. Connor, and D.E. Hinton, Toxicity Identification Evaluation Procedures for the Freshwater Alga, Selenastrum capricornutum, Abstract, Northern California Society of Environmental Toxicology and Chemistry, 6th Annual Meeting, June 24-25, 1996.

Table 27. Diazinon Concentrations in Urban Runoff.[1]

SITE	Diazinon (µg/L)	
	Storm Event	Dry Event
Sacramento		
Sump 104	1.050	0.800
Sump 111	0.500	0.400
Strong Ranch Slough	0.410	< 0.030
Chicken Ranch Slough	0.625	0.250
Morrison Creek	0.500	0.165
Elder Creek	1.100	0.080
Arcade Creek	0.400	< 0.030
Natomas East Main Drain	0.260	< 0.030
Stockton		
Mosher Slough	0.630	0.059
5 Mile Slough	1.000	0.052
Calaveras Creek	0.450	0.030
Mormon Slough	0.900	< 0.030
Lake McLeod	0.500	< 0.030
Turning Basin	0.600	< 0.030

1 Connor, May 10, 1995.

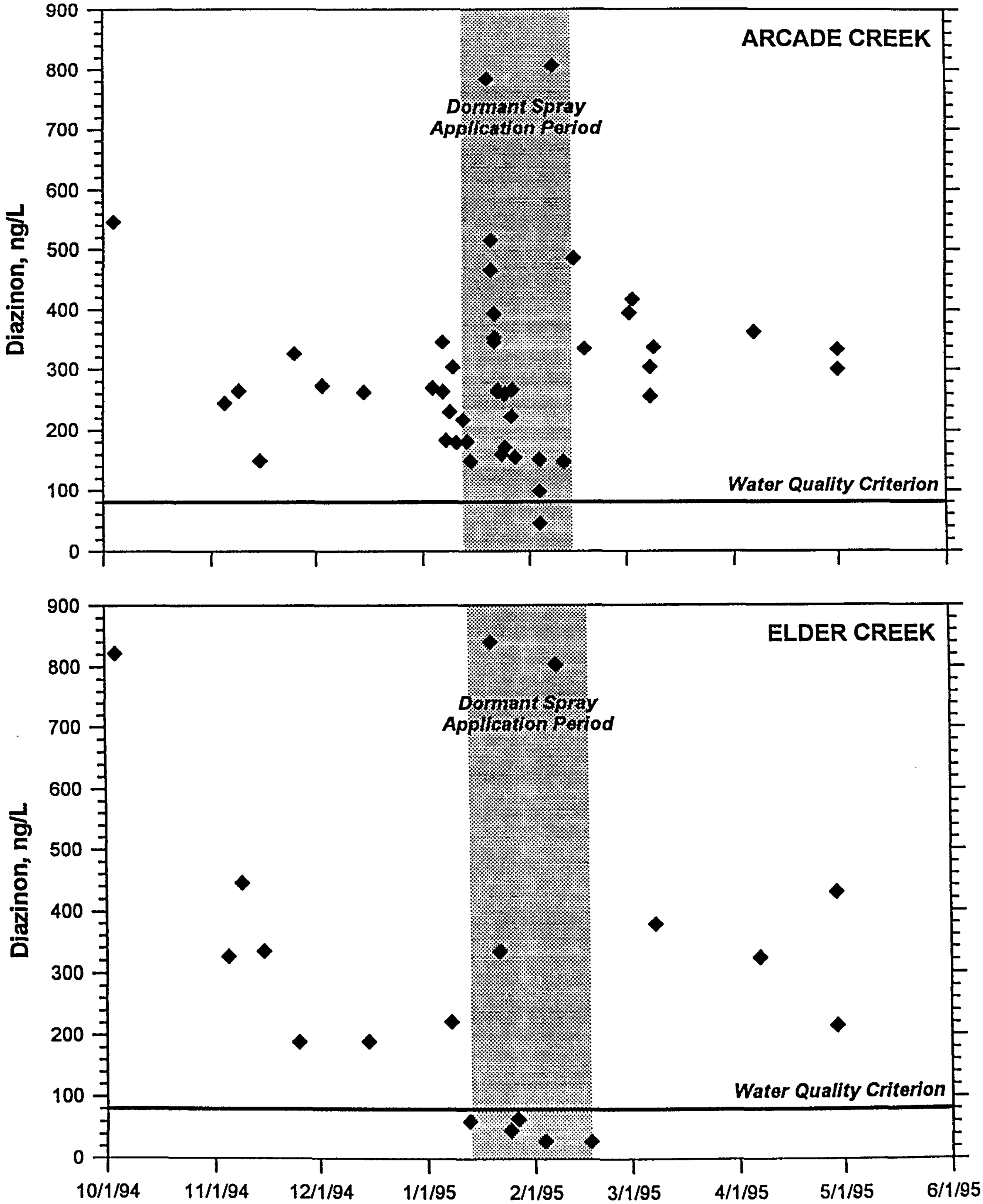
Exceeds 96-hr LC_{50} for *Ceriodaphnia* (0.47-0.51 µg/L).

Table 28. Summary of Algal Toxicity Testing Results and Herbicide Concentrations in Sacramento Stormwater Runoff, November 1994.[1]

CREEK	Drainage Area (Acres)	*Selenastrum* Growth (Algal Cells x 10^4/mL)				Herbicide Concentrations (µg/L)	
		Original Toxicity Test	Toxicity Identification Evaluation				
			Unmanipulated Sample[2]	C_8 Resin Column-Treated Sample	Percent Improvement	Diuron	Simazine
Strong Ranch Slough	5,184	67	164	227	38%	2.3	0.5
Chicken Ranch Slough	3,705	53	115	237	106%	2.5	1
Natomas East Main Drain	90,000	57	65	214	229%	5.2	2.7
Morrison Creek	90,872	48	56	252	350%	6.1	3.4
Arcade Creek	24,980	22	33	242	633%	7.5	3.3
Elder Creek	10,918	16	33	254	670%	9.8	4.8
Lab Control	-	90	92	82[3]	-11%	-	-

1 Connor, January 19, 1995.
2 The original toxicity tests were set up on 9 November, while the TIE testing was set up on 17 November. The higher algal cell counts observed in the second test suggest a loss of toxicant during the sample storage time.
3 Average of all resin column lab controls.

Figure 13. Diazinon Concentrations in Arcade and Elder Creeks*



*Connor, May 10, 1995

2.2.3 Precipitation

In 1995, the CVRWQCB measured the organophosphorus insecticide, diazinon, in precipitation at eight sites on four separate dates (Table 29) and at 14 sites between Red Bluff and Patterson on a single date (Table 30). Samples were collected in open glass pans exposed to dry and wet precipitation events. Diazinon was detected in all samples at concentrations ranging from 0.047 to 5.5 µg/L. The highest concentrations were detected in late January and early February, during the dormant spray application period. For example, prior to the dormant spray season, the diazinon concentration in Sacramento precipitation was 0.031 µg/L. During the dormant spray season, it ranged from 0.21 to 0.70 µg/L. Samples from the Sacramento Basin were comparable to those from other areas. The highest concentrations were found in samples collected near orchards. Most concentrations exceeded the Ceriodaphnia 96-hr LC50 (0.47 - 0.51 µg/L). Limited monitoring also detected carbofuran and chlorpyrifos in some samples.[162] These pesticides are used by homeowners for backyard and home insect control, are sprayed on stone fruit orchards such as almonds, prunes, and apricots, or used on alfalfa for weevil control.

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[162] Connor, May 10, 1995.

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Table 29. Diazinon Concentrations in Central Valley Rainfall, January-March, 1995.[1]

SITE	Distance from Sacramento	Diazinon Concentration in Rain Samples (µg/L)			
		1/20/95	2/8/95	2/14/95	3/3/95
Patterson	80	2.20	5.46	0.34	0.052
Tracy	60	1.01	4.18	0.46	0.31
South Stockton	52	0.92	3.73	0.93	0.58
Central Stockton	50	0.88	1.30	0.21	0.11
Central Stockton	50	0.94	2.35	0.20	0.061
North Stockton	45	0.68	0.84	0.29	0.43
South Sacramento	5	0.57	1.23	-	0.047
Sacramento	0	0.34	0.70	0.21	0.13

1 Connor, May 10, 1995.

(shaded) Exceeds 96-hr LC_{50} for Ceriodaphnia (0.47-0.51µg/L).

Table 30. Diazinon Concentrations in Central Valley Rainfall, February 8, 1995.[1]

SITE	Concentration (μg/L)
Sacramento Basin	
Red Bluff	4.09
Hamilton	1.96
Colusa	0.42
Yuba City	3.96
Nicolaus	4.46
Davis	0.89
Sacramento	0.70
South Sacramento	1.23
Delta	
North Stockton	0.84
Central Stockton	2.35
Central Stockton	1.30
South Stockton	3.73
San Joaquin Basin	
Tracy	4.18
Patterson	5.46

1 Connor, May 10, 1995.

[shaded] Exceeds 96-hr LC_{50} for <u>Ceriodaphnia</u> (0.47-0.51μg/L).

SECTION THREE
SACRAMENTO-SAN JOAQUIN DELTA

3.0 SACRAMENTO-SAN JOAQUIN DELTA

The Delta, the confluence of the Sacramento and San Joaquin Rivers, has an area of about 1,000 square miles. The Delta consists of low, flat islands bordered by levees and interlaced by a network of about 1,100 miles of waterways (Figure 14).

Toxicity and pesticide concentrations have been periodically monitored in waters, sediments, and biota since 1975 by the DWR, CVRWQCB, DPR, DFG, USGS, and SWRCB. Based on studies and routine monitoring conducted in the Delta by these agencies, the CVRWQCB has classified a number of water bodies in the area as impaired due to the presence of toxicity or elevated concentrations of metals and organics in biota and sediments. Water bodies that are impaired due to aquatic toxicity include Cache Slough above Ryer Island Ferry; the Contra Costa Canal; the Sacramento River at Freeport, Clarksburg, Walnut Grove, Isleton, Rio Vista, 1 mile below Rio Vista, and river mile 1; the San Joaquin River at Mossdale; and the mouth of Steamboat Slough. Water bodies that are impaired due to the presence of pesticides in the sediments include Georgiana Slough, Mormon Channel, Mormon Slough, the Stockton Turning Basin, Morrison Creek, and the Sacramento River at Rio Vista. Water bodies that are impaired due to the presence of elevated concentrations of pesticides in waters and biota include Clifton Court Forebay, the Delta Mendota Canal, Rock Slough, San Joaquin River from Vernalis to Mossdale and at Antioch, and the Sacramento River from Freeport to Collinsville.[163]

The results of this work are summarized for major rivers in Section 3.1 and for potential sources in Section 3.2.

3.1 DELTA WATERWAYS

The Delta is a complex series of tidally-influenced waterways. In an average year, the Sacramento River contributes about 85 percent of the freshwater to the Delta, and the San Joaquin River contributes about 10 percent. Streams on the east side of the Delta, including the Mokelumne and Cosumnes Rivers, provide the rest.[164]

Toxicity is either transported into the Delta by the major rivers or originates within the Delta. Some potential sources of internal toxicity include agricultural drainage from Delta islands, mobilization of dissolved metals from dredge material, discharges from municipal and industrial facilities, and urban runoff from cities surrounding the Delta including Stockton, Manteca, Tracy, Antioch, Brentwood, and Discovery Bay.

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[163] Barry L. Montoya, An Analysis of the Toxic Water Quality Impairments in the Sacramento-San Joaquin Delta/Estuary, CVRWQCB Report, December 1991.

[164] William J. Miller, The Delta, Report Prepared for California Urban Water Agencies, May 1993, p. 4.

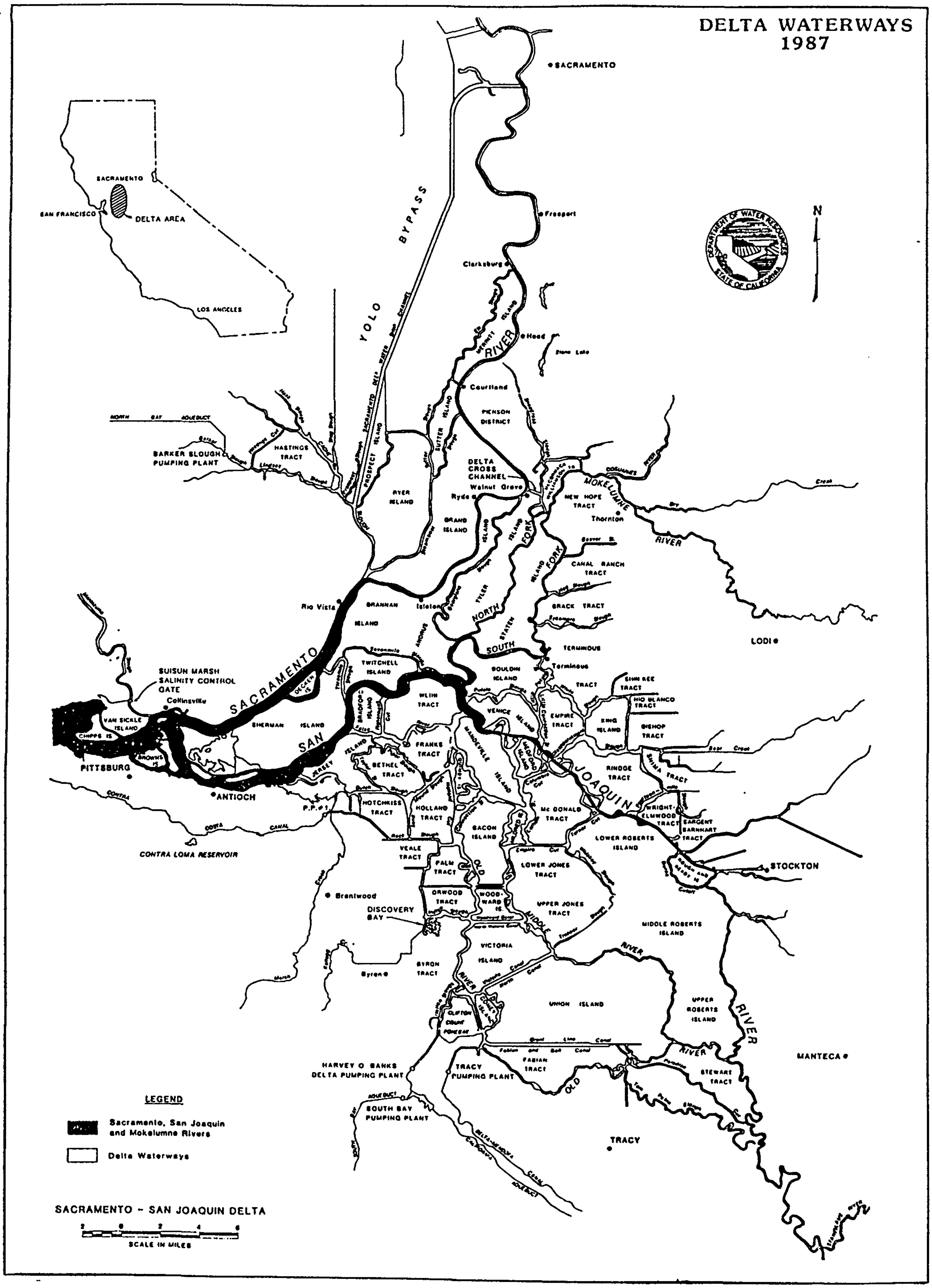

Figure 14
The Sacramento-San Joaquin Delta

Toxicity and pesticide concentrations have been monitored in Delta waters (Sec. 3.1.1), biota (Sec. 3.1.3), and sediments (Sec. 3.1.2). The principal conclusions from this work are as follows:

- Between 1987 and 1996, significant mortality to fathead minnows occurred in 4 to 50 percent of the samples and growth was also reduced in up to 100 percent of the samples. Several samples from the Sacramento River (Rio Vista, Walnut Grove) were toxic to larval striped bass. Toxicity occurred in most months.

- Between 1987 and 1994, significant mortality to Ceriodaphnia occurred in 2 to 20 percent of the samples and reproduction was significantly reduced in up to 15 percent of the samples. Significant mortality to Neomysis also occurred in about 10 percent of the samples. Most of the toxicity occurred in the April to June period. The mortality in select samples was attributed to organophosphorus and carbamate pesticides, including diazinon, chlorpyrifos, and carbofuran.

- Between 1987 and 1994, significant algal growth impairment occurred in 2 to 11 percent of the samples. Most of the toxicity occurred in the summer and winter. The impairment was generally due to nonpolar organic compounds.

- Distinct pulses of pesticides are present in the rivers following storms. Delta waterways are frequently toxic to Ceriodaphnia and periodically toxic to Selenastrum and fathead minnows during rainfall events. The Sacramento River at Rio Vista was acutely toxic to Ceriodaphnia for three consecutive days and the San Joaquin River at Vernalis for 12 consecutive days following a major storm.

- From 15 to 30 percent of the striped bass larvae collected within the Delta in 1988 to 1991 had liver alterations that are consistent with exposure to rice pesticides.

- Organochlorine pesticides are present in the sediments from the Sacramento and San Joaquin Rivers, including α-BHC, hexachlorobenzene, aldrin, dieldrin, DDT, and hexachlorocyclohexane. These sediments are toxic to estuarine amphipods, larval mussels, larval oysters, and Ceriodaphnia.

- Organochlorine pesticides and pesticide ingredients, including DDT, PCBs, toxaphene, and chlordane, are periodically detected in fish from throughout the basin. These compounds may cause high mortality in fry and impair reproduction.

3.1.1 Waters

3.1.1.1 DWR Decision 1485

The DWR has monitored pesticides in May and September since 1975 at up to 18 stations in the Delta and three stations in Suisun Bay. The furthest upstream stations are at Greene's Landing on the Sacramento River and near Vernalis on the San Joaquin River. The number of compounds monitored was increased from four[165] to 25 in 1987 and to 39 in 1988. The data are summarized in Table 31.[166]

Although the pesticides monitored by DWR were rarely detected, minimum reporting limits for many are higher than the levels that are toxic to aquatic organisms, including those for atrazine, BHC-gamma, chlordane, DDT, dieldrin, endosulfan, endrin, heptachlor, methoxychlor, simazine, and toxaphene.[167] Further, monitoring did not occur during the pesticide application period in the Delta. In addition, the more commonly detected pesticides in other monitoring programs -- the organophosphorus and carbamate pesticides -- are not included in the DWR program.

The most frequently detected pesticides are atrazine/simazine[168] and diuron. Other pesticides that have been detected less frequently at Delta stations include difolaton, dacthal, PCNB (pentachloronitrobenzene), methoxychlor, BHC (benzene hexachloride), endosulfan sulfate, and carbophenothion (Table 31).[169] Products containing difolaton, BHC, and carbophenothion are no longer registered.

Atrazine/simazine was detected 55 times at 12 sites throughout the Delta at concentrations of 0.01 to 0.24 µg/L. These triazines are emergent herbicides used to control weeds on cultivated crops. In the Delta, simazine is typically applied to orchards and vineyards during February, and

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[165] The original four compounds were atrazine/simazine, captafol, dacthal, and total chlorinated hydrocarbons expressed as DDT equivalents.

[166] DWR, Water Quality Conditions in the Sacramento-San Joaquin Delta, January 1994.

[167] DWR, January 1994, p. 57.

[168] Atrazine and simazine were not distinguishable in the early analyses that were performed and are reported as one value.

[169] The complete dataset is available in a comma-delimited ASCII file (PESTCIDE.EXE) from Karl Jacobs, DWR.

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Table 31. Pesticides Monitored Under Water Rights Decision 1485, 1975-1993.[1]

COMPOUND	Number of Analyses	Number of Detects	Detected Values (µg/L) Minimum	Detected Values (µg/L) Maximum	Location of Maximum Value Station	Location of Maximum Value Date
A-Endosulfan	130	0	-	-	-	-
Alachlor	130	0	-	-	-	-
Aldrin	130	0	-	-	-	-
Alpha BHC	130	0	-	-	-	-
Atrazine	130	0	-	-	-	-
Atrazine Simazine	55	55	0.01	0.24	D11	5/2/86
B-Endosulfan	130	0	-	-	-	-
Beta BHC	130	0	-	-	-	-
BHC	2	2	0.01	0.02	C10	5/6/76
Bolero	108	0	-	-	-	-
Captan	130	0	-	-	-	-
Chlordane Tech & Met	130	0	-	-	-	-
CIPC	108	0	-	-	-	-
Daconil in Water	108	0	-	-	-	-
Dacthal	134	4	0.01	0.48	C10	5/24/77
Delta BHC	130	0	-	-	-	-
Dicloran	108	0	-	-	-	-
Dicofol	130	0	-	-	-	-
Dieldrin	130	0	-	-	-	-
Difolatan	4	4	0.02	0.09	D12	5/2/85
Diuron	119	12	0.05	1	P8	5/6/91
Dursban	130	0	-	-	-	-
Endosulfan	130	1	0.04	0.04	C7	9/5/89
Endrin	130	0	-	-	-	-
Endrinaldehyde	130	0	-	-	-	-
Gamma BHC Lindane	130	0	-	-	-	-
Heptachlor	130	0	-	-	-	-
Heptachlor Rep	130	0	-	-	-	-
Methoxychlor	132	2	0.03	0.09	C3	9/11/78
P,P'DDD	130	0	-	-	-	-
P,P'DDE	130	0	-	-	-	-
P,P'DDT	130	0	-	-	-	-
PCB 1016	130	0	-	-	-	-
PCB 1221	130	0	-	-	-	-
PCB 1232	130	0	-	-	-	-
PCB 1242	130	0	-	-	-	-
PCB 1248	131	1	1	1	C7	5/1/90
PCB 1254	131	1	1	1	C7	5/1/90
PCB 1260	131	1	1	1	C7	5/1/90
PCNB	131	1	0.035	0.035	P2	5/7/76
Simazine	130	0	-	-	-	-
Toxaphene	130	0	-	-	-	-
Unidentifed Chlorinated Hydrocarbons	254	1	0.12	0.12	D11	5/2/85
Unknown	34	33	0.01	0.44	D12	5/24/79

1 Data from Karl Jacobs, DWR, file PESTCIDE.EXE.

atrazine is applied to corn during spring planting. The concentrations detected in the Delta are less than U.S. EPA maximum concentrations to protect freshwater aquatic life (atrazine - 1 µg/L; simazine - 10 µg/L).[170]

Diuron was detected 11 times at eight sites in the Delta at concentrations of 0.05 to 1 µg/L and at one site in Suisun Bay at 0.08 µg/L. Diuron is an herbicide that is applied to crops such as alfalfa, cotton, grapes, barley, and wheat to kill broadleaf weeds. It is also used throughout the Central Valley to control weeds along rights-of-way. The concentrations detected in the Delta are far below those known to be toxic to fish (500 - 16,000 µg/L) and invertebrates (160 - 5,900 µg/L).[171,172] They are also less than the criterion (1.6 µg/L) set by the NAS to protect freshwater aquatic life.[173] However, concentrations as low as 0.02 µg/L completely inhibit the growth of the marine motile flagellate Monochrysis lutheri and diuron has also been identified as a cause of Selenastrum toxicity in urban runoff in the Sacramento Basin (Sec. 2.2.2).[174]

3.1.1.2 DWR Municipal Water Quality Investigations Program

Under the Municipal Water Quality Investigations Program, DWR monitored 64 pesticides in 16 drinking water sources and major waterways during the summer pesticide application period, the first major winter runoff, and the spring pre-emergent herbicide application period between 1983 and 1987. Pesticides were chosen that were most likely to pose problems at water treatment plants (e.g., odor, taste, or public health impacts), rather than those that are toxic to aquatic organisms. The minimum reporting limits in these studies were frequently higher than the levels that are toxic to aquatic organisms, which generally are more sensitive to pesticides than humans. The resulting data are summarized in Table 32.

Out of 64 pesticides that were monitored, only 18 were detected at concentrations marginally above laboratory detection limits, but considerably below health-based drinking water

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[170] Jon B. Marshack, A Compilation of Water Quality Goals, Staff Report CVRWQCB, May 1993.

[171] Karel Verschueren, Handbook of Environmental Data on Organic Chemicals, Van Nostrand Reinhold Co., New York, 1983, p. 503. This reference reports a 48-hour LC50 for Pteronarcys of 1.2 µg/L. This is an error and should be 1.2 mg/L. (H.O. Sanders and O.B. Cope, The Relative Toxicities of Several Pesticides to Naiads of Three Species of Stoneflies, Limnology and Oceanography, v. 13, 1966, pp. 165-169.)

[172] Sheipline 1993, Table 43.

[173] NAS, 1973, p. 186.

[174] Ravenna Ukeles, Growth of Pure Cultures of Marine Phytoplankton in the Presence of Toxicants, Applied Microbiology, v. 10, 1962, Table 2.

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Table 32. Pesticide Data (µg/L) for Delta Waterways, 1983-1987.[1]

COMPOUND	Barker Slough at Pumping Plant			Sacramento R. at Mallard Is.			Lindsay Slough at Hastings			Sacramento R. at Greene's Lndg.		
	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range
2,4-D	4	1	< 0.25-0.7	7	0	< 0.01-< 0.5	4	1	< 0.25-0.35	7	0	< 0.01-< 0.5
4,4'-DDD	0	-	-	1	0	< 0.11	1	0	< 0.004	4	0	< 0.004-< 0.011
4,4'-DDE	0	-	-	1	0	< 0.004	1	0	< 0.002	4	0	< 0.002-< 0.006
4,4'-DDT	0	-	-	1	0	< 0.012	1	0	< 0.006	4	0	< 0.004-< 0.012
Alachlor	2	0	< 0.1	2	0	< 0.1	2	0	< 0.1	2	0	< 0.1
Aldrin	0	-	-	1	0	< 0.004	1	0	< 0.002	4	0	< 0.002-< 0.004
Atrazine	2	0	< 0.1	0	-	-	2	0	< 0.1	2	0	< 0.1
Bentazon	4	0	< 0.3-< 0.5	7	0	< 0.1-< 1.0	4	0	< 0.3-< 0.5	6	2	< 0.2-1.6
BHC-A	0	-	-	1	0	< 0.003	2	0	< 0.002	5	0	< 0.002-< 0.003
BHC-B	0	-	-	1	0	< 0.006	1	0	< 0.004	4	0	< 0.004-< 0.009
BHC-C	0	-	-	1	0	< 0.004	1	1	0.002	4	1	< 0.002-0.002
BHC-D	0	-	-	1	0	< 0.009	1	0	< 0.004	4	0	< 0.004-< 0.009
Captan	2	0	< 0.5	2	0	< 0.5	2	0	< 0.5	2	0	< 0.5
Carbaryl	2	0	< 2.0	0	-	-	2	0	< 2.0	2	0	< 2.0
Carbofuran	4	0	< 0.2-< 0.5	8	0	< 0.1-< 0.5	4	0	< 0.2-< 0.5	8	0	< 0.02-< 0.5
Chlordane	0	-	-	1	0	< 0.014	1	0	< 0.08	4	0	< 0.014-< 0.6
Chloropicrin	2	0	< 0.1	6	0	< 0.01-< 0.1	4	0	< 0.1	5	0	< 0.1
D-D Mixture	0	-	-	3	0	< 0.1-< 0.5	2	0	< 0.1	3	0	< 0.1-< 0.5
Dacthal	4	0	< 0.01-< 0.1	8	0	< 0.01-< 0.3	4	0	< 0.01-< 0.1	6	0	< 0.01-< 0.1
Diazinon	2	0	< 0.1	2	0	< 0.1	2	0	< 0.1	4	0	< 0.001-< 0.1
Dichlorovos	0	-	-	0	-	-	0	-	-	2	0	< 0.002-< 0.005
Dicofal	2	0	< 0.1-< 0.2	2	0	< 0.1-< 0.2	2	0	< 0.1-< 0.2	2	0	< 0.1-< 0.2
Dieldrin	0	-	-	1	0	< 0.002	0	-	-	4	0	< 0.001-< 0.002
Dimethoate	0	-	-	0	-	-	0	-	-	2	0	< 0.003-< 0.010
Dinoseb	2	0	< 0.25	1	0	< 0.25	2	0	< 0.25	2	0	< 0.25
Diphenamid	0	-	-	0	-	-	0	-	-	2	0	< 0.02-< 0.050
Diquat	2	0	< 40.0	1	0	< 40.0	2	0	< 40.0	1	0	< 40.0
Disulfotan	0	-	-	0	-	-	0	-	-	2	0	< 0.001
Dithiocarbamate	2	0	< 3.0-< 6.0	1	0	< 6.0	2	0	< 3.0-< 6.0	1	0	< 6.0
Endosulfan 01	0	-	-	0	-	-	1	0	< 0.003	3	0	< 0.003
Endosulfan 02	0	-	-	0	-	-	1	0	< 0.001	3	0	< 0.001-< 0.004
Endosulfan Sulfate	0	-	-	1	0	< 0.066	1	0	< 0.008	4	0	< 0.005-< 0.066
Endosulfan-A	0	-	-	1	0	< 0.014	0	-	-	1	0	< 0.014
Endosulfan-B	0	-	-	1	0	< 0.004	0	-	-	1	0	< 0.004

C—030881

Table 32. Pesticide Data (µg/L) for Delta Waterways, 1983-1987.[1]

COMPOUND	San Joaquin R. at Vernalis			Banks Pumping Plant			Delta Mendota Canal			Rock Slough		
	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range
2,4-D	10	0	< 0.01-< 0.5	8	1	< 0.01-0.1	8	0	< 0.01-< 0.5	6	0	< 0.2-< 0.5
4,4'-DDD	4	1	< 0.004-0.004	4	0	< 0.004-< 0.011	4	0	< 0.004-< 0.011	3	0	< 0.004-< 0.011
4,4'-DDE	4	1	< 0.002-0.007	4	0	< 0.002-< 0.006	4	0	< 0.002-< 0.006	3	1	< 0.002-0.003
4,4'-DDT	4	0	< 0.004-< 0.012	4	0	< 0.004-< 0.012	4	0	< 0.004-< 0.012	3	0	< 0.006-< 0.012
Alachlor	2	0	< 0.1	1	0	< 0.1	2	0	< 0.1	2	0	< 0.1
Aldrin	4	0	< 0.002-< 0.004	4	0	< 0.002-< 0.004	4	0	< 0.002-< 0.004	3	0	< 0.002-< 0.004
Atrazine	2	0	< 0.1	2	0	< 0.1	2	0	< 0.1	1	0	< 0.1
Bentazon	10	1	< 0.1-0.6	7	2	< 0.3-0.5	7	0	< 0.1-< 1.0	5	1	< 0.3-0.5
BHC-A	5	1	< 0.002-0.002	5	0	< 0.002-< 0.003	5	1	< 0.002-0.003	4	0	< 0.002-< 0.003
BHC-B	4	1	< 0.004-0.005	4	0	< 0.004-< 0.009	4	1	< 0.004-0.006	3	0	< 0.004-< 0.006
BHC-C	4	0	< 0.002-< 0.004	4	0	< 0.002-< 0.004	4	1	< 0.002-0.005	3	2	< 0.004-0.003
BHC-D	4	0	< 0.004-< 0.009	4	0	< 0.004-< 0.009	4	0	< 0.004-< 0.009	3	0	< 0.004-< 0.009
Captan	2	0	< 0.5	1	0	< 0.5	2	0	< 0.5	2	0	< 0.5
Carbaryl	2	0	< 2.0	2	0	< 2.0	2	0	< 2.0	1	0	< 2.0
Carbofuran	12	1	< 0.02-0.8	9	0	< 0.02-< 0.6	9	0	< 0.02-< 0.5	7	0	< 0.02-< 0.5
Chlordane	4	0	< 0.014-< 0.6	4	0	< 0.014-< 0.6	4	0	< 0.014-< 0.6	3	0	< 0.014-< 0.08
Chloropicrin	9	0	< 0.01-< 0.1	6	0	< 0.01-< 0.1	5	0	< 0.01-< 0.1	3	0	< 0.01-< 0.1
D-D Mixture	4	0	< 0.1-< 0.5	3	0	< 0.1-< 0.5	2	0	< 0.1	0	-	-
Dacthal	10	0	< 0.01-< 0.1	6	0	< 0.01-< 0.1	7	0	< 0.01-< 0.1	5	0	< 0.01-< 0.1
Diazinon	4	1	< 0.001-0.009	4	1	< 0.001-0.004	4	1	< 0.001-0.004	4	2	< 0.1-0.003
Dichlorovos	2	0	< 0.002-< 0.005	2	0	< 0.002-< 0.005	2	0	< 0.002-< 0.005	2	0	< 0.002-< 0.005
Dicofal	2	0	< 0.1-< 0.2	1	0	< 0.2	2	0	< 0.1-< 0.2	2	0	< 0.1-< 0.2
Dieldrin	4	1	< 0.001-0.005	4	0	< 0.001-< 0.002	4	1	< 0.001-0.003	3	0	< 0.002
Dimethoate	2	1	< 0.003-0.046	2	0	< 0.003-< 0.010	2	0	< 0.003-< 0.010	2	0	< 0.003-< 0.010
Dinoseb	2	0	< 0.25	2	0	< 0.25	2	0	< 0.25	2	0	< 0.25
Diphenamid	2	0	< 0.02-< 0.050	2	0	< 0.02-< 0.050	2	0	< 0.02-< 0.050	2	0	< 0.02-< 0.050
Diquat	2	0	< 40.0	2	0	< 40.0	2	0	< 40.0	1	0	< 40.0
Disulfotan	2	0	< 0.001	2	0	< 0.001	2	0	< 0.001	2	0	< 0.001
Dithiocarbamate	1	0	< 3.0	1	0	< 3.0	2	0	< 3.0-< 6.0	1	0	< 6.0
Endosulfan 01	3	1	< 0.003-0.004	3	0	< 0.003	3	0	< 0.003	2	0	< 0.003
Endosulfan 02	3	0	< 0.001-< 0.004	3	0	< 0.001-< 0.004	3	1	< 0.001-0.002	2	1	< 0.001-0.002
Endosulfan Sulfate	4	1	< 0.005-0.01	4	0	< 0.005-< 0.066	4	0	< 0.005-< 0.066	3	1	< 0.008-0.009
Endosulfan-A	1	0	< 0.014	1	0	< 0.014	1	0	< 0.014	1	0	< 0.014
Endosulfan-B	1	0	< 0.004	1	0	< 0.004	1	0	< 0.004	1	0	< 0.004

C—030882

Table 32. Pesticide Data (µg/L) for Delta Waterways, 1983-1987.[1]

COMPOUND	Middle River			Cache Slough			Mokelumne River			American River at WTP		
	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range
2,4-D	5	0	< 0.01-< 0.5	1	1	0.4	1	0	< 0.2	1	0	< 0.2
4,4'-DDD	0	-	-	2	0	< 0.004	4	0	< 0.004-< 0.011	4	0	< 0.004-< 0.011
4,4'-DDE	0	-	-	2	0	< 0.002	4	0	< 0.002-< 0.006	4	0	< 0.002-< 0.006
4,4'-DDT	0	-	-	2	0	< 0.006	4	0	< 0.004-< 0.012	4	0	< 0.004-< 0.012
Alachlor	2	0	< 0.1	0	-	-	0	-	-	0	-	-
Aldrin	0	-	-	2	0	< 0.002	4	0	< 0.002-< 0.004	4	0	< 0.002-< 0.004
Atrazine	0	-	-	0	-	-	0	-	-	0	-	-
Bentazon	5	0	< 0.1-< 0.5	0	-	-	0	-	-	0	-	-
BHC-A	0	-	-	3	1	< 0.002-0.002	5	0	< 0.002-< 0.003	5	0	< 0.002-< 0.003
BHC-B	0	-	-	2	0	< 0.004	4	0	< 0.004-< 0.009	4	0	< 0.004-< 0.009
BHC-C	0	-	-	2	1	< 0.002-0.003	4	2	< 0.002-0.004	4	0	< 0.002-< 0.004
BHC-D	0	-	-	2	0	< 0.004	4	0	< 0.004-< 0.009	4	0	< 0.004-< 0.009
Captan	2	0	< 0.5	0	-	-	0	-	-	0	-	-
Carbaryl	1	0	< 2.0	0	-	-	0	-	-	0	-	-
Carbofuran	5	0	< 0.2-< 0.5	1	1	1.33	2	0	< 0.02-< 0.040	2	0	< 0.02-< 0.040
Chlordane	0	-	-	2	0	< 0.08	4	0	< 0.014-< 0.6	4	0	< 0.014-< 0.6
Chloropicrin	4	0	< 0.01-< 0.1	2	0	< 0.1	0	-	-	0	-	-
D-D Mixture	2	0	< 0.1	2	0	< 0.1	0	-	-	0	-	-
Dacthal	5	0	< 0.01-< 0.1	0	-	-	0	-	-	0	-	-
Diazinon	2	0	< 0.1-< 0.2	1	1	0.008	2	0	< 0.001	2	0	< 0.001
Dichlorovos	0	-	-	1	0	< 0.005	2	0	< 0.002-< 0.005	2	0	< 0.002-< 0.005
Dicofal	2	0	< 0.1-< 0.2	0	-	-	0	-	-	0	-	-
Dieldrin	0	-	-	2	0	< 0.002	4	0	< 0.001-< 0.002	4	0	< 0.001-< 0.002
Dimethoate	0	-	-	1	0	< 0.010	2	0	< 0.003-< 0.010	2	0	< 0.003-< 0.010
Dinoseb	2	0	< 0.25	0	-	-	0	-	-	0	-	-
Diphenamid	0	-	-	1	0	< 0.050	2	0	< 0.02-< 0.050	2	0	< 0.02-< 0.050
Diquat	1	0	< 40.0	0	-	-	0	-	-	0	-	-
Disulfotan	1	0	< 0.001	2	0	< 0.001	2	0	< 0.001	2	0	< 0.001
Dithiocarbamate	1	0	< 6.0	0	-	-	0	-	-	0	-	-
Endosulfan 01	0	-	-	2	0	< 0.003	3	0	< 0.003	3	0	< 0.003
Endosulfan 02	0	-	-	2	1	< 0.001-0.005	3	0	< 0.001-< 0.004	3	0	< 0.001-< 0.004
Endosulfan Sulfate	0	-	-	2	0	< 0.008	4	0	< 0.005-< 0.066	4	0	< 0.005-< 0.066
Endosulfan-A	0	-	-	0	-	-	1	0	< 0.014	1	0	< 0.014
Endosulfan-B	0	-	-	0	-	-	1	0	< 0.004	1	0	< 0.004

Table 32. Pesticide Data (µg/L) for Delta Waterways, 1983-1987.[1]

