2005

Toxin bioaccumulation in the Coyote Creek watershed, San Jose, California

Elisa S. Wilfong
San Jose State University

Follow this and additional works at: https://scholarworks.sjsu.edu/etd_theses

Recommended Citation

Wilfong, Elisa S., "Toxin bioaccumulation in the Coyote Creek watershed, San Jose, California" (2005).
Master's Theses. 2845.
DOI: <https://doi.org/10.31979/etd.57xg-fkq3>
https://scholarworks.sjsu.edu/etd_theses/2845

This Thesis is brought to you for free and open access by the Master's Theses and Graduate Research at SJSU ScholarWorks. It has been accepted for inclusion in Master's Theses by an authorized administrator of SJSU ScholarWorks. For more information, please contact scholarworks@sjsu.edu.

NOTE TO USERS

This reproduction is the best copy available.

UMI[®]

TOXIN BIOACCUMULATION IN THE COYOTE CREEK WATERSHED
SAN JOSE, CALIFORNIA

A Thesis

Presented to

The Department of Environmental Studies

San Jose State University

In Partial Fulfillment

Of the Requirements for the

Masters of Science

by:

Elisa S. Wilfong

December 2005

UMI Number: 1432463

INFORMATION TO USERS

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleed-through, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

UMI Microform 1432463

Copyright 2006 by ProQuest Information and Learning Company.

All rights reserved. This microform edition is protected against unauthorized copying under Title 17, United States Code.

ProQuest Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

Copyright 2005

by Elisa Wilfong

ALL RIGHTS RESERVED

APPROVED FOR THE DEPARTMENT OF ENVIRONMENTAL STUDIES

Dr. Rachel O' Malley, Associate Professor
Environmental Studies, SJSU

Dr. Katherine Cushing, Assistant Professor
Environmental Studies, SJSU

Phyllis Flack, Senior Project Engineer
P.E. License #67169
Engineering/Remediation Resources Group, Inc.

APPROVED FOR THE UNIVERSITY

ABSTRACT

TOXIN BIOACCUMULATION IN THE COYOTE CREEK WATERSHED, SAN JOSE, CALIFORNIA

by: Elisa S. Wilfong

Non-point source pollution threatens our urban waterways, which threatens human health across the United States. Coyote Creek, a major watershed in San Jose, CA, has the following documented potential sources of toxins: polychlorinated biphenyls (PCBs) historically used in industry, mercury found historically, and pesticides historically and currently used in the community, which may be polluting its waterways. This study examined the contribution of surface runoff containing these toxins with bioaccumulated sampling upstream and downstream near three storm drains to determine if they were a specific non-point source of contamination into Coyote Creek. Contamination levels of PCBs, mercury, and pesticides were found along a six-mile stretch of creek that exceed water quality standards for drinking water and recommended aquatic contamination levels for freshwater habitats. The water and organisms of Coyote Creek prove to be unsafe for human consumption and pose a health risk for the local community.

For my parents Susan and Chris
for their undying love and support,
and to my husband David for which this
project would not be possible.

TABLE OF CONTENTS

SECTION	PAGE
INTRODUCTION	1
Problem Statement	4
Objectives.....	5
Hypothesis.....	5
LITERATURE REVIEW	7
METHODS	15
Study Site	15
Study Design	16
Data Collection	18
Data Analysis	21
RESULTS	27
DISCUSSION	34
CONCLUSION	40
REFERENCES CITED.....	42
APPENDIX A: RESULTS OF WATER QUALITY SAMPLING	49

TABLES

TABLE	PAGE
Table 1: 2003 RMP Bioaccumulation Results in Coyote Creek	12
Table 2: Non-Point Sources of Urban Pollution in Coyote Creek.....	17
Table 3: EPA Maximum Contaminant Levels for Drinking Water.....	23
Table 4: NOAA SQuiRT Guidelines For Freshwater Sampling.....	25
Table 5: Results of Clam Analyses.....	28
Table 6: Statistical and AF Analysis of Bioaccumulated Toxins.....	29

FIGURES

FIGURE	PAGE
Figure 1: Comparison of Water Quality Guidelines with Numeric Results of Bioaccumulation.....	32
Figure 2: Pollution Distribution at Kelly Park Sample Location.....	37
Figure 3: Total PCB Distribution in Coyote Creek.....	38
Figure 4: Total Pesticide Distribution in Coyote Creek.....	39
Figure 5: Site Location (Coyote Creek).....	46
Figure 6: Stream Discharge Points of Potential PCB Sources in San Jose, CA Silicon Valley Toxics Coalition, September 2000.....	47
Figure 7: Sampling Location Map (Coyote Creek Watershed).....	48

INTRODUCTION

The greatest degradation of water quality in the United States results from non-point source water pollution (EPA, 2005). Non-point source water pollution, once known as “diffuse” source pollution, arises from a broad group of human activities for which the pollutants have no focused point of entry into receiving watercourses. In contrast, point source pollution is generated when wastewater is routed directly into receiving water bodies at a single point source, where they can be easily measured and controlled. Consequently, non-point source water pollution is much more difficult to identify, measure, and control than are point-sources.

Non-point source water pollution results every time rain or snowmelt flows across the ground and picks up contaminants. It occurs on agricultural sites, where the water carries away fertilizers, pesticides and sediment from cropland or pastureland. It occurs at auto dismantling operations where the water carries away vehicle fluids such as oil and anti-freeze. It occurs when rain water washes away trash from sidewalks and spilled chemicals from improperly disposed of household hazardous wastes such as paint cans and cleaning solvents.

More studies are being conducted to prove that urban run-off has become a greater risk for pollutant loads to our waterways than any other land use area. The U.S. Geological Society has been closely examining pesticide use and distribution across the United States. The U.S. Geological Society has determined that pesticides are often found in higher concentrations in urban areas than in agricultural areas (USGS, 1995). With this evidence the potential for urban run-off to generate a pesticide load into urban

waterways is greater than it is in rural waterways. It is the urban environment that poses a greater risk to human health than rural environments that are outside communities.

The problem of urban run-off carries heavy costs through the risk of pollutant exposure to people and the environment. The costs could entail increased spending on health care, higher insurance and drinking water rates, declining stocks of commercial fish, loss of tourism revenues, and ecological degradation. Americans spend millions of dollars to address these issues instead of trying to control the root cause, which may well be the pollutant source from urban runoff contaminating water resources.

Most of the U.S. population lives in urban and coastal areas where the water resources are highly vulnerable to and are often severely degraded by urban run-off. Over the past 32 years after passage of the Clean Water Act in 1972, water pollution control efforts have focused primarily on point source pollution such as factories and sewage treatment plants, with less emphasis on non-point sources. Point sources are easier to regulate and monitor due to their direct pipe discharge into waterways. While these efforts have led to many water quality improvements, new efforts are now needed to address the remaining sources of water pollution, especially urban run-off pollution. Currently, with the addition of the National Pollution Discharge Elimination System (NPDES) to the Clean Water Act in 1992, the United States requires all municipalities to control pollution entering our storm drain system as well as controlling point-sources.

