NOAA Technical Memorandum NOS OMA 45

AN EVALUATION OF CANDIDATE MEASURES OF BIOLOGICAL EFFECTS FOR THE NATIONAL STATUS AND TRENDS PROGRAM

Seattle, Washington
April 1989

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

National Ocean Service

Office of Oceanography and Marine Assessment
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

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ERRATA FOR TECHNICAL MEMORANDUM NOA OMA 45

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Reference to Table 25 in second paragraph on page 41 should be Table 14.

Reference to Table 10 in first and second paragraphs on page 44 should be Table 17.

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CONTENTS

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Mr. Rick Wright and Mr. Nick Rottunda (SAIC) collected the sediment and benthos samples. Dr. David Rice, Jr. (LLNL) performed chemical analyses of the fish. Dr. Peter Thomas (University of Texas) performed hormone analyses of fish plasma. Dr. Loveday Conquest (University of Washington) provided advice on statistical methods for data analyses. Mr. Kirk Van Ness (NOAA) assisted in sampling site selection. Ms. Charlene Swartzell (NOAA) typed the manuscript and revised it innumerable times. CDR Stewart McGee (NOAA) assisted in arranging vessel logistics. The following performed the chemical analyses of sediments at SAIC: Dr. James Payne, Dr. John Clayton, Mr. Gary Farmer, Mr. Dan McNabb, Mr. Mike Guttman (organics); and Mr. R. Sims (trace metals). Ms. Roxanne Rousseau and Mr. Ian Watson (E.V.S. Consultants) assisted in the performance of the tests with *Rhepoxynius* and *Mytilus*. Mr. Darrin Greenstein, Ms. Karen Rosenthal, and Ms. Valerie Raco (SCCWRP) assisted in conducting tests with *Strongylocentrotus*. Ms. Susan Shepard and Ms. Michele Redmond helped conduct the tests with *Ampelisca*. Mr. John Williams and Mr. Carlos T. B. Frigata (Battelle Ocean Sciences Division) helped perform tests with *Dinophilus*. Ms. Susan Garner, Mr. Lawrence Lovell, Ms. Susan Watts, and Ms. Janice Callahan (MEC) conducted various tasks in the taxonomic analyses of benthic samples. Mr. Eugene Revelas and Drs. Joseph Germano and Robert Merten (SAIC) assisted in the performance of the sediment profiling survey of San Francisco Bay. Dr. Howard Harris (NOAA) provided helpful comments on an initial draft of the manuscript.

EXECUTIVE SUMMARY

An evaluation of the response and sensitivity of candidate measures of biological effects to a range in contaminant concentrations was performed in the San Francisco Bay area in 1987. The evaluation was performed to determine which, if any, of the candidate measures may be useful in the National Status and Trends (NS&T) Program of the National Oceanic and Atmospheric Administration (NOAA).

The NS&T Program analyzes three media--sediments, bottomfish, and bivalves--routinely at sites nationwide. The present evaluation included biological tests of two of those media: sediments and fish. The overall approach chosen for the evaluation involved analyses of samples collected in the field at sites that were presumed to represent a range in chemical contamination. The biological tests were performed with subsamples of samples that were also analyzed for chemical concentrations. All the tests were performed "blind," *i.e.*, without knowledge of the origin of the samples. Data from the various biological tests were then compared with each other and with the chemical data in various statistical procedures. It was presumed and hypothesized before the evaluation began that biological tests most applicable to the NS&T Program would be those that were able to indicate differences among sampling locations over a range in chemical contamination and/or between sampling locations and laboratory controls, had relatively large ranges in response among mean values for the sampling locations, had relatively small analytical errors, and indicated patterns in biological response that generally paralleled the pattern in chemical contamination.