COMPOUND	Cosumnes River			Honker Cut			North Bay Pumping Plant			Clifton Court		
	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range
2,4-D	1	0	< 0.2	1	0	< 0.2	1	0	< 0.2	2	0	< 0.2-< 0.5
4,4'-DDD	4	0	< 0.004-< 0.011	4	0	< 0.004-< 0.011	4	0	< 0.004-< 0.011	4	0	< 0.004-< 0.011
4,4'-DDE	4	0	< 0.002-< 0.006	4	0	< 0.002-< 0.006	4	0	< 0.002-< 0.006	4	0	< 0.002-< 0.006
4,4'-DDT	4	0	< 0.004-< 0.012	4	0	< 0.004-< 0.012	4	0	< 0.004-< 0.012	4	0	< 0.004-< 0.012
Alachlor	0	-	-	0	-	-	0	-	-	0	-	-
Aldrin	4	0	< 0.002-< 0.004	4	0	< 0.002-< 0.004	4	0	< 0.002-< 0.004	4	0	< 0.002-< 0.004
Atrazine	0	-	-	0	-	-	0	-	-	0	-	-
Bentazon	0	-	-	0	-	-	0	-	-	1	0	< 1.0
BHC-A	5	0	< 0.002-< 0.003	5	0	< 0.002-< 0.003	5	0	< 0.002-< 0.003	5	1	< 0.002-0.002
BHC-B	4	0	< 0.004-< 0.009	4	0	< 0.004-< 0.009	4	0	< 0.004-< 0.009	4	1	< 0.004-0.004
BHC-C	4	0	< 0.002-< 0.004	4	2	< 0.002-0.006	4	1	< 0.002-0.002	4	2	< 0.002-0.002
BHC-D	4	0	< 0.004-< 0.009	4	0	< 0.004-< 0.009	4	0	< 0.004-< 0.009	4	0	< 0.004-< 0.009
Captan	0	-	-	0	-	-	0	-	-	0	-	-
Carbaryl	0	-	-	0	-	-	0	-	-	0	-	-
Carbofuran	2	0	< 0.02-< 0.040	2	0	< 0.02-< 0.040	2	0	< 0.02-< 0.040	2	0	< 0.02-< 0.2
Chlordane	4	0	< 0.014-< 0.6	4	0	< 0.014-< 0.6	4	0	< 0.014-< 0.6	4	0	< 0.014-< 0.6
Chloropicrin	0	-	-	0	-	-	0	-	-	1	0	< 0.1
D-D Mixture	0	-	-	0	-	-	0	-	-	1	0	< 0.2
Dacthal	0	-	-	0	-	-	0	-	-	1	0	< 0.01
Diazinon	2	0	< 0.001	2	0	< 0.001	2	1	< 0.001-0.1	2	0	< 0.001-0.002
Dichlorovos	2	0	< 0.002-< 0.005	2	0	< 0.002-< 0.005	2	0	< 0.002-< 0.005	2	0	< 0.002-< 0.005
Dicofal	0	-	-	0	-	-	0	-	-	0	-	-
Dieldrin	4	0	< 0.001-< 0.002	4	0	< 0.001-< 0.002	4	0	< 0.001-< 0.002	4	1	< 0.001-0.002
Dimethoate	2	0	< 0.003-< 0.010	2	0	< 0.003-< 0.010	2	0	< 0.003-< 0.010	2	0	< 0.003-< 0.010
Dinoseb	0	-	-	0	-	-	0	-	-	0	-	-
Diphenamid	2	0	< 0.02-< 0.050	2	0	< 0.02-< 0.050	2	0	< 0.02-< 0.050	2	0	< 0.02-< 0.050
Diquat	0	-	-	0	-	-	0	-	-	0	-	-
Disulfotan	2	0	< 0.001	2	0	< 0.001	2	0	< 0.001	2	0	< 0.001
Dithiocarbamate	0	-	-	0	-	-	0	-	-	0	-	-
Endosulfan 01	3	0	< 0.003	3	0	< 0.003	3	0	< 0.003	3	0	< 0.003
Endosulfan 02	3	0	< 0.001-< 0.004	3	0	< 0.001-< 0.004	3	0	< 0.001-< 0.004	3	1	< 0.001-0.002
Endosulfan Sulfate	4	0	< 0.005-< 0.066	4	0	< 0.005-< 0.066	4	0	< 0.005-< 0.066	4	0	< 0.005-< 0.066
Endosulfan-A	1	0	< 0.014	1	0	< 0.014	1	0	< 0.014	1	0	< 0.014
Endosulfan-B	1	0	< 0.004	1	0	< 0.004	1	0	< 0.004	1	0	< 0.004

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Table 32. Pesticide Data (µg/L) for Delta Waterways, 1983-1987.[1]

COMPOUND	Barker Slough at Pumping Plant			Sacramento R. at Mallard Is.			Lindsay Slough at Hastings			Sacramento R. at Greene's Lndg.		
	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range
Endrin	0	-	-	1	0	< 0.006	1	0	< 0.004	4	0	< 0.004-< 0.006
Endrin Aldehyde	0	-	-	1	0	< 0.023	1	0	< 0.004	4	0	< 0.004-< 0.023
Ethion	0	-	-	0	-	-	0	-	-	2	0	< 0.0002-< 0.001
Glyphosate	0	-	-	0	-	-	0	-	-	1	0	< 1.0
Guthion	0	-	-	0	-	-	0	-	-	2	0	< 0.008-< 0.100
Heptachlor	0	-	-	1	0	< 0.003	1	0	< 0.002	4	0	< 0.002-< 0.003
Heptachlor Epoxide	0	-	-	1	0	< 0.083	1	0	< 0.004	4	0	< 0.003-< 0.083
Malathion	0	-	-	0	-	-	0	-	-	2	0	< 0.001-< 0.002
MCPA	2	0	< 20	6	0	< 1-< 30	4	0	< 1-< 20	4	0	< 1-< 20
Metalaxyl	2	0	< 0.05	6	0	< 0.05-< 10	2	0	< 0.05	4	0	< 0.05-< 10
Methamidophos	2	0	< 5	5	0	< 0.5-< 5	2	0	< 5	4	0	< 0.5-< 5
Methomyl	2	0	< 2.0	0	-	-	2	0	< 2.0	2	0	< 2.0
Methyl Bromide	0	-	-	3	0	< 0.5-< 0.7	2	0	< 0.5	3	0	< 0.5-< 0.7
Methyl Parathion	4	0	< 0.005-< 0.1	10	0	< 0.005-< 2.5	4	0	< 0.005-< 0.1	10	0	< 0.001-< 2.5
Molinate	4	0	< 0.05-< 0.5	6	1	< 0.05-0.94	6	1	< 0.05-1	6	1	< 0.05-0.43
Paraquat	4	0	< 10-< 20.0	8	0	< 10-< 20.0	4	0	< 10-< 20.0	6	0	< 10-< 20.0
Parathion	2	0	< 0.1	2	0	< 0.1	2	0	< 0.1	4	0	< 0.0008-< 0.1
PCB-1216	0	-	-	1	0	ND	0	-	-	1	0	ND
PCB-1221	0	-	-	1	0	ND	0	-	-	1	0	ND
PCB-1232	0	-	-	1	0	ND	0	-	-	1	0	ND
PCB-1242	0	-	-	1	0	< 0.065	0	-	-	1	0	< 0.065
PCB-1248	0	-	-	1	0	ND	0	-	-	1	0	ND
PCB-1254	0	-	-	1	0	ND	0	-	-	1	0	ND
PCB-1260	0	-	-	1	0	ND	0	-	-	1	0	ND
Propanil	2	0	< 0.5	0	-	-	2	0	< 0.5	1	0	< 0.5
Propham	2	0	< 2.0	0	-	-	2	0	< 2.0	2	0	< 2.0
Simazine	2	0	< 0.1	0	-	-	2	0	< 0.1	2	0	< 0.1
Thiobencarb	4	0	< 0.05-< 0.5	7	0	< 0.01-< 8	6	0	< 0.05-< 8	7	0	< 0.05-< 8
Toxaphene	0	-	-	1	0	< 0.24	1	0	< 0.63	4	0	< 0.24-< 0.63
Xylene	0	-	-	3	0	< 0.2-< 0.5	2	0	< 0.2-< 0.5	3	0	< 0.2-< 0.5
Total	68	1		131	1		100	3		206	4	

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Table 32. Pesticide Data (µg/L) for Delta Waterways, 1983-1987.[1]

COMPOUND	San Joaquin R. at Vernalis			Banks Pumping Plant			Delta Mendota Canal			Rock Slough		
	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range
Endrin	4	0	< 0.004-< 0.006	4	0	< 0.004-< 0.006	4	0	< 0.004-< 0.006	3	0	< 0.004-< 0.006
Endrin Aldehyde	4	0	< 0.004-< 0.023	4	0	< 0.004-< 0.023	4	0	< 0.004-< 0.023	3	0	< 0.004-< 0.023
Ethion	2	0	< 0.0002-< 0.001	2	0	< 0.0002-< 0.001	2	0	< 0.0002-< 0.001	2	0	< 0.0002-< 0.001
Glyphosate	0	-	-	0	-	-	0	-	-	0	-	-
Guthion	2	0	< 0.008-< 0.100	2	0	< 0.008-< 0.100	2	0	< 0.008-< 0.100	2	1	< 0.100-0.020
Heptachlor	4	0	< 0.002-< 0.003	4	0	< 0.002-< 0.003	4	0	< 0.002-< 0.003	3	0	< 0.002-< 0.003
Heptachlor Epoxide	4	0	< 0.003-< 0.083	4	0	< 0.003-< 0.083	4	0	< 0.003-< 0.083	3	0	< 0.004-< 0.083
Malathion	2	0	< 0.001-< 0.002	2	0	< 0.001-< 0.002	2	0	< 0.001-< 0.002	2	0	< 0.001-< 0.002
MCPA	8	0	< 1-< 30.0	3	0	< 20-< 30	5	0	< 1-< 30	3	0	< 20-< 30
Metalaxyl	8	0	< 0.05-< 10	5	0	< 0.05-< 10	5	0	< 0.05-< 10	3	0	< 0.05-< 0.4
Methamidophos	7	0	< 0.5-< 10.0	4	0	< 0.5-< 5	4	0	< 0.5-< 5	2	0	< 5
Methomyl	2	0	< 2.0	2	0	< 2.0	2	0	< 2.0	1	0	< 2.0
Methyl Bromide	4	0	< 0.5-< 0.7	3	0	< 0.5-< 0.7	2	0	< 0.5	0	-	-
Methyl Parathion	14	2	< 0.001-2.5	11	1	< 0.002-0.009	11	1	< 0.002-0.017	7	1	< 0.002-0.021
Molinate	9	2	< 0.05-0.68	6	2	< 0.5-1.4	6	1	< 0.05-0.16	4	2	< 0.5-1.4
Paraquat	10	2	< 10-74	7	0	< 10-< 20.0	7	0	< 10-< 20.0	5	0	< 10-< 20.0
Parathion	4	1	< 0.0008-0.012	4	0	< 0.0008-< 0.1	4	1	< 0.0008-0.003	4	2	< 0.1-0.003
PCB-1216	1	0	ND	1	0	ND	1	0	ND	1	0	ND
PCB-1221	1	0	ND	1	0	ND	1	0	ND	1	0	ND
PCB-1232	1	0	ND	1	0	ND	1	0	ND	1	0	ND
PCB-1242	1	0	< 0.065	1	0	< 0.065	1	0	< 0.065	1	0	< 0.065
PCB-1248	1	0	ND	1	0	ND	1	0	ND	1	0	ND
PCB-1254	1	0	ND	1	0	ND	1	0	ND	1	0	ND
PCB-1260	1	0	ND	1	0	ND	1	0	ND	1	0	ND
Propanil	2	0	< 0.5	2	0	< 0.5	2	0	< 0.5	1	0	< 0.5
Propham	2	0	< 2.0	2	0	< 2.0	2	0	< 2.0	1	0	< 2.0
Simazine	2	0	< 0.1	2	0	< 0.1	2	2	0.21-0.36	1	0	< 0.1
Thiobencarb	11	1	< 0.01-0.09	8	0	< 0.01-< 8	8	0	< 0.01-< 8	6	0	< 0.01-< 1.0
Toxaphene	4	0	< 0.24-< 0.63	4	0	< 0.24-< 0.63	4	0	< 0.24-< 0.63	3	0	< 0.24-< 0.63
Xylene	4	0	< 0.2-< 0.5	3	0	< 0.2-< 0.5	2	0	< 0.2-< 0.5	0	-	-
Total	255	19		211	7		214	11		156	14	

Table 32. Pesticide Data (µg/L) for Delta Waterways, 1983-1987.[1]

COMPOUND	Middle River			Cache Slough			Mokelumne River			American River at WTP		
	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range
Endrin	0	-	-	2	0	< 0.004	4	0	< 0.004-< 0.006	4	0	< 0.004-< 0.006
Endrin Aldehyde	0	-	-	2	0	< 0.004	4	0	< 0.004-< 0.023	4	0	< 0.004-< 0.023
Ethion	0	-	-	1	0	< 0.001	2	0	< 0.0002-< 0.001	2	0	< 0.0002-< 0.001
Glyphosate	1	0	< 1.0	0	-	-	0	-	-	0	-	-
Guthion	0	-	-	1	0	< 0.100	2	0	< 0.008-< 0.100	2	0	< 0.008-< 0.100
Heptachlor	0	-	-	2	0	< 0.002	4	0	< 0.002-< 0.003	4	0	< 0.002-< 0.003
Heptachlor Epoxide	0	-	-	2	0	< 0.004	4	0	< 0.003-< 0.083	4	0	< 0.003-< 0.083
Malathion	0	-	-	1	0	< 0.001	2	0	< 0.001-< 0.002	2	0	< 0.001-< 0.002
MCPA	3	0	< 1-< 20	2	0	< 1-< 10	0	-	-	0	-	-
Metalaxyl	3	0	< 0.05-< 10	0	-	-	0	-	-	0	-	-
Methamidophos	3	0	< 0.5-< 5	0	-	-	0	-	-	0	-	-
Methomyl	1	0	< 2.0	0	-	-	0	-	-	0	-	-
Methyl Bromide	2	0	< 0.5	2	0	< 0.5	0	-	-	0	-	-
Methyl Parathion	7	0	< 0.005-< 2.5	1	1	0.040	2	0	< 0.001-< 0.002	2	0	< 0.001-< 0.002
Molinate	4	1	< 0.5-1.1	2	0	< 0.5-< 1	0	-	-	0	-	-
Paraquat	5	0	< 10-< 20.0	0	-	-	0	-	-	0	-	-
Parathion	2	0	< 0.1	1	1	0.035	2	0	< 0.0008-< 0.001	2	0	< 0.0008-< 0.001
PCB-1216	0	-	-	0	-	-	1	0	ND	1	0	ND
PCB-1221	0	-	-	0	-	-	1	0	ND	1	0	ND
PCB-1232	0	-	-	0	-	-	1	0	ND	1	0	ND
PCB-1242	0	-	-	0	-	-	1	0	< 0.065	1	0	< 0.065
PCB-1248	0	-	-	0	-	-	1	0	ND	1	0	ND
PCB-1254	0	-	-	0	-	-	1	0	ND	1	0	ND
PCB-1260	0	-	-	0	-	-	1	0	ND	1	0	ND
Propanil	0	-	-	0	-	-	0	-	-	0	-	-
Propham	1	0	< 2.0	0	-	-	0	-	-	0	-	-
Simazine	0	-	-	0	-	-	0	-	-	0	-	-
Thiobencarb	4	0	< 0.05-< 8	3	0	< 1-< 8	1	0	< 1.0	1	0	< 1.0
Toxaphene	0	-	-	2	0	< 0.63	4	0	< 0.24-< 0.63	4	0	< 0.24-< 0.63
Xylene	2	0	< 0.2-< 0.5	2	0	< 0.2-< 0.5	0	-	-	0	-	-
Total	78	1		65	8		104	2		104	0	

Table 32. Pesticide Data (µg/L) for Delta Waterways, 1983-1987.[1]

COMPOUND	Cosumnes River			Honker Cut			North Bay Pumping Plant			Clifton Court		
	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range	No. of Samples	No. of Detects	Range
Endrin	4	0	< 0.004-< 0.006	4	0	< 0.004-< 0.006	4	0	< 0.004-< 0.006	4	0	< 0.004-< 0.006
Endrin Aldehyde	4	0	< 0.004-< 0.023	4	0	< 0.004-< 0.023	4	0	< 0.004-< 0.023	4	0	< 0.004-< 0.023
Ethion	2	0	< 0.0002-< 0.001	2	0	< 0.0002-< 0.001	2	0	< 0.0002-< 0.001	2	0	< 0.0002-< 0.001
Glyphosate	0	-	-	0	-	-	0	-	-	0	-	-
Guthion	2	0	< 0.008-< 0.100	2	0	< 0.008-< 0.100	2	0	< 0.008-< 0.100	2	0	< 0.008-< 0.100
Heptachlor	4	0	< 0.002-< 0.003	4	0	< 0.002-< 0.003	4	0	< 0.002-< 0.003	4	0	< 0.002-< 0.003
Heptachlor Epoxide	4	0	< 0.003-< 0.083	4	0	< 0.003-< 0.083	4	0	< 0.003-< 0.083	4	0	< 0.003-< 0.083
Malathion	2	0	< 0.001-< 0.002	2	0	< 0.001-< 0.002	2	0	< 0.001-< 0.002	2	0	< 0.001-< 0.002
MCPA	0	-	-	0	-	-	0	-	-	1	0	< 20
Metalaxyl	0	-	-	0	-	-	0	-	-	1	0	< 0.05
Methamidophos	0	-	-	0	-	-	0	-	-	1	0	< 5
Methomyl	0	-	-	0	-	-	0	-	-	0	-	-
Methyl Bromide	0	-	-	0	-	-	0	-	-	1	0	< 0.5
Methyl Parathion	2	0	< 0.001-< 0.002	2	0	< 0.001-< 0.002	2	0	< 0.001-< 0.002	3	1	< 0.002-0.017
Molinate	0	-	-	0	-	-	0	-	-	1	0	< 0.05
Paraquat	0	-	-	0	-	-	0	-	-	1	0	< 10
Parathion	2	0	< 0.0008-< 0.001	2	0	< 0.0008-< 0.001	2	0	< 0.0008-< 0.001	2	1	< 0.0008-0.003
PCB-1216	1	0	ND	1	0	ND	1	0	ND	1	0	ND
PCB-1221	1	0	ND	1	0	ND	1	0	ND	1	0	ND
PCB-1232	1	0	ND	1	0	ND	1	0	ND	1	0	ND
PCB-1242	1	0	< 0.065	1	0	< 0.065	1	0	< 0.065	1	0	< 0.065
PCB-1248	1	0	ND	1	0	ND	1	0	ND	1	0	ND
PCB-1254	1	0	ND	1	0	ND	1	0	ND	1	0	ND
PCB-1260	1	0	ND	1	0	ND	1	0	ND	1	0	ND
Propanil	0	-	-	0	-	-	0	-	-	0	-	-
Propham	0	-	-	0	-	-	0	-	-	0	-	-
Simazine	0	-	-	0	-	-	0	-	-	0	-	-
Thiobencarb	1	0	< 1.0	1	0	< 1.0	1	0	< 1.0	2	0	< 0.05-< 1.0
Toxaphene	4	0	< 0.24-< 0.63	4	0	< 0.24-< 0.63	4	0	< 0.24-< 0.63	4	0	< 0.24-< 0.63
Xylene	0	-	-	0	-	-	0	-	-	1	0	< 0.2
Total	104	0		104	2		104	2		118	8	

1 DWR, August 1989.

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standards. The most frequently detected pesticides were BHC-C (in 16 samples), molinate (in 11 samples), diazinon (in seven samples), methyl parathion (in seven samples), and parathion (in five samples).[175] Concentrations were generally below levels that are known to be toxic to freshwater aquatic life, except methyl parathion which exceeded the CVRWQCB performance goal of 0.13 µg/L.

3.1.1.3 CVRWQCB 1987 Bioassay Study

In 1987, the CVRWQCB conducted a bioassay study to assess the toxicity of surface waters in the Sacramento River system. Samples were collected on three dates during the rice drainage season from ten sites in the Sacramento Delta between Freeport and Chipps Island. Fathead minnow tissue growth and mortality, Ceriodaphnia reproduction and mortality, and Selenastrum growth were monitored. The fathead minnow and Ceriodaphnia mortality data were summarized in Table 18.[176]

Significant mortality to fathead minnows was found in six out of 20 samples collected within the Delta, or about 30 percent of the total. Growth was lower in all of the samples than in the control.

Significant mortality to Ceriodaphnia was found in only two out of 29 samples, or in about 7 percent of the total. Both toxic samples were from Chipps Island, and toxicity was attributed, at least in part, to elevated salinity at this station. An additional three samples, including one from Chipps Island, showed significant reproductive impairment.

3.1.1.4 CVRWQCB 1988-90 Bioassay Study

Between March 1988 and May 1990, the CVRWQCB conducted a two and one-half year bioassay study to assess the toxicity of surface waters in the Sacramento River system. Samples were collected on 18 separate dates from nine sites in the Sacramento Delta between Freeport and 1 km above the confluence of the Sacramento and San Joaquin Rivers. Fathead minnow growth and mortality, Ceriodaphnia reproduction and mortality, and Selenastrum growth were monitored at all sites. The fathead minnow mortality data were summarized in Table 1, the Ceriodaphnia mortality data in Table 2, and the Selenastrum growth data in Table 3.[177]

Significant mortality to fathead minnows was found in 11 out of 130 samples, or about 8 percent of the total. All of the toxic samples occurred in the April to June period. An additional

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[175] DWR, The Delta as a Source of Drinking Water, Monitoring Results 1983 to 1987, August 1989, p. 23.

[176] Foe, January 19, 1988.

[177] Connor et al., 1993.

six samples showed significant fathead minnow growth impairment. On a single date, May 15, 1988, the entire lower reach of the Sacramento River system to below Rio Vista was toxic to fathead minnows.

Five samples were also assayed for toxicity to larval striped bass in 96-hour static non-renewal bioassays. Three of these resulted in significant mortality to larval striped bass, including the May 15, 1988 Rio Vista sample (31 percent),[178] the May 25, 1989 Walnut Grove sample (100 percent), and the June 1, 1989 Walnut Grove sample (95.3 percent). Two other samples from Walnut Grove did not result in significant mortality.[179] Some of the larval striped bass mortality may be due to the salinity of the test solutions, as discussed in Section 2.1.1.1.

Significant mortality to Ceriodaphnia was found in 23 out of 113 samples, or about 20 percent of the total. Among these toxic samples, 18 or 78 percent of the total occurred in the April to June period. An additional ten samples showed significant Ceriodaphnia reproductive impairment.[180] Some impaired samples had no obvious upstream sources (e.g., March 9, 1988), suggesting local sources of toxicity.

Significant growth impairment to Selenastrum was found in 11 out of 105 samples, or 11 percent of the total. Most of the impaired samples occurred in the summer or winter and impairment was noted at all sites except Cache Slough and Green 7 at the confluence of the rivers.

3.1.1.5 DFG Bioassay Study

Samples were collected three times a week between April 16 and June 25, 1990 from the Sacramento River at Rio Vista and analyzed for three pesticides (carbofuran, malathion, methyl parathion), metals, and toxicity to young Neomysis and striped bass. The pesticide data were summarized in Table 21 and the mortality data in Table 22. Significant mortality to Neomysis and striped bass was found in about 10 percent of the samples. None of the pesticides that were monitored could account for the toxicity.

3.1.1.6 CVRWQCB 1991-92 Bioassay Study

Between March 1991 and August 1992, the CVRWQCB monitored quarterly fathead minnow growth and mortality, Ceriodaphnia reproduction and mortality, and Selenastrum growth at two sites in the Delta, the Sacramento River at Hood and the Mokelumne River below

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[178] Bailey, August 12, 1988, Table 2.

[179] Bailey et al., 1989, Table 1.

[180] Connor et al., 1993, Table 19.

Camanche Reservoir. Metals were also monitored, and metal TIEs were performed to determine if the metals were responsible for noted effects. The mortality data were summarized in Table 4.

No toxicity to fathead minnows or Selenastrum was observed at Hood, but 13 percent of the samples were toxic to Ceriodaphnia. The samples from downstream of Camanche Reservoir were toxic to fathead minnows 50 percent of the time and to Ceriodaphnia 11 percent of the time. TIEs suggested that metals were not responsible for the toxicity.[181]

3.1.1.7 USFWS Bioassay Study

Samples were collected weekly primarily from Hog, Sycamore, and Beaver Sloughs and assayed for Ceriodaphnia toxicity in May and June of 1994. Only one out of 60 or 2 percent of the samples were toxic, presumably because no rainfall occurred during the sampling period and little pesticide application occurred.[182]

3.1.1.8 CVRWQCB/UCD Bioassay Studies

The CVRWQCB, in collaboration with Howard Bailey at the University of California at Davis ("UCD"), have completed a number of bioassay studies in the Delta. The purpose of this work is to determine the extent, severity, and source of toxicity in the Delta using the U.S. EPA three species bioassay. Most of this data has not been published. The following summary is abstracted from a review prepared by Dr. Bailey for the Bay/Delta Oversight Council[183] and from draft reports prepared for the CVRWQCB.

Delta Channels. Twenty-four Delta sites were monitored monthly between May 1993 and May 1994 using short-term chronic tests with fathead minnows, Ceriodaphnia, and Selenastrum. Sampling sites included major waterways, back sloughs and small upland drainages, island drains, and points along the pathway of water movement across the Delta. Once toxicity was detected in routine screening, followup TIEs were conducted to determine the cause of the toxicity. Organic chemicals were analyzed in some samples using the USGS 2010 scan.

Fathead minnow bioassays were conducted on 201 samples. Among these, growth was significantly reduced in 17 or 8 percent of the total. No mortality was found in any of the

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[181] Connor et al., 1994.

[182] C. DiGiorgio, H.C. Bailey, and D.E. Hinton, Delta Water Quality Monitoring Program: 2 May - 13 June 1994, U.S. Fish and Wildlife Service, Environmental Monitoring Branch, Sacramento, 1994.

[183] Howard C. Bailey, Steve Clark, Jay Davis, and Lan Wiborg, The Effects of Toxic Contaminants in Waters of the San Francisco Bay and Delta, Report Prepared for Bay/Delta Oversight Council, 1995.

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samples. Samples collected from the main river inputs to the Delta, the Sacramento, Mokelumne and San Joaquin Rivers, were toxic most frequently, 20 percent of the time. Toxicity was restricted to samples collected from the former two rivers. Three out of nine or 33 percent of the samples from the Sacramento River at Hood reduced the growth of fathead minnows. In other work, no fathead minnow toxicity was found at Hood in seven samples collected in 1991 and 1992 (Sec. 3.1.1.6). However, samples collected upstream at Freeport Marina between December 1990 and February 1997 resulted in significant fathead minnow mortality 51 percent of the time (Sec. 2.1.1.6). Two out of eight or 25 percent of the samples from the Mokelumne River upstream from the confluence with the Cosumnes River reduced the growth of fathead minnows. In other work, four out of eight or 50 percent of the samples collected from the Mokelumne River downstream of Camanche Reservoir reduced the growth of fathead minnows. Growth was increased in half of the toxic samples after they were passed through an ion exchange column, suggesting the potential for metal toxicity.

The growth of fathead minnows was reduced in 11 percent of the samples collected from back sloughs and small upland drainages. Toxicity was found at five of the seven sites that were tested. The only sites that were not toxic are Prospect Slough and Paradise Cut. Ulatis Creek and Duck Slough reduced the growth of fathead minnows in 11 percent of the samples and French Camp Slough and Lindsay Slough reduced growth in 22 percent of the samples.

The growth of fathead minnows was reduced in 5 percent of the samples collected from island drains and points along the path of water movement across the Delta. Toxicity was detected in the Ryer Island Drain in 11 percent of the samples, in Bouldin Island Drain in 14 percent, and in Steamboat Slough, the Sacramento River at Rio Vista, and the Old River at Tracy in 13 percent of the samples. Samples from Twitchell Island Main Drain, Pierson Tract Drain, Victoria Island Main Drain, the San Joaquin River at Antioch, Old River at Highway 4, Middle River, and the Delta Mendota Canal were never toxic to fathead minnows.

Significant mortality to Ceriodaphnia was found in seven out of 237 samples, or about 3 percent of the total. Ceriodaphnia reproduction was significantly reduced in 35 out of 238 samples, or about 15 percent of the total. Samples collected from Ulatis Creek, French Camp Slough, and Paradise Cut both reduced reproduction and resulted in significant mortality. Samples from Duck, Lindsay, and Prospect Sloughs only reduced reproduction. Samples from French Camp Slough (3/23/94) and Paradise Cut (4/27/94) were acutely toxic to Ceriodaphnia.

The Paradise Cut sample remained acutely toxic when diluted to 50 percent, and a second sample collected four days later was still acutely toxic. Followup TIEs on these acutely toxic Paradise Cut samples suggest that carbofuran (4.8 µg/L) caused the Ceriodaphnia toxicity. The carbofuran concentrations found in these samples exceed the LC50 for the invertebrates Neomysis and Mysidopsis bahia and the level that has been reported safe for carp.

Similarly, the French Camp Slough sample remained toxic when diluted to 12.5 percent, and a second sample collected five days later was still acutely toxic. Followup TIEs on these acutely toxic French Camp Slough samples suggest that chlorpyrifos (0.52, 0.037 µg/L) caused the toxicity. These concentrations are known to be high enough to impair a number of organisms, including the invertebrates Neomysis, Daphnia magna and Mysidopsis bahia, the amphipod Gammarus lacustris, and the naiad life stage of the dragon fly, Pseudagrion sp.

The growth of Selenastrum was significantly reduced in only one out of 213 samples, or about 1 percent of the total. Toxicity was only found in back sloughs, and no toxicity was detected in samples collected from the main rivers, island drains, or urban runoff. However, the low frequency of algal toxicity may have been caused by nutrient limitation of the algal growth medium. Selenastrum growth appeared to be reduced most frequently in the spring and early summer when one or more of the barriers in the Old and Middle Rivers are in place. The authors speculated that the barriers may reduce tidal dilution flows, increasing water residence time and pollutant concentrations.

Several TIEs were conducted on samples from Paradise Cut, Lake McLeod, and Old River where growth was low relative to other ambient samples collected on the same day and the controls. Samples were extracted using a C-8 solid phase column and compared with unextracted samples. Extraction substantially increased growth compared to the controls, suggesting the presence of a phytotoxic organic chemical. Although simazine, metalochlor and cyanazine were elevated in some of these samples, their role in inhibiting algal growth is not known. Followup TIEs on several samples from Paradise Cut suggested that non-polar organic chemicals may have been responsible for the toxicity.[184]

Additional sampling was conducted in the Delta between December 1, 1994 and February 28, 1995. In December, samples from nine sites were tested with Selenastrum, and two sites -- Rock and Prospect Sloughs -- exhibited reduced cell numbers. Samples from 16 sites were tested with Ceriodaphnia, and three sites -- Ulatis Creek, Haas Slough, and Mosher Slough, produced complete mortality. In all three cases, TIEs identified organophosphorus pesticides as the source of toxicity. Five samples were also tested with fathead minnows, and none exhibited adverse effects on survival or growth.[185]

In January 1995, samples were collected from 12 sites in the Delta and tested with Selenastrum. Four of the sites -- Haas Slough, Duck Slough, Victoria Island Drain, and Old River -- exhibited one third to one half of the growth present in samples from other sites. The toxic samples were passed through a C-8 SPE column to remove non-polar organics and retested, which increased cell numbers by four to five fold, suggesting that non-polar organics were responsible for the toxicity. Eleven sites were also tested for toxicity to Ceriodaphnia. Complete mortality occurred in the sample from Mosher Slough. Reduced reproduction occurred in samples

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[184] Linda Deanovic, Howard Bailey, T.W. Shed, and David E. Hinton, 1993-1994 Annual Report for the Delta Monitoring Program, Draft, 1995.

[185] Deanovic et al., in preparation, cited in Bailey, et al., 1995, p. 28.

from six other sites, including Ulatis Creek, Haas Slough, Ryer Island Main Drain, Duck Slough, Pierson Tract, Victoria Island Drain, and Middle Roberts Island Drain. Diazinon and chlorpyrifos concentrations were high enough in the Mosher Slough sample to explain the acute toxicity.[186]

In summary, recent monitoring in the Delta suggests that waters are infrequently toxic to fathead minnows, Ceriodaphnia, and Selenastrum. Most of the toxicity to Ceriodaphnia and Selenastrum is found in back sloughs and small upland drainages, while most of the toxicity to fathead minnows is found in the main rivers.

Storm Event Monitoring. Since significant previous work indicated that toxicity was associated with rainfall events, toxicity was also monitored daily for several consecutive days during seven rainfall periods at Greene's Landing on the Sacramento River, at Vernalis on the San Joaquin River, and elsewhere.

In the first period, 6-hour composite samples were collected over a 2-day period at Greene's Landing on the Sacramento River. Toxicity was measured in one of the six samples to all three test organisms, including increased mortality to Ceriodaphnia and fathead minnows..[187]

In the second period, January 23-28, 1994, 100 percent mortality to Ceriodaphnia was observed in four out of five samples collected at Vernalis. Reproduction increased over time, suggesting toxicity was runoff related. On January 27, 1994, algal growth was approximately half of that observed on four previous days in the sample collected at Vernalis. A follow-up TIE suggested that the Ceriodaphnia mortality was primarily due to diazinon. Other organophosphorus pesticides may have contributed, particularly methidathion. No adverse effects were observed to Ceriodaphnia or Selenastrum in samples from Greene's Landing during this same period. However, growth of fathead minnow larvae was significantly reduced at this site in two out of five samples.[188]

In the third period, February 6-13, 1994, toxicity to Ceriodaphnia was observed in four out of eight samples collected at Vernalis. On February 9, 1994, algal growth was approximately half of that observed on other days in the sample collected at Vernalis, but none of the samples was toxic to fathead minnows. At Greene's Landing, no samples were toxic to Selenastrum, one out of eight samples was toxic to Ceriodaphnia and fathead minnows. Followup TIEs suggested that metabolically activated organophosphorus pesticides were responsible for the Ceriodaphnia toxicity. A second, non-metabolically activated chemical was implicated in one sample.[189]

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[186] Bailey et al., 1995, p. 28.

[187] Bailey et al., 1995, p. 24.

[188] Deanovic et al., 1996.

[189] Ibid.

In the fourth period, February 17-23, 1994, seven samples were collected from Vernalis. None was toxic to any of the three species.[190]

In the fifth period, January 9-14, 1995, Ceriodaphnia reproduction was significantly reduced in all five samples from Greene's Landing and in two of the six samples from Vernalis. No adverse effects were noted to fathead minnows. No adverse effects were also noted with Selenastrum at Greene's Landing, but at Vernalis, cell numbers increased over time, suggesting growth was limited by water quality at the beginning of the storm event.[191]

In the sixth period, January 23-25, 1995, three samples were collected from Vernalis and one from the Old River at Tracy. None was toxic to Selenastrum or Ceriodaphnia. Fathead minnows were not tested.[192]

In the seventh period, March 1-8, 1995, 100 percent Ceriodaphnia mortality was observed in samples from Paradise Cut, Mosher Slough, and Ulatis Creek. Ceriodaphnia reproduction was also significantly reduced in one of the four samples from Vernalis. Fathead minnow growth was also significantly reduced in the sample from Paradise Cut. Two samples from Greene's Landing were not toxic to any of the three species.[193]

In summary, during rainfall events, Delta waterways are frequently toxic to Ceriodaphnia and periodically toxic to Selenastrum and fathead minnows. Some of the Ceriodaphnia toxicity is due to organophosphorus pesticides.

3.1.1.9 Regional Monitoring Program

The San Francisco Estuary Regional Monitoring Program ("RMP") monitors conventional water quality parameters, total and dissolved metals, polynuclear aromatic hydrocarbons ("PAHs"), PCBs, pesticides, toxicity, and tissue levels of select constituents at up to 20 sites in San Francisco Bay and four sites in the Delta. The Program was authorized by the San Francisco Bay Regional Water Quality Control Board and is managed and administered by the San Francisco Estuary Institute. For the Delta stations, pesticides in waters and toxicity data are

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190 Bailey et al., 1995, p. 25.

191 Karen Luhmann, Linda Deanovic, Howard Bailey, and David Hinton, Delta Monitoring Study, Quarterly Report, December 1, 1994 to February 28, 1995, Prepared for the Central Valley Regional Water Quality Control Board, 1995.

192 Ibid.

193 Tom Kimball, Linda Deanovic, Howard Bailey, and David Hinton, Delta Routine Monitoring, Quarterly Report, March 1995 - May 1995, Prepared for the Central Valley Regional Water Quality Control Board, 1995.

discussed in this section, pesticides and toxicity in sediments in Section 3.1.2, and pesticides in tissues in Section 3.1.3.

1993. In 1993, water column toxicity was monitored in March, May, and September at the Sacramento River near Collinsville and at the San Joaquin River near Antioch using a 48-hr mollusc embryo development test and a 96-hr algal growth test. These tests were performed according to ASTM procedures. Larval Mytilus edulis were used in the March and September tests, and larval Crassostrea gigas were used in the May test due to seasonal differences in larval availability. The algal growth test used Thalassiosira pseudomona.[194] No toxicity relative to the controls was observed in the mollusc tests at either site.[195] However, the growth of Thalassiosira relative to the controls was enhanced at the Sacramento site during March and May and at the San Joaquin site during March.[196]

In 1993, dissolved and total concentrations of up to 20 different insecticides, herbicides, and fungicides were monitored in March, May, and September at the same two sites. Only the March data have been published. The total concentrations are summarized in Table 33. In contrast to other studies discussed in this report, all but five of these pesticides were detected at both stations, probably because detection limits were very low, around 1 part per quadrillion ("ppq") or about 1 picogram per liter (pg/L) for most compounds.

In March 1993, the total pesticide concentration[197] in the Sacramento River was 9,011 ppq (9.0 ng/L), of which 83 percent was in the dissolved phase. This was the highest pesticide concentration measured in the entire monitoring program that year. The compounds that occurred at the highest concentrations were dacthal (5,484 ppq or 61 percent of total), total DDT (1060 ppq or 12 percent of the total), chlorpyrifos (450 ppq or 5 percent of the total), and oxadiazon (331 ppq or 4 percent of the total). In the San Joaquin River, the total pesticide concentration was 5,927 ppq (5.9 ng/L), of which 88 percent was in the dissolved phase. The compounds that occurred at the highest concentrations were dacthal (2,496 ppq or 42 percent of the total), oxadiazon (2,081 ppq or 35 percent of the total), total DDT (591 ppq or 10 percent of the total), and dieldrin (193 ppq or 3 percent of the total).

1994. In February and August 1994, water column toxicity was monitored at the same two stations as in 1993 using the 48-hr mollusc embryo development test and a 7-day growth test using the estuarine mysid Mysidopsis bahia. Larval Mytilus edulis were used in the February test,

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[194] SFEI, San Francisco Estuary Regional Monitoring Program for Trace Substances, 1993 Annual Report, December 1, 1994, p. 10.

[195] Ibid., p. 52.

[196] Ibid., Figure 25, p. 54.

[197] The sum of the concentrations of all pesticides detected.