The United States Environmental Protection Agency (EPA) releases a summary of information on locally-issues fish advisories and safe-eating guidelines. This information is provided to EPA annually by states, territories and tribes. The EPA makes this

information easily accessible to the public each summer on its website at <http://www.epa.gov/waterscience/fish/>. Every state monitors its waters by sampling fish tissue for long-lasting pollutants. These pollutants have bioaccumulated into the fish tissue and provide a quantitative analysis of pollutant exposure to people from eating the fish. The number of fish advisories is increasing even as emissions for major pollutants are decreasing and as pollutants such as DDT and chlordane are banned in the United States. Clearly, the need for further monitoring for toxicity in waterways is needed for human health concerns from eating animal tissue out of these waterways.

A watershed management approach is a strategy for effectively protecting and restoring aquatic ecosystems and protecting human health. A monitoring plan is one part of this watershed management approach. A monitoring protocol quantifies the influence of contamination from urban run-off. Water quality monitoring is necessary to facilitate resource protection, remediation and/or restoration of a watershed. Traditionally, water quality monitoring actions have focused on direct physical and chemical measurements. The use of other indicators, complementary to traditional chemical and physical water quality monitoring techniques, can greatly enhance the assessment sensitively of and management of a watershed. In particular, biological monitoring through the analysis of toxin bioaccumulation is an important tool to assess the condition of a watershed. Bioaccumulation of a toxin provides a representative sample, over time, of water quality conditions experienced by organisms in the waterway.

Coyote Creek flows through a highly urbanized area of San Jose. The City of San Jose experiences the universal problem of “urban storm water” or rainwater that washes

over dirty surfaces such as roads, buildings and lawns and becomes a major source of pollution in the local rivers, lakes and bays. The community's drinking water supplies, fishing waters, and recreation areas are fouled by uncontrolled pollution when rainwater washes over city streets, parking lots, and suburban lawns and picks up toxic chemicals, disease-causing organisms, and dirt and trash. As more land is developed with paved roads, increasing impervious surfaces without vegetation to soak up the run-off, the urban flow of pollution has increased in local watersheds, untreated and unstopped. The need for reliable water quality information has never been greater for the public health. A monitoring program needs to be implemented as people are exposed to Coyote Creek's waters.

PROBLEM STATEMENT

Chemicals that were manufactured historically during the first half of the 20th century and currently have persistently accumulated in the environment. These synthetic chemicals were once considered harmless or even beneficial, serving as pesticides, herbicides, and resources for industrial production. Today many of these chemicals are known to cause problems for human health and the health of wildlife and ecosystems.

Human use of Coyote Creek is a concern when the toxic contamination of the water is undetermined. Coyote Creek is used for recreation and fishing. It is possible, depending on socioeconomic conditions of the west side of San Jose, that fishing is not only used for recreation but as a source of sustenance to supplement the diets of the residents. Based on observations of the author, the area studied for this thesis is degraded in quality and the surrounding households are indicative of lower economic class. For this reason, it is

very critical that the contamination status of the creek should be measured to determine if risks are being imposed on the community. Coyote Creek watershed is in need of water quality data to assess whether these chemicals have impacted the aquatic environment. Coyote creek has a series of storm drains, which channel the urban run-off from the community. These storm drains may serve as a non-point source of pollution to the creek.

OBJECTIVES

The objective of this study was to determine if storm drain outfalls can be directly studied to assess a human health risk in a creek. The following questions were addressed in this study:

1. Do urban storm drains in the Coyote Creek Watershed in San Jose, CA represent a measurable source of contamination for PCBs, mercury and pesticides?
2. Are loads of PCBs, mercury and pesticides in Coyote Creek bioaccumulating to a degree that is considered a human health risk?

HYPOTHESIS

H1: Storm drains are a source of harmful levels of contamination of PCBs, mercury and pesticides, which drain to Coyote Creek based on bioaccumulation of toxins in bivalves.

H1A: Upstream (i.e., before suspected sources of contamination) bivalve

bioaccumulation sampling will exhibit a smaller concentration of pollutant contamination

than will downstream (i.e., after suspected sources of contamination have been introduced or discharged sampling from storm drains) bivalve samples.

LITERATURE REVIEW

The earliest and most extensive study of non-point source pollution was the study done by Canada and the United States of point and non-point source pollution identification and control in the 1970s for the entire Great Lakes basin (EPA, 2004). This study was precipitated by public concern over the deterioration in water quality, including the visible evidence of algal blooms and increase in aquatic weeds. The two countries, under the bilateral International Joint Commission, established the “Pollution from Land Use Activities Reference Groups” (known as “PLUARG”) which, served as the scientific vehicle for a ten year study of pollution sources from the entire Great Lakes basin. In this study hypertrophic conditions in Lake Erie and eutrophic conditions in Lake Ontario were shown to be caused by excessive phosphorus entering the Lower Great Lakes from point and non-point sources.

This research culminated in major changes both to point and non-point source control, and it resulted in an unprecedented increase in scientific understanding of the impacts of land use activities on water quality. Non-point sources in general, and agriculture in particular, were shown to be a major source of pollution to the Great Lakes. Change in agricultural practices was in many cases, achieved by demonstrating to farmers that there were economic gains to be realized by changing land management practices (EPA, 2004).

Ecotoxicology evolved in the early 1960s when the effects of environmental contamination from polluting projects of industrial and agricultural origin became apparent (Lagadic, 2000). Methods of direct chemical analysis enable us generally to

measure the extent and level of environmental contamination, by using a limited number of samples taken from various matrices (water, soil, sediments, plants, and animals). However, this approach is often very expensive, particularly when large numbers of samples are required to characterize an area.

Biomonitoring through the use of bioindicators or biomarkers is a more cost effective and comprehensive approach to measurement of an ecosystem's health. Biomonitoring involves a process of sampling biological media in an ecological system to quantify chemical and physical properties of that ecological system. Biomonitoring is used frequently for monitoring water quality (Hart, 1994). Resident aquatic biological communities are ideal indicators for overall ecological integrity because they integrate the effects of physical and chemical perturbations.

Bioindicators provide information on the condition of the ecosystem and the extent to which it is stressed by natural or human disturbances. Bivalves are excellent organisms for biomonitoring of contaminants since they accumulate contaminants from the ambient environment, have limited mobility and are fairly resistant to contaminate effects. Accumulation of pollutants in bioaccumulator organisms enables detection and quantification of the pollutants by chemical and/or physical analysis of species samples. Numerous species of molluscs have a long life cycle (several months to a few years), which allows us to study variations in the contamination of a given site.

Biomarkers can give an indication of the distribution of contaminants in the environment. Depending on their habitat and their position in the food web, the species that are the source of biomarkers can indicate how pollutants are diluted in the medium or

are concentrated in certain parts of the ecosystem. Biomarkers enable monitoring environmental impacts on organisms, populations, and communities to provide early detection of risks to the ecosystem and human health.