The relative sensitivity, analytical precision, discriminatory power, and concordance among end-points and with sediment chemistry were compared among multiple end-points of five types of sediment toxicity tests. The tests were performed with aliquots of 15 composited, homogenized samples collected in San Francisco Bay and Tomales Bay, California. Each sample was also tested for trace metal and organic compound concentration, organic carbon content, and texture. The end-points evaluated were: survival and avoidance of solid phase sediments by the amphipods *Rhepoxynius abronius* and *Ampelisca abdita*; survival and abnormal development in the embryos of the mussel *Mytilus edulis* exposed to elutriates; fertilization success, abnormal development, echinochrome pigment content, incidences of abnormal mitotic division, micronuclei, cytological abnormalities and mitoses per embryo in the embryos of the urchin *Strongylocentrotus purpuratus* exposed to elutriates; and survival and egg production in the polychaete *Dinophilus gyrociliatus* exposed to interstitial (pore) water. Among the end-points evaluated, abnormal development of *M. edulis* embryos was the most sensitive to the samples relative to controls and had the highest precision and discriminatory power. Survival of *R. abronius* was the second most sensitive and also had a high range in response and discriminatory power. The results of both end-points (along with those of *M. edulis* survival), however, were more highly correlated with sedimentological variables than with the concentrations of chemical contaminants. The end-point of *A. abdita* survival had relatively high analytical precision, moderate discriminatory power and was relatively highly correlated with several chemicals, but had comparatively low sensitivity relative to controls. Abnormal development and echinochrome content in *S. purpuratus* had relatively high precision and results were relatively highly correlated with several chemicals, but discriminatory power was moderate and the abnormal development results contradicted those of many of the other end-points. Several of the cytological/cytogenetic end-points of this test measured in only five samples indicated a wide range in response and strong correlations with chemical data, but precision was relatively low. The test of *D. gyrociliatus* egg production was intermediate in sensitivity, had relatively low precision and discriminatory power, and was highly correlated with several organic chemical groups. The results of this pore water test were not highly correlated with those of the solid phase and elutriate tests. The authors conclude that, since different toxicological mechanisms may occur in the responses of organisms to complex media such as sediments, multiple toxicity tests are needed to comprehensively assess the quality of marine sediments.

Analyses of benthic communities were performed with two methods: "traditional" taxonomic analyses of animals collected with a grab sampler and retained on a 1-millimeter (mm) screen; and analyses of horizontal sediment profiling photographs taken with a remotely operated camera. The taxonomic analyses showed that the benthos were very similar among the three stations sampled at each site, but quite distinct among the sites. Total abundance, species richness, measures of total biomass, and indices of dominance and species diversity all indicated significant differences among sites. Molluscs were dominant at one site, polychaetes at another (the reference site), and crustaceans were dominant at two others. No data are available thus far for the most contaminated site. The major differences in benthos composition among sites could be attributable to "natural" types of stress such as periods of lowered salinity or scouring, as well as to differences in chemical contamination.

A survey of 69 sites in the San Francisco Bay estuary was performed with a sediment profiling camera. A variety of sedimentological and biological parameters was recorded during analyses of the photographs. There were 4 of the 69 sites which corresponded with those sampled for bioassays, benthos, and chemical analyses. Signs of sediment organic enrichment or anoxia were recorded at very few of the sites. Some sites in the peripheral waterways of Redwood Creek, Oakland Inner Harbor, and Richmond Harbor showed indications of enriched sediments. Among the four sites sampled for toxicity, benthos, and chemical analyses the most contaminated site showed several indications of slightly elevated organic enrichment and contamination by bacterial indicators of sewage. The successional stage in benthic communities at that site, however, was not remarkably different from that at the other three sites. The sediment profiling photography technique provided data quickly on important characteristics of the surficial sediments.

The starry flounder (*Platichthys stellatus*), a bottom-dwelling flatfish, was collected at six sites and tested for contamination of the tissues by chlorinated hydrocarbons and a variety of measures of the health of the fish. The biological measures included analyses of hepatic aryl hydrocarbon hydroxylase (AHH) activity, counts of micronucleated erythrocytes in the blood, analyses of steroid hormone content in the plasma, and analyses of the induction of the hepatic cytochrome P-450 enzyme system. All were performed on subsamples of the same fish. Fish were collected during two periods: November and December 1986 and January and February 1987. Fish caught in the latter period were spawned to also determine impaired reproductive success in addition to the other measures.