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Table 33. Total Pesticide Concentrations* (pg/L) in the Delta Waters Measured in the Regional Monitoring Program in 1993-1995.[1]

River	Station Name	Collection Date	Total Chlordanes[2]	Total DDTs[3]	Total HCHs[4]	alpha-Chlordane	cis-Nonachlor	gamma-Chlordane	Heptachlor	Heptachlor epoxide	Oxychlordane	Hexachlorobenzene	trans-Nonachlor	Chlorpyrifos	Dacthal	o,p'-DDD	o,p'-DDE	o,p'-DDT
Sacramento	Collinsville	3/5/93	124	1060	129	29	ND[5]	34	ND			53	61	457	5484	104	29	NA
Sacramento	Collinsville	2/9/94	95	270.2	1126.0	24	5.7	21.6	NA	14.7	ND	15.1	28.6	1416.0	5208.2	9.8	5.9	ND
Sacramento	Collinsville	4/28/94	128	591.6	386.8	27	9.2	27.0	1.3	31.2	1.0	26.0	30.6	NA	631.0	50.0	6.6	ND
Sacramento	Collinsville	8/23/94	132	282.5	1506.0	25	9.3	29.9	11.0	34.0	3.4	16.4	19.9	NA	518.5	16.8	7.7	ND
Sacramento	Collinsville	2/15/95	106	435	51	18	5	16	ND	54	ND	11	13	58	770	8	16	ND
Sacramento	Collinsville	4/18/95	83	728	115	19	3	23	ND	12	ND	32	26	69	57	11	29	1
Sacramento	Collinsville	8/23/95	116	470	27	30	6	28	2	18	ND	3	32	21	209	35	15	3.0
Sacramento	Rio Vista	4/7/94	156	277	13	94	ND	19		Q	ND		43	801	1924	32	4	Q
Sacramento	Rio Vista	4/13/94	241	413	327	153	1	66		Q	ND		21	1928	2380	30	8	Q
Sacramento	Rio Vista	5/6/94	158	421	151	62	3	70		Q	ND		23	1388	1235	36	8	Q
Sacramento	Rio Vista	5/11/94	231	537	337	128	13	40		ND	ND		50	1474	2881	56	6	Q
Sacramento	Rio Vista	5/18/94	253	474	403	143	9	58		Q	ND		43	2087	1670	49	11	Q
Sacramento	Rio Vista	5/25/94	186	590	150	108	20	37		Q	ND		21	1018	861	60	11	Q
San Joaquin	Antioch	3/5/93	45	591	86	10	ND	16	ND			26	19	114	2496	38	14	NA
San Joaquin	Antioch	2/9/94	184	364.4	197.4	41	5.7	96.2	NA	14.9	ND	77.6	26.8	640.0	3010.5	13.2	8.3	M
San Joaquin	Antioch	4/28/94	108	430.4	708.9	21	8.2	21.7	ND	32.0	1.2	42.0	23.5	NA	771.0	31.0	5.4	ND
San Joaquin	Antioch	8/23/94	125	210.0	883.1	28	8.9	38.0	1.0	29.0	3.2	12.5	17.2	NA	510.0	7.6	4.4	ND
San Joaquin	Antioch	2/15/95	254	366	78	28	4	30	ND	170	3	27	19	183	1212	ND	14	ND
San Joaquin	Antioch	4/18/95	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	240	NA	NA	NA	NA
San Joaquin	Antioch	8/23/95	165	399	47	49	10	43	4	15	4	17	40	20	284	7	7	1
San Joaquin	Manteca	4/7/94	465	8363	348	69	Q	100		ND	ND		296	16181	2821	262	161	357
San Joaquin	Manteca	4/13/94	777	9915		104	106	170		Q	ND		397	13214	3891	401	190	Q
San Joaquin	Manteca	5/6/94	841	10329	30	161	Q	150		ND	ND		530	9549	3070	354	269	Q
San Joaquin	Manteca	5/11/94	706	5921	1444	301	M	116		Q	ND		289	14759	4132	271	138	Q
San Joaquin	Manteca	5/18/94	705	7943	243	83	M	150		ND	Q		472	13400	2673	306	195	Q
San Joaquin	Manteca	5/25/94	482	6415	228	49	M	106		Q	ND		327	5264	1800	248	185	Q

1 SFEI, 1994, 1995, 1997.
2 Total chlordanes = Σ alpha-Chlordane + cis-Nonachlor + gamma-Chlordane + Heptachlor + Heptachlor epoxide + Oxychlordane + trans-Nonachlor.
3 Total DDTs = Σ o,p'-DDD + o,p'-DDE + o,p'-DDT + p,p'-DDD + p,p'-DDE + p,p'-DDT.
4 Total HCHs = Σ alpha-HCH + beta-HCH + delta-HCH + gamma-HCH.
5 ND = not detected; NA = not analyzed; Q = present but not quantifiable; M = matrix interference; blank = not included in program; CE = coelution.
* The following pesticides were measured in 1994 but not detected: mirex, methylchlorpyrifos, and toxaphene. Mirex was measured but not detected in 1995.

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Table 33. Total Pesticide Concentrations* (pg/L) in the Delta Waters Measured in the Regional Monitoring Program in 1993-1995.[1]

River	Station Name	Collection Date	p,p'-DDD	p,p'-DDE	p,p'-DDMU	p,p'-DDT	Diazinon	Dieldrin	Endosulfan I	Endosulfan II	Endosulfan sulfate	Endrin	alpha-HCH	beta-HCH	delta-HCH	gamma-HCH	Trifluralin	Oxadiazon
Sacramento	Collinsville	3/5/93	106	769	91	52		224	27	ND	ND		6	ND		123		331
Sacramento	Collinsville	2/9/94	52.1	191.9	23.7	10.4	46629	193.0	Q	Q	ND	NA	186.4	ND	NA	939.6	1947.1	2621.9
Sacramento	Collinsville	4/28/94	210.0	298.0	NA	27.0	2500	179.5	ND	ND	ND	CE	70.0	26.8	ND	290.0	NA	157.0
Sacramento	Collinsville	8/23/94	82.0	142.0	NA	34.0	1400	7.1	ND	ND	ND	ND	346.8	118.0	38.0	1003.2	NA	77.0
Sacramento	Collinsville	2/15/95	53	352		6	7800	30	ND	ND	ND	ND	14	8	8	21		283
Sacramento	Collinsville	4/18/95	127	548		11	3900	3	ND	ND	ND	ND	33	18	21	43		26
Sacramento	Collinsville	8/23/95	99	310		9	1500	169	ND	ND	ND	ND	ND	14	4	10		7
Sacramento	Rio Vista	4/7/94	43	198	39	ND	5807	343	ND	ND			13	Q		Q	ND	1321
Sacramento	Rio Vista	4/13/94	77	294	15	4	5106	139	ND	ND			Q	Q		Q	327	960
Sacramento	Rio Vista	5/6/94	75	294	13	8	3481	149	ND	ND			Q	ND		ND	151	539
Sacramento	Rio Vista	5/11/94	106	355	10	14	15556	213	Q	ND			Q	Q		Q	337	3498
Sacramento	Rio Vista	5/18/94	126	278	28	10	10463	268	ND	ND			Q	ND		Q	403	1627
Sacramento	Rio Vista	5/25/94	118	391	8	10	7100	167	ND	ND			Q	Q		Q	150	948
San Joaquin	Antioch	3/5/93	68	399	61	72		193	4	18	45		2	14		70		2081
San Joaquin	Antioch	2/9/94	76.2	236.1	19.4	30.5	35259	149.6	ND	ND	M	NA	36.3	7.1	NA	154.0	1225.2	2802.6
San Joaquin	Antioch	4/28/94	113.0	269.0	NA	12.0	ND	179.0	ND	ND	ND	CE	86.0	291.9	ND	331.0	NA	17.0
San Joaquin	Antioch	8/23/94	36.0	121.0	NA	41.0	1200	2.0	ND	ND	ND	12.0	200.0	66.0	ND	617.1	NA	144.0
San Joaquin	Antioch	2/15/95	66	270		16	7600	ND	ND	ND	ND	ND	28	35	ND	15		130
San Joaquin	Antioch	4/18/95	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA
San Joaquin	Antioch	8/23/95	229	229		9	1900	75	ND	ND	ND	ND	5	22	4	15		8
San Joaquin	Manteca	4/7/94	565	6348	ND	670	5230	511	ND	ND			87	33		228	4812	4058
San Joaquin	Manteca	4/13/94	802	7494	126	1028	6769	569	ND	ND			Q	Q		Q	8735	1370
San Joaquin	Manteca	5/6/94	408	8810	ND	488	1599	637	M	28			16	Q		14	6888	406
San Joaquin	Manteca	5/11/94	223	5079	4	210	7943	376	ND	ND			271	430		743	5648	1320
San Joaquin	Manteca	5/18/94	730	6330	109	382	26485	508	Q	1			46	53		144	4180	1012
San Joaquin	Manteca	5/25/94	M	5982	ND	M	9012	454	Q	ND			45	46		137	3912	1179

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and larval Crassostrea gigas were used in the August test. No toxicity relative to the controls was observed in either test at either site.[198] In May 1994, a static-renewal, 10-day striped bass bioassay was also conducted at two new sites, the Sacramento River at Rio Vista and the San Joaquin River at Manteca. However, the striped bass tests failed because minimum acceptable survival requirements of 60 percent in the control treatments were not met.[199]

In 1994, dissolved and total concentrations of up to 29 different insecticides, herbicides, and fungicides were monitored in February, April, and August at the Sacramento River near Collinsville and at the San Joaquin River near Antioch. Six samples were also collected approximately weekly between April 6 and May 24, 1994 at the Sacramento River at Rio Vista and at the San Joaquin River at Manteca. The total concentrations are summarized in Table 33.[200]

The compounds that were most frequently detected at the highest concentrations were diazinon, chlorpyrifos, and dacthal. The highest concentrations of these and other pesticides occurred in the San Joaquin River. Diazinon was present at concentrations of 1,200 to 46,629 ppq and was the only pesticide that was present at higher concentrations at the downstream stations (Collinsville and Antioch) than at the upstream stations (Rio Vista and Manteca). Neither diazinon nor oxadiazon was correlated with any other pesticide, while both chlorpyrifos and dacthal were correlated with most other pesticides. Total and dissolved diazinon concentrations were correlated with Sacramento River flow. Chlorpyrifos was present at concentrations of 640 to 16,181 ppq, and dacthal was present at concentrations of 510 to 5,208 ppq.[201]

1995. In February and August 1995, water column toxicity was monitored in the Sacramento River near Collinsville and in the San Joaquin River near Antioch. Two bioassays were used, a 48-hour Mytilus edulis test and a 7-day Mysidopsis bahia test. Survival was significantly reduced in the Mysidopsis test compared to the control in February at Antioch, but not at Collinsville. The bivalve tests failed. In February, survival was poor in the controls and in August, the stocks did not produce viable sperm or eggs, which resulted in extremely poor fertilization or development.

In 1994, dissolved and total concentrations of up to 28 different insecticides, herbicides, and fungicides were monitored in February, April, and August in the Sacramento River near Collinsville and the San Joaquin River near Antioch. The total concentrations are summarized in

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198 SFEI, San Francisco Estuary Regional Monitoring Program for Trace Substances, 1994 Annual Report, 1995, pp. 64 and 278.

199 Ibid., p. 65.

200 Ibid., Tables 3.9 and 3.19.

201 Ibid., p. 78.

Table 33. Results are similar to those report for 1994. The compounds present in the highest concentrations and detected most frequently were diazinon, chlorpyrifos, and dacthal.[202]

3.1.1.10 USGS Study

The USGS collected water samples daily in January and February 1993 from Delta channels. On the San Joaquin side, samples were collected from the San Joaquin River at Vernalis and Stockton and from Middle and Old Rivers. On the Sacramento side, samples were collected from the Sacramento River at Sacramento and Rio Vista. Samples were also collected in Suisun Bay at Chipps Island and Martinez. Samples were analyzed for diazinon, methidathion, chlorpyrifos, and malathion. Samples from Rio Vista and Vernalis were assayed for toxicity to Ceriodaphnia.

Distinct pulses of pesticides were found following major storms in the San Joaquin River in January and February (Figure 15), in Old and Middle Rivers in January and February (Figure 16), and in the Sacramento River in February (Figure 17) and could be tracked downstream. Peaks in the San Joaquin River were bimodal, suggesting multiple sources. Concentrations generally decreased and the peaks broadened as the pulses moved seaward due to tidal mixing. Sacramento River water at Rio Vista was acutely toxic to Ceriodaphnia for three consecutive days and San Joaquin River water at Vernalis for 12 consecutive days. The toxicity at Vernalis coincided with elevated diazinon concentrations (Figure 18).[203] The diazinon data were separately published and are discussed below.

Diazinon was primarily applied at the end of January 1993 during two weeks of dry weather. A series of rainstorms began in early February. Pulses of diazinon were observed in both rivers in February following the rainfall. A single pulse was observed in the Sacramento River and two pulses in the San Joaquin River, similar to results described above for other chemicals. Riverine diazinon pulses were well defined, with elevated concentrations measured for a few days to weeks at a time. Diazinon and flow pulses generally coincided in time.

On the Sacramento side, river water flows past Rio Vista to Chipps Island and then Martinez. Concentrations in this area decreased and the pulses broadened as they moved downstream due to tidal mixing. The pulse traveled the 43 miles from Sacramento to Rio Vista in about 1.5 days, the 16.5 miles to Chipps Island in another 1.5 days, and the 14.5 miles to Martinez in 3 days. The average velocity of the peak decreased from 28 mi/day between Sacramento and Rio Vista to 11 mi/day between Rio Vista and Chipps Island to 5 mi/day between

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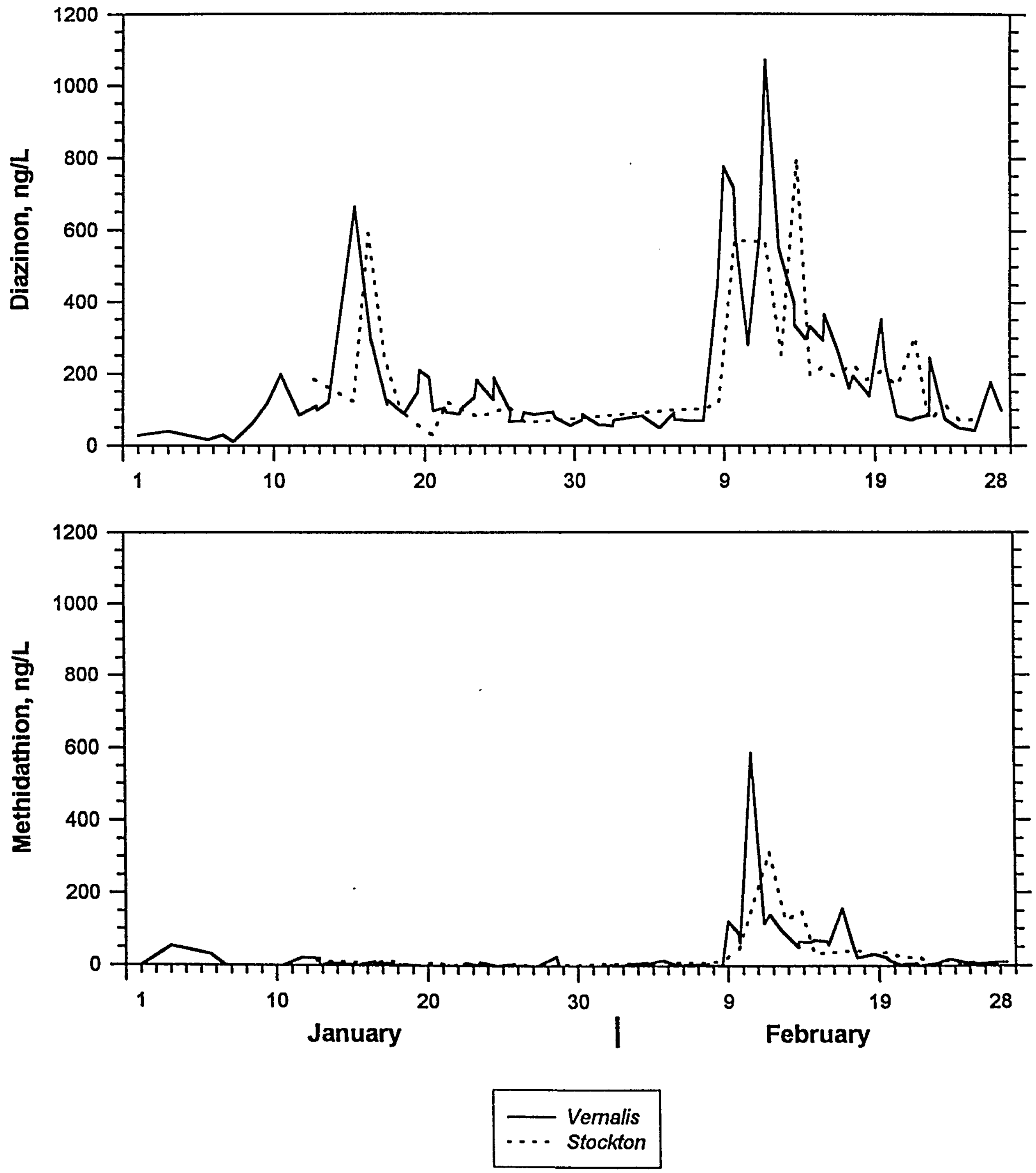
[202] SFEI, Regional Monitoring Program for Trace Substances, 1995 Annual Report, 1997, pp. 30, A-35 to A-37.

[203] Kathryn M. Kuivila and Christopher G. Foe, Concentrations, Transport and Biological Effects of Dormant Spray Pesticides in the San Francisco Estuary, California, Environmental Toxicology and Chemistry, v. 14, no. 7, 1995.

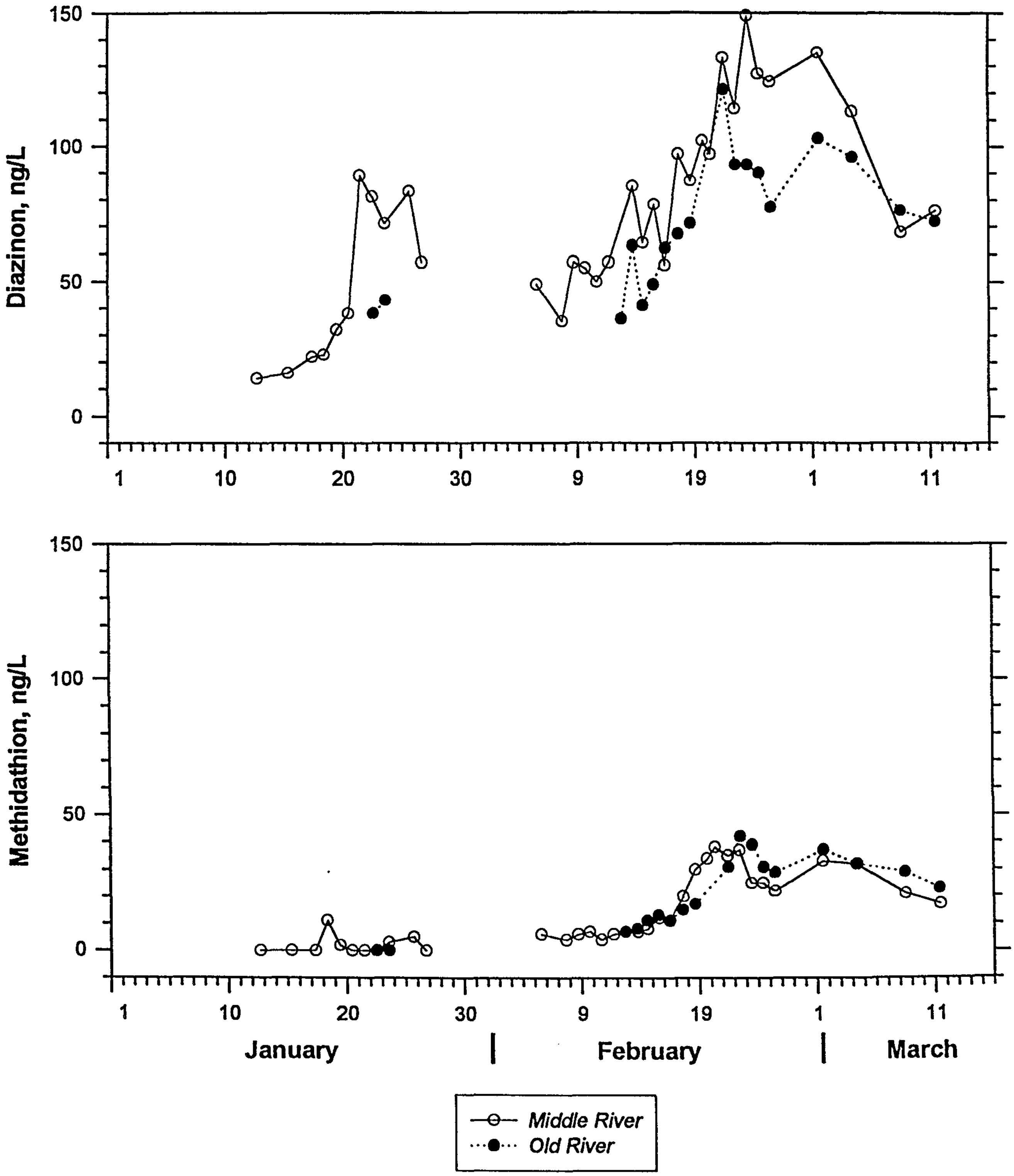
Figure 15. Concentrations of Diazinon and Methidathion, San Joaquin River at Vernalis and Stockton, January and February 1993



C —0 3 0 9 0 1

C-030901

Figure 16. Concentrations of Diazinon and Methidathion, Middle River and Old River, January through March 1993



C—0 3 0 9 0 2

C-030902

Figure 17. Concentrations of Diazinon and Methidathion, Sacramento River to San Francisco Bay, February 1993

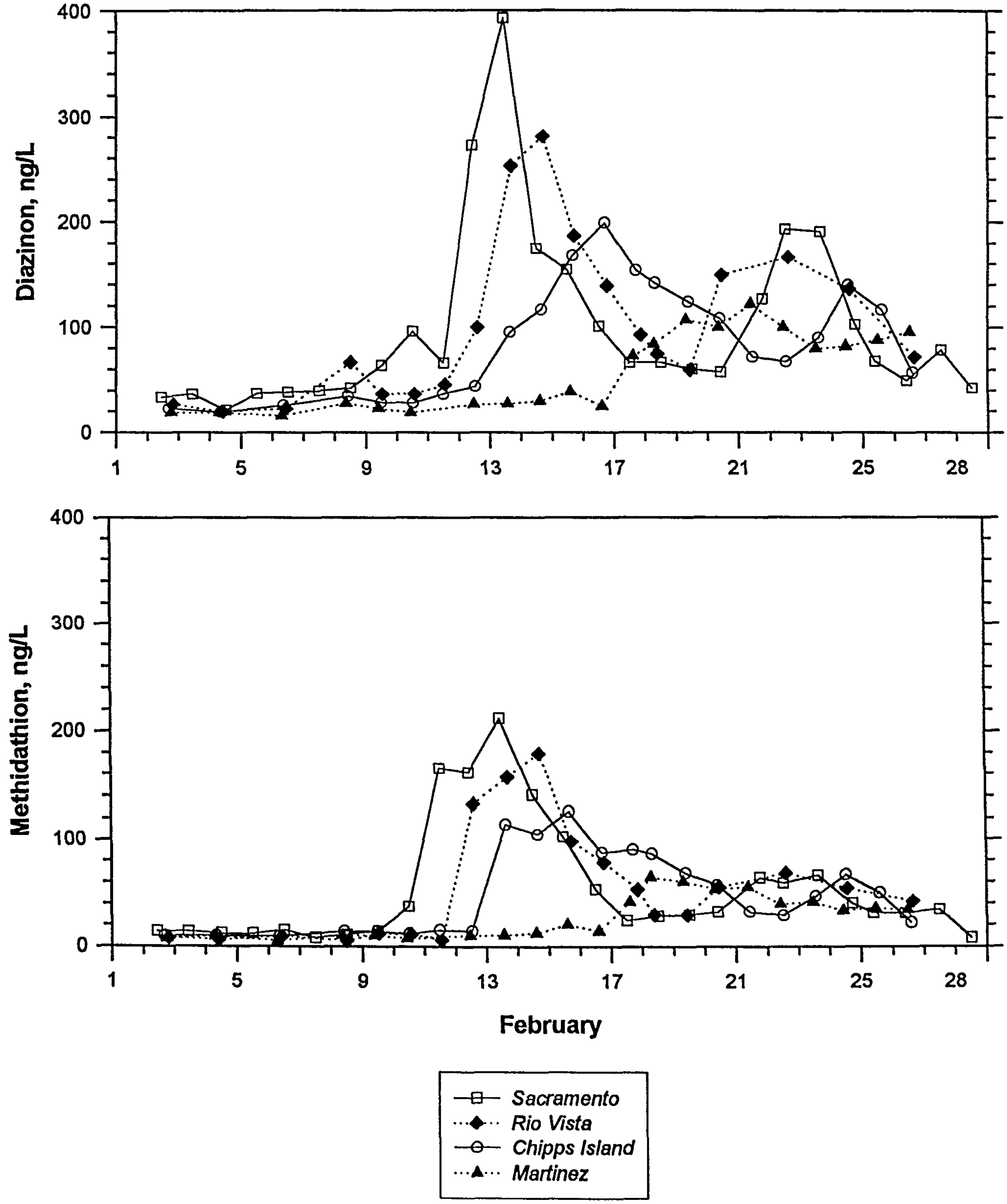
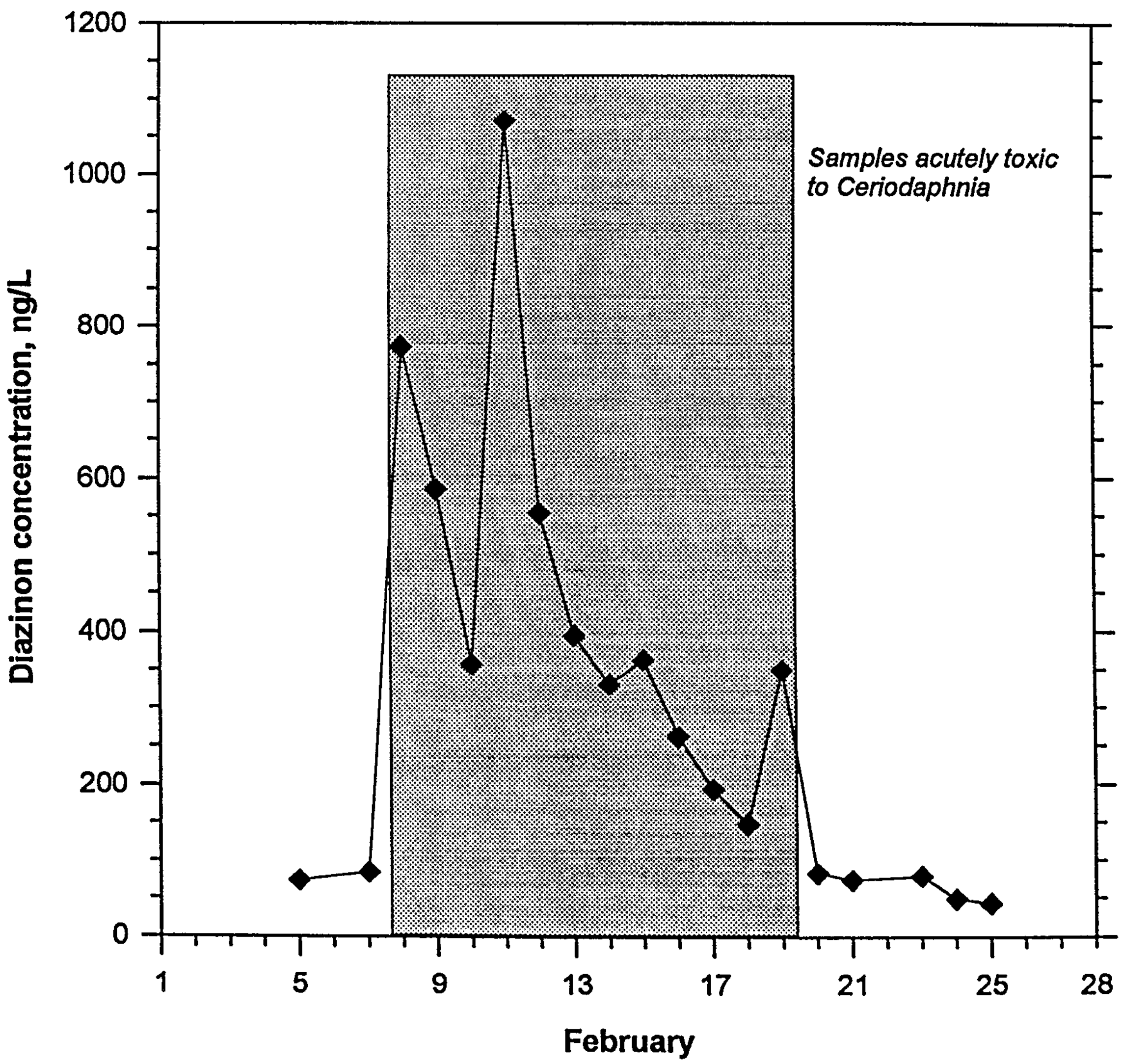


Figure 18. Diazinon Concentrations and Water Toxicity, February 1993; San Joaquin River at Vernalis



Chipps Island and Martinez. The decrease in velocity is probably due to increasing influence of tidal mixing in the lower estuary. Peak concentrations were reduced from 400 ng/L at Sacramento to 281 ng/L at Rio Vista, to 199 ng/L at Chipps Island, to 107 ng/L at Martinez.

In contrast, on the San Joaquin side, well-defined pulses of diazinon were present at Vernalis and 2 days later at Stockton. However, well-defined pulses were not observed in Old and Middle Rivers. Instead, diazinon concentrations steadily increased from 35 ng/L up to 149 ng/L throughout February.[204]

3.1.1.11 Striped Bass Feeding Study

Striped bass larvae were collected from up to 13 sites along the Sacramento and San Joaquin Rivers within the Delta in 1988 to 1991 and morphometric and histopathological studies conducted to determine whether food was limiting. Liver alterations consistent with exposure to rice pesticides were seen in 26 to 30 percent of the larvae from 1988 to 1990, and 15 percent in 1991.[205] The decrease may have been due to the implementation of on-farm management practices.

Livers of normal larvae include hepatocytes with large and abundant mitochondria and rough endoplasmic reticulum. These hepatocytes are uniform and show no vacuolation. Larvae from striped bass collected in the Delta contained altered hepatocytes that were enlarged, showing swollen mitochondria and swollen, apparently fluid-filled, cisternae of the endoplasmic reticulum. Vacuolated hepatocytes are common in adult fish exposed to pollutants, including pesticides. Similar liver alterations were produced by the rice pesticides methyl parathion, carbofuran, and molinate in laboratory bioassays.

3.1.2 Sediments

3.1.2.1 USGS Sediment Monitoring

Bed sediments from the Mokelumne River at Woodbridge were measured in October 1992 by the USGS for organochlorine pesticides. These results are discussed in Section 4.1.2 and summarized in Table 34. They indicate that low concentrations of DDT and its degradation

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[204] Kathryn M. Kuivila, Diazinon Concentrations in the Sacramento and San Joaquin Rivers and San Francisco Bay, California, USGS Open-File Report 93-440, 1993.

[205] William A. Bennett, David J. Ostrach, and David E. Hinton, Larval Striped Bass Condition in a Drought-Stricken Estuary: Evaluating Pelagic Food-Web Limitation, Ecological Applications, v. 5, no. 3, 1995, pp. 680-692.

Table 34. Concentrations of Organic Contaminants in Sediments from the San Joaquin River and its Tributaries (October 1992) [µg/Kg dry weight][1]

Compound	SITE										
	Salt Slough		Orestimba Creek		Dry Creek		San Joaquin River at Patterson		Mokelumne River at Woodbridge*	TID 5*	San Joaquin River at Vernalis*
	Bed Sediment	Suspended Sediment	Bed Sediment	Suspended Sediment	Bed Sediment	Suspended Sediment	Bed Sediment	Suspended Sediment			
DDE	3.5	17	115	212	2.0	59	1.4	61	2.5	2.6	11
DDD	1.0	4.0	14	32	0.7	9.6	0.4	10	1.9	1.0	1.9
DDT	0.4	3.3	39	59	0.8	6.3	0.4	4.4	1.1	1.1	1.6
Total DDT	4.9	24	170	303	3.5	75	2.2	75	5.5	4.7	15
γ-Chlordane	0.8	< 0.5	1.2	2.1	1.6	50	0.7	5.2	3.5	1.7	1.1
α-Chlordane	0.7	7.8	0.9	2.9	1.0	55	0.7	< 0.5	2.3	1.3	0.9
Trans-nonachlor	1.0	< 0.5	1.2	2.6	1.6	38	< 0.5	7.1	3.0	1.6	1.2
Cis-nonachlor	< 0.5	5.7	0.8	2.1	1.1	17	0.7	5.8	1.5	1.0	0.7
Total chlordane	2.5	14	4.1	9.7	5.3	160	2.1	18	10.3	5.6	3.9
DCPA	< 0.5	< 0.5	7.3	19	1.1	48	0.4	41	0.4	< 0.5	0.8
Dicofol	< 0.5	< 0.5	23.7	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	6.8
Dieldrin	< 0.5	< 0.5	4.6	10	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Chlorpyrifos	< 0.5	< 0.5	< 0.5	< 0.5	2.8	153	< 0.5	< 0.5	1.1	1.8	< 0.5
Atrazine	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Simazine	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Dimethoate	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Diazinon	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5

1 Pereira et al. 1996

* Bed sediments

products (0.5-22 μg/kg), chlordanes (1.5-7.7 μg/kg), dacthal (0.4 μg/kg), and chlorpyrifos (1.1 μg/kg) are present in bed sediments from this location.[206]

3.1.2.2 Regional Monitoring Program

The RMP, previously described in Section 3.1.1.9, measured 22 pesticides in sediments from the Sacramento River near Collinsville and the San Joaquin River near Antioch in September 1993, February and August 1994, and February and August 1995. These compounds include aldrin, chlordanes, DDTs, dieldrin, endrin, hexachlorobenzene, hexachlorocyclohexanes, and mirex. All concentrations were less than the detection limits, which were typically about 0.15 μg/kg, except α-BHC (0.20 μg/kg), HCB (0.17 μg/kg), and aldrin (0.19 μg/kg) in the San Joaquin River; dieldrin (0.19 μg/kg) in the Sacramento River; and DDTs (0.2 - 2.08 μg/kg) and HCHs (0.23 - 0.37 μg/kg) in both rivers.[207]

Sediment toxicity was also monitored at both of these stations in March and September 1993, February and August 1994, and February and August 1995. Whole sediments were assayed in a 10-day acute mortality test using the estuarine amphipod Eohaustorius estuarius and a water extract of the sediments in a bivalve embryo development test using either larval mussels (Mytilus edulis) or larval oysters (Crassostrea gigas).

In March 1993, both tests and all three endpoints (amphipod mortality, mussel survival and development) indicated significant toxicity at the Sacramento River site. At the San Joaquin site, significant toxicity was observed for the mussel survival and development endpoints. In September 1993, both sites showed significantly lower development by oyster larvae, and amphipod mortality was significantly increased at the San Joaquin site.[208]

In 1994, percent normal development in mussels was significantly reduced at both stations in February and August compared to the control. No toxicity was found in 1994 in the amphipod tests.[209]

In 1995, percent normal development in the mussels was significantly reduced (0 percent) compared to the controls at both sites. The February Antioch sample also significantly reduced

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[206] Wilfred E. Pereira, Joseph L. Domagalski, Frances D. Hostettler, Larry R. Brown and John B. Rapp, Occurrence and Accumulation of Pesticides and Organic Contaminants in River Sediment, Water and Clam Tissues from the San Joaquin River and Tributaries, California, Environmental Toxicology and Chemistry, v. 15, no. 2, 1996, pp. 172-180.

[207] SFEI, 1994, pp. 187-188; SFEI, 1995, Table 3.24; SFEIR, 1977, p. A-48.

[208] SFEI, 1994, pp. 91-92.

[209] SFEI, 1995, p. 109.

the survival (80 percent) of the amphipods compared to the controls. No toxicity to the amphipods was found in any of the other tests.[210]

3.1.2.3 Sediment Toxicity Reconnaissance Studies

Two reconnaissance studies of sediment toxicity have been conducted in the Sacramento Basin. In 1992, the DFG assayed the toxicity of sediments from Camanche Reservoir downstream from the abandoned Penn Mine using the ASTM 10-day Hyalella azteca bulk sediment test. No significant toxicity (15 percent mortality) compared to the control was found at a deposition site where fine particles were accumulating.[211]

Pacific Eco-Risk Laboratories and the CVRWQCB measured sediment toxicity at eight sites in the Delta. Toxicity was assayed using the Hyalella test for bulk sediments and the three-brood Ceriodaphnia test for sediment elutriates and site water. Elutriates were prepared from site water, and when site water was toxic, with control water (well water). The sites tested are the Sacramento River at Rio Vista, Sacramento River at Green 25 (between Rinelge Tract and Roberts Island, south of Turner Cut), Duck Slough (drainage from Reclamation District 999), Smith Canal (urban runoff from Stockton), Port of Stockton (adjacent to ore loading facility), Old Mormon Slough (industrial; adjacent to the McCormick & Baxter wood treatment facility, a Superfund site), Rough & Ready Island (in shipping channel), and Stockton Turning Basin (a dry bulk loading area). The latter five sites are near Stockton. Samples were collected in June and July 1995.

Sediment toxicity was significantly different from controls in samples collected from seven of these sites. Bulk sediment samples caused significant mortality to Hyalella in eight replicate samples collected from Green 25 (56 percent), Port of Stockton (35 percent), Smith Canal (16 percent), Stockton Turning Basin (19 percent), Duck Slough (15 percent), Old Mormon Slough (37 percent and 14 percent), and Rough & Ready Island (53 percent). (Parentheticals are percent mortality.) These results are not surprising since these sites were selected because they were known or suspected to be toxic. For example, sediments and biota from Old Mormon Slough, which is adjacent to the McCormick and Baxter wood treatment facility loading dock, contain dioxins and PCBs (Sec. 3.1.2.4). Duck Slough and Smith Canal were selected because surface water samples from this site were known to be toxic to fathead minnow and Ceriodaphnia. Green 25 was selected because elevated concentrations of trace metals are present in sediments.

Sediment elutriates also significantly reduced Ceriodaphnia reproduction at six of the seven sites that displayed significant bulk sediment toxicity -- Green 25, Smith Canal, Port of

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210 SFEIR, 1977, pp. 102, A-49.

211 Fujimura, November 1, 1996.

Stockton, Stockton Turning Basin, Duck Slough, and Rough & Ready Island. However, no significant mortality to Ceriodaphnia occurred in any of the elutriate and overlying waters.[212]

3.1.2.4 Department of Health Services Study

The California Department of Health Services conducted a study to assess the presence of dioxins and PCBs in bed sediments and biota collected from the San Joaquin River near the McCormick and Baxter wood treatment facility in Stockton. Sediments were collected from eight sites, four in the Stockton Deep Water Ship Channel, two in Mormon Slough, and two upstream of the facility. The fish and clam data are discussed in Section 3.1.3.3.