Driven by human health concerns and protection of wildlife, a significant focus of PCB research has been the accumulation of PCBs in fish. The industrial land use near the Hudson and the Delaware River estuaries has been studied for PCB contamination. The Hudson River estuary has enormous spatial variation in PCB contamination due in large part to historical point source and non-point source discharges (Ashley, 2003). Striped bass and American eels were collected along the Hudson and Delaware River estuary to determine localized contamination. Research has found patterns of accumulated PCBs in sub-populations of American eels and striped bass inhabiting these two estuaries and surrounding coastal waters. The American eels proved to be a good bioindicator due to their limited home range within the studied area. American eel and striped bass sampling along the study site indicated that the Hudson River estuary is heavily contaminated with PCBs (Ashley, 2003).

Common pesticides such as DDT and CHL (chlordane compounds) have been found in the liver of Japanese common squid (*Todarodes pacificus*) collected from the waters around Japan during a study in 2003. This species of squid had been used as a bioindicator for pollution monitoring PCBs and organotin compounds. Analysis of the growth and seasonal variation of contamination concentrations in the squid species reflected the pollution levels in seawater where and when they were collected, regardless of body-size and season (Ueno, 2003).

Two mollusk species in Malaysia were used as bioindicators for heavy metals in 1998. These mollusks are used as food sources and were studied to determine present human health risks. Sampling sites were along riverbanks both upstream and downstream of possible sources of historical sediment contamination from heavy metals. The mollusk species collected from the study area were contaminated with arsenic, copper, and zinc. The levels of metals found in the samples were at their maximum allowable concentration for seafood as stipulated by Malaysia's Food Act (1983). The residents along the study site who collect and consume these mollusks are at high risk of heavy metal poisoning.

What has been and continues to be the problem in these international and national studies of bioaccumulation are the follow-up measures needed to alert the public and find the source of the contamination. It has been established that bioindicators are valuable for the data that they carry in their tissue for the type of pollutant present in waterways and where the pollutant is traveling. Now, the question remains as to the upstream pollutant source location and how the contaminated area can be mitigated to alleviate human health risks.

Several organizations conduct water quality studies in the San Francisco Bay. The San Francisco Estuary Institute (SFEI) conducts an annual regional monitoring program (RMP) for the perimeter of the San Francisco Bay Region (Luoma, 1996). The RMP has been analyzing bivalve tissue, sediment and water quality samples for trace contaminants since 1993 (RMP, 2003). The RMP's overall goal is to provide data and interpretation that helps to address certain information needs of the Regional Water Board. The RMP

survey includes one sampling location at the mouth of Coyote Creek that feeds into the San Francisco Bay (RMP, 2003).

TABLE 1: 2003 RMP Bioaccumulation Results in Coyote Creek

The RMP results are only available for PCB, Dieldrin, Chlordanes, and DDT (pesticides), and PBDEs (fire retardants) at the mouth of Coyote Creek. The concentrations are available in parts per billion (ppb) dry weight.

Location	Dieldrin	Sum Chlordanes	Sum DDTs	Sum PCBs	Sum PBDEs
Coyote Creek	7.8	4.39	32	141	31

Source: Regional Monitoring Program, 2003.

Since 2001, the RMP began using screening values developed for monitoring contaminant concentrations in finfish (RMP, 2003). These screening values were developed following U.S. EPA guidance (EPA, 1995) for evaluation of contaminants in fish tissue in a study from two California lakes and are defined as concentrations of target analytes in fish or shellfish tissues that are a potential public health concern. The total concentration of PCBs found in 2003 by the RMP, exceed the RMP's screening value of 140 ppb. The screening values are used for comparison purposes only and do not suggest a possible public health concern.

The Silicon Valley Toxics Coalition (SVTC) used bioaccumulation to study the contamination downstream along Coyote Creek from the year 2000 to 2002 (Robinson, 2003). In an effort to develop a community outreach program to educate the citizens and schools in the neighborhood, the SVTC conducted a water quality study along Coyote Creek. The Clean Streams/Clean Bay project was formed as a partnership between the local high schools and the SVTC, and the City of San Jose Environmental Services Division. The SVTC utilized the methods previously established by the California State Mussel Watch Program (McMurtry, 2000). The project demonstrated that a partnership between a high school, an environmental advocacy organization and a public agency laboratory could produce useful scientific information in support of the State of California's efforts to identify the sources of PCBs discharged to the S.F. Bay.

The SVTC data include two locations downstream along Coyote Creek. These two locations were Coyote Creek at the Montague Expressway (Figure 6) and one in the Sunnyvale East Channel under the Tasman Drive Bridge. Deployment was completed in

an 11-week period, beginning in the spring of 2000. At the time the clams were transplanted, resident clams were also collected from Coyote Creek. Unfortunately, the results of this study were lost in the SVTC offices and are not available.

In general, both the RMP study and the SVTC study, bivalves were collected from uncontaminated sites and transplanted to stations in the Estuary or Coyote Creek. The RMP conducted their study during the wet season (February through May) and the dry season (June through September). The SVTC conducted their 2000 study during the months of May through July. Contaminant concentrations in the animals' tissues and the animals' biological condition (expressed as the ratio of dry weight and shell cavity volume) were measured before deployment (referred to as time zero or background samples) and at the end of the 90-100 day deployment period. Survival during deployment was also measured. Composites of tissue were made from 40-60 individual bivalves from each site before and after deployment for analyses of trace contaminants (Robinson, 2003). This method of monitoring has been used internationally, as well, and is an effective means to quantify any possible contamination in a waterway.

METHODS

STUDY SITE

Coyote Creek is the longest creek in Santa Clara County, California (Figure 5). It flows for 100 km, starting in the mountains of Henry Coe State Park, filling Coyote and Anderson Reservoirs, and then flowing down through the Coyote and Santa Clara Valleys and San Jose. Coyote Creek flows south, then turns west and northwest at the confluence of east and middle forks, each 24 km long. Coyote Creek drains Santa Clara County's largest watershed (320 square miles), encompassing most of the eastern foothills, the city of Milpitas, and portions of the cities of San Jose and Morgan Hill.

Coyote Creek's climate is Mediterranean, typical of coastal California. The microclimate varies greatly with elevation and the amount of coastal influence; however, areas with more coastal influence experience moderate temperatures year round, with fog likely from June through mid-August. Most of the precipitation comes in the winter months, with April through October normally being very dry.

Human inhabitation in the close proximity to Coyote Creek includes recreational facilities along much of its length, such as the Coyote Creek Trail. The Coyote Creek lagoon and the Alviso salt ponds trails are the last extensions of publicly accessible land along Coyote Creek before it flows into the San Francisco Bay.

Habitats within the Coyote Creek watershed include serpentine grassland, annual grassland, agriculture land and riparian habitats as well as suburban and rural areas of San Jose. Vegetation along the banks of Coyote Creek is typical of oak woodland and California riparian habitats.