Fish from two sites in San Francisco Bay were generally more contaminated with a mixture of compounds than those from a coastal reference site and a reference site in the Bay. However, the distinction in the chemical concentrations between sites was not as clear as with the sediments. The range in contaminant concentrations and the absolute values were not particularly high among the sampling sites for both fish and sediments. This observation corroborated the conditions that were anticipated, based upon previous knowledge of contamination of San Francisco Bay and vicinity. It was presumed that the sensitivity of various candidate measures of effects could be tested most accurately by sampling locations that would not be grossly contaminated (*i.e.*, where even the least sensitive tests would indicate effects) and that would generally mimic conditions often encountered in the NS&T Program (which, thus far, has mostly avoided highly contaminated areas).

The incidence of micronucleated erythrocytes in the fish was significantly lower in fish from the coastal reference site than in fish from most of the sites in San Francisco Bay. Incidences in fish among the sites in San Francisco Bay were not distinguishable. The measures of micronuclei formation (especially detached micronuclei) appear to be sensitive, applicable to several species, relatively high in between-site discriminatory power in some species, and correlated with the concentrations of organic compounds, but also are relatively highly variable among fish caught at the same site. Cytochrome "P-450E" content and ethoxyresorufin-O-deethylase (EROD) activities in the liver microsomes of the fish were significantly higher in fish from sites near urban centers than in fish from a coastal

reference site. The suite of cytochrome P-450/EROD/P-450E measures appear to be sensitive, relatively low in within-site variability, relatively high in between-site discriminatory power, correlated with contaminant concentrations, and have indicated a similar pattern in response among species. Fish from the most contaminated sites often had the highest AHH activity, but differences between sites were not significant. Compared to the other measures performed with fish, the AHH activity analyses were less sensitive, had moderate within-site variability, had moderate between-site discriminatory power, but were correlated with chemical concentrations. Data from tests of plasma steroid hormone analyses did not show any significant differences among sites. Interpretation of the results of measures of impaired reproductive success in the fish was confounded by small sample sizes. Generally, there was good concordance between the biological measures and the data for some chemicals. Also, there generally was good, but not significant, concordance among the measures of cytochrome P-450 induction, AHH activity, and micronuclei incidence.

It is apparent from this evaluation and previous use of the tests that most of the biological measures generally perform well and could qualify as candidates for future use in the NS&T Program. However, certain of the tests appear to better meet the criteria for inclusion in the Program. They include the tests of acute toxicity of sediments with bivalve larvae and amphipods; tests of mutagenicity/genotoxicity in echinoderm larvae exposed to sediments; AHH and EROD activities and cytochrome P-450 content in liver microsomes of fish; and counts of erythrocyte micronuclei in fish. The use of sediment photography profiling techniques is best suited for evaluations of organic enrichment of depositional sediments and assessments of recovery of disturbed benthic habitats. The pore water bioassay needs further testing and evaluation to fully develop this very promising technique. Plasma steroid hormone content in fish can be influenced by a wide variety of factors. The data gathered in the present evaluation did not indicate significiant differences between sites under the conditions extant at that time. Although tests of impairment of reproductive success through spawning studies have provided useful and pollution-sensitive information in research with *P. stellatus* and other bottomfish, they were difficult to evaluate in this study because of the small sample sizes.

It is also apparent from this evaluation and that performed at the Group of Experts on the Effects of Pollutants (GEEP) workshop that no single measure of biological effects can suffice for determining the biological effects of pollution. The complexity and multitude of biological responses to contaminants cannot be expressed with any single test, just as the complex mixture of chemicals in most urban areas cannot be indicated with the quantification of any single chemical. A suite of complementary tests can be selected from those evaluated in this study and tailored to meet specific programmatic needs and used to assess the occurrence and severity of effects associated with elevated contaminant levels. Therefore, in order to maintain flexibility needed to satisfy various (unforeseen) programmatic objectives, all of the biological measures should be considered as potential candidates and none should be eliminated from future potential use. All have certain strengths and weakness that should be considered in selection of a suite of tests to meet specific objectives.