Low concentrations of dioxins and PCB toxic equivalents ("TEQs") were detected at all sites including the controls. PCB concentrations ranged from 0.12 at a control site to 8.06 ng/kg TEQ. Dioxin concentrations ranged from 0.91 at a control site to 672 ng/kg. All concentrations are dry weight. Dioxin congener patterns were consistent with pentachlorophenol, which was used at the plant for wood preservation. The highest concentrations of dioxins were found closest to the McCormick and Baxter facility.[213]

3.1.3 Biota

3.1.3.1 SWRCB Toxic Substances Monitoring Program

Since 1978, the SWRCB has monitored pesticides, pesticide ingredients, and pesticide byproducts in fish from 14 stations within the Delta, including two on the Sacramento River (at Rio Vista and Hood), two on the San Joaquin River (at Twitchell Island and French Camp Slough), two on the Mokelumne River, and one each on Old River, White Slough, Walker Slough, Beach Lake, Cosumnes River, the Cross Canal, Paradise Cut, and the Stockton Deep Water Channel. The analyses were performed on either muscle tissue (filet), or when only very small fish were available, on a whole body composite. Over 50 percent of the samples were four species -- carp, channel catfish, white catfish, and largemouth bass. The minimum and maximum detected values are summarized in Table 35.[214]

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[212] Ogle et al., August 1996.

[213] D.G. Hayward, M.X. Petreas, J.J. Winkler, P. Visita, M. McKinnery, and R.D. Stephens, Investigation of a Wood Treatment Facility: Impact on an Aquatic Ecosystem in the San Joaquin River, Stockton, California, Archives of Environmental Contamination and Toxicology, v. 30, 1996, pp. 30-39.

[214] The data were obtained from the SWRCB electronic bulletin board (916-657-9722) in a file called TSM.LOTUS.ZIP. The data have also been published by the SWRCB, 1990-93.

Table 35. Pesticides in Fish (µg/Kg wet weight) from the Delta, 1978-1993.[1]

STATION	Aldrin		Total Chlordane		Chlorpyrifos		Dacthal		Total DDT	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Beach Lake	nd	nd	7.5	274.8	nd	nd	7.9	18	34	1,125
Cosumnes River	nd	nd	13.1	13.1	nd	nd	nd	nd	80	80
Cross Canal	nd	nd	18.9	18.9	nd	nd	nd	nd	53	410
Mokelumne River/Woodbridge	nd	nd	nd	nd	nd	nd	nd	nd	12	167
Mokelumne River/Lodi Lake	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Old River	nd	nd	6.4	6.4	nd	nd	nd	nd	7.4	219
Paradise Cut/Tracy	nd	nd	32.2	411.1	17	26	5.1	6	155	5,332
Sacramento River/Hood	133	133	9.5	129	nd	nd	16	16	7	1,078
Sacramento River/Rio Vista	nd	nd	7	37.5	18	18	17	17	81	377
San Joaquin River/French Camp Slough	nd	nd	nd	nd	nd	nd	nd	nd	33	33
San Joaquin River/Twitchell Island	nd	nd	14.8	158	nd	nd	nd	nd	99	656
Stockton Deep Water Channel	nd	nd	15.3	15.3	nd	nd	nd	nd	24	246
Walker Slough	nd	nd	nd	nd	nd	nd	nd	nd	386	386
White Slough/Lodi	nd	nd	5.4	5.4	nd	nd	nd	nd	180	180

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Table 35. Pesticides in Fish (µg/Kg wet weight) from the Delta, 1978-1993.[1]

STATION	Dicofol		DBP		Dieldrin		Total Endosulfan		Total HCH	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Beach Lake	nd	nd	nd	nd	23	23	nd	nd	2.3	2.3
Cosumnes River	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cross Canal	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Mokelumne River/Woodbridge	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Mokelumne River/Lodi Lake	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Old River	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Paradise Cut/Tracy	nd	nd	nd	nd	7	60	5	261	6	7.8
Sacramento River/Hood	nd	nd	nd	nd	64	28	6.4	11	2	6.1
Sacramento River/Rio Vista	nd	nd	nd	nd	6.9	38	nd	nd	nd	nd
San Joaquin River/French Camp Slough	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
San Joaquin River/Twitchell Island	nd	nd	nd	nd	16	16	nd	nd	2.2	2.2
Stockton Deep Water Channel	nd	nd	nd	nd	8.2	8.2	nd	nd	nd	nd
Walker Slough	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
White Slough/Lodi	nd	nd	nd	nd	8.6	8.6	nd	nd	nd	nd

Table 35. Pesticides in Fish (µg/Kg wet weight) from the Delta, 1978-1993.[1]

STATION	Heptachlor epoxide		Hexachlorobenzene		Methyl parathion		Total PCB		Toxaphene	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Beach Lake	nd	nd	2.1	2.1	nd	nd	410	500	nd	nd
Cosumnes River	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cross Canal	nd	nd	nd	nd	nd	nd	59	59	nd	nd
Mokelumne River/Woodbridge	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Mokelumne River/Lodi Lake	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Old River	nd	nd	nd	nd	nd	nd	130	130	nd	nd
Paradise Cut/Tracy	7.9	7.9	2.2	7.8	nd	nd	75	370	200	2,400
Sacramento River/Hood	nd	nd	2	3.6	nd	nd	50	480	100	1,040
Sacramento River/Rio Vista	nd	nd	nd	nd	nd	nd	170	170	nd	nd
San Joaquin River/French Camp Slough	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
San Joaquin River/Twitchell Island	nd	nd	3.5	3.5	nd	nd	86	980	410	410
Stockton Deep Water Channel	nd	nd	nd	nd	nd	nd	100	240	nd	nd
Walker Slough	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
White Slough/Lodi	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

1 SWRCB data from file TSMLOTUS.ZIP

C-030912

Pesticides were detected in fish from 13 of the 14 stations. However, they were generally detected less frequently and their concentrations were lower than in the San Joaquin Basin (Sec. 4.1.3). The most frequently detected pesticides and pesticide ingredients were DDT (7 - 5,332 μg/kg), dieldrin (6.9 - 60 μg/kg), chlordane (5.4 - 411 μg/kg), and PCBs (50 - 980 μg/kg), which are no longer registered for use in California. The concentrations of the most frequently detected pesticides were plotted against time and the graphs visually inspected to determine if there were any trends in the data. Generally, the concentrations of DDT, dieldrin, and chlordane have increased since 1978, while PCBs peaked in 1986 and have declined since then.

Other compounds that were detected include aldrin (in one sample), chlorpyrifos (in three samples), dacthal (in six samples), endosulfan (in six samples), HCH (in seven samples), heptachlor epoxide (in one sample), hexachlorobenzene (in nine samples), and toxaphene (in 11 samples). Aldrin, HCH, hexachlorobenzene, and toxaphene are no longer registered for use in California.

The biological significance of these concentrations is uncertain. Although fish may survive relatively high residue concentrations in their body fats, residues concentrated in the eggs of mature fish may be lethal to developing fry. It is well known that organochlorine pesticides accumulate in eggs and that up to 100 percent loss of fry occur when eggs contain significant quantities.[215] As discussed in Section 2.1.3.2, many of these organochlorine compounds are weakly estrogenic, and synergistic interactions of combinations of them may adversely affect reproduction in exposed organisms.

However, some samples collected in the Delta exceeded levels established by the NAS to protect predators. Paradise Cut at Tracy and the Sacramento River at Hood were the most contaminated sites. DDT, banned since 1972, was found in one sample each from Beach Lake and the San Joaquin River at Twitchell Island, three samples from Hood on the Sacramento River and in four samples from Paradise Cut/Tracy at levels that exceeded the NAS criterion of 1,000 μg/kg. As discussed in Section 2.1.3.2, many of the DDT concentrations are high enough (>0.21 μg/kg wet weight) that mothers who frequently consume the fish could have breast milk DDT concentrations high enough to expose infants to unsafe levels. Chlordane, formerly widely used in urban areas to control ants and termites, exceeded the NAS criterion of 100 μg/kg in three samples from Hood, four from Paradise Cut/Tracy, and one sample each from Beach Lake and Twitchell Island. Toxaphene, banned since 1986, also exceeded the NAS criterion of 100 μg/kg at several sites, including in five samples each from Hood and Paradise Cut/Tracy and one sample from Twitchell Island. PCBs exceeded the NAS criterion of 500 μg/kg once at Twitchell Island and Beach Lake. Endosulfan exceeded the NAS criterion of 100 μg/kg in one sample from Paradise Cut/Tracy (Table 10).

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[215] NAS, 1973, p. 184.

C-030913

3.1.3.2 RMP Monitoring Program

The RMP Program, previously described in Section 3.1.1.9, also monitored pesticides in bivalve tissue at two stations, the Sacramento River near Collinsville and the San Joaquin River near Antioch. Seven different pesticide and pesticide groups were measured including chlordanes, DDTs, hexachlorocyclohexanes, aldrin, dieldrin, endrin, and mirex. The data are summarized in Table 36.

In October 1993, pesticides were measured in clams from the two river stations. In the Sacramento River, the total pesticide content of tissue was 222 µg/kg. The major components were DDTs (168 µg/kg), which comprised 76 percent of the total, chlordanes (34 µg/kg), which comprised 15 percent of the total, dieldrin (7.79 µg/kg), and aldrin (3.74 µg/kg). All other compounds were present at less than 2 µg/kg. In the San Joaquin River in 1993, the total pesticide content of tissue was 220 µg/kg. The major components were similar to the Sacramento River, namely DDTs (161 µg/kg), chlordanes (37 µg/kg), dieldrin (7.23 µg/kg), and aldrin (5.11 µg/kg).[216] In 1994, pesticides were measured in clams at the same two sites in May and September with similar results. Total DDTs ranged from 212 to 267 µg/kg and chlordanes from 55 to 69 µg/kg.[217] In 1995, pesticides were measured in clams at the same two sites in April and September with similar results. Total DDTs ranged from 209 to 246 µg/kg and chlordanes from 36 to 49 µg/kg.[218]

3.1.3.3 Department of Health Services Study

The California Department of Health Services conducted a study to assess the presence of dioxins and PCBs in bed sediments and biota collected from the San Joaquin River near the McCormick and Baxter wood treatment facility in Stockton. Fish were collected in February 1992 from Old Mormon Slough and in the Stockton Deep Water Ship Channel. Freshwater clams (Corbicula fluminea) were transplanted in these areas in March 1992, and sediments were collected from eight locations. Sediment data are discussed in Section 3.1.2.2.

All clams exhibited high mortality rates (25 to 83 percent), presumably due to an unhealthy source population from Rio Vista. Very low concentrations of PCBs (4.0 - 23.8 ng/kg) and dioxins (3.0 - 26.8 ng/kg) toxic equivalents ("TEQ") were found at all sites including the control. PCB levels in clams were weakly associated with sediment levels.

Fish sampled include three carp, two striped bass, two blue gills, and four largemouth bass. Concentrations of PCBs and dioxins were low in both the fillet and whole fish. PCBs

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216 SFEI, 1994, pp. 202-203.

217 SFEI, 1995, Table 3.29.

218 SFEI, 1977, p. A-61.

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Table 36. Pesticides in Clam Tissue (µg/kg) from the Delta Measured in the Regional Monitoring Program in 1993 and 1994.[1]

River	Station Name	Collection Date	Total Chlordanes[2]	Total DDTs[3]	Total HCHs[4]	alpha-Chlordane	cis-Nonachlor	gamma-Chlordane	Heptachlor	Heptachlor epoxide	Oxychlordane	Hexachlorobenzene	trans-Nonachlor	Aldrin	Dieldrin	Endrin	Mirex
Sacramento	Collinsville	10/7/93	34.87	167.84		8.67	4.86	9.49	ND[5]	ND	1.28	2.19	10.57	3.74	7.79	1.50	ND
Sacramento	Collinsville	5/6/94	65.95	261.3	8.61	18.48	10.52	14.8	3.03	1.07	0.76		17.29	1.9	14.57	0.61	0.99
Sacramento	Collinsville	9/14/94	54.78	238.1	3.88	11.57	11.41	12.65	ND	ND	1.37		17.78	2.65	14.59	ND	2.22
San Joaquin	Antioch	10/7/93	37.07	161.35		9.56	5.21	10.23	ND	ND	1.24	4.23	10.83	5.11	7.23	ND	ND
San Joaquin	Antioch	5/6/94	55.76	212.2	10.43	15.88	7.98	12.15	ND	0.98	1.61		17.16	4.99	12.77	0.8	ND
San Joaquin	Antioch	9/14/94	68.55	266.9	14.86	17.05	13.01	12.61	2.61	2.2	1.68		19.39	7.46	13.52	4.33	1.25

1 SFEI 1994, 1995
2 Total chlordanes = Σ alpha-Chlordane + cis-Nonachlor + gamma-Chlordane + Heptachlor + Heptachlor epoxide + Oxychlordane + trans-Nonachlor
3 Total DDTs = Σ 2,2'-o,p'-DDD + 2,2'-o,p'-DDE + 2,2'-o,p'-DDT + 4,4'-p,p'-DDD + 4,4'-p,p'-DDE + 4,4'-p,p'-DDT
4 Total HCHs = Σ alpha-HCH + beta-HCH + delta-HCH + gamma-HCH
5 ND = not detected; blank = not included in program.

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Table 36. Pesticides in Clam Tissue (µg/kg) from the Delta Measured in the Regional Monitoring Program in 1993 and 1994.[1]

River	Station Name	Collection Date	2,4'-o,p'-DDD	2,4'-o,p'-DDE	2,4'-o,p'-DDT	4,4'-p,p'-DDD	4,4'-p,p'-DDE	4,4'-p,p'-DDT	alpha-BHC	beta-BHC	delta-BHC	gamma-BHC	alpha-HCH	beta-HCH	delta-HCH	gamma-HCH
Sacramento	Collinsville	10/7/93	3.23	ND	2.09	42.76	108.98	10.78	1.5	ND	ND	3.63				
Sacramento	Collinsville	5/6/94	5.38	8.48	11.67	52.89	172.11	10.75					2.28	ND	ND	6.33
Sacramento	Collinsville	9/14/94	6.77	1.32	1.33	80.59	132.25	15.86					0.75	ND	ND	3.13
San Joaquin	Antioch	10/7/93	3.43	ND	2.22	41.58	105.22	8.90	1.34	ND	ND	3.52				
San Joaquin	Antioch	5/6/94	3.88	5.23	4.84	48.73	134.39	15.14					1.9	ND	0.54	7.99
San Joaquin	Antioch	9/14/94	6.22	6.9	10.75	80.85	148.66	13.49					ND	ND	ND	14.86

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ranged from 0.36 to 9.0 ng/kg TEQ in fillet and from 3.0 to 42 ng/kg TEQ in whole fish. Dioxins ranged from 0.25 to 1.5 ng/kg TEQ in fillet and from 1.4 to 5.9 ng/kg TEQ in the whole fish. All concentrations are wet weight.[219] No dioxins were detected in fish collected in 1983 at three other sites in the Central Valley, including the San Joaquin River at Vernalis (<0.8 pg/g), the Merced River at Happy Isles Bridge (<0.7 pg/g), and the Sacramento River at Hood (<2.8 pg/g).[220]

3.1.3.4 USGS Corbicula Studies

In October 1992, Corbicula fluminea were collected from three sites in the San Joaquin Basin and one site in the Delta and analyzed for select pesticides, including organochlorine pesticides, organophosphorus insecticides and triazine herbicides, among others. The data are summarized in Table 37. The concentrations of DDT and its degradation products were lower in samples collected from the Mokelumne River than from San Joaquin Basin sites. Other pesticides were also generally at the lower end of the range in clams collected from the Mokelumne River than from sites in the San Joaquin. Data from the San Joaquin sites are discussed in Section 4.1.3.5.[221]

3.2 SOURCES

The toxicity and pesticides detected in Delta waterways originate from urban and agricultural use of pesticides. The following sections explore potential sources, including agriculture (Sec. 3.2.1), urban runoff (Sec. 3.2.2), and precipitation (Sec. 3.2.3). Municipal effluents may also contribute to the toxicity, but were not reviewed in this work. The principal conclusions from the work reviewed below are as follows:

- Winter runoff from orchards was toxic to Ceriodaphnia in 33 percent of the samples. Most of the toxicity was due to diazinon and methidathion.

- Spring runoff from alfalfa was toxic to Ceriodaphnia in 13 percent of the samples. Most of the explainable toxicity was due to diazinon and carbofuran.

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[219] Hayward et al., 1996.

[220] Douglas W. Kuehl, Brian C. Butterworth, Alexander McBride, Steven Kroner, and Donald Bahnick, Contamination of Fish by 2,3,7,8-Tetrachlorodibenzo-p-Dioxin: A Survey of Fish from Major Watershed in the United States, Chemosphere, v. 18, nos. 9/10, 1989, pp. 1997-2014.

[221] Pereira et al., 1996.

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Table 37. Concentrations of Organic Contaminants in *Corbicula* Samples from the San Joaquin River and its Tributaries (1992) [µg/Kg wet weight][1]

Compound	SITE			
	Orestimba Creek	Dry Creek	Mokelumne River	Stanislaus River
DDE	3300	25	13	22
DDD	390	0.5	0.5	< 0.5
DDT	660	3.1	1.0	1.7
Total DDT	4350	29	15	24
γ-Chlordane	9.2	7.2	6.1	1.7
α-Chlordane	7.5	4.7	5.6	1.7
Trans-nonachlor	13	11	12	7.7
Cis-nonachlor	9.9	9.0	8.9	6.9
Total chlordane	40	32	33	18
DCPA	150	< 0.5	< 0.5	< 0.5
Dicofol	97	< 0.5	< 0.5	< 0.5
Dieldrin	< 0.5	< 0.5	< 0.5	< 0.5
Chlorpyrifos	7.2	< 0.5	< 0.5	< 0.5
Trifluralin	20	1.4	< 0.5	< 0.5

1 Pereira et al. 1996

- Urban runoff was toxic to Ceriodaphnia in 75 percent of the samples. Most of the toxicity was due to organophosphorus pesticides, primarily diazinon and chlorpyrifos.

3.2.1 Agriculture

The Delta islands support a variety of crops, primarily truck and field crops as well as some orchards. Irrigation water is siphoned or pumped from Delta channels over levees into ditches. Subsurface drainage collects in open ditches and is pumped back into the Delta channels. There are about 260 individual agricultural drains that discharge about 400,000 acre feet per year of drainage. Pesticides are applied in summer and spring. Most of the drainage is discharged to Delta channels during two periods - June to July when fields are irrigated and November to January when fields are flooded and drained to leach out salts.[222]

3.2.1.1 DWR Municipal Water Quality Investigations Program

The DWR has monitored pesticides in some of these drains to evaluate potential health effects of the Delta as a source of drinking water. Pesticides were chosen that were most likely to pose problems at water treatment plants (e.g., odor, taste, or public health impacts), rather than those that are toxic to aquatic organisms. The minimum reporting limits in these studies were frequently higher than the levels that are toxic to aquatic organisms, which generally are more sensitive to pesticides than humans.

Under the Municipal Water Quality Investigations Program, previously called the Interagency Delta Health Aspects Monitoring Program, DWR monitored 30 pesticides in three agricultural drains between 1983 and 1987 during the summer pesticide application period, the first major winter runoff, and the spring pre-emergent herbicide application period. The resulting data are summarized in Table 38. Only five pesticides were detected at concentrations marginally above laboratory detection limits, but considerably below health-based drinking water standards.[223]

Molinate, a rice herbicide, was the most frequently detected pesticide. It was detected once in June 1988 in the drain at Grand Island (0.40 µg/L) and Empire Tract (0.11 µg/L) and once in July 1986 in the drain at Empire Tract (0.3 µg/L) and Tyler Island (1.1 µg/L). Atrazine was detected once in August 1987 at 0.18 µg/L in the drain at Empire Tract. Bentazon was detected once in July 1986 in the drains at Empire Tract (0.3 µg/L) and Tyler Island (2.8 µg/L). Thiobencarb (Bolero), another rice herbicide, was detected once in August 1987 at 1.7 µg/L in the drain at Grand Island. Glyphosate (Roundup) was detected once in September 1987 at 10

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[222] Brown and Caldwell, 1990, p. 4-68.

[223] DWR, The Delta as a Source of Drinking Water, Monitoring Results 1983 to 1987, August 1989, p. 23.

Table 38. Pesticides in Agricultural Drains in the Delta, 1983-1987.[1]

PESTICIDE	DRAIN AT GRAND ISLAND			DRAIN AT EMPIRE TRACT			DRAIN AT TYLER ISLAND		
	Number of Samples	Number of Detects	Range (µg/L)	Number of Samples	Number of Detects	Range (µg/L)	Number of Samples	Number of Detects	Range (µg/L)
2,4-D	6	0	< 0.01 - < 0.5	8	3	< 0.01 - 1.0	2	0	< 0.2 - < 0.5
Alachlor	2	0	< 0.1	2	0	< 0.01 - < 0.5	2	0	< 0.1
Atrazine	2	0	< 0.1	2	1	< 0.1 - 0.18	0		
Bentazon	6	0	< 0.01 - < 0.5	8	1	< 0.1 - < 1.0	2	1	< 1.0 - 2.8
Captan	2	0	< 0.5	2	0	< 0.5 - < 2.5	0		
Carbaryl	2	0	< 2.0	2	0	< 2.0	0		
Carbofuran	6	0	< 0.2 - < 0.6	8	0	< 0.1 - < 0.5	2	0	< 0.2 - < 0.5
Chloropicrin	4	0	< 0.1	6	0	< 0.1	2	0	< 0.01 - < 0.1
D-D mixture	2	0	< 0.1	4	0	< 0.1 - < 0.5	1	0	< 0.2
Dacthal	4	0	< 0.01 - < 0.05	6	0	< 0.01 - < 0.3	2	0	< 0.01 - < 0.04
Diazinon	2	0	< 0.1	2	0	< 0.1	0		
Dicofal	2	0	< 0.1 - < 0.2	2	0	< 0.2 - < 0.5	0		
Dinoseb	2	0	< 0.25	2	0	< 0.25	0		
Diquat	2	0	< 40.0	2	0	< 40.0	0		
Dithiocarbamate	2	0	< 3.0 - < 6.0	2	0	< 3.0 - < 6.0	0		
Glyphosate	2	0	< 1.0	2	1	< 2.0 - 10.0	0		
MCPA	4	0	< 1 - < 20	6	0	< 1 - < 20	2	0	< 20 - < 30
Metalaxyl	4	0	< 0.05 - < 10	6	0	< 0.05 - 10	2	0	< 0.05 - < 0.4
Methamidophos	4	0	< 0.5 - < 5	6	0	< 0.5 - < 5	1	0	< 5
Methomyl	2	0	< 2.0	2	0	< 2.0	0		
Methyl Bromide	2	0	< 0.5	4	0	< 0.5 - < 0.7	1	0	< 0.5
Methyl Parathion	8	0	< 0.005 - < 2.5	10	0	< 0.005 - < 2.5	2	0	< 0.005 - < 0.01
Molinate	6	1	< 0.05 - < 0.5	8	2	< 0.05 - < 1	1	0	< 0.05
Paraquat	6	0	< 10 - < 20	8	0	< 10 - < 20	2	0	< 10 - < 20
Parathion	2	0	< 0.1	2	0	< 0.1	0		
Propanil	2	0	< 0.5	2	0	< 0.5	0		
Propham	2	0	< 2.0	2	0	< 2.0	0		
Simazine	2	0	< 0.1	2	0	< 0.1	0		
Thiobencarb	6	1	< 0.05 - < 8	8	0	< 0.05 - < 8	2	0	< 0.01 - < 0.05
Xylene	2	0	< 0.2 - < 0.5	4	0	< 0.2 - < 0.5	1	0	< 0.2

1 DWR 1989, Table G-1.

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μg/L in the drain at Empire Tract.[224] None of these concentrations exceeds levels that are known to be toxic to aquatic organisms. However, criteria to protect aquatic life do not exist for bentazon and glyphosate. The thiobencarb concentration exceeds the CVRWQCB performance goal (1.5 μg/L).

3.2.1.2 DWR Delta Islands Drainage Investigation

In 1988, a one-time comprehensive survey under the Delta Islands Drainage Investigation was conducted to determine the influence of agricultural drainage on Delta water. Twenty-six pesticides were measured in 30 agricultural drains in July 1988. Pesticides selected were those likely to be present at that time with the highest reported use and water solubility. Sampling was conducted in July because it is the peak month of pesticide application and summer drainage discharge. The data are summarized in Table 39.

Only six pesticides were detected, of which three -- atrazine, bentazon, and molinate -- were previously detected in the earlier DWR work cited above. Two triazines -- atrazine and simazine -- were the most frequently detected pesticide. These were also the most frequently detected pesticides in surface waters in the Delta (Sec. 3.1.1.1). These herbicides are used to control annual grasses and broad-leaved weeds for vine, fruit, and vegetable crops.

All concentrations were less than State and federal drinking water standards except one sample exceeded the federal MCL (4 μg/L) for simazine.[225] Atrazine was present at 0.13 to 0.91 μg/L in six drains. Simazine was detected at 0.1 to 8.4 μg/L in five drains. Bentazon (2.5 μg/L), carbaryl (8.5 μg/L), methamidophos (4.6 μg/L), and molinate (0.76 μg/L) were detected in one drain each.[226] None of these concentrations exceed levels that are known to be toxic to aquatic organisms, except the carbaryl concentration.[227] Carbaryl is toxic to several crustaceans at concentrations in the vicinity of 8.5 μg/L, including Palaemonetes kadiakensis (96-hr NOEL 5.6 μg/L), Orconectes nais (96-hr NOEL 8.6 μg/L), Simocephalus serrulatus (48-hr NOEL 7.6 μg/L), Daphnia pulex (48-hr NOEL 6.4 μg/L), Daphnia magna (63-day NOEL 5.0 μg/L), egg/prezoeal of Cancer magister (24-hr prevention of hatching/molting 6 μg/L), and Palaemon

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[224] DWR, August 1989, Table G-1.

[225] DWR, Municipal Water Quality Investigation Program New Parameter Workplan, May 1995, p. 4.

[226] DWR, Delta Island Drainage Investigation Report of the Interagency Delta Health Aspects Monitoring Program. A Summary of Observations During Consecutive Dry Year Conditions, Water Years 1987 and 1988, July 1990, pp. 34-35.

[227] Marshack, May 1993; Royal Society of Chemistry, The Agrochemicals Handbook, Third Edition, Update 5, January 1994; and Karel Verschueren, Handbook of Environmental Data on Organic Chemicals, Second Edition, Van Nostrand Reinhold Co., New York, 1983.

Table 39. Pesticides in Agricultural Drains in the Delta, July 1988.[1]

STATION NAME	EC (uS/cm)	CONCENTRATION (µg/L) 2,4-D	Alachlor	Atrazine	Bentazon	Captan	Carbaryl	Carbofuran	Dacthal	Diazinon	Dicofol	Dinoseb	Ethyl Parathion	MCPA	Methamidophos	Methyl Parathion	Molinate	Nudrin	Orthene	Paraquat	Propanil	Proparagite	Propham	Simazine	Thiobencarb	Triforine	Ziram
BOULDIN1	178	-[2]	-	0.60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BOULDIN2	202	-	-	0.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BRANNANPP03	1010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BRANNANPP04	579	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
COLUSA	554	-	-	-	2.5	-	-	-	-	-	-	-	-	-	-	-	0.76	-	-	-	-	-	-	-	-	-	-
EGBERTPP01	297	-	-	-	-	-	8.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KINGISPP01	439	-	-	0.13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KINGISPP02	652	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MCCORWIL01	166	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MOSSDALE01	1000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MOSSDALE04	1120	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-	-	-
MOSSDALE10	992	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-	-	-
MOSSDALE11	1080	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-
NETHERLAND01	222	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NETHERLAND02	206	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PESCADERO01	1280	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PESCADERO02	1560	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PESCADERO03	1850	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PESCADERO04	1890	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PIERSONPP01	268	-	-	0.34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PROSPECTPP01	183	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RINDGEPP02	870	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RIOBLANCO01	739	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SHIMATR	577	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	-	-	-
TERMPP01	425	-	-	0.41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TERMPP02	542	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UPEGBERTPP01	344	-	-	0.91	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UPEGBERTPP02	277	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UPEGBERTPP03	331	-	-	-	-	-	-	-	-	-	-	-	-	-	4.6	-	-	-	-	-	-	-	-	8.4	-	-	-
UPJONESPP02	860	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1 DWR 1990, Table 3.
2 Below reporting limit.

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macrodactylus (96-hr TL50 7.0 µg/L).[228] The carbaryl concentration also exceeds the criterion (0.02 µg/L) established by the NAS to protect freshwater aquatic life.[229]

3.2.1.3 CVRWQCB Bioassay Study

The application of dormant sprays to orchards and of weevil control insecticides to alfalfa contribute pesticide residues to receiving waters in winter and early spring.

Orchard Study. A bioassay study was conducted by the CVRWQCB in the winter of 1992 to assess the toxicity of orchard runoff in the Sacramento Basin and the Delta. A series of major storms occurred during the study between February 4 and 20. Six stations were located on water courses draining small watersheds with more than 10 percent of their acreage in orchard and five were located on major rivers. Ceriodaphnia toxicity was assayed in all samples and organophosphorus and carbamate pesticides were measured in toxic samples.[230] The toxicity data were summarized in Table 24. A more intensive study was conducted in 1994-95 by the CVRWQCB and SWRCB, but the results have not been published yet.

Among the samples collected in the Delta, 16 out of 48 or 33 percent were toxic to Ceriodaphnia. Among those that were toxic, five were from major rivers and the balance from small creeks. Nearly half of the toxic samples were collected during major storms between February 4 and 20. Six pesticides were detected in the toxic samples -- diazinon (0.02 - 2.79 µg/L), diuron (0.10 - 30.6 µg/L), methidathion (0.13 - 2.45 µg/L), bromocil (1.32 - 7.5 µg/L), propham (9.2 - 17.7 µg/L), and chlorpyrifos (0.01 µg/L). Concentrations were high enough to explain partial or complete toxicity in all but two of the samples. Based on comparisons with Ceriodaphnia LC50s, most of the toxicity was attributed to diazinon and methidathion.[231]

Alfalfa Study. A bioassay study was conducted by the CVRWQCB in the spring of 1992 to assess the toxicity of runoff from the main alfalfa growing areas. Only three small to intermediate-sized rainstorms occurred during the study, which was a dry spring. Thirteen stations were located around the periphery of the Delta, including four main drains on Delta islands, three small waterways, and six large waterways. Ceriodaphnia toxicity was assayed in all

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[228] Verschueren, 1983, p. 336.

[229] NAS, 1973, p. 186.

[230] Christopher Foe and Robert Sheipline, Pesticides in Surface Water from Applications on Orchards and Alfalfa During the Winter and Spring of 1991-92, CVRWQCB Staff Report, February 1993.

[231] Foe and Sheipline, 1993, Table 3.

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samples and organophosphorus and carbamate pesticides were determined in most toxic samples.[232] The toxicity data are summarized in Table 40.

Out of 103 samples, 13 or 13 percent were toxic to Ceriodaphnia. Among those that were toxic, seven were from small waterways, four from major waterways, and two from agricultural drains. No relationship between toxicity and precipitation was evident. Four pesticides were detected in toxic samples - diazinon (0.01 - 0.24 µg/L), diuron (3.6 µg/L), carbofuran (1.0 - 1.9 µg/L), and chlorpyrifos (0.01 µg/L). Detected pesticide concentrations could only explain partial or complete toxicity in three out of the 13 toxic samples. Carbofuran and diazinon were responsible for most of the explainable toxicity.

3.2.1.4 CVRWQCB/UCD Bioassay Study

Five Delta island drains were monitored monthly between May 1993 and May 1994 using short-term chronic tests with fathead minnows, Ceriodaphnia, and Selenastrum. Significant toxicity to fathead minnows was observed 7 percent of the time. Ceriodaphnia reproduction was significantly reduced 8 percent of the time. No toxicity to Selenastrum was observed.[233]

3.2.2 Urban Runoff

The CVRWQCB performed toxicity tests on urban runoff collected in February 1994 from six sumps and runoff-dominated streams in the Stockton area. The results are summarized in Table 26. In 75 percent of the samples, 100 percent Ceriodaphnia mortality was observed. The addition of PBO reduced the toxicity at most sites, suggesting that organophosphorus pesticides are the likely toxicants. This is supported by the diazinon concentrations (0.19 - >1.0 µg/L),[234] which exceeded the Ceriodaphnia 96-hr LC50 (0.47 - 0.51 µg/L) in many samples. However, the addition of PBO failed to reduce or eliminate the toxicity in several samples including those from Mosher Slough (2/6/94), Five Mile Creek, Mormon Slough (2/7/94), and Turning Basin (2/7/94), suggesting that other toxicants also are present or not enough PBO was added.[235] Similar results were obtained during the 1994-1995 rainfall season.[236]

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[232] Foe and Sheipline, 1993, Table 8.

[233] Deanovic et al., 1995.

[234] The Ceriodaphnia 48-hour LC50 for diazinon ranges from 0.27 to 0.48 µg/L.

[235] Valerie Connor, Toxicity and Diazinon Levels Associated with Urban Storm Runoff, CVRWQCB memorandum to Jerry Bruns, February 15, 1994.

[236] Bailey et al., 1995, p. 47.

Table 40. Alfalfa Study, *Ceriodaphnia* Mortality in Water Samples Collected from the Delta, 1992.[1]

STATION	Percent Mortality[3]							
	3/9/92	3/16/92	3/23/92	3/30/92	4/6/92	4/13/92	4/20/92	4/27/92
Drains								
Fabian Tract Drain[2]	0	0	0	0	10	0	0	0
Bishop Tract Main Drain[2]	0	100	100	0	0	0	0	0
Elkhorn Slough on Ryer Island[2]	0	0	0	0	10	0	20	20
Sutter Island Main Drain[2]	0	10	0	0	0	0	0	0
Small Watersheds								
Paradise Cut at Paradise Road[3]	60	100	0	10	0	100	30	0
Ulatis Creek at Salem Road[3]	0	100	100*	0	70*	10	10	10
Tom Paine Slough[3]	-	10	0	0	0	0	0	0
Large Waterways								
Old River at Tracy Road[3]	0	100	0	0	0	0	10	0
Delta Mendota Canal at Byron Road[3]	0	0	0	0	0	20	30	30
Bishop Cut at Eight Mile Road[3]	0	0	0	0	0	100*	20	0
Cache Slough at Liberty Island Road[3]	0	0	0	0	0	20	10	20
Cache Slough at Ryer Island Road[3]	0	10	0	0	10	10	30	0
Steamboat Slough off Grand Island[3]	0	0	0	0	0	0	10	0
Laboratory Control	0	0	0	10	0	10	0	10

1 Foe and Sheipline 1993, Table 8.
2 Four-day bioassay test.
3 Seven-day bioassay test.
* Pesticide concentrations high enough to explain partial or complete toxicity.
[shaded] Significant mortality is defined as any sample exhibiting 30% higher mortality than the laboratory control.

3.2.3 Precipitation

In 1995, the CVRWQCB measured the organophosphorus insecticide, diazinon, in precipitation at eight sites on four separate dates (Table 29) and at 14 sites between Red Bluff and Patterson on a single date (Table 30). Samples were collected in open glass pans exposed to dry and wet deposition events. The samples from the Delta were comparable to those from other areas. Diazinon was detected in all samples at concentrations ranging from 0.047 to 5.5 µg/L. The highest concentrations were found in samples collected near orchards. Most concentrations exceeded Ceriodaphnia 96-hr LC50s. Carbofuran and chlorpyrifos also were detected.[237] These pesticides are used by homeowners for backyard and home insect control, are sprayed on stone fruit orchards such as almonds, prunes and apricots, or used on alfalfa for weevil control.

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[237] Connor, May 10, 1995.

SECTION FOUR
SAN JOAQUIN BASIN

4.0 SAN JOAQUIN BASIN

The San Joaquin Basin, drained by the San Joaquin River, has an area of about 16,000 square miles. There are four principal sources of water in the basin - the major rivers, the San Joaquin River and its eastside tributaries; eastside constructed agricultural drains; westside agriculturally dominated creeks; and westside constructed agricultural drains.

Toxicity and pesticide concentrations have been periodically monitored in waters, sediments, and biota since the 1960s by the CVRWQCB, DPR, DFG, USGS, USFWS and SWRCB. The results of this work are summarized for major rivers in Section 4.1 and for potential sources in Section 4.2.