A 6-mile stretch of Coyote Creek was chosen as a study site from a thorough investigation by the SVTC to find all potential sources of PCBs along Coyote Creek (Robinson, 2003) (Figure 6). SVTC compiled a list of the names and addresses of local industries that may have used PCBs after reviewing documents, contacting experts in PCBs and environmental representatives from industries, and searching City Directories in 1950s and 1960s (McMurtry, 2000). After reviewing the PCB investigation by SVTC, three storm drains were selected for this study due to their close proximity to the PCB potential sources for polluting urban run-off. One potential source is located along Highway 101, has storm water discharge to Lower Silver Creek at a point 1/2 mile upstream of its confluence with Coyote Creek. The second source discharges into Coyote Creek 3.4 miles south of local road 1280. The third source location is an electrical substation where site storm water runoff discharges to the creek south of Curtner Avenue.

STUDY DESIGN

The non-point sources of pollution to Coyote Creek vary from historic and current land use activities (Table 2).

TABLE 2: Non-Point Sources of Urban Pollution in Coyote Creek

These non-point sources of urban pollution are not the only potential contaminants in Coyote Creek. The extent of potential non-point source pollutants running into Coyote Creek was extensive for this thesis study. The pollutants investigated in this study were considered most widespread within the area, most toxic to human health, and quantifiable through the study's bioaccumulation efforts.

Urban Areas	Source of runoff	Pollutants examined
Residential, Commercial, and Industrial	Urban runoff from roofs, streets, parking lots, etc. routed directly to receiving waters; local industries and businesses may discharge wastes to street gutters and storm drains; and street cleaning.	Pesticides and organic contaminants (PCBs).
Mineral extraction	Runoff from historic mine wastes, quarries, and well sites.	Mercury

PCBs, mercury and pesticides were chosen for this study to analyze the water quality of Coyote Creek by measuring chemical bioaccumulation in the tissue samples of freshwater clams. The method of biomonitoring was consistent with the protocol established by the California State Mussel Watch Program and the methods utilized by the SFEI. To assess the possible pollution discharge from each of the three chosen storm drains, clams were deployed upstream and downstream from the storm drains (Figure 7) within the 6-mile study site of potential PCB contamination (Figure 6). The clam deployment took place during the spring of 2004 (March to May, 2004), the fall of 2004 (August to November, 2004) and the spring of 2005 (late February to late May, 2005).

DATA COLLECTION

The reasons for monitoring contaminant concentrations in bivalve tissue are two-fold. First, bivalves integrate the bioavailable portion of contaminants in the water column over time, and second, for many contaminants, bivalves are good indicators of contaminant transfer from water into the food web. Bivalves will accumulate certain contaminants in concentrations much greater than those found in ambient water (Vinogradov, 1959). This phenomenon is a result of the limited ability of bivalves to regulate the concentrations of most contaminants in their tissues, which is why active biomonitoring has been widely applied by the California State Mussel Watch Program (Phillips, 1988).

Prior to each clam deployment, a total of approximately 300 freshwater clams (*Corbicula fluminea*) were purchased for each sampling event. The clams were obtained

from a private distributor, to reduce the potential of contamination. Before transfer to the monitoring sites the clams were stored in a pre-washed cooler and kept cool, not frozen, with double-bagged ice. The clams remained cool for a maximum of three days before being deployed into Coyote Creek.

Prior to deploying, the clams were sorted according to size. The average length and width of each clam was measured. Clams 1 inch or less in length and width were separated from the larger clams. The clams were placed in marine-quality bright polyethylene mesh bags (61 centimeters long, 15.24 centimeters in diameter, 1.27 centimeter mesh). Each bag was divided into 2 segments (one per monitoring site) by knots. Clams were evenly distributed in the mesh bags according to approximate volume of tissue. Ten large clams were sufficient per segment of mesh bag. Thirteen to fifteen smaller clams were sufficient per segment of mesh bag. When shucked, the tissue sample for each clam constituted at least 1-gram dry weight (Robinson, 2003). The clams were then placed back in a cooler with wet ice, pending deployment in Coyote Creek. A random subset of 30-45 clams was selected within 2 hours of arrival and kept frozen as “time zero samples” and analyzed separately. These clams provided the baseline set of samples in the experiment.

Clams were transplanted at the monitoring sites, preferably in a deep pool. One-meter long construction stakes with drilled holes were driven into the streambed at a depth of 30.48 centimeters (Robinson, 2003). Clam bags were attached between the construction stakes using sturdy zip-ties, wrapping the loose mesh around and through the pre-drilled holes in the stakes (Robinson, 2003). Clams were placed so that they were

resting on the streambed, or just above it, away from debris that could become entangled in the mesh. The tops of the stakes were affixed with orange caps for identification during high water. Clam bags were marked with tags identifying the monitoring sample, number and location, and contact information for the project. Two clam bags were deployed at each monitoring location, within 0.5-2.5 meters of each other. The bags were placed along the creek approximately 1-meter depths at each monitoring site. Duplicate samples were required in case one bag was vandalized, for quality assurance, and to ensure that ample tissue was available for analyses.

Clams were deployed at each the monitoring site for 90-100 days. The clam bags were checked weekly for consistent exposure in the water and for damage and mortality of the clams. Dead clams were recorded and removed during each sampling event. At the conclusion of deployment, the clams were removed from the water, rinsed in deionized water and placed in plastic bags. The clams were put on ice in pre-cleaned coolers and transported to a subcontracted lab for analysis. Before dissection, batches of clams were partially thawed and inspected for mortality. Empty shells were removed, counted and discarded. The tissues were homogenized in the lab to a smooth consistency, rinsed, and then analyzed. Clam tissue samples were tested for PCBs using EPA method 8082, mercury using EPA method 7471, and pesticides using EPA method 8081A.

Both physical and chemical stream properties influence the health of aquatic communities. To assist with the interpretation of the bioaccumulation study, the

following physical and chemical water parameters were measured and recorded in the field at the sampling sites during deployment and pickup of the clams:

- Temperature
- Creek Flow rate
- Dissolved Oxygen (DO)
- Turbidity
- pH

These chemical parameters influence the bioaccumulation of toxins. Dissolved oxygen is affected by pollution. Dissolved oxygen can range from 0-18 parts per million (ppm), but most natural water systems require 5-6 ppm to support a diverse population (EPA, 2005). Temperature affects dissolved oxygen, photosynthesis, metabolic rate of organisms, and sensitivity to toxins and diseases. Turbidity is a measure of water clarity, which is impacted by fine sediment in suspension. The measure of free hydrogen ions is pH. A pH below 6.5 is acidic to an aquatic ecosystem and a pH above 8.5 is basic to an aquatic ecosystem. Conductivity is a measure of the amount of dissolved ions in a water sample for transmitting an electrical current. Conductivity is an indicator of the productivity of water since it measures nutrients dissolved in water. The flow rate controls oxygen content, temperature, turbidity, composition of streambed, and food availability.