INTRODUCTION

The goal of the National Status and Trends (NS&T) Program is to determine the status of and trends in environmental quality of marine and estuarine areas of the United States. To satisfy that goal, NOAA has begun monitoring the concentration of selected, potentially toxic, chemical contaminants (*e.g.*, NOAA, 1987). The NS&T Program is currently analyzing sediment samples from about 200 sites, bivalve samples from about 150 sites, and fish samples from 50 sites nationwide for chemical contaminants. Quantitative data are generated for a large suite of potentially toxic contaminants at each of these sites annually. The analyses, however, include only very limited tests of biological significance of the contaminants that are found in the test media. There are no standards with which to judge the biological relevance of the contaminant data from sediments, bivalves, and biota. Until such standards are developed and accepted, additional empirical evidence is needed to determine which sites are sufficiently contaminated to be of some biological concern.

An evaluation of prospective measures of biological effects was initiated in San Francisco Bay in 1987 to determine the relative attributes or performance of selected tests that may be most useful in the NS&T Program. Those measures of effects that are most promising will be used on a broader scale as a part of the NS&T Program testing protocols. This report summarizes the results of that evaluation.

APPROACH

The overall approach taken was to solicit the scientific community for suggested measures of biological effects, select those candidates that best met specific programmatic criteria, and evaluate their performance over a range in contamination in a selected location. This approach was roughly analogous to that taken by the Group of Experts on the Effects of Pollutants (GEEP) of the Intergovernmental Oceanographic Commission (IOC) in a practical workshop on biological effects of contaminants held in Oslo, Norway in August, 1986 (Bayne *et al.*, 1988). In that workshop, a wide variety of biological tests was evaluated, including some that were evaluated in this study.

The relative sensitivities of a variety of animals for use in sediment toxicity tests have been evaluated in previous studies (*e.g.*, Swartz *et al.* 1979; Williams *et al.*, 1986; Chapman *et al.*, 1984; Chapman, 1987; Giesy *et al.*, 1988). Acute mortality, measures of abnormal larval development, impaired physiological functions, altered behavior, and chromosomal damage were recorded in these previous evaluations of toxicity tests. Some tests evaluated in this study, notably the 10-d solid phase test with *R. abronius* (Swartz *et al.*, 1985) and the 48-h elutriate test with bivalve embryos (Chapman and Morgan 1983), have been used in many regional assessments of sediment toxicity (*e.g.*, Williams *et al.*, 1986; Swartz *et al.*, 1982; Chapman *et al.*, 1987; Swartz *et al.*, 1986). Some others are relatively new and had not been evaluated previously.

The solicitation was issued in 1986 and required that suggested tests meet, as well as possible, eight criteria. Those criteria specified that the biological tests:

(1) Include end-point(s) that is (are) of significance to the longevity (survival) or reproductive success of the organism(s);

(2) Be usable in distinguishing spatial gradients among sampling sites and long-term trends at each site in effects of exposure to chemical contaminants;

(3) Be sensitive indicators of exposure to mixtures of toxic chemicals;

(4) Be of marine or estuarine organisms;

(5) Be applicable throughout most of a broad biogeographic zone along any of the three U. S. coastlines;

(6) Be relatively insensitive to natural environmental variables or include some means of accounting for the contributory influence of those variables;

(7) Be feasible during all seasons, from a variety of vessels and operating conditions and in a variety of environments; and

(8) Be inexpensive and feasible by more than one laboratory.

The solicitation for proposals was issued by NOAA in 1986 and resulted in the submittal of 47 proposals. Eight of those were selected as best meeting the criteria. In addition, three other types of analyses were funded to support and augment the biological tests. In total, the following numerous tests and analyses were performed by the following contractors:

(1) Collection and chemical analyses of surficial sediments (Battelle New England Ocean Sciences Division and Science Applications International Corporation (SAIC));

(2) Solid phase sediment toxicity test with the amphipod *Rhepoxynius abronius* (E.V.S. Consultants);

(3) Solid phase sediment toxicity test with the amphipod *Ampelisca abdita* (Springborn-Life Sciences and SAIC);