4.1 MAJOR RIVERS

The major rivers in the basin are the San Joaquin, Merced, Bear, Tuolumne, and Stanislaus Rivers (Figure 19). Toxicity and pesticide concentrations have been monitored in waters (Sec. 4.1.1), sediments (Sec. 4.1.2), and biota (Sec. 4.1.3). The principal conclusions from this work are as follows:

- Significant mortality to fathead minnows occurs in up to 5 percent of the samples from the major rivers.
- Significant mortality to Ceriodaphnia occurs in 3 to 22 percent of the samples and to Neomysis in about 7 percent of the samples. Most of the toxicity occurs between January and June in the mainstem of the San Joaquin River between the Merced and Stanislaus Rivers. Toxicity is believed to be primarily due to runoff and irrigation return flows from row and orchard crops.
- The most frequently detected pesticides are simazine and diazinon, which are present at Vernalis 70 and 80 percent of the time, respectively. Diazinon concentrations frequently exceed criteria set to protect freshwater aquatic life.
- Although little sediment toxicity data are available, three agriculturally dominated sites were toxic to amphipods and two to Ceriodaphnia.
- Distinct pulses of pesticides lasting several days are present in the rivers following storms. Pulse concentrations are high enough to cause 100 percent mortality to Ceriodaphnia for up to 12 consecutive days.
- The concentrations of organophosphorus and carbamate pesticides, including diazinon, ethyl parathion, carbaryl and chlorpyrifos, have

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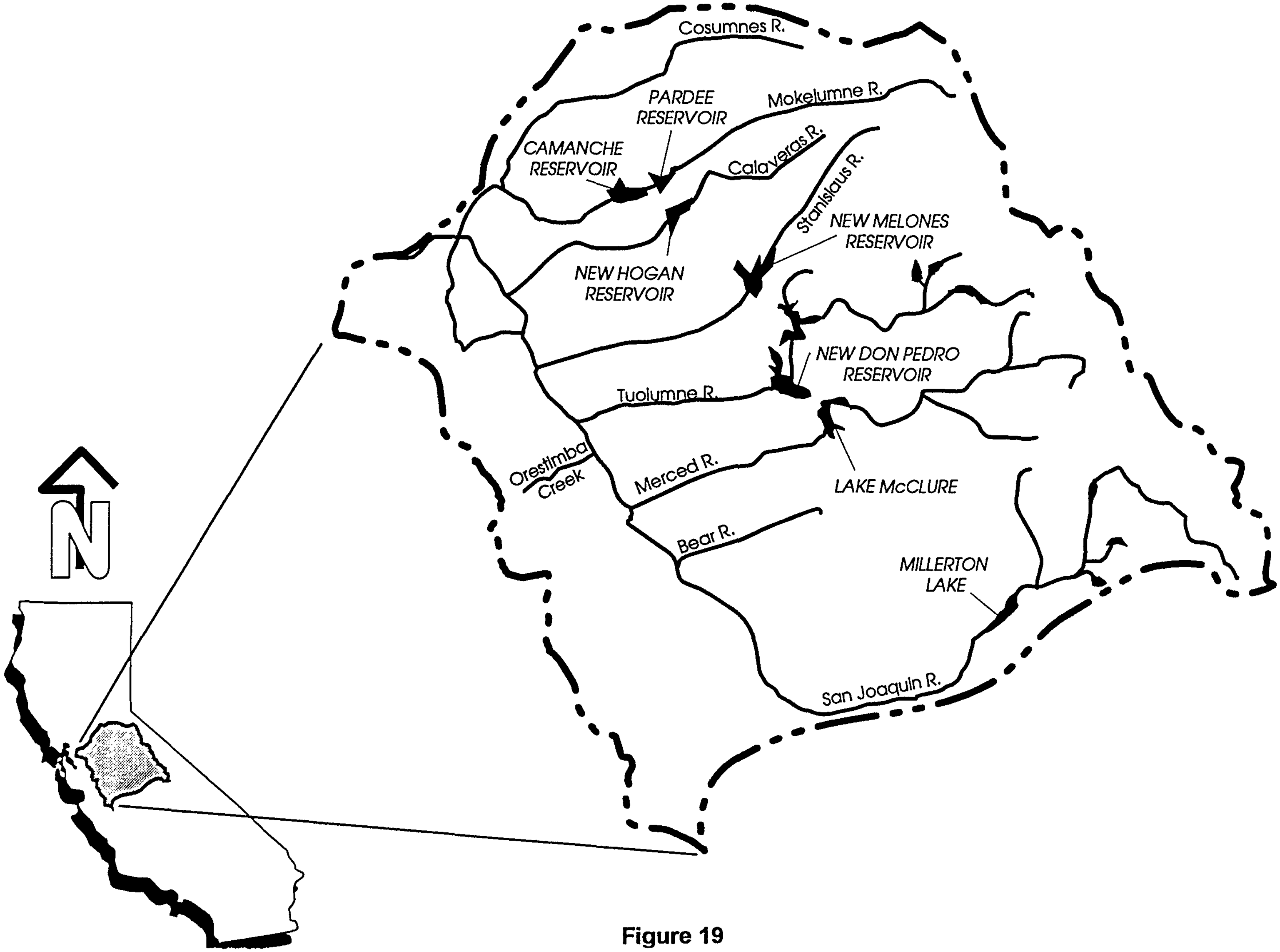

Figure 19

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frequently exceeded criteria to protect freshwater aquatic life. Concentrations also frequently exceeded those known to be toxic to organisms at the base of the foodchain, primarily invertebrates.

- Organochlorine pesticides and pesticide ingredients, including DDT, DDD, DDE, dieldrin and PCBs, are present at elevated concentrations in bottom sediments throughout the basin. The San Joaquin River has among the highest concentrations among major rivers of the United States.

- Organochlorine pesticides in fish from throughout the basin, including DDT, toxaphene and chlordane, frequently exceed levels established by the National Academy of Sciences and the U.S. Food and Drug Administration to protect public health. These compounds may also cause high mortality in fry and impair reproduction.

4.1.1 Waters

4.1.1.1 CVRWQCB 1988-90 Bioassay Study

Between February 1988 and June 1990, the CVRWQCB conducted a two and one-half year bioassay study to assess the toxicity of surface waters in the San Joaquin River system.[238] Samples were collected from 17 sites representative of sources of San Joaquin River water between the Mendota Pool and Mossdale, and upstream and downstream of these sources. Fathead minnow, Ceriodaphnia, and Selenastrum toxicity were monitored at all sites using the U.S. EPA three-species bioassay, and select samples were also analyzed for pesticides. The fathead minnow mortality data are summarized in Table 41, the Ceriodaphnia mortality data in Table 42, the Selenastrum growth data in Table 43, and the pesticide data in Table 44.

Significant mortality to fathead minnows was found in 24 out of 268 samples, or about 9 percent of the total. Among these toxic samples, 14 were from agriculturally dominated sites, which were toxic 18 percent of the time, and ten were from major rivers, which were toxic 5 percent of the time. Significant fathead minnow mortality was observed only once on each of the San Joaquin, Merced, Tuolumne, and Stanislaus Rivers. An additional five samples exhibited reduced growth.

Toxicity to Ceriodaphnia, on the other hand, was more common. Significant mortality to Ceriodaphnia was found in 55 out of 204 samples, or about 27 percent of the total. Among these toxic samples, 23 were from agriculturally dominated sites, which were toxic 38 percent of the time, and 32 from major rivers, which were toxic 22 percent of the time. A 43-mile reach of the San Joaquin River between Hills Ferry and Airport Way (roughly, between the Merced and

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[238] Christopher Foe and Valerie Connor, San Joaquin Watershed Bioassay Results, 1988-90, CVRWQCB Staff Report, July 1991b.

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Table 41. Fathead Minnow Mortality (%) in Water Samples Collected from the San Joaquin Basin, 1988-1990.[1]

Location	1988						1989							1990		
	2/24	3/30	6/29	8/1	9/28	11/29	1/25	3/6	5/8	6/16	8/3	10/13	12/13	2/8	3/27	6/18
Mendota Pool	0	10	0	0	10	10	10	13	17	0	17	0	7	**40**	3	7
Bear Creek	0	23	0	3	0	17	13	7	0	7	**37**	0	7	37	3	0
*Salt Slough	7	7	0	3	0	13	0	7	10	0	7	0	10	23	3	0
SJR[2] at Fremont Ford	0	3	0	7	0	7	7	0	3	3	16	0	7	23	0	0
*Los Banos Creek	3	17	0	3	0	27	10	**33**	10	0	20	0	3	27	7	**97**
SJR at Hill's Ferry	0	3	0	10	0	7	7	0	27	3	7	27	7	27	7	3
Merced River	10	7	0	7	3	**77**	3	**40**	10	0	17	0	3	**47**	7	-
*Orestimba Creek	13	0	0	3	3	17	3	7	3	0	16	0	10	33	0	7
SJR at Crow's Landing	3	10	0	3	7	3	10	0	10	0	23	3	3	**40**	3	0
*TID 5[3]	**100**	20	0	3	13	**100**	**100**	**100**	**100**	3	13	**100**	**100**	**100**	**80**	13
SJR at Laird Park	3	3	3	13	7	13	7	10	0	3	20	0	3	47	30	7
Tuolumne River	**67**	3	0	0	7	**37**	10	17	0	0	20	0	13	10	0	-
SJR at Maze Blvd.	10	3	3	3	7	0	0	7	10	0	30	10	10	33	0	7
Stanislaus River	**37**	3	0	7	17	**40**	10	23	3	3	23	0	13	27	7	-
SJR at Airport Way	**30**	7	0	0	0	0	7	16	7	7	17	0	3	30	0	-
*New Jerusalem Drive	0	7	3	3	**100**	17	7	**100**	17	0	**53**	3	13	27	0	3
SJR at Mossdale	0	3	0	3	3	6	20	6	3	7	23	3	10	27	3	7
Laboratory Control	0	0	0	3	0	3	0	0	17	0	3	16	10	10	3	0

1 Foe and Connor, 1991, Table 2.
2 SJR=San Joaquin River.
3 TID 5=Turlock Irrigation District Lateral No. 5.
* Predominantly agricultural drainage.
[Shaded] Significant mortality is defined as any sample with both statistically greater ($P<0.05$) and 30 percent higher mortality than the laboratory control.

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Table 42. *Ceriodaphnia* Mortality (%) in Water Samples Collected from the San Joaquin Basin, 1988-1990.[1]

Location	1988					1989				1990		
	2/24	3/30	8/1	8/30	9/28	3/6	5/8	10/13	12/13	2/8	5/21	6/18
Mendota Pool	0	0	0	0	30	30	10	30	0	0	30	0
Bear Creek	10	10	20	10	30	30	10	0	0	100	10	10
*Salt Slough	10	0	20	10	70	10	10	10	0	10	10	0
SJR[2] at Fremont Ford	20	90	10	20	60	0	10	10	0	0	10	0
*Los Banos Creek	70	10	10	20	60	0	0	20	0	0	50	0
SJR at Hill's Ferry	20	50	10	10	90	10	100	30	0	10	0	0
Merced River	0	0	0	33	10	20	0	50	0	100	10	0
*Orestimba Creek	100	100	40	43	0	0	30	30	0	100	40	60
SJR at Crow's Landing	100	60	60	0	40	100	10	50	10	100	20	0
*TID 5[3]	100	100	0	100	30	100	60	80	100	100	100	20
SJR at Laird Park	100	100	10	10	90	0	100	50	10	100	10	0
Tuolumne River	10	0	10	6	70	10	0	30	10	0	0	0
SJR at Maze Blvd.	100	40	0	100	80	10	40	20	10	100	0	0
Stanislaus River	0	0	10	10	10	20	0	30	10	0	10	10
SJR at Airport Way	70	0	0	89	10	0	10	10	0	100	10	0
*New Jerusalem Drive	70	10	30	20	100	100	0	20	30	20	0	50
SJR at Mossdale	10	0	0	10	0	10	20	0	10	0	20	10
Laboratory Control	10	10	20	0	20	20	0	10	10	20	10	0

1 Foe and Connor, 1991, Table 8.
2 SJR=San Joaquin River.
3 TID 5=Turlock Irrigation District Lateral No. 5.
* Predominantly agricultural drainage.
Significant mortality is defined as any sample exhibiting 30% higher mortality than the laboratory control.

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Table 43. *Selenastrum* Chlorophyll *a* Concentrations (µg/L) in Water Samples Collected from the San Joaquin Basin, 1988-1990.[1]

Location	1988						1989						1990			
	2/24	3/30	6/29	8/30	9/28	11/29	1/25	3/6	5/8	6/16	8/3	10/13	3/27	4/24	5/21	6/18
Mendota Pool	34	169	18	38	60	78	206	180	21	136	106	69	115	118	512	285
Bear Creek	42	165	49	20	62	181	178	182	54	180	149	69	299	187	828	316
*Salt Slough	54	175	22	133	55	213	229	156	103	152	272	89	274	169	901	413
SJR[2] at Fremont Ford	31	217	15	23	47	185	243	163	54	283	201	84	235	166	693	537
*Los Banos Creek	41	353	69	35	65	293	161	163	192	322	218	176	748	161	698	690
SJR at Hill's Ferry	41	257	42	92	16	205	170	106	69	167	202	218	129	219	669	582
Merced River	35	175	23	108	70	79	181	105	122	160	244	44	145	163	521	239
*Orestimba Creek	46	204	23	118	46	32	169	156	44	375	168	87	154	145	741	326
SJR at Crow's Landing	38	243	24	89	39	152	227	164	76	185	234	115	291	137	709	575
*TID 5[3]	31	317	32	139	68	407	256	201	195	28	148	142	287	282	325	645
SJR at Laird Park	40	257	33	113	31	153	203	196	85	122	184	107	586	156	950	563
Tuolumne River	33	218	24	88	71	44	181	132	127	158	96	44	275	147	1137	561
SJR at Maze Blvd.	32	329	19	127	55	46	165	193	132	156	209	346	349	111	1006	643
Stanislaus River	30	161	28	35	65	61	144	96	82	139	123	65	79	158	461	229
SJR at Airport Way	37	246	30	83	39	114	139	215	137	229	248	144	22	141	602	443
*New Jerusalem Drive	19	215	22	27	73	186	206	1	174	198	94	88	34	155	1035	511
SJR at Mossdale	33	203	41	90	49	121	161	157	71	142	201	113	191	-	293	248
Laboratory Control	25	237	20	5	54	15	24	12	6	31	27	6	44	52	149	94

1 Foe and Connor, 1991, Table 15.
2 SJR=San Joaquin River.
3 TID 5=Turlock Irrigation District Lateral No. 5.
* Predominantly agricultural drainage.
(shaded) Enhanced growth is defined as any sample with both statistically greater ($P<0.05$) and at least 30 percent more chlorophyll *a* production than the corresponding Mendota Pool sample.

Table 44. Pesticides in Surface Waters in the San Joaquin Basin.

Date	Site	Pesticide	Concentration[4] (µg/L)
6/16/89[1]	SJR at Laird Park	Eptam	0.5
		Diazinon	0.4*
		Carbaryl	0.6*
	SJR at Maze Road	Eptam	1.0
		Diazinon	0.6*
		Carbaryl	0.4*
	SJR at Airport Way	Eptam	3.1
		Diazinon	0.5*
		Carbaryl	0.6*
2/8/90[2]	SJR at Crows Landing	Diazinon	0.15*
		Parathion	0.12*
		Diuron	0.22
	SJR at Laird Park	Diazinon	0.17*
		Parathion	0.25*
		Diuron	0.65
	SJR at Maze Road	Diazinon	0.16*
		Parathion	0.24*
	SJR at Airport Way	Diazinon	0.13*
		Parathion	0.20*
		Diuron	0.43
2/21/90[2]	Merced River	Diazinon	0.24*
		Parathion	0.19*
		Diuron	0.40
	SJR at Crow's Landing	Diuron	1.14
	SJR at Laird Park	Diuron	1.34
3/27/90[3]	SJR at Laird Park	Carbofuran	0.24
	SJR at Maze Road	Diazinon	0.07*
		Carbofuran	0.25

1 Foe, October 20, 1989, Table 2.
2 Foe, June 25, 1990a, Table 3.
3 Foe, June 25, 1990b, Table 1.
4 The concentrations recommended to protect aquatic life are a minimum of 0.02 µg/L for carbaryl, a maximum of 0.009 µg/L for diazinon, a 1-hr maximum for parathion of 0.065 µg/L (Marshack, 1993), and a maximum of 1.6 µg/L for diuron (NAS 1973). Exceedances are indicated by an asterisk (*).

Stanislaus Rivers) tested toxic to Ceriodaphnia 33 percent of the time. Toxicity appeared to be caused by organophosphorus and carbamate pesticides in runoff and drainage from row and orchard crops.[239] Agricultural drainage in this river section comprises 40 to 45 percent of the river's flow above the confluence of the Stanislaus River and is carried into the river by 76 drains.

Algal production was lower 45 percent of the time in the Mendota Pool than elsewhere during both irrigation and non-irrigation seasons. No cause was apparent.

Select organophosphorus pesticides were measured in toxic samples.[240] The concentrations of diazinon (0.13 - 0.17 µg/L), parathion (0.12 - 0.25 µg/L), and carbaryl (0.4 - 0.6 µg/L) exceeded U.S. EPA[241] or NAS[242] criteria recommended to protect freshwater aquatic life by factors of 4 to 67 (Table 44). Parathion is no longer registered for use in California.

4.1.1.2 DPR/DFG 1991-93 Bioassay Study

A 2-year followup study was conducted by the DPR in collaboration with the DFG. The study focused on three seasons of high insecticide use, winter dormant spray, spring, and summer. Between April 1991 and February 1993, the DFG monitored Ceriodaphnia and Neomysis mortality,[243] and the DPR concentrations of select organophosphorus, carbamate, and endosulfan

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239 Foe and Connor, July 1991b, pp. 17-20.

240 Christopher Foe, Detection of Pesticides in the San Joaquin River on 27 March and 24 April, 1990, CVRWQCB memorandum to Dennis W. Westcot and Jerry A. Bruns, June 25, 1990; Christopher Foe, Detection of Pesticides in the San Joaquin Watershed During February 1990, CVRWQCB memorandum to Dennis W. Westcot and Jerry A. Bruns, June 25, 1990; and Christopher Foe, Detection of Pesticides in the San Joaquin River on 16 June 1989, CVRWQCB memorandum to Dennis W. Westcot, October 20, 1989.

241 Marshack, May 1993.

242 NAS, 1973, p. 186.

243 Robert Fujimura, Memoranda to San Joaquin River Group Members, Department of Pesticide Regulation: Lab No. P-1426, November 6, 1991; Lab No. P-1425, November 6, 1991; Lab No. P-1532, February 23, 1993; Lab No. P-1534, March 22, 1993; Lab No. P-1539, March 23, 1993; and Lab No. P-1540, March 26, 1993.

pesticides[244] at up to 23 sites above, in, and below all representative major sources of San Joaquin River water from Stevenson to Vernalis. The mortality data are summarized in Table 45.

Significant mortality to Ceriodaphnia was found in 22 out of 93 samples, or about 24 percent of the total, comparable to that found in the 1988-90 CVRWQCB study (27 percent). Among these toxic samples, 13 were from agriculturally dominated creeks and constructed drains, which were toxic 33 percent of the time, and nine were from major rivers and canals, which were toxic 17 percent of the time. The main stem of the San Joaquin River between the Merced and Stanislaus rivers was toxic 11 percent of the time, compared with 33 percent in the CVRWQCB 1988-90 bioassay study. Differences may have been due to differences in hydrological conditions, irrigation patterns, or test conditions. The CVRWQCB test organisms were exposed for 6 to 8 days (until at least 60 percent of the survivors had three broods) while the DFG organisms were exposed for only 4 days.

Significant mortality to Neomysis was found in 13 out of 93 samples, or about 14 percent of the total. Among these toxic samples, eight were from agriculturally dominated creeks and constructed drains, which were toxic 21 percent of the time and four were from major rivers and canals, which were toxic 7 percent of the time.

The most frequently detected pesticides were diazinon (0.05 - 31.2 µg/L), methomyl (0.05 - 1.84 µg/L), and dimethoate (0.05 - 2.44 µg/L). Other pesticides that were detected include chlorpyrifos (0.05 - 0.34 µg/L), methidathion (0.07 - 10.7 µg/L), carbaryl (0.05 - 3.95 µg/L), oxamyl (0.05 - 0.27 µg/L), and methiocarb (0.06 - 0.11 µg/L). The winter dormant spray data are discussed in Section 4.1.1.7.

Diazinon concentrations exceeded those recommended by the DFG (1-hour average of 0.08 µg/L)[245] and the NAS (maximum of 0.009 µg/L)[246] to protect aquatic life. Diazinon concentrations also periodically exceeded levels that are acutely toxic to cladocerans (0.47 - 2.2 µg/L) and mysids (3.6 - 4.8 µg/L), but were well below levels that are toxic to fish (168 - 6,800

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244 Lisa Ross, Preliminary Results of the San Joaquin River Study, March and April 1991, Memorandum to John Sanders, November 4, 1991; Lisa Ross, Preliminary Results of the San Joaquin River Study, Summer 1991, Memorandum to Kean S. Goh, May 21, 1992; Lisa Ross, Preliminary Results of the San Joaquin River Study, Winter 1991-92, Memorandum to Kean Goh, May 22, 1992; Lisa Ross, Preliminary Results of the San Joaquin River Study, Spring 1992, Memorandum to Randy Segawa, January 29, 1993; Lisa Ross, Preliminary Results of the San Joaquin River Study, Summer 1992, Memorandum to Kean S. Goh, September 22, 1993; Lisa Ross, Preliminary Results of the San Joaquin River Study, Winter 1992-93, Memorandum to Kean Goh, September 23, 1993.

245 Menconi and Cox, 1994, p. ii.

246 Marshack, May 1993, and NAS, 1973.

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Table 45. *Ceriodaphnia* and *Neomysis* 96-hr Mortality (%) in Water Samples Collected from the San Joaquin Basin, 1991-1992.[1]

Location	4/2 - 4/4/91		7/23 - 8/3/91		2/17 - 2/19/92		4/14 - 4/17/92		7/27 - 7/31/92		1/14 - 1/17/93	
	CD[2]	NM[2]	CD	NM	CD	NM	CD	NM	CD	NM	CD	NM
SJR[2] at Stevenson	0	50	-	-	20	14	0	0	10	0	0	0
+Salt Slough	10	10	-	-	0	0	0	0	0	5	0	0
+Mud Slough	38	15	-	-	0	5	10	0	10	5	0	0
+Los Banos Creek	90	11	-	-	0	0	100	45	-	-	0	0
+Newman Wasteway	0	5	-	-	100*	100	10	15	0	5	100*	30*
Merced River	0	5	-	-	100	5	0	0	0	15	0	10
SJR at Hill's Ferry	0	19	0-10	0-5	0	5	0	5	40	0	11	5
+Orestimba Creek	-	-	-	-	100*	5	100*	14	0	5	0	10
+TID 5[2]	100**	100**	-	-	100**	100**	0	90**	0	33	80**	95**
SJR near Patterson	0	15	0-30	0-30	0	0	0	0	0	5	0	0
+Del Puerto Creek	0	0	-	-	45	0	0	5	10	5	0	48
SJR at Laird Park	0	5	0-40	5-16	10	5	70	5	10	5	0	0
Tuolumne River	80	68	-	-	10	0	0	5	0	5	0	5
+Ingram/Hospital Creek	15	11	-	-	100	5	0	15	0	15	20	15
SJR at Maze Blvd.	10	28	-	-	0	0	30	0	10	0	0	5
Stanislaus River	0	0	-	-	0	5	10	0	10	10	0	10
SJR near Vernalis	0	16	-	-	100	0	10	5	0	0	0	0
SJR at Fremont Ford	-	-	-	-	0	5	10	0	0	0	0	0
+Spanish Grant Drain	-	-	-	-	-	-	-	-	-	-	100	0
Merced River at Oakdale	-	-	-	-	-	-	-	-	-	-	10	5
Livingston Canal	-	-	-	-	-	-	-	-	-	-	100*	50
Laboratory Control												

1 Fujimura, 1991-1993.
2 CD=*Ceriodaphnia dubia*; NM=*Neomysis mercedis*; SJR=San Joaquin River, TID 5= Turlock Irrigation District Lateral No. 5.
\+ Predominantly agricultural drainage.
* Pesticide concentrations high enough to explain toxicity.
** Low dissolved oxygen and high ammonia concentrations may explain toxicity.
(shaded) Significant mortality is defined as any sample exhibiting 30% higher mortality than the laboratory control.

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μg/L).[247] The chlorpyrifos concentrations exceeded those recommended by the U.S. EPA (maximum 1-hr of 0.083 μg/L)[248] and the DFG (acute 0.07 μg/L) to protect freshwater aquatic life.[249] Concentrations of chlorpyrifos also periodically exceeded levels that are acutely toxic to cladocerans (0.06 - 1.1 μg/L), mysids (0.029 - 0.30 μg/L), amphipods (0.071 - 0.17 μg/L) and brown shrimp (0.20 μg/L), but not other organisms.[250] Carbaryl concentrations exceeded the U.S. EPA criterion established to protect freshwater aquatic life (maximum of 0.02 μg/L),[251] while oxamyl and methomyl concentrations were less than invertebrate LC50s.[252] The maximum methidathion concentration (10.7 μg/L) exceeded levels that are acutely toxic to American lobster (10 μg/L) and bluegill (9 μg/L), and the maximum dimethoate concentration (2.44 μg/L) exceeded levels that are acutely toxic to green crab (0.3 - 1 μg/L), common shrimp (0.3 - 1 μg/L), and Cyclops strenuus (2 μg/L). The maximum concentration of methiocarb (0.11 μg/L) was less than concentrations that are acutely toxic to invertebrates, fish, and algae.[253]

4.1.1.3 CVRWQCB 1991-92 Bioassay Study

A followup study was also conducted by the CVRWQCB. Between February 1991 and June 1992, Ceriodaphnia toxicity and pesticide concentrations were monitored at 13 sites between Salt Slough and the San Joaquin River at Airport Way. The toxicity data are summarized in Table 46 and the pesticide data in Table 47.[254]

Significant mortality to Ceriodaphnia was found in 131 out of 559 samples, or about 23 percent of the total. This is consistent with the earlier CVRWQCB and DPR bioassay studies, which found 27 and 24 percent of the samples, respectively, were toxic to Ceriodaphnia. Pesticide concentrations were sufficiently elevated in 64 percent of these to at least partially

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247 Menconi and Cox, 1994, Table B-1.

248 Marshack, May 1993.

249 Mary Menconi and Angela Paul, Hazard Assessment of the Insecticide Chlorpyrifos to Aquatic Organisms in the Sacramento-San Joaquin River System, DFG Administrative Report 94-1, 1994, p. ii.

250 Menconi and Paul, 1994, Table A-1.

251 Marshack, May 1993.

252 Sheipline, September 1993, Tables 8 and 13.

253 U.S. EPA, AQUIRE database, March 28, 1996.

254 Christopher Foe, Insecticide Concentration and Invertebrate Bioassay Mortality in Agricultural Return Water from the San Joaquin Basin, CVRWQCB Staff Report, December 1995.

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Table 46. *Ceriodaphnia* Mortality (%) in Water Samples Collected from the San Joaquin Basin, 1991-1992.[1]

Location	1991																		
	2/25	3/4	3/19	4/4	4/18	5/3	5/15	5/28	6/12	6/26	7/2	7/15	7/30	8/16	9/6	9/18	9/26	10/9	10/24
*Salt Slough[2]											20	10	0	10	0	0	20		
SJR[3] at Hill's Ferry[2]		0	10	10	30	0	0	10	100	0	0	10	0	0	0	0	0	0	10
SJR at Laird Park[2]	0	0	20	0	0	0	0	20	100	0	10	10	0	0	0	10	10	0	0
SJR at Airport Way[2]	0	20	10	10	10	10	20	20	10	0	0	0	0	0	0	0	0	0	0
Merced River[2]	0	0	0	0	0	0	0	10	0	10								80	0
Tuolumne River[2]	0	0	0	0	20	20	0	10	0	0								0	0
Stanislaus River[2]	10		0	0	50	0	0	0	40	10								20	0
*TID 6[3]	0			30			0	100		10		40		10	10	0		0	
*TID 5	0	100	100	90	0	0		0	0	0			0	0	0	0	10		0
*TID 3	0	100	100	100	0	0	0		0	0	0	0	10	0	0			10	
*Orestimba Creek	80	100	100		100	0	100	0	10	0	0	10	100			0	0	0	10
*Del Puerto Creek	0	100	100	0	20	10	100	100	0		0	0	0	0	10	0	10	0	0
*Ingram-Hospital Cks.	0	100	100	10	0	0	100	100	90	0	0	0		0	100	0	10	0	100
*Spanish Grant Drain	0	100	100		40	10	100	100	90	0	0	10	10	20	0	10	0	0	0
Laboratory Control	0	0	0	10	10	0	0	0	0	0	0	0	10	0	0	0	0	0	0

1 Foe, 1995, Table 6.
2 Results are for a 7-day test after November 25, 1991. All other results are for 4-day tests.
3 SJR=San Joaquin River; TID (#)=Turlock Irrigation District Lateral No. (3, 5, or 6).
* Predominantly agricultural drainage.
[shaded] Significant mortality is defined as any sample with 30 percent higher mortality than the laboratory control.

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Table 46. *Ceriodaphnia* Mortality (%) in Water Samples Collected from the San Joaquin Basin, 1991-1992.[1]

Location	1991							1992											
	10/30	11/13	11/25	12/4	12/11	12/18	12/23	1/5	1/13	2/3	2/10	2/17	2/24	3/2	3/9	3/16	3/24	3/30	4/6
*Salt Slough[2]														0	10	100	0		0
SJR[3] at Hill's Ferry[2]	0	0	0	0	10	10	10	10	0	10	0	0	0	0	0	80	0	0	0
SJR at Laird Park[2]	0	0	0	0	0	0	10	0	0	0	10		20		100	0	10	0	30
SJR at Airport Way[2]	0	0	0	30	10	10	10	0	20	0	0	100	20	10	100	20	0	10	0
Merced River[2]	0	0	0	40	20	10	0	0	0	0	0	100	0	0	60	20	10	10	0
Tuolumne River[2]	0	10	0	10	0	10	0		0	0	20	100	0	0	0	10	0	0	0
Stanislaus River[2]	0	10	0	20	10	10	10	0	20	0		10	10	0		0	20	30	10
*TID 6[3]			100		20		10	0	100	100	100	100	0	0	10	0	0	0	100
*TID 5	0	0	0	0	10	100	0	60	100	100	100	100	100		100	0	0	0	0
*TID 3		0			0	0		100			100	100	100	100	100	100	100	0	
*Orestimba Creek		0	0	0	50			0		10	100	100			100		100	0	0
*Del Puerto Creek	0	0	0	0		100	100	100	100	100	100	0	0	0	0	30	100	0	90
*Ingram-Hospital Cks.		0	0	100	10		100	100		0	100	0	100	0	100	100	100	0	0
*Spanish Grant Drain	0	0		0	0	30	30	100			90	100	20	0	10	0	100	0	0
Laboratory Control	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10

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Table 46. ***Ceriodaphnia*** **Mortality (%) in Water Samples Collected from the San Joaquin Basin, 1991-1992.**[1]

Location	1992									
	4/13	4/20	4/27	5/4	5/11	5/18	5/25	6/1	6/15	6/22
*Salt Slough[2]	100	10	0	30	0	10	0	0	10	10
SJR[3] at Hill's Ferry[2]	0	10	0	0	20	0	0	0	0	0
SJR at Laird Park[2]	0	0	10	0	10	0	20	0	0	10
SJR at Airport Way[2]	0	0	30	20	10	10	20	0	0	0
Merced River[2]	100	0	0	10	0		0	0	20	50
Tuolumne River[2]	20	10	10	30	10	0	0	0	10	60
Stanislaus River[2]	10	0	10	40		10	30	0	0	60
*TID 6[3]	20	0	10	0	50	0		100	0	0
*TID 5		0	0	0	0	0		0	0	0
*TID 3	10		20	0	10	0				100
*Orestimba Creek	0	80	100	100	100	10	100	0	0	100
*Del Puerto Creek	0	0	0	100	100	0	100	0	0	0
*Ingram-Hospital Cks.	0	10	30	100	100	100	100	0	0	20
*Spanish Grant Drain	60	100	100	100	100	100		100	0	100
Laboratory Control	0	0	10	0	0	0	0	0	0	0

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Table 47. Summary Statistics for Pesticide Detections in the San Joaquin Study, 1991-1992.[1]

PESTICIDES	Frequency of Detection	Number of Detections	Mean Concentration (ppb)	Median Concentration (ppb)	Range	Number of Samples Exceeding: NAS[2]	DFG[3]	EPA[4]	Basin Plan[5]	Number of Samples Exceeding Lowest *Ceriodaphnia* LOEC[6]
Diazinon	65.4	178	0.14	0.04	0.01 - 2.60	178	84			52
Chlorpyrifos	55.2	150	0.07	0.02	0.01 - 1.60		82	45		38
Parathion, ethyl	18	49	0.16	0.03	0.01 - 2.10			31		20
Fonofos	15.4	42	0.07	0.03	0.01 - 0.54					3
Malathion	5.1	14	0.10	0.01	0.01 - 0.42			6	6	
Carbaryl	3.6	6	2.9	1.9	0.06 - 8.4			?		0
Methomyl	1.8	3	3.7	3.2	2.6 - 5.4					0
DEF	1.1	2	0.01	0.01	0.01					
Ethion	0.7	2	0.03	0.03	0.01 - 0.05			?		
Parathion, methyl	0.4	1	0.02	0.02			?		0	
Isofenfos	0.4	1	0.07	0.07						
Disyston	0.4	1	0.06	0.06						
Carbofuran	0.6	1	0.8	0.8			1		1	0

1 Foe, 1995, Table 12.
2 NAS 1973 criterion for diazinon (0.009 μg/L).
3 DFG Hazard Assessment Criteria Reports for diazinon (0.04 μg/L), chlorpyrifos (0.015 μg/L), and carbofuran (0.4 μg/L).
4 U.S. EPA recommended freshwater criteria to protect aquatic life for chlorpyrifos (0.041 μg/L), ethyl parathion (0.013 μg/L), and malathion (0.1 μg/L).
5 Basin Plan performance goals for malathion (0.1 μg/L), methyl parathion (0.13 μg/L), and carbofuran (0.4 μg/L).
6 Foe, 1995, Table 13.

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explain the observed mortality. Twenty-four of the toxic samples were collected from the major rivers, which were toxic 9 percent of the time, and 106 from agriculturally dominated creeks and constructed drains, which were toxic 35 percent of the time. This is consistent with both the 1988-90 CVRWQCB and DPR bioassay studies, which found the major rivers were toxic 17 to 22 percent of the time and agriculturally derived waters were toxic 33 to 38 percent of the time. However, the 43 mile reach of the San Joaquin River between the Merced and Stanislaus rivers that tested toxic 33 percent of the time in the original study was only toxic 6 percent of the time in this study and 11 percent of the time in DPR bioassay study. No statistically significant differences were detected in the frequency of toxicity among years or location.

All water samples that tested toxic, except seven, were analyzed for organophosphorus and carbamate pesticides. Sixty-four percent contained pesticides at concentrations greater than half the LC50. In addition, 120 nontoxic samples were also analyzed for organophosphorus pesticides. All concentrations were less than half the LC50, except a single sample. Diazinon was the most frequently detected pesticide. Sixty-five percent of the samples exceeded the NAS aquatic life criterion for diazinon (maximum of 0.009 μg/L) and 31 percent exceeded the DFG criterion recommended to protect freshwater aquatic life (4-day average of 0.04 μg/L). Other frequently detected pesticides include chlorpyrifos, ethyl parathion, and fonofos, which were detected in 55, 18, and 15 percent of the samples, respectively. The concentrations of these other pesticides also frequently exceeded criteria established to protect aquatic life. Ethyl parathion is no longer registered for use in California.

4.1.1.4 USGS-CVRWQCB 1993 Bioassay Study

In a joint study by the USGS and CVRWQCB, water samples were collected twice a day at Vernalis in January and February 1993, assayed for 7-day Ceriodaphnia toxicity, and analyzed for several pesticides. Only diazinon was detected in January, while diazinon, methidathion, and chlorpyrifos were detected in February. Pesticides were detected after rainfall and were present in distinct pulses at Vernalis (Figure 15). One hundred percent Ceriodaphnia mortality was observed for 12 consecutive days in February. The bioassay mortality corresponded with the highest diazinon concentrations (Figure 18), which were sufficiently elevated to explain most of the mortality.[255]

4.1.1.5 USGS Pesticide Monitoring

The USGS has periodically monitored pesticides in the San Joaquin Basin. In September 1985, the USGS monitored pesticides at several sites in the San Joaquin Basin, including Salt Slough near Stevinson, San Joaquin River at Fremont Ford Bridge, Mud Slough near Gustine, Merced River near Stevinson, San Joaquin River near Newman, San Joaquin River near

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[255] Kathryn M. Kuivila and Christopher G. Foe, Concentrations, Transport and Biological Effects of Dormant Spray Pesticides in the San Francisco Estuary, California, Accepted for publication in Environmental Toxicology and Chemistry, v. 14, no. 7, 1995.

Patterson, San Joaquin River at Maze Road Bridge, San Joaquin River near Vernalis, and Tuolumne River at Modesto, among others. Pesticides were rarely detected and were present at low concentrations. The only compounds that were detected are diazinon in five samples (0.01 - 0.07 μg/L), dicamba in four samples (0.01 - 0.05 μg/L), 2,4-D in three samples (0.06 - 0.16 μg/L), parathion in three samples (0.01 - 0.15 μg/L), and ethion in two samples (0.01 μg/L). The data for the San Joaquin River at Vernalis are summarized in Table 48.[256]

Pesticides were subsequently monitored monthly between October 1988 and September 1989 in the San Joaquin River at Vernalis. Several compounds were detected including cyanazine (0.10 μg/L), DDE (0.002 - 0.010 μg/L), DDT (0.010 μg/L), diazinon (0.01 μg/L), dieldrin (0.001 μg/L), ethion (0.01 μg/L), lindane (0.001 - 0.002 μg/L), methyl parathion (0.08 μg/L), metolachlor (0.1 μg/L), and parathion (0.01 - 0.05 μg/L) (Table 48).[257] Most of these samples were not collected during pesticide application periods.

Dissolved concentrations of select pesticides, including organochlorine pesticides, organophosphorus insecticides, and triazine herbicides were measured in October 1992 in Salt Slough, Orestimba Creek, Dry Creek, the San Joaquin River at Patterson, and the Mokelumne River at Woodbridge (in the Delta). The only substances that were detected were DDT and its degradation products in Orestimba Creek, dacthal (0.9-1140 ng/L), atrazine (29-33 ng/L), simazine (20-41 ng/L), dimethoate (51-101 ng/L), and diazinon (1.8-720 ng/L) (Table 49).[258]

Pesticides were subsequently monitored at Vernalis between January 1991 and April 1994. Samples were collected daily and typically 2-day composites prepared and analyzed for up to 20 pesticides. Summary statistics are presented in Table 50. The most frequently detected pesticides were simazine and diazinon, which were present 70 and 80 percent of the time, respectively. These were also the most frequently detected pesticides in the Sacramento River. Other frequently detected pesticides include metolachlor (44 percent),[259] dacthal (38 percent), eptam (39 percent), and cyanazine (31 percent). Pesticides were detected much more frequently than on the Sacramento River (Sec. 2.1.1.5). None of the pesticides that were detected except diazinon and

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[256] L.R. Shelton and L.K. Miller, Water-Quality Data, San Joaquin Valley California, March 1985 to March 1987, USGS Open-File Report 88-479, 1988.

[257] USGS, Water Resources Data, California, Water Year 1989, Volume 3. Southern Central Valley Basins and the Great Basin from Walker River to Truckee River, USGS Water-Data Report CA-89-1, 1989, pp. 367-369.

[258] Pereira et al., 1996.

[259] Percent of time detected.

Table 48. Total Pesticide Concentrations at San Joaquin River at Vernalis.