DATA ANALYSIS

Because of the variability among individual clams, composite samples of tissue were analyzed from each deployment sample site (up to 30 individuals). There were two samples from each deployment site to insure samples would be available from each

sampling site in case of mortality. Analyses of the clam tissue samples were based on parts per million (ppm) wet weight or part per billion (ppb) wet weight. A simple T-test value was calculated between the upstream and downstream samples from each storm drain location to determine the statistical change from the different reaches of stream from the outflow source of contamination. The uptake of contaminants found in the clams was presented in Table 5 to compare transplanted clams with the control group of clams.

Absolute tissue concentrations were determined by comparing concentrations at the end of the deployment to the control tissue concentrations. In addition to using the absolute tissue concentration this report used accumulation factors (AFs) to indicate accumulation or depuration (loss of constituents from bivalve tissue) during the 90-day deployment period. The accumulation factor is calculated by dividing the contaminant concentration in transplants by the control clam concentration at time zero. An AF less than one indicates that contaminant concentrations in the clam decreased during the deployment period, while an AF above one indicates contaminant accumulation.

In order to determine if there is a health concern with Coyote Creek's waters the results were compared with national guidelines. This study's results were compared to the EPA's National Primary Drinking Water Regulations. The following maximum contaminant levels (MCLs) are adapted by the EPA:

TABLE 3: EPA Maximum Contaminant Levels for Drinking Water

Analyte	Maximum Contaminant Level (MCL)	Units
Mercury	0.002	ppm
PCBs	0.0005	ppm
Chlordane	0.002	ppm
Endrin	0.002	ppm
Heptachlor	0.0004	ppm
Heptachlor epoxide	0.0002	ppm
Hexachlorobenzene	0.001	ppm
Lindane	0.0002	ppm
Methoxychlor	0.04	ppm

ppm: parts per million

Source: Federal Environmental Protection Agency, Title 22 drinking water standards

The national primary drinking water regulations are legally enforceable standards that apply to public water systems. The primary standards protect public health by limiting the levels of contaminants in drinking water. If levels of contaminants in bivalve tissue sampled during this thesis study exceed drinking water standards, then the tissues were considered to contain amplified levels of pollutants that then would be ingested by humans. There are no bioaccumulated levels for contaminants that are enforceable.

The National Oceanic and Atmospheric Administration (NOAA) screening quick reference tables, or SQuiRT, present screening concentrations for inorganic and organic contaminants in various environmental media. The SQuiRT guidelines were developed for internal use by the Coastal Protection and the Restoration Division (CPR) of NOAA. The CPR Division identifies potential impacts to coastal resources and habitats likely to be affected by hazardous waste sites. To initially identify substances, which may threaten resources of concern to NOAA (aquatic organisms), environmental concentrations were compared to these screening levels. These tables are intended to provide preliminary screening purposes only. They do not represent official NOAA policy and do not constitute criteria or clean-up levels.

As a guideline for comparison the available SQuiRT screening concentrations for the toxins studied in this thesis are as follows:

TABLE 4: NOAA SQuiRT Guidelines For Freshwater Sampling

Analyte	Freshwater acute guideline in parts per billion (ppb)	Freshwater chronic guideline in parts per billion (ppb)
Mercury	2.4-1.4	0.012-0.77
PCBs	2	0.014
Aldrin	1.5	NA
Chlordane	1.2	0.00215
DDD	0.6	NA
DDE	1050	NA
DDT	0.55	0.0005
Dieldrin	0.24	0.056
Endosulfan (alpha and beta)	0.11	0.028
Endrin	0.086	0.036
Heptachlor	0.26	0.0019
Heptachlor Epoxide	0.26	0.0019
Hexachlorobenzene	6 (proposed)	3.68 (proposed)
Hexachlorobutadiene	90	9.3
Lindane	0.95	0.08
Methoxychlor	NA	0.03

NA: Not Available
ppb: Parts per billion

Source: National Oceanic and Atmospheric Administration, 2000.

The SQUIRT guidelines for freshwater sampling are not legally enforceable. If levels of contaminants in bivalve tissue sampled during this thesis study exceed these guidelines for freshwater, then the tissues will contain amplified levels of pollutants that could potentially harm humans who ingest animal tissue from Coyote Creek. Based on the level of amplification, a human consuming animal tissue from Coyote Creek could exceed these screening guidelines for the contaminants studied based on a ppb unit of measurement, regardless of water versus tissue sampled.

This study attempted to determine whether concentrations of toxin contamination differ upstream and downstream from storm drain discharges along Coyote Creek. The results were compared to the EPA drinking water standards and the guidelines set forth by the NOAA SQUIRT tables to provide baseline water quality data for future assessment and quantification of the health of the Coyote Creek ecosystem. It is important to note that the EPA drinking water standards and the SQUIRT guidelines are not bioaccumulated standards.

RESULTS

Clam tissue collected in Coyote Creek exhibited bioaccumulated toxins for all three sampling events (Table 5). Data is not available upstream nor downstream at the Santa Clara Street sample location during the fall 2004 sample run, as well as upstream at the Santa Clara Street sample location during the spring 2005 sample run. During the fall 2004 run the clam bags were vandalized by local homeless who cut them from their stakes, so no clams were retrieved during the deployment collection. During the spring 2005 run the clam bags were vandalized again and left on shore, so there was a 100% mortality rate for the clams removed from the water.

The control clam sets all exhibited a non-detect (ND) for all analyses. A non-detect for control clam sets indicates that the control clam sets did not contain any toxin amounts above the detection limits for the constituents analyzed. The control clam sets show a baseline of zero contamination before each clam deployment event to prove that the clams purchased for this study were free of any residual contamination before deployed into the field. Mercury was not included in the final set of clams due to financial constraints of this study.

Any detection of contamination during the clam analysis displayed an AF calculation of more than one, which indicated that toxins accumulated in the clam tissue (Table 6). A total of nine detections were accountable to illustrate that clam bioaccumulation was taking place during this thesis study.

TABLE 5: Results of Clam Analyses

Sample Location	Deployment Date/Time	Collection Date	Total Pesticide Result (ppb wet weight)	Total PCB Result (ppm wet weight)	Total Mercury Result (ppm wet weight)
Spring 2004					
Control set	NA	032304	ND	ND	ND
Downstream Kelly	030904/7:30	051804	13.9	ND	ND
Upstream Kelly	030904/7:35	051804	20.6	ND	ND
Downstream Santa Clara	030904/8:20	051804	71.7	0.0894	ND
Upstream Santa Clara	030904/8:30	051804	89.77	0.0768	ND
Downstream Mabury	030904/9:30	051804	ND	0.0372	ND
Upstream Mabury	030904/9:00	051804	ND	ND	ND
Fall 2004					
Control set	NA	102704	ND	ND	ND
Upstream Kelly	102204/9:00	012805	ND	ND	0.0206
Downstream Kelly	102204/8:45	012805	ND	ND	ND
Upstream Mabury	102204/11:15	012805	ND	ND	ND
Downstream Mabury	102204/10:55	012805	ND	ND	ND
Spring 2005					
Control Set	NA	012805	ND	ND	ND
DS Kelly	012805/8:35	042205	ND	0.103	N/A
US Kelly	012805/8:50	042205	ND	ND	N/A
US Mabury	012805/10:45	042205	ND	ND	N/A
DS Mabury	012805/10:35	042205	ND	ND	N/A
DS Santa Clara	012805/9:55	042205	ND	ND	N/A