(4) Sediment elutriate toxicity test with the larvae of the mussel *Mytilus edulis* (E.V.S. Consultants);

(5) Sediment elutriate toxicity test with the larvae of the sea urchins *Strongylocentrotus purpuratus, S. droebachiensis,* and *Lytechinus pictus* (Southern California Coastal Water Research Project (SCCWRP));

(6) Sediment pore water toxicity test with the polychaete *Dinophilus gyrociliatus* (Battelle New England Ocean Sciences Division);

(7) Taxonomic analyses of benthic community structure (SAIC and Marine Ecological Consultants (MEC));

(8) Analyses of sedimentological and biological characteristics with sediment profiling photography (SAIC);

(9) Fish collection, tissue chemical analyses, aryl hydrocarbon hydroxylase (AHH) analyses, (Lawrence Livermore National Laboratory (LLNL)) and plasma steroid hormone analyses (University of Texas);

(10) Fish blood micronucleated erythrocyte analyses (SCCWRP); and

(11) Fish liver cytochrome P-450 and ethoyresorufinn-O-deethylase (EROD) enzyme analyses (Woods Hole Oceanographic Institution (WHOI)).

Among the three media (sediments, fish, and bivalves) that NOAA routinely analyzes in the NS&T Program, candidate measures of effects were evaluated for two: sediments and

fish. All the tests under evaluation had been developed and tested to varying degrees in laboratory and field research.

Field sampling logistics, sample handling, and data analyses were performed separately for the work with fish and sediments, though some of the sites overlapped. Sampling sites were selected to represent a range in contamination from relatively highly contaminated conditions to pristine. Data from previous studies, including those by the NS&T Program (*e.g.*, NOAA, 1987), were used to select the sampling sites.

In an attempt to reduce costs, as many sediment sampling sites as possible that are routinely sampled in the NS&T Program annually were used in the evaluation. As a result, the sediments were sampled using the NS&T Program protocol: three stations sampled at each site. Four sites from the NS&T Program were sampled in the San Francisco Bay area: Yerba Buena Island (YB), San Pablo Bay (SP), Vallejo (VA), and Tomales Bay (TB). Three samples (numbers 1, 2, and 3) from the Oakland Inner Harbor (near 37°47'11"N, 122°14'50"W) were expected to be relatively highly contaminated. Three samples each collected near Yerba Buena Island (numbers 4, 5, and 6; near 37°50'16"N, 122°20"W), near Vallejo (numbers 7, 8, and 9; near 38°04'10"N, 122°14'17"W), and in southwestern San Pablo Bay (numbers 10, 11, and 12; near 38°01'35"N, 122°25'36"W) were expected to be moderately contaminated. Three samples (numbers 13, 14, and 15) from Tomales Bay (near 38°09'02"N, 122°53'55"W), a remote embayment located north of San Francisco Bay, were expected to be minimally contaminated. The locations of the sites are illustrated in Figure 1. In the data evaluation, the 15 samples were treated either as (1) 15 independent sampling stations or (2) three replicates of each of the five sites in accordance with NS&T Program sampling protocols. Tests of samples from the respective animal collection sites were also performed concurrently with each toxicity test and treated as laboratory controls. Since the participating laboratories were scattered, the same material was not used as controls for all the toxicity tests. This disparity is recognized as a weakness in the study design, especially since none of the control samples was analyzed for chemical concentrations. Nevertheless, the controls served as independent test media for evaluating the viability and internal consistency of the test organisms and for determining which test samples were "toxic", *i.e.*, significantly different from respective controls. Five separate grab samples were collected at each station for the benthic community analyses. Finally, an independent survey of 69 sites in the San Francisco Bay estuary was performed, using a sediment profiling camera.

The fish sampling sites were: in the Oakland Outer Harbor (OK), off Berkeley (BK), in San Pablo Bay (SP), off Vallejo (VJ), off the mouth of the Russian River (RR) (reference site), and off Santa Cruz (SC) in Monterey Bay. The former two (OK, BK) were expected to be relatively highly contaminated, VJ was expected to be moderately contaminated, and RR, SP, and SC were expected to be minimally contaminated reference sites. The species selected for the fish analyses was the *Platichthys stellatus*. It had been the subject of extensive research on availability, contamination, and measures of biological effects in the Bay (Spies and Rice, 1988).