COMPOUND	CONCENTRATION (µg/L)	
	9/25/85[1]	10/88-9/89[2]
2,4,5-T	< 0.01	-
2,4-D	< 0.01	-
2,4-DP	< 0.01	-
Alachlor	-	< 0.10
Aldrin	-	< 0.001 - < 0.010
Ametryne	< 0.10	< 0.10
Atrazine	< 0.10	< 0.10
Chlordane	-	< 0.1
Cyanazine	< 0.10	< 0.10 - 0.10
DDD	-	< 0.001 - 0.010
DDE	-	< 0.001 - 0.010
DDT	-	< 0.001 - 0.010
Diazinon	0.01	< 0.01 - 0.01
Dicamba	< 0.01	-
Dieldrin	-	< 0.001 - < 0.010
Endosulfan	-	< 0.001 - < 0.010
Endrin	-	< 0.001 - < 0.010
Ethion	< 0.01	< 0.01 - 0.01
Heptachlor	-	< 0.001 - < 0.010
Heptachlor epoxide	-	< 0.001 - < 0.010
Lindane	-	< 0.001 - < 0.010
Malathion	< 0.01	< 0.01
Methomyl	< 2.0	-
Methoxychlor	-	< 0.01
Methyl parathion	< 0.01	< 0.01 - 0.08
Methyltrithion	< 0.01	< 0.01
Metolachlor	-	< 0.1 - 0.1
Metribuzin	-	< 0.1
Mirex	-	< 0.01
Parathion	< 0.01	< 0.01 - 0.05
PCB	-	< 1
Perthane	-	< 0.1
Picloram	< 0.01	-
Prometone	< 0.1	< 0.1
Prometryne	< 0.1	< 0.1
Propazine	< 0.10	< 0.10
Propham	< 2.0	-
Sevin	< 2.0	-
Silvex	< 0.01	-
Simazine	< 0.10	< 0.10
Simetryne	< 0.1	< 0.1
Toxaphene	-	< 1
Trifuralin	-	< 0.10
Trithion	< 0.01	< 0.01

1 USGS 1988.
2 USGS 1989.

Table 49. Concentrations of Organic Contaminants in Water Samples from the San Joaquin River and its Tributaries (1992) [ng/L][1]

Compound	SITE				
	Salt Slough	Orestimba Creek	Dry Creek	San Joaquin River at Patterson	Mokelumne River at Woodbridge
DDE	< 1.0	19	< 1.0	< 1.0	< 1.0
DDD	< 1.0	3.5	< 1.0	< 1.0	< 1.0
DDT	< 1.0	2.0	< 1.0	< 1.0	< 1.0
Total DDT	< 1.0	24	< 1.0	< 1.0	< 1.0
γ-Chlordane	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
α-Chlordane	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Trans-nonachlor	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Cis-nonachlor	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Total chlordane	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
DCPA	0.9	1140	54	120	< 1.0
Dicofol	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Dieldrin	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Chlorpyrifos	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Atrazine	33	27	< 1.0	33	29
Simazine	20	25	< 1.0	26	41
Dimethoate	< 1.0	101	< 1.0	51	< 1.0
Diazinon	< 1.0	< 1.0	720	12	1.8

1 Pereira et al. 1996

Table 50. Summary of USGS Pesticide Data for the San Joaquin River, 1991-1994.[1]

Pesticide	Number of Analyses	Number of Detects	Maximum Detected Value (ng/L)	Median Detected Value (ng/L)	Percentile of Median Detected Value[2]
Alachlor	346	0	-	-	-
Atrazine	640	0	-	-	-
Butylate	346	0	-	-	-
Carbaryl	515	88	197	18	92%
Carbofuran	640	76	100	25	94%
Chlorpyrifos	640	40	43	9	97%
Cyanazine	192	59	803	150	85%
Dacthal	293	111	181	13	81%
Diazinon	640	447	714	20	65%
Eptam	293	113	674	21	81%
Fonofos	640	0	-	-	-
Malathion	640	0	-	-	-
Methidathion	515	89	802	32	91%
Metolachlor	293	129	117	22	78%
Molinate	515	7	145	59	99%
Napropamide	346	0	-	-	-
Pebulate	347	6	1,046	458	99%
Simazine	640	514	1,747	72	60%
Thiobencarb	640	43	528	11	97%
Trifluralin	640	0	-	-	-

1 MacCoy et al., 1995.
2 P = (1-[((x-1)/2)/(x+y-1)])*100, where x=number of detects, y=number of nondetects.

carbaryl is known to be toxic at the concentrations that were measured.[260] Diazinon concentrations frequently exceeded the criterion set to protect freshwater aquatic life (0.009 μg/L)[261] and the LC50 of the midge (0.03 μg/L),[262] an insect which is eaten by young salmon. Carbaryl also frequently exceeded the criterion set to protect freshwater aquatic life (0.02 μg/L).[263]

The most frequently detected pesticides were present in distinct pulses which lasted several months. Diazinon pulses were present between December and March and again between July and August in 1991, 1992, and 1993 (Figure 20). A simazine pulse was present between December and April of 1993 and 1994 (Figure 21). A metolachlor pulse was present between February and August in 1993 and 1994 (Figure 22). A dacthal pulse was present between January and April of 1993 and 1994 (Figure 23).[264] Some of these pulses coincide with the time when young striped bass, chinook salmon, green sturgeon, white sturgeon, and delta smelt are present in the river. Although these types of pesticides are not typically toxic to fish, no data on the toxicity of these pesticides to sensitive life stages of these fish were found.

In another study, the USGS monitored diazinon and chlorpyrifos concentrations during a storm from February 8 to February 11, 1993 at six sites in the San Joaquin River system.[265] These pesticides are sprayed on dormant orchards in the San Joaquin Valley in December through February to control insects. The data are summarized in Table 51. The study concluded that the first major storm following pesticide application mobilizes most of the diazinon that is available to be transported from the orchard, roughly 0.1 percent of the amount that is applied. Similar work was conducted in 1994, except streams on the eastside of the valley were emphasized.[266]

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[260] John H. Montgomery, Agrochemicals Desk Reference, Lewis Publishers, 1993; Royal Society of Chemistry 1994; Verschueren 1983.

[261] Marshack, May 1993.

[262] Sheipline, September 1993, p. 72.

[263] Marshack, May 1993.

[264] Dorene MacCoy, Kathryn L. Crepeau, and Kathryn M. Kuivila, Dissolved Pesticide Data for the San Joaquin River at Vernalis and the Sacramento River at Sacramento, California, 1991-94, USGS Open-File Report 95-110, 1995.

[265] Joseph L. Domagalski, Nonpoint Sources of Pesticides in the San Joaquin River, California: Input from Winter Storms, 1992-93, USGS Open-File Report 95-165, 1995.

[266] Charlie Kratzer and Christopher Foe, Pesticide Transport in the San Joaquin River and San Francisco Bay-Delta, Presentation at the Bay-Delta Modeling Forum, Toxics and Water Quality, August 25, 1995.

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Table 51. **Summary of Diazinon and Chlorpyrifos Concentrations in the San Joaquin River System During the Storm of February 7-11, 1993.**

Location	Date Measured	Time	Diazinon Concentration (µg/L)	Chlorpyrifos Concentration (µg/L)
Orestimba Creek	2/8	1000	0.54	0.12
		1200	1.7	0.058
		1445	3.8	0.041
		1700	3.2	0.025
		1900	0.7	0.013
	2/9	1315	0.14	0.01
Del Puerto Creek	2/8	1315	5.4	< 0.025
	2/9	1030	0.12	< 0.025
Spanish Grant Drain	2/8	1500	1.6	< 0.025
	2/9	1205	0.3	< 0.025
Central California Irrigation District Canal	2/8	1630	7.0	< 0.025
	2/9	1430	0.4	< 0.025
Merced River	2/8	1100	0.12	0.045
		1300	0.14	0.048
		1345	0.12	0.047
	2/9	1100	0.5	0.083
	2/11	1100	2.5	0.26

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Figure 20
Diazinon Concentrations in Water Samples from the San Joaquin River at Vernalis

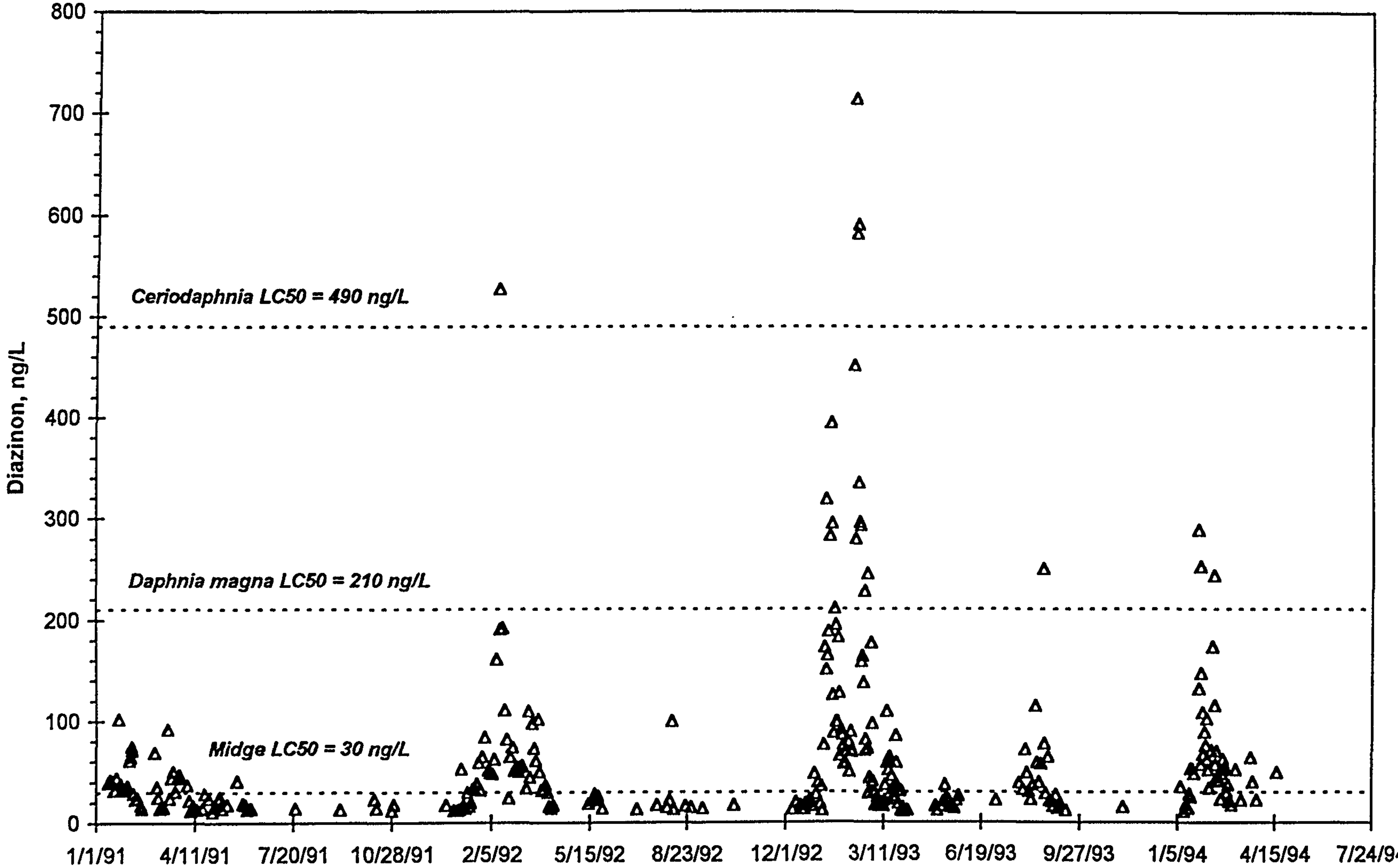

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Figure 21
Simazine Concentrations in Water Samples from the San Joaquin River at Vernalis

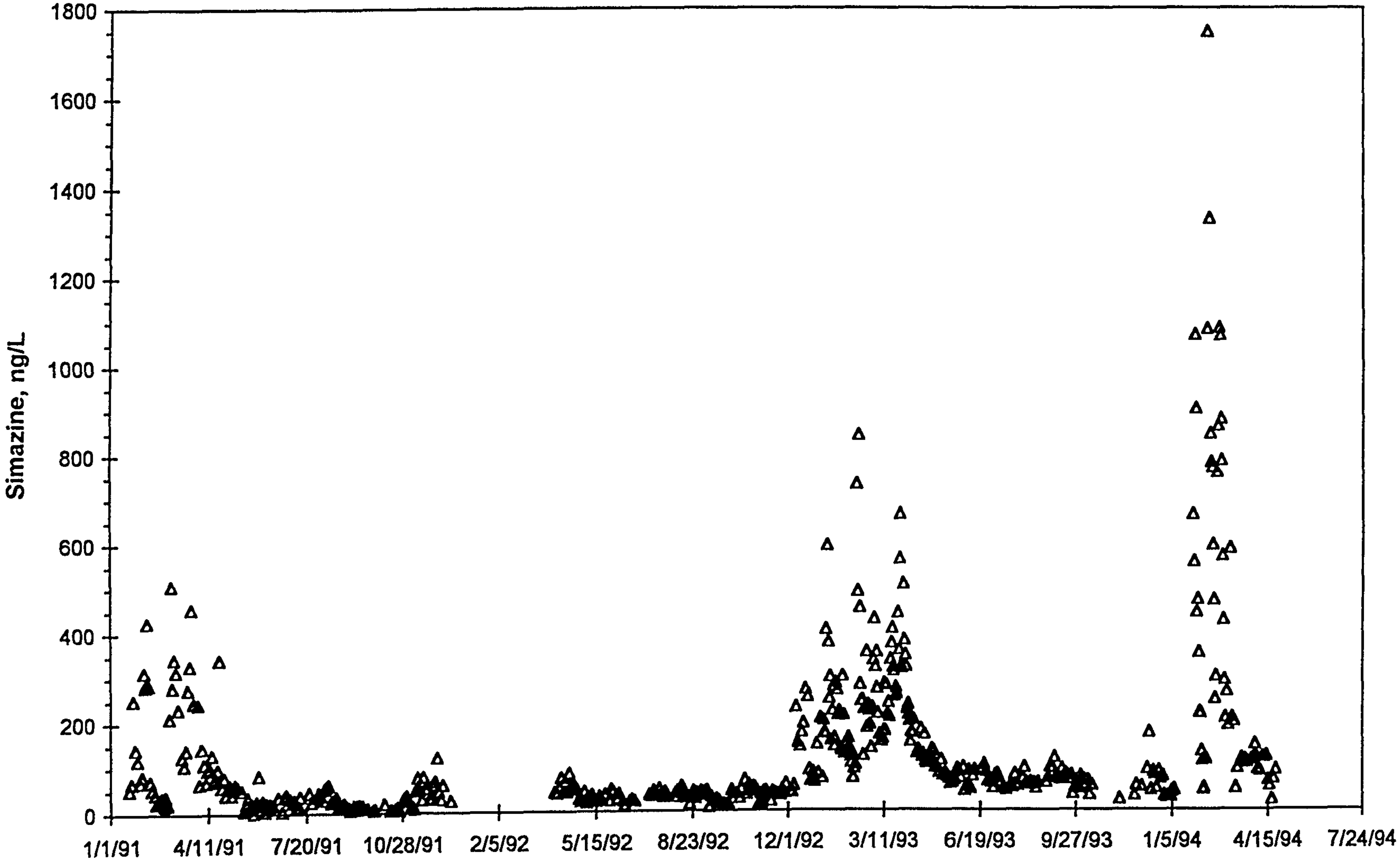

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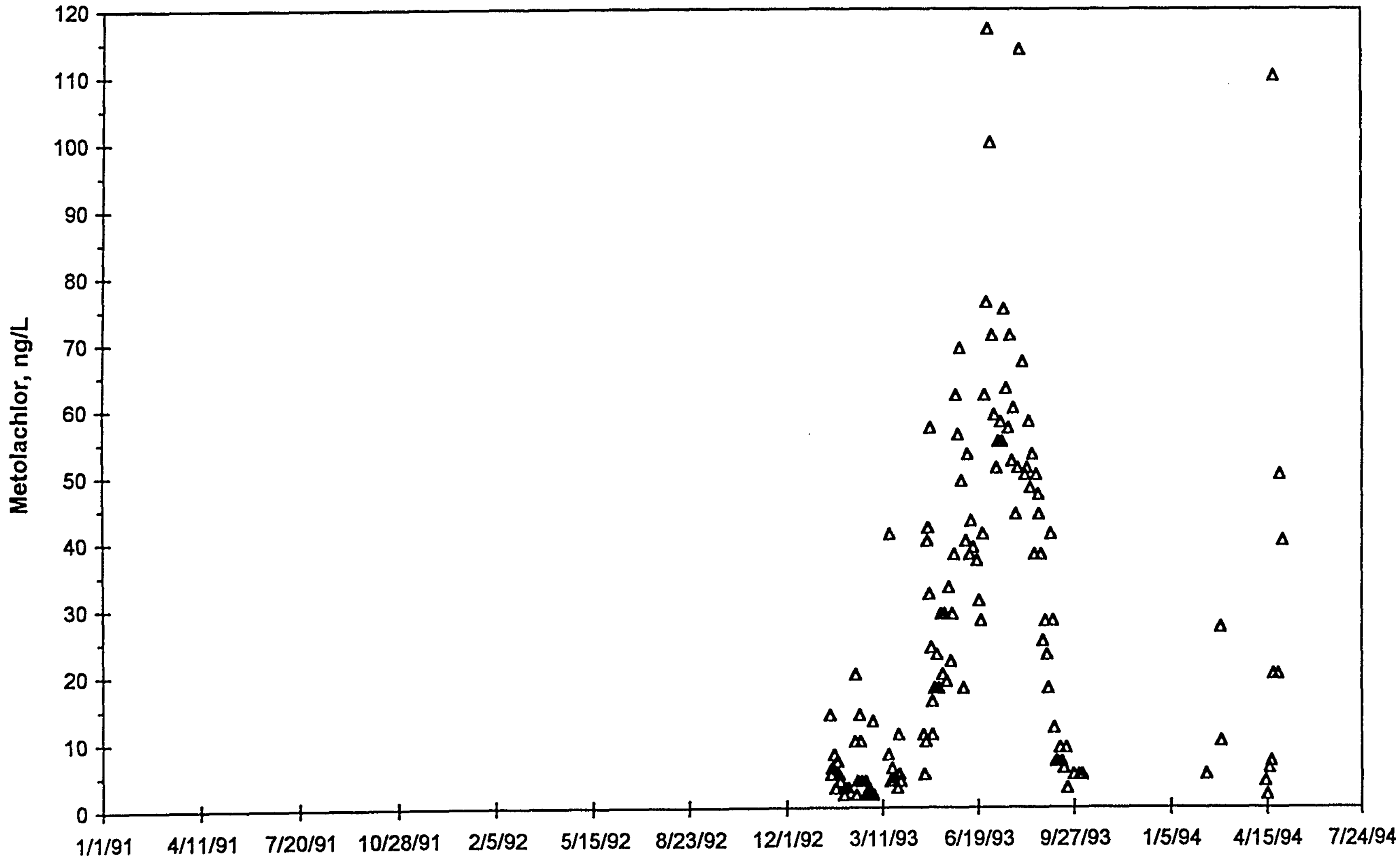
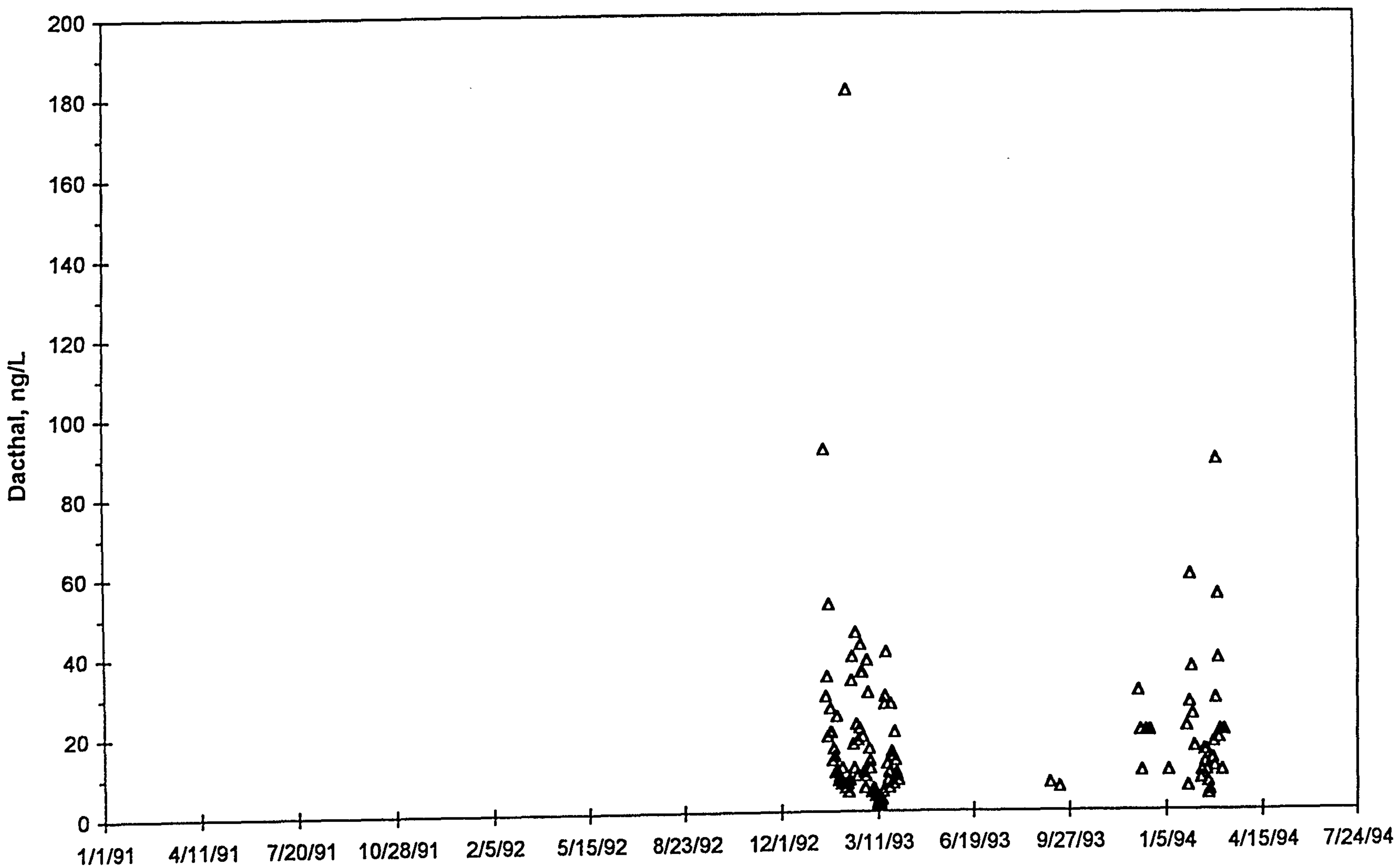
Figure 22
Metolachlor Concentrations in Water Samples from the San Joaquin River at Vernalis



C — 0 3 0 9 5 2

Figure 23
Dacthal Concentrations in Water Samples from the San Joaquin River at Vernalis



In the 1993 study, diazinon concentrations ranged from 0.12 to 7.0 µg/L and generally peaked on the rising arm of the hydrograph. Diazinon concentrations continuously exceeded concentrations recommended by the DFG (1-hr average of 0.08 µg/L) and the NAS (maximum of 0.009 µg/L) to protect aquatic life. Diazinon concentrations also frequently exceeded levels that are acutely toxic to cladocerans (0.47 - 2.2 µg/L) and mysids (3.6 - 4.8 µg/L), but were well below levels that are toxic to fish (168 - 6,800 µg/L). The values in parentheses are LC50s.

The chlorpyrifos concentrations ranged from <0.025 to 0.26 µg/L and periodically exceeded concentrations recommended by the U.S. EPA (maximum 1-hr 0.083 µg/L) and the DFG (acute 0.07 µg/L) to protect freshwater aquatic life. Concentrations also periodically exceeded levels that are acutely toxic to cladocerans (0.06 - 1.1 µg/L), mysids (0.029 - 0.30 µg/L), amphipods (0.071 - 0.17 µg/L) and brown shrimp (0.20 µg/L), but not other organisms.[267]

4.1.1.6 Four River Study

The Department of Pesticide Regulation ("DPR") in cooperation with the California Department of Fish and Game ("DFG") monitored pesticides for one year in four rivers in California -- the Merced, Sacramento, Russian, and Salinas Rivers. The Merced River monitoring site is located about one mile upstream from the Merced River's confluence with the San Joaquin River. Three-day composite samples were collected weekly from June 18, 1994 to June 12, 1995. The samples were analyzed for organophosphorus, carbamate, and endosulfan pesticides, and acute toxicity determined in 96-hr bioassays with fathead minnows and Ceriodaphnia.

Dimethoate was detected in two samples from September 2-5 and September 23-26 at 0.13 µg/L. No criteria have been established for dimethoate to protect freshwater aquatic organisms. However, this concentration is substantially lower than 96-hr LC50s for algae, invertebrates, and fish.[268] Diazinon was detected on January 9, 30, and February 2 at concentrations of 0.11, 0.077, and 0.17 µg/L, respectively. All of these concentrations exceed the maximum recommended by the NAS to protect freshwater aquatic life (0.009 µg/L) and the 4-day average criterion (0.04 µg/L) recommended by the DFG to protect freshwater aquatic life.[269] Methidathion was detected on January 9, 16, February 2, and March 13 at concentrations of 0.22, 0.11, 0.13, and 0.061 µg/L, respectively. Currently, there are no criteria for methidathion to protect freshwater aquatic life. However, all of these concentrations are substantially lower than LC50s for freshwater algae, invertebrates, and fish.[270] Finally, 3-hydroxycarbofuran, a

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[267] Menconi and Paul, 1994, Table A-1.

[268] U.S. EPA, AQUIRE database, March 28, 1996.

[269] Menconi and Cox, 1994.

[270] U.S. EPA, AQUIRE database, March 28, 1996.

degradation product of carbofuran, was detected on January 30. Currently, there are no criteria for 3-hydroxycarbofuran or its parent compound to protect freshwater aquatic life.[271]

No significant mortality to larval fathead minnows was observed. However, significant mortality to Ceriodaphnia occurred in one out of 30 samples, or 3 percent of the total. No pesticides were detected in the toxic February 10, 1995 sample, which resulted in 25 percent mortality.

4.1.1.7 DPR Winter Dormant Spray Insecticide Monitoring

In response to the CVRWQCB bioassay studies, the DPR monitored insecticides during three periods of peak use, winter dormant spray, spring, and summer seasons. The DPR work focused on insecticides because the CVRWQCB work (Sec. 4.1.1.1) demonstrated toxicity to Ceriodaphnia, an invertebrate. Insecticides target invertebrates. Preliminary results were discussed in Section 4.1.1.2. The winter dormant spray study has been published and is discussed here.[272]

The dormant spray season usually occurs from December to February, with the highest applications typically occurring in January. Many growers apply insecticides, typically chlorpyrifos, diazinon, methidathion and weed oil, to control over-wintering peach twig borer and San Jose scale. Ethyl parathion was also commonly used until the U.S. EPA banned it at the end of 1991. The use of diazinon increased 30 percent after the ban on ethyl parathion.

Samples were collected from 17 sites in the San Joaquin Basin in two separate studies. Samples were collected twice a week from the San Joaquin River at Laird Park to establish temporal patterns. In addition, the mass loading of insecticides into the San Joaquin River was determined using spatially distributed sampling (Lagrangian surveys) during the first two storm events in the winters of 1992 and 1993. All samples were analyzed for water quality parameters (dissolved oxygen, electrical conductivity, ammonia, pH, total suspended sediment, total organic carbon) and insecticide (organophosphate, carbamate, endosulfan) concentrations. Wet and dry deposition samples were also collected during the 1992-93 season and analyzed for organophosphates. The results of the deposition work are discussed in Section 4.2.2.

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[271] Kevin P. Bennett, Preliminary Results of the Four Rivers Monitoring Study -- Merced River, First and Second Quarters, Summer/Fall 1994, DPR Memorandum to Roger Sava, March 9, 1995 and Kevin P. Bennett, Preliminary Results of the Four River Monitoring Study, Merced River, Third and Fourth Quarters, December through June, 1994-1995, DPR Memorandum to Roger Sava, August 7, 1995.

[272] L.J. Ross, R. Stein, J. Hsu, J. White, and K. Hefner, Distribution and Mass Loading of Insecticides in the San Joaquin River, California, Winter 1991-92 and 1992-93, DPR Report EH 96-02, May 1997.

Nine insecticides and three degradation products were detected during the winters of 1991-92 and 1992-93. Of the 108 water samples collected during the two winter seasons, 12 percent contained the carbamate insecticide carbaryl and 10, 19, and 72 percent contained the organophosphate insecticides chlorpyrifos, methidathion, and diazinon, respectively. Chlorpyrifos concentrations exceeded the U.S. EPA acute water quality criterion of 0.083 µg/L established to protect freshwater life at one site, the Newman Wasteway. Diazinon concentrations exceeded the DFG's acute criterion of 0.08 µg/L in 19 of 34 samples collected in the San Joaquin River at Laird Park and at 12 of 23 sites sampled during the four Lagrangian surveys. Criteria are not available for methidathion and carbaryl.

The Turlock Irrigation District Drain #5 (TID5) consistently had poor water quality and typically had the lowest dissolved oxygen, highest total ammonia, and highest total organic carbon concentrations. This drain carries municipal wastewaters from the City of Turlock treatment plant located upstream of the sampling point, runoff from dairies, tailwater from row and orchard crops, and operational spill water. The CVRWQCB bioassay studies found that waters in this drain were toxic to Ceriodaphnia 75 percent of the time, presumably due to high ammonia, low dissolved oxygen, and high insecticide concentrations (Sec. 4.2.1.1).

Peak concentrations of insecticides coincided with rain events and peak river discharge and were higher in 1992-93 (a wet winter) than in 1991-92 (a dry winter). The Lagrangian surveys demonstrated that the Newman Wasteway, Orestimba Creek, and the Merced and Tuolumne Rivers were major contributors to insecticide loads measured in the San Joaquin River. During the February 1993 storm, 0.01, 0.08, and 0.5 percent of the amount of chlorpyrifos, diazinon, and methidathion applied between storms was transported in streams and creeks to the San Joaquin River at Vernalis. Insecticides appear to be transported conservatively through the watershed, because mass loads were additive to within ± 30 percent. Rainfall is not a significant source of insecticides in the river.

The DPR investigated the effectiveness of cover crops to reduce the concentrations of dormant sprays in orchard runoff. In February 1990, the row middles of a peach orchard were subjected to three treatments: (1) bare soil; (2) clover cover; and (3) oats cover. Diazinon, chlorpyrifos, and methidathion were applied with a mini air-blast sprayer. Precipitation runoff water was individually collected from each treatment row in each block. Water was collected at 30-minute intervals between 0 and 3 hours of runoff during the first two storm events that occurred between January 16 and 18, 1996, 12 and 14 days after insecticide application. Runoff concentrations of all three insecticides and the volume of water leaving each treatment row were measured.

For all three insecticides, runoff concentrations were lowest for clover, followed by oats, and then bare soil. During the first rain event, average concentrations for chlorpyrifos were 23, 11, and 22 µg/L for the bare soil, clover, and oat treatments, respectively. For diazinon, they were 68, 25, and 37 µg/L for the bare soil, clover, and oat treatments, respectively. For methidathion, they were 170, 58, and 110 µg/L for these treatments. Similar results were obtained for the second rainfall event. Mass runoff was reduced by as much as 74 percent for the clover cover, compared to bare soil. Because 90, 56, and 41 percent of the mass of chlorpyrifos, diazinon, and methidathion, respectively, were associated with particulates, the authors speculated that other soil erosion control methods may also be useful in reducing the amount of insecticides in runoff waters.[273]

4.1.2 Sediments

4.1.2.1 USGS Studies

The USGS sampled bed sediments of the San Joaquin River system for organochlorine pesticides during October 7-11, 1985. The resulting data are summarized in Table 52. Residues of DDD, DDE, DDT, and dieldrin were widespread in the fine-grained bed sediments despite little or no use of these pesticides for more than 15 years. Dieldrin and DDT are no longer registered for use in California. The highest concentrations occurred in bed sediments of westside tributary streams that primarily carry agriculturally derived waters, particularly Orestimba and Hospital Creek. The San Joaquin River had among the highest bed-sediment concentrations of these compounds of major rivers in the United States.[274] Several other organochlorine pesticides were analyzed in a single sample from the San Joaquin River near Vernalis on October 9, 1985. PCBs, pesticide ingredients, were detected at 2 µg/kg. Other organochlorine pesticides were not detected, including aldrin (<0.1 µg/kg), lindane (<0.1 µg/kg), endrin (<0.1 µg/kg), heptachlor (<0.1 µg/kg), heptachlor epoxide (<0.1 µg/kg), PCN (<1.0 µg/kg), and perthane (<1.0 µg/kg).[275]

The USGS also monitored organochlorine pesticides monthly in bottom sediments of the San Joaquin River near Vernalis between October 1988 and August 1989. Several were detected, consistent with the earlier study, including DDD in seven samples (0.1 - 0.3 µg/kg), DDE in ten samples (0.2 - 0.6 µg/kg), and DDT in three samples (0.1 - 0.2 µg/kg). No chlordane (<1.0 µg/kg), dieldrin (<0.1 µg/kg), endosulfan (<0.1 µg/kg), endrin (<0.1 µg/kg), heptachlor (<0.1 µg/kg), or heptachlor epoxide (<0.1 µg/kg) were detected.[276]

Bed sediments and suspended sediments from the San Joaquin River and its tributaries were measured in October 1992 for polynuclear aromatic hydrocarbons ("PAHs") (not discussed

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[273] L.J. Ross, K.P. Bennett, K.D. Kim, K. Hefner, and J. Hernandez, Reducing Dormant Spray Runoff from Orchards, DPR Report EH-97-03, July 1997.

[274] Robert J. Gilliom and Daphne G. Clifton, Organochlorine Pesticide Residues in Bed Sediments of the San Joaquin River, California, Water Resources Bulletin, v. 26, no. 1, 1990, pp. 11-24.

[275] Shelton and Miller, 1988.

[276] USGS, 1989.

Table 32. Concentrations of Organochlorine Pesticides Detected in Bed Sediments of the San Joaquin Basin, October 1985.[1]

SITE	PESTICIDE CONCENTRATIONS (µg/Kg)*							
	Chlordane	DDD	DDE	DDT	Dieldrin	Endosulfan	Mirex	Toxaphene
Mendota Pool Area								
Fresno Slough	< 1.0	1.6	6.4	< 0.1	< 0.1	< 0.1	< 0.1	< 10
SJR below Mendota Pool	< 1.0	< 0.1	0.9	< 0.1	< 0.1	< 0.1	< 0.1	< 10
SJR near Firebaugh	1.0	0.9	3.5	0.6	0.1	< 0.1	< 0.1	< 10
SJR near Dos Palos	< 1.0	0.3	0.4	0.2	< 0.1	< 0.1	< 0.1	< 10
Intermittent San Joaquin River								
SJR near Washington Bridge	< 1.0	1.6	3.8	< 0.1	< 0.1	< 0.1	< 0.1	< 10
SJR near Turner Island	< 1.0	11	58	< 0.1	4.4	2.6	0.4	< 10
Mariposa Slough	< 1.0	1.6	3.9	< 0.1	0.7	0.8	< 0.1	< 10
Salt and Mud Sloughs								
Salt Slough	< 1.0	7.2	12	< 0.1	0.9	< 0.1	< 0.1	< 10
Mud Slough	< 1.0	0.7	1.3	< 0.1	0.1	< 0.1	< 0.1	< 10
Santa Fe Canal	< 1.0	< 0.1	0.4	< 0.1	< 0.1	< 0.1	< 0.1	< 10
Los Banos Creek	< 1.0	0.2	0.6	< 0.1	< 0.1	< 0.1	< 0.1	< 10
Eastside Tributaries								
Merced River near Stevinson	< 1.0	3.9	4.2	49	0.3	< 0.1	< 0.1	< 10
Tuolumne River at Modesto	< 1.0	< 0.1	0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 10
Stanislaus River at Ripon	2.0	1.3	2.4	1.1	0.1	< 0.1	0.1	< 10
Bear Creek near Stevinson	< 1.0	< 0.1	0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 10
Westside Tributaries								
Newman Wasteway	< 1.0	21	130	< 0.1	2.0	< 0.1	< 0.1	< 10
Orestimba Creek	< 1.0	180	430	55	6.8	15	< 0.1	< 10
Del Puerto Creek	< 1.0	29	73	< 0.1	1.4	< 0.1	< 0.1	250
Ingram Creek	< 1.0	260	250	420	4.9	87	< 0.1	< 10
Hospital Creek	< 1.0	58	170	60	8.9	< 0.1	< 0.1	< 10
Jerusalem Wasteway	< 1.0	3.9	6.2	< 0.1	0.2	< 0.1	< 0.1	< 10
Perennial San Joaquin River								
SJR near Stevinson	1.0	0.3	1.2	< 0.1	< 0.1	< 0.1	< 0.1	< 10
SJR at Fremont Ford Bridge	< 1.0	0.3	0.7	< 0.1	< 0.1	< 0.1	< 0.1	< 10
SJR near Vernalis	3.0	3.2	7.1	1.3	1.0	< 0.1	< 0.1	< 10

1 Gilliom and Clifton, 1990, Table 3.

* Endrin, heptachlor, heptachlor epoxide, lindane, methoxychlor, and perthane were analyzed for but not detected in any of the samples.

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here) and select pesticides, including organochlorine pesticides, organophosphorus insecticides, and triazine herbicides. The results were summarized in Table 34.

Low levels of DDT and its degradation products were detected in bed and suspended sediments at all sites except Orestimba Creek, which contained elevated concentrations of DDT, DDD, and DDE. The concentrations of DDE in sediments were greater than those of DDD or DDT. Ratios of DDE/DDT in bed sediment ranged from 2.3 to 8.8 and in suspended sediment from 3.4 to 13.9. DDE is enriched in these sediments because DDT is degraded under aerobic conditions to DDE by microorganisms in agricultural soils. The agricultural areas drained by Orestimba Creek and other westside tributaries were intensively farmed during the period of heaviest use of DDT, from about 1950 to 1972, when the use of DDT was banned.

Dicofol was also detected in Orestimba Creek (23.7 µg/kg). Dicofol, which is manufactured from DDT, has been reported to contain significant amounts of DDT, DDD, and DDE as manufacturing impurities. Nearly 550,000 lbs of dicofol were used in the San Joaquin Valley in 1991 and may represent a continuing source of DDT and its degradation products in the San Joaquin watershed. Other pesticides that were detected in sediments include chlordane, nonachlor, dacthal, and dieldrin. Concentrations of total chlordane were higher in suspended sediments from Dry Creek (160 µg/kg) than other sites. Because chlordane is used as a termiticide around building foundations, the elevated concentrations in Dry Creek probably originate from urban runoff from Modesto, some of which enters Dry Creek. Concentrations of dacthal and dieldrin were higher in sediments from Orestimba Creek than the other sites.[277]

This work was generally extended in a subsequent study that collected bed sediments in October 1992 from 21 sites on or near the San Joaquin Valley floor and analyzed them for 32 organochlorine compounds and PAHs (not discussed here). The data are summarized in Table 53.

Among these, 15 compounds were detected in bed sediment, including cis-chlordane (2.1 µg/kg), trans-chlordane (2.3 µg/kg), dacthal (<5-32 µg/kg), op'-DDD (<1-15 µg/kg), pp'-DDD (<1-39 µg/kg), op'-DDE (<1-11 µg/kg), pp'-DDE (<1-240 µg/kg), pp'-DDT (<2-68 µg/kg), dieldrin (<1-9.7 µg/kg), cis-nonachlor (<1-1.5 µg/kg), trans-nonachlor (<1-2.3 µg/kg), cis-permethrin (<5-16 µg/kg), trans-permethrin (<5-15 µg/kg), and toxaphene (<100-630 µg/kg). Sediment concentrations are dry weight. The most frequently detected compound was pp'-DDE. Concentrations of total DDT were highest in sediments from west-side sites. While concentrations of organochlorine compounds in sediments appear to have declined since the earlier USGS studies discussed above, concentrations of many compounds, particularly of DDT and its degradation products, remain high relative to national values.