ND: Non-detected

ppm: Parts per million

NA: Not Applicable

ppb: Parts per billion

TABLE 6: Statistical and AF Analysis of Bioaccumulated Toxins

Storm Drain Sample Area	Spring 2004 AF Value	Fall 2004 AF Value	Spring 2005 AF Value	Total Sample Runs T-test Value for Storm Drain
Upstream Kelly	Pesticides: 20.6 PCBs: 0 Mercury: 0	Pesticides: 0 PCBs: 0 Mercury: 0.0206	Pesticides: 0 PCBs: 0 Mercury: NA	Pesticides: $t_{cals}=2.471$ $t_{crit}=2.776$ PCBs: $t_{cals}=0.421$ $t_{crit}=2.776$ Mercury: $t_{cals}=0.121$ $t_{crit}=4.303$
Downstream Kelly	Pesticides: 13.9 PCBs: 0 Mercury: 0	Pesticides: 0 PCBs: 0 Mercury: 0	Pesticides: 0 PCBs: 0.103 Mercury: NA	
Upstream Santa Clara	Pesticides: 89.77 PCBs: 0.0768 Mercury: 0	NA	NA	Pesticides: $t_{cals}=6.183$ $t_{crit}=12.706$ PCBs: $t_{cals}=0.415$ $t_{crit}=12.706$ Mercury: $t_{cals}=0$ $t_{crit}=0$
Downstream Santa Clara	Pesticides: 71.7 PCBs: 0.0894 Mercury: 0	NA	Pesticides: 0 PCBs: 0 Mercury: NA	
Upstream Mabury	Pesticides: 0 PCBs: 0 Mercury: 0	Pesticides: 0 PCBs: 0 Mercury: 0	Pesticides: 0 PCBs: 0 Mercury: NA	Pesticides: $t_{cals}=0$ $t_{crit}=0$ PCBs: $t_{cals}=0.146$ $t_{crit}=2.776$ Mercury: $t_{cals}=0$ $t_{crit}=0$
Downstream Mabury	Pesticides: 0 PCBs: 0.0372 Mercury: 0	Pesticides: 0 PCBs: 0 Mercury: 0	Pesticides: 0 PCBs: 0 Mercury: NA	

The Santa Clara Street sampling location made statistical analysis difficult. More data sets would be necessary to ascertain a variance to prove or disprove the thesis H1A hypothesis. Also, lack of concentration detected for mercury for the Santa Clara Street sampling location and for mercury and pesticides for the Mabury Street sampling location resulted in a t-test calculation of zero. There weren't enough detected concentrations to calculate the statistical analysis. More detectable concentrations would be necessary to prove or disprove this thesis H1A hypothesis. However, the lack of detections does display a reduced rate of contamination for Coyote Creek over time.

Where concentrations were available, the t value was calculated for each contaminant for each storm drain using the three sampling event data. The t values did not exceed the critical t values for each contaminant for each drain. Thus, the calculated t values were unable to prove the H1A hypothesis, which stated: Upstream (i.e., before suspected sources of contamination) bivalve bioaccumulation sampling will exhibit a smaller concentration of pollutant contamination than will downstream (i.e., after suspected sources of contamination have been introduced or discharged sampling from storm drains) bivalve samples. However, hypothesis H1, which stated: storm drains are a source of harmful levels of contamination, which drain to Coyote Creek based on bioaccumulation of toxins in bivalves, was supported.

During the deployment of the clam sets, water quality parameters were taken to calculate average concentrations for chemical and physical characteristics of the sample sites. During the water sampling, depth of water was added as a physical characteristic

due to the extreme rain events that occurred during the thesis study to illustrate the level of water influencing the sampling runs.

A total of 25 water quality samples were taken during the course of the thesis study (Appendix A). The sampling purpose was an attempt to characterize Coyote Creek's waters to find any parameters that would negatively influence the bioaccumulation of toxins in the clams. No parameters detected negatively influenced the bioaccumulation during this study. The average DO value for the total 25 samples was 12.06 mg/L, the maximum: 16.57 mg/L, the minimum: 5.83 mg/L. The average temperature for the total 25 samples was 13.64 degrees Celsius, the maximum: 17 degrees Celsius, the minimum: 11.3 degrees Celsius. The average turbidity of the 25 water samples taken was 184 ntu, the maximum: 2213 ntu, the minimum: 0 ntu. Ph values were only available for 15 samples due to instrument error. The average pH value was 7.23. The average flow rate for the 25 samples was 0.82 mph. Each sampling location had an increase in flow rate during storm events. The average depth of water exceeded 5 feet towards the center of the creek at the Santa Clara Street and Mabury Street sampling locations. During the winter storms all three sampling locations had an increase in water levels and flow rate.

The bioaccumulation results were compared to the EPA drinking water standards and the guidelines set forth by the NOAA SQuiRT tables to provide baseline water quality data for future ecological assessment of Coyote Creek and quantification of the health concerns to people using Coyote Creek's waters (Figure 1). All the tissue samples with numeric results for mercury and PCBs exceeded the acute and chronic SQuiRT guidelines for freshwater sampling. All the samples with numeric results for pesticides only

Figure 1: Comparison of Water Quality Guidelines with Numeric Results of Bioaccumulation

exceeded the chronic SquiRT guidelines for pesticides. The highest level of PCB concentration found in clam tissue was 103 ppb or 51.5 times over the 2 ppb suggested level by the SquiRT guidelines for acute exposure to PCBs. All the bioaccumulated toxins exceeded the EPA MCL drinking water standards for mercury, and PCBs. Two out of four samples located at Santa Clara Street exceeded the MCL for total pesticides. The highest level of contamination was PCB concentration found in clam tissue downstream in Kelly Park with 103 ppb or 206 times over the 0.5 ppb concentration limit of PCBs in drinking water.

DISCUSSION

Coyote Creek's waterways are impaired with PCB, mercury, and pesticide contamination. The sample location that exhibited contamination for pesticides, mercury and PCBs was the Kelly Park sample location (Figure 2). The concentration for PCBs peaked during the spring of 2005. Reasons for this peak are unknown since no detection of PCBs was found throughout the study except during the spring 2005 sample event. The concentration of PCBs at Kelly Park during the spring 2005 sample event could be an isolated incident or possible influence of contamination from the ambient environment.

Pesticides were also not predictable in concentration at the Kelly Park sampling location. Pesticides were detected during the spring 2004 sampling event and not detected during the rest of the study (Figure 2). These patterns of detection may be indicative to maintenance activities for the park lawn and garden areas adjacent to Coyote Creek. Kelly Park exhibited the only detection for mercury during the fall 2004 sampling event.