All analyses were performed "blind," *i.e.*, without knowledge of the station or site from which the samples were collected. Following the calculation of mean values for each station or site for each measure, the data were subjected to a variety of statistical procedures to comparatively evaluate the performance of the biological measures.

All measures of biological effects performed with feral organisms or complex environmental samples (e.g., sediments) are subject to several sources of variability. Each species has different degrees of tolerance to contaminants and natural factors. Also, the tolerance of individual organisms varies depending upon age, condition, natural sources of stress, genotype, *etc.* Chemical analyses of environmental samples do not provide information for all chemicals that are potentially toxic. They do not indicate which chemicals or portions of chemical concentrations are bioavailable. Good reliable measures of effects are needed to stand alone as independent indicators of biologically significant stress without the benefit of or confusion with synoptic chemical data. Nevertheless, the most

powerful biological measures will be those which provide significant indications of effects over, say, order-of-magnitude gradients or differences in contamination. Therefore, the evaluation of the performance of these tests mainly focused upon their sensitivity, precision, and discriminatory power, and, to a lesser extent, upon their concordance with the matching chemical data.

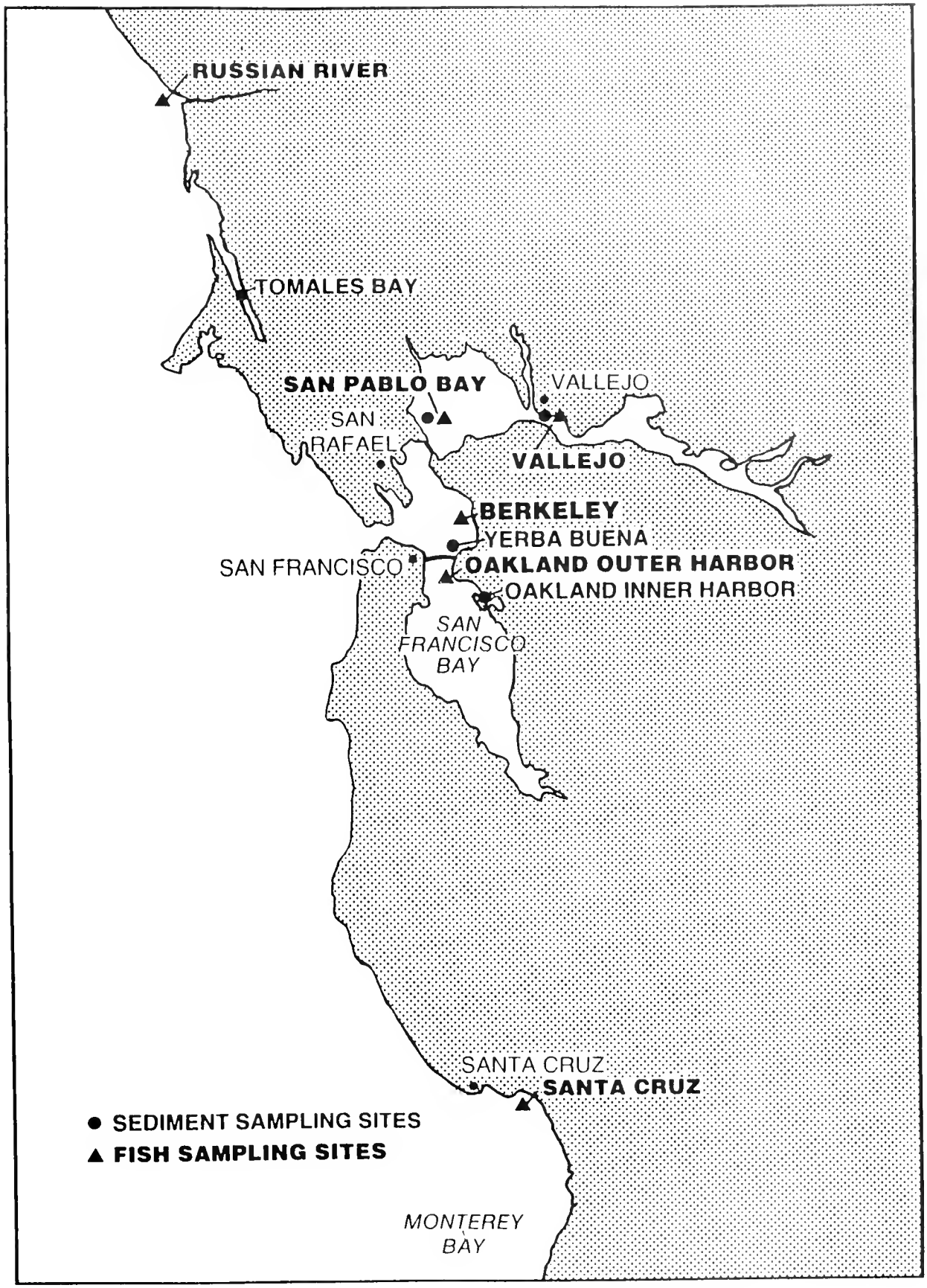

Figure 1. Fish and sediment sampling sites in the San Francisco Bay area.

METHODS

Sediment Sampling

The NS&T Program protocols include collection of sediments at each of three stations per sampling site. Accordingly, in this evaluation, three stations, generally separated by 50 to 100 meters, were sampled at each site. Samples were collected with a $0.1m^2$ Young grab sampler (similar to a modified Van Veen grab sampler). Multiple (usually 6 to 10) grab samples were taken at each station and the upper 1 centimeter (cm) of sediment was removed with a Teflon-lined, stainless-steel, calibrated scoop. These 1-cm thick samples were collected in a stainless steel, Teflon-lined basin until about 7 liters (L) of sediment had been accumulated and composited from each station. The sediments then were homogenized for approximately 5 min. with a Teflon-lined steel spoon until the composited sample appeared homogeneous. Portions of varying sizes of the composited sample from each station then were removed for each of the chemical and sedimentological analyses and toxicity tests. Care was taken to avoid contamination of the samples. Sampling was conducted in February 1987.