Several sites exceeded U.S. EPA draft sediment criteria for organochlorine compounds. Four sites exceeded the draft criteria for pp'-DDT (828 µg/kg): Tuolumne River near Modesto

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[277] Pereira et al., 1996.

Table 53. Concentrations of Organochlorine Compounds in Tissue of Biota and Sediment from Streams of the San Joaquin Valley in October 1992.[1]

SITE	cis-Chlordane		trans-Chlordane		Dacthal		op'-DDD		pp'-DDD		op'-DDE		pp'-DDE		op'-DDT		pp'-DDT	
	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S
Kings River below Pine Flat Reservoir	< 5	< 1	< 5	< 1	< 5	< 5	< 5	< 1	< 5	< 1	< 5	< 1	< 5	< 1	< 5	< 2	< 5	< 2
Tuolumne River at Old La Grange Bridge	< 5	< 1	< 5	< 1	< 5	< 5	< 5	< 1	< 5	< 1	< 5	< 1	< 5	< 1	< 5	< 2	< 5	< 2
Kings River at People's Weir	< 5	-	< 5	-	< 5	-	< 5	-	< 5	-	< 5	-	16.0	-	< 5	-	< 5	-
Kings River at Empire Weir #2	< 5	< 1	< 5	< 1	< 5	< 5	< 5	< 1	5.7	< 1	< 5	< 1	95	< 1	< 5	< 2	< 5	< 2
Merced River near Stevinson	< 5	< 1	< 5	< 1	< 5	< 5	< 5	< 1	< 5	< 1	< 5	< 1	22.0	1.6	< 5	< 2	< 5	< 2
Tuolumne River at Modesto	< 5	< 1	< 5	< 1	< 5	< 5*	< 5	1.0	< 5	4.0	< 5	< 1	14.0	31.0	< 5	< 2*	< 5	13.5
Dry Creek in Modesto	< 5	< 1	< 5	< 1	< 5	< 5	< 5	< 1	< 5	< 1	< 5	< 1	11.0	2.3	< 5	< 2	< 5	< 2
Turlock Irrigation District Lateral #3	< 5	< 1	< 5	< 1	< 5	< 5	< 5	< 1	< 5	< 1	< 5	1	6.3	3.7	< 5	< 2	< 5	< 2
Stanislaus River near Ripon	< 5	< 1	< 5	< 1	< 5	< 5	< 5	M	< 5	M	< 5	< 1	6.1	1.5	< 5	M	< 5	M
Mokelumne River near Woodbridge	< 5	2.1	< 5	2.3	< 5	< 5	< 5	< 1	< 5	< 1	< 5	< 1	5.8	3.5	< 5	< 2	< 5	< 2
Salt Slough near Stevinson	< 5	< 1	< 5	< 1	< 5	< 5	< 5	< 1	22.0	1.2	< 5	< 1	320.0	3.3	< 5	< 2	< 5	< 2
Salt Slough near Stevinson [D]	-	< 1	-	< 1	-	< 5	-	< 1	-	1.4	-	< 1	-	5.7	-	< 2	-	< 2
Mud Slough near Gustine	< 5	< 1	< 5	< 1	< 5	< 5	< 5	< 1	9.8	< 1	< 5	< 1	69.5	1.4	< 5	< 2	< 5	< 2

Table 53. Concentrations of Organochlorine Compounds in Tissue of Biota and Sediment from Streams of the San Joaquin Valley in October 1992.[1]

SITE	Total DDT		Dieldrin		cis-Nonachlor		trans-Nonachlor		cis-Permethrin		trans-Permethrin		Toxaphene		PCBs	
	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S
Kings River below Pine Flat Reservoir	0	0	< 5	< 1	< 5	< 1	< 5	< 1	NA	< 5	NA	< 5	< 100	< 100	< 50	< 100
Tuolumne River at Old La Grange Bridge	0	0	< 5	< 1	< 5	< 1	< 5	< 1	NA	< 5	NA	< 5	< 100	< 100	< 50	< 100
Kings River at People's Weir	16.0	-	< 5	-	< 5	< 1	< 5	< 1	NA	-	NA	-	< 100	-	< 50	-
Kings River at Empire Weir #2	100.7	0.0	< 5	< 1	< 5	< 1	< 5	< 1	NA	< 5	NA	< 5	< 100	< 100	< 50	< 100
Merced River near Stevinson	22.0	1.6	< 5	< 1	< 5	< 1	< 5	< 1	NA	< 5	NA	< 5	< 100	< 100	< 50	< 100
Tuolumne River at Modesto	14.0	49.5	< 5	< 1	< 5	< 1	< 5	< 1	NA	< 5	NA	< 5	< 100	< 100	< 50	< 100
Dry Creek in Modesto	11.0	2.3	< 5	< 1	< 5	< 1	< 5	< 1	NA	< 5	NA	< 5	< 100	< 100	< 50	< 100
Turlock Irrigation District Lateral #3	6.3	4.7	< 5	< 1	< 5	< 1	< 5	< 1	NA	< 5	NA	< 5	< 100	< 100	< 50	< 100
Stanislaus River near Ripon	6.1	1.5	< 5	< 1	< 5	< 1	< 5	< 1	NA	U	NA	U	< 100	< 100	< 50	< 100
Mokelumne River near Woodbridge	5.8	3.5	< 5	< 1	< 5	1.5	< 5	2.3	NA	< 5	NA	< 5	< 100	< 100	< 50	< 100
Salt Slough near Stevinson	342.0	4.5	5.9	< 1	< 5	< 1	< 5	< 1	NA	< 5	NA	< 5	< 100	< 100	< 50	< 100
Salt Slough near Stevinson [D]	-	7.1	-	< 1	-	< 1	-	< 1	NA	< 5	NA	< 5	-	< 100	-	< 100
Mud Slough near Gustine	79.3	1.4	< 5	< 1	< 5	< 1	< 5	< 1	NA	< 5	NA	< 5	< 100	< 100	< 50	< 100

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Table 53. Concentrations of Organochlorine Compounds in Tissue of Biota and Sediment from Streams of the San Joaquin Valley in October 1992.[1]

SITE	cis-Chlordane		trans-Chlordane		Dacthal		op'-DDD		pp'-DDD		op'-DDE		pp'-DDE		op'-DDT		pp'-DDT	
	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S
San Joaquin River near Stevinson	< 5	< 1	< 5	< 1	< 5	< 5	< 5	< 1	< 5	< 1	< 5	< 1	50.0	< 1	< 5	< 2	< 5	< 2
San Joaquin River near Patterson	< 5	< 1	< 5	< 1	23	< 5	< 5	< 1	24	< 1	< 5	< 1	480.0	1.0	< 5	< 2	5.9	< 2
San Joaquin River near Vernalis	< 5	< 1	< 5	< 1	33.0	< 5	< 9	< 1	18.0	2.9	5.4	< 1	240.0	7.9	< 9	< 2	32.0	2.4
Orestimba Creek at River Road	< 5	U	< 5	U	270.0	32.0	20.0	15.0	100.0	39.0	22.0	11.0	1100.0	240.0	36.0	42.0	220.0	68.0
Orestimba Creek at River Road [D]	-	< 1	-	< 1	-	25.0	-	4.9	-	38.0	-	4.4	-	174.0	-	30.0	-	51.0
Spanish Grant Drain	< 5	< 1	< 5	< 1	360.0	< 7	< 37	< 1	< 40	11.0	12.0	1.8	1600.0	80.0	< 5	3.2	580.0	13.0
Spanish Grant Drain [D]	-	< 1	-	< 1	-	5.0	-	M	-	M	-	1.9	-	87.0	-	M	-	M
Del Puerto Creek at Vineyard Road	< 5	< 1	< 5	< 1	11.0	< 5*	7.4	1.7	27.0	10.2	14.0	2.3	350.0	69.0	18.0	3.9	93.0	33.0

1 Brown, 1996. Values for duplicate sediment samples are tabulated under the site name appended with a [D]. Values of Total DDT assume a value of 0 when a compound was not detected. For statistical tests, a value of one-half of the reporting limit was used. "-" , no data; "*", analyte was positively identified as present but the concentration was below the reporting limit and could not be accurately quantified; "M", analyte broke down into other DDT compounds during injection. Concentrations were reported by the laboratory as the sum of pp'-DDX or op'-DDX compounds; "NA", not analyzed in this media; "S", sediment: µg/Kg dry weight; "T", tissue: µg/Kg wet weight; "U", analyte deleted due to interferences.

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Table 53. Concentrations of Organochlorine Compounds in Tissue of Biota and Sediment from Streams of the San Joaquin Valley in October 1992.[1]

SITE	Total DDT		Dieldrin		cis-Nonachlor		trans-Nonachlor		cis-Permethrin		trans-Permethrin		Toxaphene		PCBs	
	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S
San Joaquin River near Stevinson	50.0	0.0	5.5	< 1	< 5	< 1	< 5	< 1	NA	< 5	NA	< 5	< 100	< 100	< 50	< 100
San Joaquin River near Patterson	509.9	1.0	< 5	< 1	< 5	< 1	< 5	< 1	NA	< 5	NA	< 5	< 100	< 100	52	< 100
San Joaquin River near Vernalis	295.4	13.2	< 5	< 1	< 5	< 1	< 5	< 1	NA	< 5	NA	< 5	160.0	< 100	< 50	< 100
Orestimba Creek at River Road	1498.0	415.0	9.8	9.7	< 5	U	< 5	U	NA	< 5	NA	< 5	440.0	630.0	< 50	< 100
Orestimba Creek at River Road [D]	-	302.3	-	3.5	-	< 1	-	< 1	-	< 5	-	< 5	NA	240	NA	< 100
Spanish Grant Drain	2192.0	109.0	< 35	2.5	< 5	< 1	< 5	< 1	NA	< 5	NA	< 5	2000.0	< 100	57.0	< 100
Spanish Grant Drain [D]	-	110.3	-	1.3	-	< 1	-	< 1	-	U	-	U	NA	< 100	NA	< 100
Del Puerto Creek at Vineyard Road	509.4	120.1	< 5	1.0	< 5	< 1	< 5	< 1	NA	16	NA	15	< 100	< 100	< 50	< 100

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(1,467 µg/kg), Orestimba Creek (9189 µg/kg), Spanish Grant Drain (1,566 µg/kg), and Del Puerto Creek (3,882 µg/kg). Two samples from Orestimba Creek (85 and 135 µg/kg) also exceeded the draft criteria (64.7 µg/kg) for toxaphene. All concentrations are dry weight standardized by TOC. A number of sites also exceeded Canadian interim sediment quality guidelines.[278]

In another study, bed sediments were collected from the Don Pedro Reservoir on the Tuolumne River and the San Joaquin River at Fremont Ford and Mossdale in October 1992 and analyzed for six phenols, six phthalates, and 52 PAHs. Concentrations of phenols (ND to 18 µg/kg), phthalates (ND to 10 µg/kg), and PAHs (27 to 39 µg/kg) were at the lower end of the range among those detected at 22 other sites across the United States.[279]

4.1.2.2 Reconnaissance Toxicity Studies

Both the DFG and the CVRWQCB have conducted reconnaissance studies on sediment toxicity in the San Joaquin Basin. In 1992, the DFG assayed sediment toxicity at three sites using the ASTM 10-day Hyalella azteca bulk sediment test. They found 10 percent mortality in the San Joaquin River at Laird Park, no mortality in the Stanislaus River at Caswell State Park, and 22 percent mortality in Hospital/Ingram Creek.[280]

In other tests, the CVRWQCB measured sediment toxicity at three additional sites. Toxicity was assayed using the Hyalella test for bulk sediments and the three-brood Ceriodaphnia test for sediment elutriates and site water. Elutriates were prepared from site water, and when site water was toxic, with control water (well water).

In eight replicate Hyalella bulk sediment tests, they found 7 percent mortality in Mud Slough samples, 38 percent mortality in TID Lateral #5, and 40 percent mortality in Orestimba Creek. The latter two were significantly different from the controls, which had 5 percent mortality. In the Ceriodaphnia elutriate tests, they found 30 percent mortality in the elutriate and none in the overlying waters from Mud Slough. The number of offspring in the elutriate from Mud Slough was significantly lower (11.3 neonates/adult) than the control (18.6 neonates/adult), but not the site water (25.5 neonates/adult). The elutriate from TID Lateral #5 was not tested,

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278 Larry R. Brown, Concentrations of Chlorinated Organic Compounds in Biota in Relation to Concentrations in Bed Sediment in Streams of the San Joaquin Valley, California, Submitted to Archives of Environmental Contamination and Toxicology, October 1996.

279 Steven L. Goodbred, Robert J. Gilliom, Timothy S. Gross, Nancy P. Denslow, Wade L. Bryant, and Trenton R. Schoeb, Reconnaissance of 17ß-Estradiol, 11-Ketotestosterone, Vitellogenin, and Gonad Histopathology in Common Carp of United States Streams: Potential for Contaminant-Induced Endocrine Disruption, USGS Open-File Report 96-627, 1997.

280 Fujimura, November 1, 1996.

but the site water contained no toxicity. In Orestimba Creek, the overlying site water resulted in 100 percent mortality to Ceriodaphnia, but no significant toxicity was found in the elutriate prepared from well water (15 percent mortality).[281]

4.1.3 Biota

4.1.3.1 DFG Fish Kill Reports

As discussed in Section 2.1.3.1, the DFG has inventoried fish and wildlife losses due to pesticides throughout the State since 1965. These reports indicate that in the 1960s through the 1980s, thousands of fish were typically killed annually from the application of pesticides in the San Joaquin Basin, ranging from 500 fish in 1983 and 1989 to 77,600 in 1982. Those who report and compile these reports generally believe that they are underestimates, because many fish kills are not reported, and among those that are, the game warden frequently arrives after the evidence has been removed by scavengers and it is not possible to inventory the damage. The most commonly reported pesticides causing fish kills are DDT, toxaphene, chlordane, acrolein (magnacide), endosulfan (thiodan), and copper compounds.

Most of these pesticides have been banned (DDT, toxaphene, chlordane) or restricted in use (acrolein, endosulfan). Acrolein, which is an herbicide and algicide injected directly into water to control submerged and floating weeds in irrigation ditches and canals, can only be used in canals which end at the field and thus would normally not support fish life. Endosulfan, an insecticide used for vegetable crops, is currently restricted to use only in the Imperial Valley. As a result of these bans and restrictions, the number of fish kills reported in the 1990s in the San Joaquin Basin has generally declined and currently number in the hundreds (Table 54).

4.1.3.2 SWRCB Toxic Substances Monitoring Program

Since 1978, the SWRCB has monitored pesticides, pesticide ingredients, and pesticide byproducts in fish from up to 24 stations, including four on the Merced River, two on the Tuolumne River, one on the Stanislaus River, and eight on the San Joaquin River. The analyses are performed on either muscle tissue (filet), or when only very small fish are available, on a whole body composite. Over 50 percent of the samples were four species -- carp, channel catfish, white catfish, and largemouth bass. The minimum and maximum detected values are summarized in Table 55.[282]

Pesticides were detected in fish from all stations. The most frequently detected pesticides were toxaphene (100 - 14,000 µg/kg), DDT (5.1 - 7,267 µg/kg), chlordane (5.7 - 227 µg/kg),

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[281] Ogle et al., August 1996.

[282] The data were obtained from the SWRCB electronic bulletin board (916-657-9722) in a file called TSM.LOTUS.ZIP. The data have also been published by SWRCB, 1990-93.

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Table 54. Fish Kills by Pesticides in the San Joaquin Basin, 1965-1996.

Year	No. of Fish Killed	Fish Species Killed	Responsible Pesticide	County
1965	75	Bluegills	Sevin	San Joaquin
1965	2	Bullhead catfish	Unknown	Stanislaus
1965	750	Carp	Sevin	San Joaquin
1965	25	Carp	Unknown	Fresno-Madera
1965	25	Carp	Unknown	Merced
1965	75	Catfish	Sevin	San Joaquin
1965	25	Largemouth bass	Unknown	Fresno-Madera
1965	25	Sucker	Unknown	Fresno-Madera
1965	1,000+	Trout	DDT	Amador
1965	25	White catfish	Unknown	Fresno-Madera
1965	1,000	White catfish	Unknown	Merced
1966	20	Bass	Unknown	San Joaquin
1966	1	Black bass	DDT, Thiodan	San Joaquin
1966	7	Black bass	DDT, Thiodan	San Joaquin
1966	200	Black bass	Thiodan	San Joaquin
1966	5,500	Carp	DDT, Thiodan	San Joaquin
1966	1,000+	Carp	DDT, Thiodan	San Joaquin
1966	750	Carp	Socal #2	Stanislaus
1966	2,000	Carp	Thiodan	San Joaquin
1966	25	Carp	Unknown	San Joaquin
1966	25	Catfish	Socal #2	Stanislaus
1966	200	Catfish	Thiodan	San Joaquin
1966	30	Catfish	Unknown	San Joaquin
1966	25	Crappie	Socal #2	Stanislaus
1966	1,325	Goldfish	Thiodan, Dieldrin	Merced
1966	3	Steelhead	DDT, Thiodan	San Joaquin
1966	3	Steelhead	DDT, Thiodan	San Joaquin
1966	300	Sunfish	Unknown	San Joaquin
1966	250	White catfish	Thiodan	San Joaquin
1967	90	Brown trout	Rotenone	Amador
1967	3	Carp	DDT, Toxaphene	Fresno
1967	1,000+	Carp	Herbicide (for moss)	San Joaquin
1967	2	Striped bass	Dinitro	Merced
1967	5,000	Threadfin shad	Herbicide (for moss)	San Joaquin
1967	1	White catfish	Dinitro	Merced
1968	250+	Bluegill	Pesticide	Fresno
1968	75+	Largemouth bass	Pesticide	Fresno
1968	25+	Shad	Herbicide	Fresno-Merced
1968	25+	Smallmouth bass	Pesticide	Fresno
1968	1,000+	Striped bass	Herbicide	Fresno-Merced
1968	75+	Striped bass	Unknown	Fresno-Merced
1969	250	Bluegill	Thiodan	San Joaquin
1969	1,000+	Bluegill	Thiodan	San Joaquin
1969	25	Bluegill	Thiodan	San Joaquin
1969	1,000+	Carp	Thiodan	San Joaquin
1969	250	Catfish	Thiodan	San Joaquin

Table 54. Fish Kills by Pesticides in the San Joaquin Basin, 1965-1996.

Year	No. of Fish Killed	Fish Species Killed	Responsible Pesticide	County
1969	25	Catfish	Thiodan	San Joaquin
1969	75	Crappie	Thiodan	San Joaquin
1969	750	Perch	Thiodan	San Joaquin
1969	250	Sacramento pike	Thiodan	San Joaquin
1969	25	Striped bass	Thiodan	San Joaquin
1970	3	Bluegill	Unknown pesticide	Fresno
1970	1,000+	Channel catfish	Thiodan, sulfa dust	Merced
1971	NR	-	-	-
1972	500	Black bass	Guthion	San Joaquin
1972	500	Bluegill	Guthion	San Joaquin
1972	500	Carp	Guthion	San Joaquin
1972	500	Catfish	Guthion	San Joaquin
1972	500	Crappie	Guthion	San Joaquin
1973	NR	-	-	-
1974	NR	-	-	-
1975	NR	-	-	-
1976	1,000	Carp	Unknown (field dusting)	San Joaquin
1976	1,000	Squawfish	Unknown (field dusting)	San Joaquin
1977	1-50	Bluegill	Copper sulfate	Amador-Calaveras
1977	101-500	Carp	Copper sulfate	Amador-Calaveras
1977	1-50	Squawfish	Copper sulfate	Amador-Calaveras
1977	101-500	Trout	Copper sulfate	Amador-Calaveras
1977	101-500	Trout	Copper sulfate	Amador
1978	1,000+	Carp	Unknown	San Joaquin
1979	1-50	Bluegill	Unknown	San Joaquin
1979	101-500	Bluegill	Unknown	Fresno
1979	51-100	Carp	Magnacide H (acrolein)	Madera
1979	501-1,000	Carp	Unknown	San Joaquin
1979	51-100	Crappie	Unknown	Fresno
1979	1-50	Largemouth bass	Unknown	San Joaquin
1979	51-100	Largemouth bass	Unknown	Fresno
1979	501-1,000	Mississippi silverside	Unknown	San Joaquin
1979	501-1,000	Oriental goby	Unknown	San Joaquin
1979	501-1,000	Rainbow trout	Copper sulfate	Tuolumne
1979	100,000	White catfish	Unknown	San Joaquin
1980	101-500	Bluegill	Thiodan	San Joaquin
1980	101-500	Catfish	Thiodan	San Joaquin
1981	NR	-	-	-
1982	2,000	Bluegill	Thiodan	Fresno
1982	10,000	Carp	Thiodan	Fresno
1982	6,000	Catfish	Thiodan	Fresno
1982	1,000	Crappie	Thiodan	Fresno
1982	50,000	Goldfish	Thiodan	Fresno
1982	500	Largemouth bass	Thiodan	Fresno
1982	5,000	Shad	Thiodan	Fresno
1982	<1,000	Shiners	Toxaphene	El Dorado

Table 54. Fish Kills by Pesticides in the San Joaquin Basin, 1965-1996.

Year	No. of Fish Killed	Fish Species Killed	Responsible Pesticide	County
1982	100	Striped bass	Thiodan	Fresno
1982	1,000+	Suckers	Toxaphene	El Dorado
1982	1,000+	Trout	Toxaphene	El Dorado
1983	50	Black bass	Magnacide H (acrolein)	San Joaquin
1983	100	Bullhead	Magnacide H (acrolein)	San Joaquin
1983	200	Carp	Magnacide H (acrolein)	San Joaquin
1983	50	Catfish	Magnacide H (acrolein)	San Joaquin
1983	<100	Perch	Magnacide H (acrolein)	San Joaquin
1984	500	Bluegill	Magnacide H (acrolein)	Fresno
1984	200	Goldfish-Carp	Magnacide H (acrolein)	Fresno
1984	50	Largemouth bass	Magnacide H (acrolein)	Fresno
1984	100	Sucker	Magnacide H (acrolein)	Fresno
1984	200	White catfish	Magnacide H (acrolein)	Fresno
1987	30	Black bass	Unknown pesticide	Merced
1987	80	Bluegill & Crappie	Unknown pesticide	Merced
1987	10	Carp	Thiodan, Phosdrin	Fresno
1987	20	Carp	Unknown pesticide	Merced
1987	350	Catfish	Thiodan, Phosdrin	Fresno
1987	6	Catfish	Unknown pesticide	Merced
1987	400	Threadfin shad	Thiodan, Phosdrin	Fresno
1988	NR	-	-	-
1989	many	Bass/Bluegill/Gambusia	Unknown insecticide	Fresno
1990	NR	-	-	-
1991	4,000	Crayfish	Carbofuran	San Joaquin
1991	3,000	Fish	Carbofuran	San Joaquin
1992	NR	-	-	-
1993	NR	-	-	-
1994	NR	-	-	-
1995	16	Brown trout	Copper	Amador

NR = None Reported

Table 55. Pesticides in Fish (µg/Kg wet weight) from the San Joaquin Basin, 1978-1993.[1]

STATION	Aldrin		Total Chlordane		Chlorpyrifos		Dacthal		Total DDT	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Huntington Lake/Rancherio Creek	nd	nd	nd	nd	nd	nd	nd	nd	12	12
Kesterson N.W.R./Pond 2	nd	nd	nd	nd	nd	nd	nd	nd	29	29
Kesterson N.W.R./Pond 5	nd	nd	nd	nd	nd	nd	nd	nd	23	23
Mendota Pool	nd	nd	nd	nd	nd	nd	nd	nd	120	233
Merced River/East Side Drain	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Merced River/Hagaman County Park	nd	nd	7	30.2	nd	nd	nd	nd	49	1,077
Merced River/Hatfield St Recreation Area	nd	nd	47.4	47.4	nd	nd	nd	nd	52	698
Merced River/McConnell State Park	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Mud Slough	nd	nd	nd	nd	nd	nd	nd	nd	146	146
O'Neill Forebay/California Aqueduct	nd	nd	7	23	nd	nd	7	7	110	289
Salt Slough	nd	nd	5.7	5.7	11	11	11	11	296	665
San Joaquin River/Fremont Ford	nd	nd	nd	nd	nd	nd	nd	nd	398	398
San Joaquin River/Highway 152 Bridge	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
San Joaquin River/Mossdale	nd	nd	nd	nd	nd	nd	nd	nd	100	140
San Joaquin River/Newman	nd	nd	nd	nd	34	34	nd	nd	379	379
San Joaquin River/Orestimba Cr/Bell Road	nd	nd	nd	nd	nd	nd	nd	nd	14	14
San Joaquin River/Orestimba Creek	nd	nd	14.3	14.3	nd	nd	79	79	7,267	7,267
San Joaquin River/Skaggs Road	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
San Joaquin River/Vernalis	nd	nd	21	540	84	84	10	14	5.1	5,180
Stanislaus River	nd	nd	21	227.2	nd	nd	10	14	40	4,149
Tuolumne River/Modesto	nd	nd	nd	nd	nd	nd	nd	nd	10	10
Tuolumne River/San Joaquin River	nd	nd	7	102.8	nd	nd	nd	nd	9	2,570

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Table 55. Pesticides in Fish (µg/Kg wet weight) from the San Joaquin Basin, 1978-1993.[1]

STATION	Dicofol		DBP		Dieldrin		Total Endosulfan		Total HCH	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Huntington Lake/Rancherio Creek	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Kesterson N.W.R./Pond 2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Kesterson N.W.R./Pond 5	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Mendota Pool	nd	nd	nd	nd	nd	nd	120	120	nd	nd
Merced River/East Side Drain	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Merced River/Hagaman County Park	nd	nd	nd	nd	6	13	nd	nd	nd	nd
Merced River/Hatfield St Recreation Area	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Merced River/McConnell State Park	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Mud Slough	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
O'Neill Forebay/California Aqueduct	nd	nd	nd	nd	5	7	nd	nd	2	3
Salt Slough	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
San Joaquin River/Fremont Ford	nd	nd	nd	nd	12	12	nd	nd	nd	nd
San Joaquin River/Highway 152 Bridge	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
San Joaquin River/Mossdale	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
San Joaquin River/Newman	nd	nd	nd	nd	6.7	6.7	nd	nd	nd	nd
San Joaquin River/Orestimba Cr/Bell Road	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
San Joaquin River/Orestimba Creek	nd	nd	nd	nd	39	39	42	42	nd	nd
San Joaquin River/Skaggs Road	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
San Joaquin River/Vernalis	480	480	79	180	5	53	8	596	2.1	3
Stanislaus River	160	160	nd	nd	12	24	10	25	20	20
Tuolumne River/Modesto	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Tuolumne River/San Joaquin River	200	200	36	36	6	13	300	300	nd	nd

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Table 55. Pesticides in Fish (µg/Kg wet weight) from the San Joaquin Basin, 1978-1993.[1]

STATION	Heptachlor epoxide		Hexachlorobenzene		Methyl parathion		Total PCB		Toxaphene	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Huntington Lake/Rancherio Creek	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Kesterson N.W.R./Pond 2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Kesterson N.W.R./Pond 5	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Mendota Pool	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Merced River/East Side Drain	nd	nd	nd	nd	nd	nd	nd	nd	100	100
Merced River/Hagaman County Park	nd	nd	2.6	2.6	nd	nd	nd	nd	100	1,040
Merced River/Hatfield St Recreation Area	nd	nd	nd	nd	nd	nd	nd	nd	780	780
Merced River/McConnell State Park	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Mud Slough	nd	nd	nd	nd	nd	nd	nd	nd	400	400
O'Neill Forebay/California Aqueduct	nd	nd	nd	nd	nd	nd	130	233	nd	nd
Salt Slough	nd	nd	nd	nd	nd	nd	nd	nd	130	500
San Joaquin River/Fremont Ford	nd	nd	nd	nd	nd	nd	nd	nd	200	200
San Joaquin River/Highway 152 Bridge	nd	nd	nd	nd	nd	nd	nd	nd	100	100
San Joaquin River/Mossdale	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
San Joaquin River/Newman	nd	nd	nd	nd	nd	nd	nd	nd	180	180
San Joaquin River/Orestimba Cr/Bell Road	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
San Joaquin River/Orestimba Creek	nd	nd	3.2	3.2	nd	nd	nd	nd	940	940
San Joaquin River/Skaggs Road	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
San Joaquin River/Vernalis	5.5	11	2	7.5	nd	nd	50	314	190	14,000
Stanislaus River	nd	nd	2.2	3.7	nd	nd	50	470	270	2,800
Tuolumne River/Modesto	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Tuolumne River/San Joaquin River	nd	nd	2.1	2.7	nd	nd	55	234	380	2,300

1 SWRCB data from file TSMLOTUS.ZIP

PCBs (50 - 470 µg/kg), and dieldrin (5 - 53 µg/kg), which are no longer registered for general use. The concentrations of the most frequently detected pesticides were plotted against time and the graphs visually inspected to determine if there were any trends in the data. Generally, the concentrations of dieldrin, PCBs, DDT, and chlordane appear to have increased since 1978, while toxaphene appears to have peaked in the mid 1980s and declined since then.

Other compounds that were detected include chlorpyrifos (in three samples), dacthal (in eight samples), dicofol (in four samples), DBP (in three samples), endosulfan (in 18 samples), HCH, heptachlor epoxide, and hexachlorobenzene. Hexachlorobenzene and HCH are no longer registered for use in California.

The biological significance of these concentrations is uncertain. Although fish may survive relatively high residue concentrations in their body fats, residues concentrated in the eggs of mature fish may be lethal to developing fry. It is well known that organochlorine pesticides accumulate in eggs and that up to 100 percent loss of fry occur when eggs contain significant quantities.[283] As discussed in Section 2.1.3.2, many of these organochlorine compounds are weakly estrogenic, and synergistic interactions of combinations of them may adversely affect reproduction in exposed organisms.

However, many samples collected in the basin exceeded levels established by the NAS to protect predators and the U.S. Food and Drug Administration ("FDA") to protect public health. Almost every year since 1978, DDT was found at Vernalis at levels that exceed the NAS criterion of 1,000 µg/kg. DDT has also exceeded the FDA action level of 5,000 µg/kg on the San Joaquin River at Vernalis and at Orestimba Creek. As discussed in Section 2.1.3.2, these DDT concentrations are high enough (>0.21 µg/kg wet weight) that mothers who frequently consume the fish could have breast milk DDT concentrations high enough to expose infants to unsafe levels. DDT has been banned since 1972. Toxaphene exceeded the NAS criterion of 100 µg/kg in 80 percent of the samples, including many from Salt Slough and the Merced, Stanislaus, and Tuolumne Rivers and in 84 percent of the samples collected from the San Joaquin River at Vernalis. Toxaphene was banned in California in 1986, but was formerly widely used as a pesticide and to remove parasites on livestock. Chlordane, formerly widely used in urban areas to control ants and termites, exceeded the NAS criterion of 100 µg/kg in the one sample from the Tuolumne River, two from the Stanislaus River, and six from the San Joaquin River at Vernalis. Two samples from Vernalis also exceeded the FDA action level of 300 µg/kg. Endosulfan also periodically exceeded the NAS criterion of 100 µg/kg in the Mendota Pool, at Vernalis, and on the Tuolumne River (Table 10). The use of endosulfan has been restricted by DPR since 1992.

4.1.3.3 USFWS 1981 Study

In July 1981, the USFWS collected bluegills (Lepomis macrochirus) and common carp (Cyprinus carpio) from eight sites in the San Joaquin Basin -- five on the San Joaquin River, two

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[283] NAS, 1973, p. 184.

on the Merced River, and one on Salt Slough -- and analyzed them for 21 organochlorine pesticides. Residues of p,p'-DDE were detected in all samples of both species (0.013 - 1.9 mg/kg). Parenthetical data are whole-body, wet-weight concentrations. Six other compounds were also present in both species at one or more of the collection sites: chlordane (0.002 - 0.27 mg/kg), p,p'-DDD (0 - 0.35 mg/kg), o,p'-DDT (0 - 0.002 mg/kg), p,p'-DDT (0 - 0.092 mg/kg), dacthal (0 - 0.54 mg/kg), and dieldrin (0 - 0.067). Concentrations of most of these compounds were generally higher in carp than in bluegills. Some compounds were found only in carp, including α-BHC (0 - 0.003 mg/kg), Aroclor 1260 (0 - 0.013 mg/kg), and toxaphene (0 - 3.12 mg/kg). Concentrations of most of these compounds increased from upstream to downstream. In carp, concentrations of two compounds, total DDT (1.43 to 2.21 mg/kg) and toxaphene (3.12 mg/kg), exceeded concentrations recommended by NAS to protect predators.[284] These results are generally consistent with the SWRCB Toxic Substances Monitoring Program.

4.1.3.4 USFWS National Pesticide Monitoring Program

The USFWS National Pesticide Monitoring Program has periodically monitored organochlorine pesticides in fish from up to 112 stations in major drainages throughout the United States since the mid-1960s. Two of these stations are located in California -- the Sacramento River at Sacramento (Station 39) and the San Joaquin River at Los Banos (Station 40). The results of these studies have been reported in a number of journal articles (Sec. 2.1.3.3). The fish commonly caught at the San Joaquin station include black crappie, carp, white catfish, Sacramento blackfish, and channel catfish. The most commonly detected compounds were DDE, DDD, DDT, PCBs, and dieldrin.

4.1.3.5 USGS Corbicula Studies

In October 1992, Corbicula fluminea were collected from four sites in the San Joaquin Basin, Orestimba Creek, Dry Creek, Mokelumne River (in the Delta), and the Stanislaus River and analyzed for select pesticides, including organochlorine pesticides, organophosphorus insecticides, and triazine herbicides, among others. The data were summarized in Table 37.

Pesticides detected in the clams include DDE (13-3300 µg/kg), DDD (<0.5-390 µg/kg), DDT (1.0-660 µg/kg), gamma-chlordane (1.7-9.2 µg/kg), alpha-chlordane (1.7-7.5 µg/kg), trans-nonachlor (7.7-13 µg/kg), cis-nonachlor (6.9-9.9 µg/kg), dacthal (<0.5-150 µg/kg), dicofol (<0.5-97 µg/kg), chlorpyrifos (<0.5-7.2 µg/kg), and trifluralin (<0.5-20 µg/kg). All concentrations are wet weight.

The distributions of pesticides in the clams were similar to those in bed and suspended sediment discussed in Section 4.1.2. The highest concentrations of pesticides were present in

[284] Michael K. Saiki and Christopher J. Schmitt, Organochlorine Chemical Residues in Bluegills and Common Carp from the Irrigated San Joaquin Valley Floor, California, Archives of Environmental Contamination and Toxicology, v. 15, 1986, pp. 357-366.

clams from Orestimba Creek. Concentrations of DDT in clams from Orestimba Creek were greater than those in sediment by more than an order of magnitude, indicating efficient bioaccumulation and poor elimination. Concentrations of DDE were greater than DDT or DDD, indicating that uptake of these compounds was primarily from the bed and suspended sediment (Sec. 4.1.2.1). Except for Dry Creek, concentrations of chlordane in clams were generally greater than concentrations in bed and suspended sediment. Bioconcentration factors for Orestimba Creek were 5.52 for DDT, 5.05 for DDD, 5.24 for DDE, and 2.10 for dacthal.[285]

This work was extended in a subsequent study that collected Corbicula from 18 sites on or near the San Joaquin Valley floor and fish and crayfish from a smaller number of sites in October and November 1992. Samples were analyzed for 30 organochlorine compounds. The data are summarized in Table 53.

Among the 30 compounds that were analyzed, 10 were detected in tissues, including dacthal (<5-360 μg/kg), op'-DDD (<1-20 μg/kg), pp'-DDD (<1-100 μg/kg), op'-DDE (<1-22 μg/kg), pp'-DDE (<1-1,600 μg/kg), op'-DDT (<5-36 μg/kg), pp'-DDT (<5-580 μg/kg), dieldrin (<5-9.8 μg/kg), toxaphene (<100-2,000 μg/kg), and PCBs (<50-57 μg/kg). Tissue concentrations are wet weight. While concentrations of organochlorine compounds appear to have declined since the 1970s when many of these compounds were banned, concentrations, particularly of DDT compounds, remain high relative to national values in both tissues and sediments (Sec. 4.1.2.1).

The most frequently detected compound was pp'-DDE. Concentrations of total DDT were highest in biota collected from west-side sites. The frequency of occurrence for compounds found in tissue and sediment (Sec. 4.1.2) are similar. Concentrations of total DDT and toxaphene in tissues exceeded NAS levels set to protect fish-eating wildlife in several samples, consistent with the SWRCB Toxic Substances Monitoring Program (Sec. 4.1.3.1). TOC normalized sediment data accounted for 67 percent of the variability in total DDT concentrations in tissue samples. Concentrations of total DDT in tissues were also significantly correlated with specific conductance (r^2=0.66, p<0.01), pH (r^2=58, p<0.01), and total alkalinity (r^2=0.31, p<0.05).[286]

4.1.3.6 USGS Endocrine Disruption Study

A reconnaissance study of sex steroid hormones and other biomarkers in common carp was conducted by the USGS in 1994 to determine whether endocrine disruption may be occurring in fish in United States streams and to evaluate relations between endocrine disruption and contaminant levels. The endocrine system in animals consists of glands that produce hormones that enter the bloodstream to maintain physiological homeostasis. Previous studies have found correlations between specific impairments of reproductive activity and elevated tissue

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285 Pereira et al., 1996.

286 Brown, 1996.

concentrations of xenobiotics, including organochlorine pesticides, PCBs, dioxins, and phenols. Reproductive injuries reported to date include reduced fertility, hatchability, and viability of offspring; impaired reproductive hormone activity; altered sexual development and behavior including demasculinization and feminization; alteration of immune and behavioral function; and abnormal thyroid function and development. Slow growth, atrophy, and lower metabolic rates have also been reported. These types of abnormalities can be caused by disruption of normal endocrine function.[287]

Six hundred and forty-seven carp were sampled during the period of gonadal maturation after spawning between August 29 and December 14, 1994 from 25 sites throughout the United States. Three of the test sites were located in the San Joaquin Basin: (1) Don Pedro Reservoir on the Tuolumne River; (2) San Joaquin River at Fremont Ford; and (3) San Joaquin River at Mossdale. An attempt was made to collect 10 to 15 fish of each sex at each site. Plasma samples were analyzed for the sex steroid hormones 17ß-estradiol, 11-ketotestosterone and testosterone, and for vitellogenin, an estrogen-inducible phosphoprotein that is a precursor of egg yolk. Twenty-seven organochlorine pesticides and total PCBs were analyzed in 25 tissue samples. Composite bed sediment samples were collected during 1992 to 1995 at 22 sites and analyzed for 52 PAHs, six phenols, six phthalates, and organic carbon. The sediment data are discussed in Section 4.1.2.1. At 11 sites, 7 to 34 filtered water samples were collected during 1993 to 1994 and analyzed for 52 pesticides including amides, carbamates, dinitroanilines, organochlorines, organophosphates, pyrethroids, triazine herbicides, and uracils.