The contamination throughout the study site varied. The most upstream of sampling areas (Kelly Park) did exhibit a higher concentration of PCBs at 103 ppb than the most downstream sampled area (Mabury Street) at 37.2 ppb (Figure 3). The pesticides results, however, increased in concentration downstream near Santa Clara Street (Figure 4). This could be indicative of geographic pesticides use in the area since the Santa Clara sampling location was adjacent to a municipal park. There were numeric results for pesticides near the Santa Clara Street and Kelly Park sampling locations. Both of these

sampling locations are near fields connected to parks with large lawn areas as opposed to the Mabury Street sampling location that is adjacent to a gravel road and overpass street. Pesticide use may be more prevalent near the Santa Clara Street and Kelly Park due to fertilization, and spraying of pesticides to maintain the grounds of the parks. A mercury concentration was only found upstream in Kelly Park.

Mercury contamination is less of a threat to Coyote Creek due to the distant proximity of historic mercury mines. The adjacent watershed directly parallel to Coyote Creek is the Guadalupe River, which is impacted by mercury from the Almaden mercury mine, which has been historically mined during the 20th century. Coyote Creek doesn't have the mercury loads from history mining activities. This may have influenced the lack of data found in mercury detection during the thesis study. However, recent concern for mercury contamination is prevalent throughout the entire state of California with the California Regional Water Quality Board development of TMDLs (total maximum daily load). Wind blown sources of mercury from crematories and the continual production of products containing mercury such as fluorescent tubes and dental fillings should be considered a source of mercury to a watershed.

This thesis study was able to support two detections, where a downstream sample of clam tissue exhibited a greater concentration of contamination than an upstream sample from the storm drain studied. The Kelly Park and Santa Clara Street locations both exhibited greater pesticide detections in clam tissue downstream than upstream during the spring 2004 sampling event. The Kelly Park location exhibited a greater downstream stream detection of PCBs from the fall 2004 sampling event to the spring 2005 sampling

event. This trend was experienced over a greater span of time but the increase in PCB contamination was significant from the fall to the spring sampling events. This detection study from a storm drain out flow can possibly be used as a direct link to pollutant loads to Coyote Creek. A correlation could be made based on the data available to prove the upstream sampling from storm drains (approximately 100 feet from the drain) has lower concentrations of toxins than downstream sampling from the storm drain with further study.

Figure 2: Pollution Distribution At Kelly Park Sample Location

Figure 3: Total PCB Distribution in Coyote Creek

Figure 4: Total Pesticide Distribution in Coyote Creek

CONCLUSION

Coyote Creek's waterways are impaired with PCB, mercury, and pesticide contamination. People fishing or digging up shellfish for sustenance in Coyote Creek are at risk from bioaccumulated toxins. Exposure to accumulated pesticides from Coyote Creek would be a chronic issue of concern for human health and for the ecology of the creek. Any human consumption of clams in Coyote Creek could expose the consumer to levels of mercury, PCBs, and pesticides that exceed drinking water standards for potable water.

This study supports that Coyote Creek is impaired with toxins, which imposes a health risk to people. One detection of mercury was found at the Kelly Park location, which exceeded the suggested SquiRT guidelines and MCL drinking water standard. PCB concentrations were found to be higher upstream in Coyote Creek than downstream within the 6-mile stretch of the sampled area of this study. Pesticide levels were highest at the Santa Clara Street and Kelly Street sample locations.

The pesticide data needs more follow up with an investigation of the pesticide use within the area of the Santa Clara Street and Kelly Park sampling locations. Heavy use of pesticides and fertilizers on the park grounds without integrated pest management (IPM) could be a source of impairment to water quality in Coyote Creek. A program needs to be developed by the City of San Jose to utilized IPM practices and limit the use of toxic pesticides in parks, not only to protect water quality in creeks but also to limit the exposure of pesticide contamination of children since children are more susceptible to toxic contamination due to their untried immune systems.

Generally, PCB levels were more concentrated upstream in Coyote Creek. Further investigation is needed to find which specific sources (if available) are perhaps not mitigated for storm water. Baseline levels most likely exist within Coyote Creek's sediment. This must be taken into consideration when trying to find the source of PCB contamination. Sediment sampling could be instituted along the sampled 6-mile stretch to investigate historic loads of PCBs, mercury, and pesticides to understand all the sources of toxins to Coyote Creek.

The investigation of the Coyote Creek watershed is in need of a 'watershed management approach,' which combines all the elements of urban run-off possibly polluting the watershed as well as the big picture assessment of human activities, which have the potential of polluting the creek. A watershed management approach involves the entire community to engage in pollution prevention practices. Monitoring the flow and distribution of pollutants in Coyote Creek's waterways is a tool to begin this assessment of pollutant prevention to stop human health concerns from Coyote Creek. Now that pollutants have been found in this study over three seasons, the next step in managing the Coyote Creek watershed is to investigate the sources of pollution and create a management plan to educate the public of the health hazards from the water and aquatic life consumption. Then a change in activities needs to occur in the community to stop the current use of products such as pesticides that are polluting Coyote Creek as well as investigating the pollutant sources that have been banned from production or have decreased in use (i.e., PCBs and mercury) to eliminate their exposure to urban run-off.

REFERENCES CITED

- Ashley, Jeffrey. T.F. 2003. A comparison of congeneric PCB patterns in American eels and striped bass from the Hudson and Delaware River estuaries. *Marine Pollution Bulletin*. 1294-1308.
- California Regional Water Quality Control Board San Francisco Bay Region. 2001 *PCBs in San Francisco Bay: Sources and Loadings Report*.
- Division of Water Quality, State Water Resources Control Board. 1988. *California State Mussel Watch ten-year data summary, 1977-1987. Water Quality Monitoring Report No. 87-3*.
- Environmental Protection Agency. 1995. Methods for Sampling and Analyzing Contaminants in Fish and Shellfish Tissue. U.S. EPA document #823-R-95-007. <http://www.epa.gov/OST/fishadvice/vol11/doc2ndx.html>.
- Environmental Protection Agency. 2004. www.epa.gov/volunteer/stream/vms54.html.
- Environmental Protection Agency. 2004. <http://www.epa.gov/waterscience/fish/>.
- Environmental Protection Agency. 2005. <http://www.epa.gov/owow/nps/qa.html>.
- Hart, D.D. 1994. Building a stronger partnership between ecological research and biological monitoring. *Journal of the North American Benthological Society*. 13:110-116.
- Hornberger, Michelle. 2000. I. Linkage of bioaccumulation and biological effects to