All toxicity tests were performed with five laboratory replicates or aliquots of the composited sediments per station. The sediment samples for chemical analyses were frozen at -40°C and stored for a maximum of 60 days until the analyses were performed. The toxicity tests were performed on three phases of the sediments: solid, elutriate, and pore water. All except the pore water test were conducted on nonfrozen samples held for no more than 5 days.

Fish Sampling

Starry founder (*Platichthys stellatus*) were collected twice: in November/December 1986 when fish were anticipated to be late in the reproductive cycle but not yet ready to spawn, and January/February 1987 when the fish were expected to be sexually mature. Fish were captured with 5- and 7-m otter trawls towed for 20 min. in water depths of 2.5 to 7 meters behind a research vessel. A target of 30 and 10 to 15 fish per site was set for each sampling period, respectively, to facilitate determinations of between-site differences in measures of effects. Fish less than 20 cm were not retained. When more than 15 fish were caught at a station, more of the larger, sexually mature individuals were kept.

Immediately upon capture of the fish, they were bled from either the caudal vein, gill arch, or heart to obtain samples for the micronuclei and hormone analyses. A 1-milliliter (mL) blood sample was centrifuged in the field and frozen at -76°C for the future hormone analyses. A blood smear was prepared on a slide, fixed in alcohol, and kept in cold storage for the micronuclei analyses.

Captured fish were maintained on the vessel in flowing bay water until transported to the recirculating marine aquaria at LLNL. Fish were sacrificed the day following capture. Solvent-rinsed tools were used to remove livers and the gonads, which were weighed and aliquots of each put aside for subsequent analyses. For each fish, the gonadosomatic index (GSI) was calculated as [gonad weight/(body weight - gonad weight)] x 1,000. The hepatosomatic index (HSI) was calculated similarly. Standard length was determined for each fish. The fish were kept alive until just before necropsy. Liver and ovary were removed and frozen at -76°C for enzyme and chemical analyses. An additional subsample of ovary was collected and fixed in Davidson's fluid for histological examination.