The USGS concluded that "fish in some streams within all regions studied may be experiencing some degree of endocrine disruption." Mean site concentrations of steroid hormones spanned two orders of magnitude for both sexes. Most correlation coefficients between biomarkers and contaminants were negative. Contaminants that had significant correlations (α=0.05) with biomarkers were organochlorine pesticides, phenols, and dissolved pesticides. The strongest pattern common to both males and females was a negative correlation between the ratio of 17ß-estradiol to 11-ketotestosterone and dissolved pesticides.

Concentrations of biomarkers and organochlorine pesticides in tissues at sites in the San Joaquin Basin were within the range of those reported at other sites, except the highest mean vitellogenin in female carp was reported for the San Joaquin River at Mossdale. For San Joaquin Basin stations, no organochlorine pesticides were detected in Asiatic clams from Don Pedro Reservoir and no PCBs were detected in tissues from any site in the San Joaquin Basin. Dissolved pesticide concentrations (0.38 to 0.81 µg/L) were also at the lower end of the range among sites tested.[288]

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[287] U.S. EPA, Special Report on Environmental Endocrine Disruption: An Effects Assessment and Analysis, Report EPA/630/R-96/012, February 1997.

[288] Goodbred et al., 1997.

4.2 SOURCES

The toxicity and pesticides detected in major rivers originate from home and farm use of pesticides. The following sections explore potential sources, including agriculture (Sec. 4.2.1), urban runoff (Sec. 4.2.3), and precipitation (Sec. 4.2.2). Municipal effluents may also contribute to the toxicity, but were not reviewed in this work. The principal conclusions from the work reviewed below are as follows:

- Waters in agriculturally dominated creeks and constructed drains cause significant mortality to fathead minnows in about 18 percent of the samples. Subsurface drainwater is toxic to both chinook salmon and striped bass.

- Waters in agriculturally dominated creeks and constructed drains cause significant mortality to Ceriodaphnia in 33 to 38 percent of the samples and to Neomysis in about 21 percent of the samples. Waters from one drain were toxic 75 to 80 percent of the time. Most of the mortality is believed to be due to ammonia from dairies and organophosphorus and carbamate pesticides from agricultural runoff and irrigation return flows.

- Elevated concentrations of organophosphorus insecticides are present in precipitation and urban runoff. Detected concentrations exceed levels that are toxic to organisms at the base of the foodchain, primarily invertebrates.

4.2.1 Agriculture

Irrigated agriculture is currently the most prevalent land use in the San Joaquin Basin. In 1990, 428 different pesticides with a combined active ingredient weight of about 28 million pounds[289] were applied to a wide variety of crops including grapes, stone fruit, field crops, truck crops, and some rice. In most counties in the San Joaquin Basin, 815 to 4,300 pounds of pesticides are applied per square mile annually.[290] Unlike the Sacramento Basin, no single crop dominates. The west side of the San Joaquin River is dominated by a mix of field, vegetable and orchard crops grown primarily for human consumption, including beans, tomatoes, melons, apricots, almonds, and walnuts. The east side is dominated by field crops grown primarily to support the large local dairy industry -- corn, oats, alfalfa, and pasture -- and orchard crops, principally almonds, peaches, and walnuts.

Agricultural drainage consists of both surface runoff and subsurface discharges. Surface runoff is discharged directly into the lower reaches of eastside streams, the westside streams, and

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[289] DPR, Monthly Pesticide Use Report by County, 1990.

[290] Brown and Caldwell, October 1990, Figure 4-16.

into the San Joaquin River from the east and west. Subsurface drainage consists of water collected by a network of shallow tile drains designed to intercept and transport percolating water. Subsurface drainage is common on the west side of the San Joaquin River where near surface clays have restricted percolation and caused high water table conditions.[291] During the irrigation season, typically April to October, 40 to 45 percent of the flow of the San Joaquin River may be surface and subsurface agricultural drainage.

Toxicity and pesticide concentrations in agriculturally derived waters -- drainage and runoff -- have been monitored in four major studies between 1987 and 1993 conducted by the CVRWQCB, DPR, DFG, and USGS.

4.2.1.1 CVRWQCB 1988-90 Bioassay Study

The CVRWQCB monitored fathead minnow, Ceriodaphnia, and Selenastrum toxicity in five typical agricultural drains from 1988 to 1990 -- Salt Slough, Los Banos Creek, Turlock Irrigation District Lateral No. 5 ("TID5"), Orestimba Creek, and New Jerusalem drain.[292] Salt Slough is the principal conveyance of agricultural tail and tile drain water from western Merced and Fresno counties. Los Banos Creek carries a combination of irrigation district operational spill water and tailwater from Merced County. TID5 carries a combination of TID operational spill water, tailwater from row and orchard crops, runoff from dairies, and wastewater from the City of Turlock Wastewater Treatment Plant. Orestimba Creek carries a combination of Central California Irrigation District operational spill water and tailwater from row and orchard crops in western Stanislaus County. New Jerusalem drain carries predominately subsurface tile drain water from western San Joaquin County.

The results of the fathead minnow and Ceriodaphnia mortality tests were summarized in Tables 41 and 42, respectively. Significant mortality to Ceriodaphnia was observed in all of the agriculturally derived waters, and 38 percent of the samples were toxic. Seventy-five percent of the samples from TID5 were toxic, possibly due to high ammonia and low dissolved oxygen concentrations. Ceriodaphnia toxicity was attributed to organophosphorus and carbamate insecticides from runoff from orchard and row crops (Table 56).[293,294] Significant mortality to

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[291] Brown and Caldwell, October 1990, pp. 4-59 to 4-60.

[292] Foe and Connor, July 1991b, p. 4.

[293] Ibid., p. 17-19.

[294] Christopher Foe, Detection of Pesticides in the New Jerusalem Drain, San Joaquin County, California, on 28 September, 1988, CVRWQCB memorandum to Dennis W. Westcot and Rudy J. Schnagl, January 17, 1989; Christopher Foe, Second Instance of the Detection of Pesticides in New Jerusalem Drain, San Joaquin County, California, CVRWQCB memorandum to Dennis W. Westcot and Rudy J. Schnagl, April 26, 1989; Foe, June 25, 1990a; and Foe, June 25, 1990b.

Table 56. Pesticides in Agricultural Drains in the San Joaquin Basin.

Date	Site	Pesticide	Concentration (µg/L)
9/28/88	New Jerusalem Drain[1]	Methomyl	17.4
		Carbaryl	0.95
		Heptachlor epoxide	0.07
		Endosulfan I	1.6
		Endosulfan II	0.7
		Mevinphos	0.3
		Diazinon	1.0
		Dimethoate	7.7
		Methidathion	0.4
		Methyl parathion	0.4
		Ethyl parathion	0.9
		Methamidophos	1.4
3/6/89	New Jerusalem Drain[2]	Chlorpyrifos	1,470
		Mevinphos	290
		Carbaryl	60
		Copper	9,860
		Arsenic	57
2/8/90	Orestimba Creek[3]	Diazinon	1.59
		Parathion	1.83
		Diuron	1.29
2/21/90	Orestimba Creek[3]	Diazinon	0.28
		Parathion	0.25
		Diuron	2.34
3/27/90	TID 5[4]	Dimethoate	1.3

1 Foe, January 17, 1989, Table 2.
2 Foe, April 26, 1989, Table 1.
3 Foe, June 25, 1990a, Table 3.
4 Foe, June 25, 1990b, Table 1.

fathead minnows was observed in 18 percent of the samples in three of the five drains -- TID5, Los Banos Creek, and New Jerusalem drain. The toxicity at the first two sites was attributed to ammonia and at the latter to pesticides.[295] The concentrations of diazinon, ethyl parathion, chlorpyrifos, and carbaryl exceeded EPA criteria to protect freshwater aquatic life.[296]

4.2.1.2 DPR 1991-93 Bioassay Study

A 2-year followup study was conducted by the DPR in collaboration with the DFG. Ceriodaphnia and Neomysis toxicity were monitored at up to nine sites that predominantly carried agricultural drainage (indicated by a + in Table 45). Significant mortality to one or both of the test organisms was observed at all of these sites except Salt Slough. Significant mortality to Ceriodaphnia was found in 33 percent of the samples and to Neomysis in 21 percent of the samples. Eighty percent of the samples from TID5 caused significant mortality, possibly due to low dissolved oxygen and high ammonia concentrations. Although pesticide concentrations were high enough in six out of 35 toxic samples to explain the majority of the observed mortality (indicated by an asterisk on Table 45), most remains unexplained.

4.2.1.3 CVRWQCB 1991-92 Bioassay Study

In a followup study in 1991-92, the CVRWQCB monitored Ceriodaphnia toxicity in eight agricultural drains. TID Lateral Nos. 6, 5 and 3 were sampled as representative of eastside agricultural drains while Orestimba, Del Puerto, and Ingram-Hospital Creeks, Salt Slough, and the Spanish Grant Combined Drain were monitored as representative of westside agriculturally dominated creeks and constructed drains.

Significant toxicity was observed at all of these sites during all months except August and November (Table 46). Significant mortality to Ceriodaphnia was observed in 35 percent of the samples, compared with 33 percent in the DPR bioassay study and 38 percent in the 1988-90 CVRWQCB bioassay study. No statistically significant differences were detected in the frequency of toxicity among years and location (eastside versus westside), but toxicity was greater during the first six months of the year. Most of the Ceriodaphnia mortality was restricted to two time periods -- January to March and April to June. In the January-March period, 52 percent of the samples were toxic and in the April-June period, 38 percent were toxic, compared to 8 percent in July-September and 19 percent in October-December. The January-March period is the rainy season and toxicity was attributed to off-target movement of insecticides from orchards, alfalfa, sugarbeets and truck farming. The April-June period is the irrigation season and most of the water in agriculturally-dominated creeks and constructed drains is irrigation return flows. Toxicity during this period was attributed to tailwater from row and orchard crops.

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[295] Foe and Connor, July 1991, p. 12-13.

[296] Foe and Connor, July 1991, Table 7.

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Five insecticides -- diazinon, chlorpyrifos, fonofos, carbaryl, and parathion -- appear responsible for most of the toxicity. Parathion is no longer registered for use in California. Ammonia also significantly contributed to the toxicity of samples from TID5 and TID6, consistent with the 1988-90 CVRWQCB and DPR bioassay studies. Chlorpyrifos was detected with equal frequency in drains from both sides of the valley. It is a wide spectrum insecticide used on walnuts, almonds, apples and corn, among other crops. Diazinon was detected 97 percent of the time in westside samples compared with only 23 percent in eastside samples. Diazinon is used on almonds, melons, tomatoes, peaches, apricots, and walnuts. Fonofos was only detected in samples from the westside. It is broadcast and incorporated into the soil by tillage prior to planting and is used on beans and tomatoes. Carbaryl was only detected in samples from the westside. It is a foliar spray that is used on almonds, beans, corn, grapes, peaches, and tomatoes.[297]

4.2.1.4 USGS Sediment Study

The USGS measured the DDD, DDE, DDT, and dieldrin concentrations in unfiltered water from Orestimba Creek in July, August, and September of 1987. Although these pesticides have not been registered for use since the 1970s, both DDE and DDT were detected. The concentration of DDE (0.04 - 0.10 μg/L) and DDT (0.03-0.09 μg/L)[298] exceeded the U.S. EPA 24-hour water quality criterion (0.001 μg/L) by factors of 30 to 100.

4.2.1.5 USFWS Bioassay

The U.S. Fish and Wildlife Service ("USFWS") exposed juvenile chinook salmon and striped bass to serial dilutions (100, 50, 25, and 12.5 percent) of agricultural subsurface drainwater, reconstituted drainwater, and reconstituted seawater in 28-day static renewal bioassays. Trace elements were analyzed in waters (B, Cr, Cu, Mo, Se) and fish (B, Mo, Se). The tile drainwater was collected from sump 20 at the Westlands Water District.

Survival of chinook salmon was significantly reduced by exposure to 100 percent drainwater, but not to diluted drainwater or other water types. Dilution water was collected from the San Joaquin River at Crows Landing Road. After 28 days of exposure, mortality was 77 percent in 100 percent drainwater compared to 0 percent in all other dilutions. Deaths first occurred on day 19 and progressed at a rate of about 1.6 fish per day through the end of the 28-day test. The salmon ate food only during the first eight days and thereafter, they mouthed the food and spit it out. All of the salmon developed a blackish tinge. Lengths and weights of chinook salmon were significantly lower after 14 days and 28 days of exposure to drainwater and after 28 days of exposure to reconstituted drainwater but not seawater. Growth generally increased with dilution by San Joaquin River water.

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297 Foe, December 1995.

298 Gilliom and Clifton, 1990, Table 5.

Survival of striped bass was significantly reduced by exposure to 100 percent drainwater and reconstituted drainwater but not reconstituted seawater. Although not statistically significant, dilution responses were evident. Dilution water was collected in the Delta at the Tracy Fish Collection Facility. All of the striped bass exposed to 100 percent drainwater died by day 23.

The drainwater contained elevated concentrations of sodium (3,600 - 4,900 mg/L), sulfate (7,400 - 10,000 mg/L), chloride (970 - 1,100 mg/L), calcium (440 mg/L), magnesium (120-140 mg/L), boron (48.8 - 49.3 mg/L), molybdenum (663 - 766 µg/L), and selenium (158-218 µg/L) and lower concentrations of chromium (24 - 25 µg/L) and copper (4.0 - 4.3 µg/L). Chinook salmon and striped bass exposed to 100 percent drainwater accumulated high concentrations of boron (190 - 200 µg/g), but relatively little molybdenum (<0.30 - 0.67 µg/g) or selenium (2.0 - 2.1 µg/g). Parenthetical data are whole-body, dry-weight concentrations.

The authors concluded that drainwater was toxic to chinook salmon and striped bass, primarily due to high concentrations of major ions present in atypical ratios, to high concentrations of sulfate, or to both. High concentrations of boron and selenium also may have contributed to the toxicity.[299] However, major ions were probably not a factor for chinook salmon since no toxicity was observed in reconstituted drainwater, in which concentrations of major ions were the same as actual drainwater. Likewise, metals were probably not a factor for striped bass because the toxicity of actual drainwater and reconstituted drainwater (which contained no metals) were about the same. This study did not consider pesticides, which could have contributed to the toxicity.

4.2.2 Precipitation

Pesticides were measured in precipitation and dry deposition at three sites in the Fresno area between October 1981 and April 1983. The data are summarized in Table 57.[300] The organophosphorus pesticides parathion, malathion, and diazinon were most frequently detected in rainfall. Diazinon and parathion were present at the highest concentrations in rainfall and also were detected in dry deposition. These two insecticides are used in the San Joaquin Valley primarily as dormant sprays on fruit trees, and the most common application method is a high-volume, truck-mounted sprayer that tends to suspend large quantities of spray into the air. Some

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[299] Michael K. Saiki, Mark R. Jennings, and Raymond H. Wiedmeyer, Toxicity of Agricultural Subsurface Drainwater from the San Joaquin Valley, California, to Juvenile Chinook Salmon and Striped Bass, Transactions of the American Fisheries Society, v. 121, 1992, pp. 78-93.

[300] Richard N. Oltmann and Michael V. Shulters, Rainfall and Runoff Quantity and Quality Characteristics of Four Urban Land-Use Catchments in Fresno, California, October 1981 to April 1983, U.S. Geological Survey Open-File Report 84-710, 1987, Tables 6-8 and 26-27.

Table 57. Pesticides in Rainfall and Dry Deposition in the Fresno Area, October 1981-April 1983.

COMPOUND	RAINFALL[1]				DRY DEPOSITION[2]		
	Number of Samples	Detection Status	Mean (µg/L)	Range (µg/L)	Number of Samples	Detection Status	Range (µg/Kg)
Organochlorine compounds							
Aldrin	50	ND		< 0.01	2	ND	
Chlordane	50	D	0.12	< 0.10 - 0.40	2	D	270 - 610
DDD	50	ND		< 0.01	2	ND	
DDE	50	D	0.01	< 0.01 - 0.02	2	D	13 - 30
DDT	50	ND		< 0.01	2	ND	
Dieldrin	50	D	0.01	< 0.01 - 0.02	2	ND	
Endosulfan	50	D	0.02	< 0.01 - 0.08	2	ND	
Endrin	50	ND		< 0.01	2	ND	
Heptachlor	50	ND		< 0.01	2	ND	
Heptachlor epoxide	50	ND		< 0.01	2	ND	
Lindane	50	D	0.01	< 0.01 - 0.04	2	D	13 - 30
Methoxychlor	50	D	0.01	< 0.01 - 0.12	2	D	30
Mirex	50	ND		< 0.01	2	ND	
Perthane	50	ND		< 0.1	2	ND	
Toxaphene	50	ND		< 1	2	ND	
Organophosphorous compounds							
Diazinon	54	D	0.15	0.01 - 0.93	2	D	120 - 180
Ethion	54	D*		< 0.01	2	ND	
Malathion	54	D	0.03	< 0.01 - 0.11	2	D	200 - 850
Methyl parathion	54	D*	0.01	< 0.01 - 0.01	2	ND	
Methyl trithion	54	ND		< 0.01	2	ND	
Parathion	54	D	0.24	< 0.01 - 1.0	2	ND	
Trithion	54	ND		< 0.01	2	ND	
Carbamate Insecticides							
Methomyl	10	ND		< 2			
Propham	10	ND		< 2			
Sevin	10	ND		< 2			
Chlorphenoxy acid herbicides							
2,4-D	44	D	0.02	< 0.01 - 0.08	2	ND	
2,4-DP	44	ND		< 0.01	2	ND	
2,4,5-T	44	ND		< 0.01	2	ND	
Silvex	44	ND		< 0.01	2	ND	

* Detected for only one sample.
1 Oltmann and Shulters, 1987, Tables 6-8.
2 Oltmann and Shulters, 1987, Tables 26-27.

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diazinon was detected in September, October and November, but parathion did not appear until late December and January.[301] Parathion is no longer registered for use in California.

Several organochlorine insecticides and the chlorophenoxy acid herbicide 2,4-D were also detected in rainfall, though not as frequently or in as large concentrations as parathion and diazinon. The organochlorine insecticides also were detected in dry deposition. These pesticides are applied primarily by aircraft in the San Joaquin Valley.[302]

Pesticides were subsequently measured in fog water collected at three sites in the San Joaquin Valley in 1985[303] and at one site in 1986.[304] The results of these measurements are summarized in Table 58. The organophosphorus insecticides (diazinon, parathion, chlorpyrifos, methidathion, malathion, methyl parathion) and their oxygen analogues (oxons) were the most numerous. Several classes of herbicides were also detected including s-triazines (atrazine, simazine), dinitroaniline (pendimethalin), and chloracetanilides (alachlor, metolachlor). The concentrations were two orders of magnitude higher than normally found in rain and significantly more vapor was present in fog water than would dissolve in an ideal solution at equilibrium.

Wet and dry deposition samples were collected during the 1992-93 winter dormant spray season and analyzed for organophosphates. Carbamate and endosulfan were also analyzed when sufficient sample was available. Samples were collected at three locations: Caswell State Park along the Stanislaus River, George Hatfield State Recreation Area along the Merced River, and McConnell State Recreation Area along the Merced River. The results of the measurements are summarized in Table 59. Diazinon was detected in most precipitation samples at concentrations ranging from 0.06 to 1.61 μg/L. Most concentrations exceed the DFG acute criterion of 0.08 μg/L and are high enough to be toxic to Ceriodaphnia. Chlorpyrifos and the diazinon oxygen analogue, diazinon oxon, were also detected in some samples. Carbamates and endosulfan were not detected in rain water.[305]

In 1995, the CVRWQCB measured the organophosphorus insecticide, diazinon, in precipitation at 14 sites between Red Bluff and Patterson on a single date (Table 30). Samples

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[301] Oltmann and Shulters, 1987, p. 116.

[302] Oltmann and Shulters, 1987, p. 120.

[303] D.E. Glotfelty, J.N. Seiber, and L.A. Liljedahl, Pesticides in Fog, Nature, v. 325, February 12, 1987, pp. 602-605.

[304] D.E. Glotfelty, M.S. Majewski, and J.N. Seiber, Distribution of Several Organophosphorus Insecticides and their Oxygen Analogues in a Foggy Atmosphere, Environmental Science and Technology, v. 24, 1990, pp. 353-357.

[305] Ross et al., May 1997.

Table 58. Pesticides in Fog Water in the San Joaquin Basin, 1985-1986.

COMPOUND	CONCENTRATION (ng/L)			
	Parlier[1] 1/13/85	Corcoran[1] 1/13/85	Lodi[1] 1/19/85	Parlier[2] 1/8-1/13/86
Diazinon	16,600	11,800	22,000	310 - 18,000
Parathion	12,400	5,800	51,400	2,700 - 39,000
Chlorpyrifos	1,020	320	6,500	390 - 7,700
Methidathion	840	570	15,500	93 - 4,800
Malathion	70	110	350	-
Paraoxon	9,000	950	184,000	72 - 34,000
Methidathion oxon	120	ND	8,200	200 - 7,300
Chlorpyrifos oxon	170	ND	800	< 60 - 5,600
Diazoxon	190	ND	ND	420 - 28,000
DEF	250	800	ND	-
Atrazine	270	320	700	-
Simazine	390	110	1,200	-
Pendimethalin	1,370	3,620	ND	-

1 D.E. Glotfelty, J.N. Seiber, and L.A. Liljedahl, 1987, Table 1.
2 D.E. Glotfelty, M.S. Majewski, and J.N. Seiber, 1990, Table II.

Table 59. Organophosphates Detected in Wet and Dry Deposition Collected During the 1992-93 Winter Season.

Date	Site[1]	Inches Rain[2]	Wet Deposition[3] (μg/L)	Dry Deposition[4]
1/8/93	6	NA[5]	Diazinon 0.09, 0.11[6]	NA
	16	NA	Diazinon 0.88	NA
1/11/93	6	0.45	ND[7]	-
	16	0.32	Diazinon 0.06	-
1/14/93	6	1.45	Diazinon 0.11, 0.09[6]	NA
	16	1.13	Diazinon 0.25	NA
1/17/93	6	0.61	Diazinon 0.15	-
	16	0.82	Diazinon 0.06	-
1/21/93	6	0.80	Diazinon 0.37 D. oxon 0.08	NA
	16	0.98	Chlorpyrifos 0.05 Diazinon 0.53 D. oxon 0.08	NA
1/25/93	6	0		-
	16	0.21	Diazinon 0.10	-
	24	0		Methidathion
2/1/93	6	0		-
	16	0		Diazinon Methidathion
	24	0		Chlorpyrifos Diazinon Methidathion
2/4/93	6	0		NA
	16	0		NA
	24	0		NA
2/8/93	6	1.99	Diazinon 0.53, 0.48[6] D. oxon 0.07	Diazinon D. oxon
	16	1.05	Chlorpyrifos 0.09 Diazinon 1.9 D. oxon 0.12	Diazinon D. oxon
	24	1.17	Chlorpyrifos 0.34 Diazinon 1.53 D. oxon 0.14	- - -
2/11/93	6	0.31	Diazinon 0.11	NA
	16	0.96	Diazinon 0.62 D. oxon 0.10	NA
	24	0.48	Chlorpyrifos 0.14 Diazinon 1.61 D. oxon 0.22	-
2/15/93	6	0		-
	16	0.01		-
	24	0		-

Table 59. Organophosphates Detected in Wet and Dry Deposition Collected During the 1992-93 Winter Season.

Date	Site[1]	Inches Rain[2]	Wet Deposition[3] (µg/L)	Dry Deposition[4]
2/18/93	6	0.37	Diazinon 0.42 D. oxon 0.07	NA
	16	0.35	Diazinon 0.25 D. oxon 0.08	NA
	24	0.36	Diazinon 0.37 D. oxon 0.11	NA
2/22/93	6	0.34	NA	-
	16	1.67	Diazinon 0.33, 0.32[6]	-
	24	NA	Chlorpyrifos 0.06 Diazinon 0.26	-
2/25/93	6	0.18	ND[8]	NA
	16	0.04	NA	NA
	24	0.38	Chlorpyrifos 0.06 Diazinon 0.19	NA
3/1/93	6	0.48	Diazinon 0.14 D. oxon 0.06	-
	16	0.72	Diazinon 0.10	-
	24	0.33	Diazinon 0.16 D. oxon 0.06	-

1 Sites: 6 = Merced River at Hatfield State Recreation Area; 16 = Stanislaus River at Caswell Memorial State Park; 24 = Merced River at McConnell State Recreation Area.
2 Inches of rain collected since prior sampling date. Rain gauges were deployed on 1/5/93, 1/5/93, and 1/21/93, for sites 6, 16, and 24, respectively.
3 Carbamates and endosulfans were also analyzed when enough rain water was available (i.e., >0.6" and >1.2" for carbamates and endosulfans, respectively). Carbamate and endosulfan residues were not detected in rain water.
4 Dry deposition reported as + or -.
5 Not available.
6 Duplicate samples analyzed by the organophosphate and endosulfan screens. Samples were not acidified.
7 None detected.
8 Detection limit was 0.01µg/L because less than 400 mL was available for analysis.

were collected in open glass pans exposed to dry and wet precipitation events. Diazinon was detected in all samples at concentrations ranging from 0.042 to 5.5 µg/L. The samples from the San Joaquin Basin were comparable to those from other areas. The highest concentrations were found in samples collected near orchards. Most concentrations were high enough to be acutely toxic to Ceriodaphnia. Carbofuran and chlorpyrifos also were detected in some samples.[306] These pesticides are used by homeowners for backyard and home insect control, are sprayed on stone fruit orchards such as almonds, prunes and apricots, or used on alfalfa for weevil control.

4.2.3 Urban Runoff

The City of Modesto discharges urban runoff into Dry Creek, which discharges into the Tuolumne River. The City monitored organophosphorus pesticides at upstream and downstream sites along both Dry Creek and the Tuolumne River at hourly intervals during an August 1994 dry weather and an October 1994 storm event. No pesticides were detected in any sample collected during the dry weather monitoring. However, malathion and diazinon were detected during wet weather monitoring.

During the October storm, malathion was detected in six out of seven samples collected at the upstream location on Dry Creek at concentrations ranging from 0.1 to 20 µg/L. At the downstream location, malathion was detected in ten out of 11 samples at concentrations ranging from 0.2 to 1.3 µg/L. Diazinon was also detected in seven out of 11 samples at concentrations ranging from 0.3 to 1.0 µg/L. On the Tuolumne River, no pesticides were detected at the upstream location. At the downstream station, malathion was detected in ten out of 14 samples at concentrations ranging from 0.1 to 0.7 µg/L. Diazinon was detected in a single sample at 0.2 µg/L. The authors concluded that the malathion and diazinon at downstream stations originated from upstream agricultural runoff and urban runoff from the City of Modesto.[307] All of the malathion concentrations equal or exceed the maximum criterion of 0.1 µg/L set to protect freshwater aquatic life.[308] All of the diazinon concentration exceed the 1-hour average concentration of 0.08 µg/L set by the DFG to protect freshwater aquatic life.[309]

Pesticides were measured in urban runoff from four catchments with differing land uses in the Fresno area between October 1981 and April 1983. The data are summarized in Table 60.[310]

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306 Valerie Connor, Pesticide Toxicity in Urban Storm Runoff, Presentation at CVRWQCB, May 10, 1995.

307 City of Modesto, 1994/1995 Annual Progress Report, July 1, 1995.

308 Marshack, May 1993.

309 Menconi and Cox, 1994, p. ii.

310 Oltmann and Shulters, 1987, Tables 12-15.

Table 60. Pesticides in Storm Water Runoff from the Fresno Area, October 1981-April 1983.[1]

COMPOUND	Number of Samples	Detection Status	Industrial Catchment Median (µg/L)	Industrial Catchment Range (µg/L)	Single-Family Residential Catchment Median (µg/L)	Single-Family Residential Catchment Range (µg/L)	Multiple-Family Residential Catchment Median (µg/L)	Multiple-Family Residential Catchment Range (µg/L)	Commercial Catchment Median (µg/L)	Commercial Catchment Range (µg/L)
Organochlorine compounds										
Aldrin	86	D*		< 0.01		< 0.01	< 0.01	< 0.01 - 0.02		< 0.01
Chlordane	84	D	< 0.10	< 0.10 - 0.30	0.10	0.10 - 0.30	0.10	< 0.10 - 1.2	0.10	< 0.10 - 0.30
DDD	86	ND		< 0.01		< 0.01		< 0.01		< 0.01
DDE	86	D	0.01	< 0.01 - 0.03		< 0.01	< 0.01	< 0.01 - 0.06		< 0.01
DDT	86	D		< 0.01		< 0.01		< 0.01		< 0.01
Dieldrin	86	D	< 0.01	< 0.01 - 0.02		< 0.01	< 0.01	< 0.01 - 0.02		< 0.01
Endosulfan	86	D	< 0.01	< 0.01 - 0.02		< 0.01		< 0.01	< 0.01	< 0.01 - 0.07
Endrin	86	D*		< 0.01		< 0.01		< 0.01		< 0.01
Heptachlor	86	ND		< 0.01		< 0.01		< 0.01		< 0.01
Heptachlor epoxide	86	ND		< 0.01		< 0.01		< 0.01		< 0.01
Lindane	86	D	0.03	0.01 - 0.27	0.03	0.01 - 0.06	0.01	< 0.01 - 0.03	0.01	0.01 - 0.03
Methoxychlor	86	D	< 0.01	< 0.01 - 0.03	< 0.01	< 0.01 - 0.19	< 0.01	< 0.01 - 0.02		< 0.01
Mirex	86	ND		< 0.01		< 0.01		< 0.01		< 0.01
Perthane	86	ND		< 0.1		< 0.01		< 0.1		< 0.1
Toxaphene	86	ND		< 1						
Organophosphorous compounds										
Diazinon	85	D	0.53	0.14 - 3.3	0.27	0.11 - 1.1	0.22	0.06 - 8.1	0.39	0.13 - 18
Ethion	86	ND		< 0.01		< 0.01		< 0.01		< 0.01
Malathion	85	D	0.44	0.20 - 3.0	0.99	0.19 - 13	0.49	0.08 - 14	0.23	0.08 - 1.4
Methyl parathion	85	D*		< 0.01	< 0.01	< 0.01 - 0.03		< 0.01	< 0.01	< 0.01 - 0.03
Methyl trithion	86	ND		< 0.01		< 0.01		< 0.01		< 0.01
Parathion	85	D	< 0.01	< 0.01 - 0.38	0.13	< 0.01 - 0.92	0.06	< 0.01 - 2.5	0.09	< 0.01 - 0.90
Trithion	86	ND		< 0.01		< 2		< 0.01		< 0.01
Carbamate Insecticides										
Methomyl	27	ND		< 2		< 2		< 2		< 2
Propham	27	ND		< 2		< 0.01		< 2		< 2
Sevin	27	ND		< 2		< 2		< 2		< 2
Chlorphenoxy acid herbicides										
2,4-D	84	D	0.03	< 0.01 - 3.2	0.07	< 0.01 - 1.7	0.08	< 0.01 - 3.7	0.01	< 0.01 - 0.63
2,4-DP	84	ND		< 0.01		< 2		< 0.01		< 0.01
2,4,5-T	84	ND		< 0.01		< 0.01		< 0.01		< 0.01
Silvex	84	D	< 0.01	< 0.01 - 0.07	< 0.01	< 0.01 - 0.03		< 0.01		< 0.01

* Detected for only one sample.

1 Oltmann and Shulters, 1987, Tables 12-15

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Seven organochlorine pesticides (chlordane, DDE, DDT, dieldrin, endosulfan, lindane, methoxychlor), three organophosphorus insecticides (diazinon, malathion, parathion), and two chlorophenoxy acid herbicides (2,4-D, silvex) were detected. Of these, only DDT and silvex were regularly detected in the runoff but not in the rain, suggesting local urban sources. Of the ten pesticides detected in the rain (Table 57), only parathion, diazinon, malathion, chlordane, lindane, and 2,4-D occurred regularly in urban runoff. Parathion, malathion, and diazinon were present at the highest concentrations in storm water runoff. Chlordane occurred more frequently in the runoff than in rain and was more frequently detected in the residential and commercial catchments than in the industrial catchment, probably because it is used in urban areas to control ants and termites.[311]

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[311] Oltmann and Shulters, 1987, p. 121.

SECTION FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This literature review indicates that pesticides and aquatic toxicity are ubiquitous in surface waters of the Sacramento and San Joaquin basins and the Delta. Pesticides are found at elevated concentrations in waters, sediments, and tissues collected throughout the area. Rainfall, urban runoff, agricultural drainage, agriculturally dominated streams, and sediments and water of the Sacramento and San Joaquin rivers and their tributaries are periodically toxic. Bioassay and chemical testing demonstrate that surface waters are toxic to sensitive algae, invertebrates, and fish species.

There is evidence that pesticides have adversely affected fish in the Sacramento and San Joaquin basins and the Delta. Fish kills were common in the 1960s, 1970s, and 1980s. More recently, larval fathead minnow toxicity and growth impairment has been found in the Sacramento River and to a lesser extent in the San Joaquin River and the Delta. There has been a persistent toxicity problem in the Sacramento River at Freeport since 1990. The toxicity to larval fathead minnows in the upper Sacramento River watershed (above and in the vicinity of Lake Shasta) is believed to be caused primarily by metals from acid mine drainage. The toxicity in the remainder of the watershed is believed to be caused primarily by runoff and irrigation return flows from agricultural lands and urban runoff. In addition, fish from the Bay-Delta ecosystem have elevated concentrations of organochlorine pesticides and pesticide ingredients in their tissues. Adult striped bass from the Sacramento River have exhibited lesions, parasitism, and discolored fatty livers while eggs from these fish had high mortality rates and produced deformed embryos or larvae with skeletal deformities and other abnormalities.

There is evidence that invertebrate species that provide food for fish have been adversely affected by pesticides. Sacramento and San Joaquin river water has historically impaired reproduction and caused mortality of invertebrate species. In February 1993, 100 percent mortality to Ceriodaphnia was observed for 12 consecutive days in the San Joaquin River at Vernalis. Although most of this toxicity has not been adequately explained chemically, where it has, it has been attributed to organophosphorus and carbamate pesticides.

There is also evidence that ambient waters are periodically toxic to algae. In the Sacramento Basin, the toxicity is primarily due to metals in the upper watershed, although urban runoff toxicity is sometimes due to metals, the herbicide diuron, and other unidentified organics. Less extensive testing of algal toxicity has been done in the Delta and San Joaquin Basin.

There has been fairly limited testing of native species. Testing conducted with Neomysis, Chinook salmon and the non-native but commercially important striped bass, have shown toxicity to these organisms in agricultural drainage, the major rivers and sediments.

Sediments from throughout the system have been found to be toxic to amphipods, Ceriodaphnia, rainbow trout fry, chinook salmon fry, and larval fathead minnows. Metals are believed to be the cause of the toxicity, particularly in the upper Sacramento River watershed. Organochlorine pesticides may be contributing factors in other areas of the system.

A number of focused toxicity studies has been conducted since 1986 on the Sacramento and San Joaquin rivers and the Delta. However, there has been no long-term comprehensive study designed to characterize the extent of toxicity, the sources of toxicity throughout the system, the specific chemicals responsible for toxicity, and the impacts of toxics on aquatic resources.

5.2 RECOMMENDATIONS

This literature review suggests that significant additional work is needed in the following major areas:

5.2.1 Species of Concern

Toxicity testing with native species should be conducted in the Bay-Delta ecosystem to more clearly define the impacts of toxicants on species of concern. This literature review clearly indicates that the waters in the study area are toxic to some forms of freshwater aquatic life. However, the majority of the work has focused on species that are not of concern or that are not common in the study area.

Most of the toxicity testing has used fathead minnows which are widely acknowledged to be less sensitive to many chemicals than most other fish. Limited testing has been conducted using larval striped bass and swim-up chinook salmon fry. Fish species that have experienced major declines, including delta smelt and splittail, have not been tested at all. Similarly, the principal food organisms of the fish of concern have also not been tested, with the exception of limited testing of Neomysis.

Therefore, a large scale ambient toxicity monitoring program should be implemented to assess the extent of ambient toxicity to native species of concern. In addition, toxicity data (e.g. LC50s, NOECs) should be developed for the pesticides applied in the largest quantities in the Central Valley or most frequently detected in the Bay-Delta ecosystem. Very little toxicity data are available for many of the major pesticides applied in the region, such as ziram, cyanazine, and alachlor. Likewise, virtually no toxicity data are available for any of the commonly used pesticides to sensitive life stages of many of the species of concern such as splittail, delta smelt, sturgeon, and American shad.

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5.2.2 Population Level Effects

While ambient toxicity testing has demonstrated that chemicals periodically kill larval fish and their food organisms, virtually no work has been completed to determine whether the observed mortality affects the abundance of adult fish. Future toxicity testing should be coupled with fundamental research on the effects of toxicants on populations of organisms. The Interagency Ecological Program ("IEP") Contaminant Effects Project Work Team is pursuing studies designed to identify population level effects. However, these efforts are hampered by inadequate funding. This work team has only received $75,000 a year for two years. IEP should substantially increase the budget for this work team so that more of this critically important work can be conducted on population level effects of toxicants. The DPR Pesticide Use Database should also be used to explore long-term trends between pesticide application rates, estimated in-stream concentrations, and fish abundance.

5.2.3 Comprehensive Monitoring Program

A long-term comprehensive monitoring program is needed to characterize the extent of toxicity, the sensitive species, the sources of toxicity throughout the system, and the impacts of toxics on aquatic resources. Toxicity monitoring throughout the major rivers and tributaries, as well as the major sources of pollutants (agricultural drainage, mine drainage, and urban runoff), should be conducted frequently (at least monthly) and over several years to identify seasonal patterns in the distribution of toxicity. When toxicity is found, TIEs should be conducted to identify the chemicals responsible for the toxicity.

Fairly extensive testing has been conducted on rice drainage and the effects of rice drainage on the Sacramento River. However, there has been very little work done on drainage from other agricultural crops. Limited testing has shown that runoff from orchards is toxic to standard test organisms. A comprehensive monitoring program should include testing of other agricultural crops, municipal and industrial discharges, and urban runoff as potential sources of toxicity.

There is currently no funding mechanism to support a comprehensive monitoring program. The Sacramento River Watershed Program will be conducting toxicity testing of the Sacramento River and the mouths of the major tributaries but this program does not contain sufficient funding to monitor minor tributaries that provide critical habitat to salmon, native species, or sources of toxicity. Funding for future years is uncertain. There is currently no long-term comprehensive monitoring being conducted or planned for the San Joaquin Basin or most of the Delta.

5.2.4 Regulatory Program

Regulatory agencies need to focus control efforts on agricultural drainage and runoff and urban runoff. Although elevated concentrations of pesticides and toxicity commonly occur throughout the fish rearing period in critical habitat areas, efforts of regulatory agencies to control pesticides from farms and urban runoff have been largely concentrated on the rice industry. DPR is developing information on best management practices for controlling pesticides in agricultural runoff. These efforts should continue to be supported by State funding.

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