- changes in pollutant loads in South San Francisco Bay. *Environmental Science and Technology*, 34:2401-2409.
- Hummel, H., R.H. Bogaards, J. Nieuwenhuize, L. DeWolf, and J.M. VanLiere. 1990. Spatial and seasonal differences in the PCB content of the mussel *Mytilus edulis*. *Science of the Total Environment*, 92:155-163.
- Lagadic, Laurent. 2000. *Use of Biomarkers For Environmental Quality Assessment*. Science Publishers, Inc. Enfield, NH.
- Martincic, D., Z. Kwokal, Z. Peharec, D. Margus, and M. Branica. 1992. Distribution of Zn, Pb, Cd, and Cu between seawater and transplanted mussels (*Mytilus galloprovincialis*). *Science of the Total Environment*, 119:211-230.
- McMurtry, Richard. 2000. *PCBs and Clams in Creeks: The Results of An Environmental Partnership*.
- Robinson, Virginia. 2003. *Clean Streams/Clean Bay Community Watershed Monitoring Project: The Results of An Environmental Partnership*.
- San Francisco Estuary Institute. 1996. *A comparison of selenium and mercury concentrations in transplanted and resident bivalves from north San Francisco Bay. In 1995 Annual Report: San Francisco Estuary Regional Monitoring Program for Trace Substances*. By: S.N. Luoma and R. Linville. Oakland, CA. pp. 160-170.
- San Francisco Estuary Institute RMP. 2003. *RMP, Regional Monitoring Program for Trace Substances 2003*. Richmond CA. pp. 4.1-4.17.
- Santa Clara Valley Urban Runoff Pollution Prevention Program. 2003. *Assessment of*

Stream Ecosystem Functions for the Coyote Creek Watershed, Coyote Creek Watershed Integrated Pilot Assessment Final Report, by Lucy A.J. Buchan and Paul J. Randall. Funded by the SC program.

State Water Resources Control Board. 1994. *State Mussel Watch Program, 1987-1993 Data Report*. By: Rasmussen. D. 94-1WQ.

Todd C. and D. Roux. 2000. *Design of an Aquatic Biomonitoring Programme, Using the South African River Health Programme as a Case Study*.

Ueno, D. 2003. Specific accumulation of polychlorinated byphenyls and organochlorine pesticides in Japanese common squid as a bioindicator. *Environmental Pollution* 125:227-235.

U.S. Geological Survey. 1995. National Water Quality Assessment Program Report. Reston, VA.

U.S. Geological Survey. 1999-2000. *Near field receiving water monitoring of trace metals in clams (Macoma balthica) and sediments near the Palo Alto Water Quality Control Plant in South San Francisco Bay, California*.

Vinogradov, A.P. 1959. *The geochemistry of rare and dispersed chemical elements in soils*. Chapman and Hall, London.

Wu, R.S.S. and C.D. Levings. 1980. Mortality, growth and fecundity of transplanted mussel and barnacle populations near a pulp mill outfall. *Marine Pollution Bulletin* 11:11-15.

Young, D.R., T.C. Heesen, and D.J. McDermott. 1976. An offshore biomonitoring

system for chlorinated hydrocarbons. *Marine Pollution Bulletin*. 7:156-159.

FIGURE 5: SITE LOCATION (COYOTE CREEK)

Figure 6: Stream Discharge Points of Potential PCB Sources in San Jose, CA, Silicon Valley Toxics Coalition, September 2000

Figure 7:
Sampling Location Map (Coyote Creek Watershed)

Legend

Highways	Storm Drain
Rivers	Sample Sites
Study Site	

APPENDIX A: RESULTS OF WATER QUALITY SAMPLING

Sample Site	Date	Time	Temperature	pH	DO	Turbidity	Flow rate	Depth of Water
US Kelly Park	2/10/04	14:20p m	11.6 Celsius	5.26	15 mg/L	73 ntu	0 mph	2.5 ft.
DS Kelly Park	2/10/04	14:18p m	11.6 Celsius	6.40	12.25 mg/L	190 ntu	0 mph	1.9 ft.
US Santa Clara St.	2/10/04	12:11p m	11.3 Celsius	8.49	16.57 mg/L	33 ntu	0 mph	3 ft.
DS Santa Clara St.	2/10/04	12:10p m	12.5 Celsius	6.36	12 mg/L	10 ntu	0 mph	>3 ft.
US Mabury St.	2/10/04	10:46am	11.4 Celsius	7.49	15.2 mg/L	15 ntu	0 mph	2 ft.
DS Mabury St.	2/10/04	10:50am	12.2 Celsius	5.83	5.83 mg/L	10 ntu	0.05 mph	>3 ft.
DS Kelly Park	2/24/04	8:10am	12.4 Celsius	7.28	11.22 mg/L	12 ntu	2 mph	1.5 ft.
US Kelly Park	2/24/04	8:17am	12.3 Celsius	6.44	11.4 mg/L	6 ntu	1 mph	3.5 ft.
Kelly Park at Storm Drain	2/24/04	8:25am	13.7 Celsius	7.29	10.51 mg/L	85 ntu	0 mph	NA
DS Kelly Park	3/9/04	8:05am	14.8 Celsius	NA	10.8 mg/L	15 ntu	0.5 mph	1.7 ft.
US Kelly Park	3/9/04	8:26am	14.3 Celsius	NA	10.7 mg/L	12 ntu	0.5 mph	2.2 ft.
US Mabury St.	3/9/04	11:00am	16.4 Celsius	NA	11.59 mg/L	0 ntu	1 mph	1.6 ft.

DS Mabury St.	3/9/04	11:35	16.9 Celsius	NA	11.69 mg/L	78 ntu	0 mph	3 ft.
US Kelly Park	10/22/04	10:26am	15 Celsius	NA	11.8 mg/L	18 ntu	0 mph	1.5 ft
DS Kelly Park	10/22/04	10:49am	15 Celsius	NA	11.4 mg/L	24 ntu	0.89 mph	1.9 ft
DS Santa Clara St	10/22/05	11:30am	15 Celsius	NA	11.5 mg/L	60 ntu	0 mph	5 ft
US Santa Clara St.	10/22/04	11:57am	16 Celsius	NA	11.2 mg/L	25 ntu	0 mph	5+ ft at center
DS Mabury St.	10/22/04	12:40p m	17 Celsius	NA	11.1 mg/L	6 ntu	0 mph	5+ ft at center
US Mabury St.	10/22/04	13:03p m	17 Celsius	NA	10.5 mg/L	23 ntu	0.5 mph	5+ at center
US Kelly Park	1/28/05	8:50am	13 Celsius	7.91	13.56 mg/L	219 ntu	5 mph	4 ft
DS Kelly Park	1/28/05	8:30am	13.1 Celsius	7.80	12.78	220 ntu	9 mph	5+ ft at center
DS Santa Clara St.	1/28/05	10:15am	11.9 Celsius	7.91	12.84 mg/L	274 ntu	0.5 mph	5+ ft at center
US Santa Clara St.	1/28/05	9:45am	12 Celsius	8.04	13.85 mg/L	754 ntu	0 mph	5+ ft at center
US Mabury St.	1/28/05	11:10am	12.4 Celsius	8.01	13.42 mg/L	213 ntu	0 mph	5+ ft at center
DS Mabury St.	1/28/05	10:55am	12.3 Celsius	7.96	12.90 mg/L	2213 ntu	0 mph	5+ ft at center

DS: downstream
ft: feet
mg/L: milligrams per liter

mph: miles per hour
NA: Not Available
ntu: nephelometric units

US: upstream