Female fish captured in January/February were taken to the laboratory in Livermore to be spawned for an evaluation of measures of reproductive success.

Solid Phase Sediment Toxicity Test with the Amphipod *Rhepoxynius abronius*

This toxicity test has been tested and evaluated extensively (Swartz *et al.*, 1985; Mearns *et al.*, 1986; DeWitt *et al.*, 1988) and used in many environmental surveys (Williams *et al.*, 1986; Swartz *et al.*, 1982; Swartz *et al.*, 1986), primarily in the Pacific Northwest.

Animal collections. The burrowing infaunal amphipods, *Rhepoxynius abronius*, were collected subtidally from West Beach, a relatively remote site on Whidbey Island (Washington State), using a bottom trawl.

Test Procedures. Following their arrival in the laboratory, amphipods were kept in holding containers filled with fresh seawater (28 parts per thousand (ppt) salinity) and maintained at 15 ± 1°C under continuous light until used in testing. Cultures were aerated but not fed during acclimation and were held for 5 days prior to testing. Amphipods were hand sorted from sediments and identifications were confirmed using a Wild M5 dissecting microscope. Individuals that were damaged, dead, or unable to rebury in acclimation sediments were discarded.

Acute lethality of sediments was measured in a 10-day exposure to test sediments following the methodology of Swartz *et al.* (1985) as amended by Chapman and Becker (1986). A 2-cm layer of test sediment was placed in 1-L glass jars and covered with 800 mL of clean seawater (28 ppt salinity). The interstitial salinities of all test containers were measured after seawater addition and found to be 27 ± 2 ppt. Each beaker was seeded randomly and without knowledge of station identification with 20 amphipods, covered, and aerated. Six replicates were run per station. Five beakers were used to determine toxicity, while a sixth beaker was used to measure water chemistry daily (pH, dissolved oxygen, salinity, temperature). Containers were checked daily to establish trends in mortality and sediment avoidance, and also to gently sink any amphipods which had emerged from the sediment overnight and become trapped by surface tension at the air/water interface. A control sediment from the amphipod collection site was tested concurrently with the sediments from the five sites. This site had been previously documented to be nontoxic to amphipods (Tetra Tech, 1985).

After 10 days, sediments were sieved (0.5-mm screen), and live and dead amphipods were removed and counted. Amphipods were considered dead when there was no response to physical stimulation and microscopic examination revealed no evidence of pleopod or other movement. Missing amphipods were assumed to have died and decomposed prior to the termination of the bioassay (Swartz *et al.*, 1982; 1985). The amphipod avoidance end-point was determined from daily counts of amphipods that had emerged from the sediments. At the end of the 10-d exposure, live amphipods were transferred to a fingerbowl containing a 2-cm deep layer of control sediment and clean bioassay water. The number of individuals that had reburied within 1 hour was recorded to determine the percent reburial end-point. All but sample numbers 8 and 9 were tested in the first batch.

Parallel reference toxicant bioassays (96-h LC50 tests in clean water without sediment) were conducted using sodium pentachlorophenate (NaPCP). A 100 parts per million (ppm) stock solution of NaPCP was prepared in a 0.04 mole (mol) solution of sodium hydroxide using anhydrous grade pentachlorophenol (Sigma Chemicals), following procedures described in Niimi and McFadden (1982). Bioassay concentrations were prepared in duplicate by volumetric dilution of the NaPCP stock solution with filtered seawater. The concentrations of NaPCP tested were: 1,000, 750, 560, 320, 180, and 100 µg/L.

Solid Phase Sediment Toxicity Test with the Amphipod *Ampelisca abdita*

This toxcicity test has been developed in New England by Scott and Redmond (in press) and has thus far been used on a limited basis in environmental surveys (Gentile *et al.*, 1987).

Animal collections. Tube-forming amphipods, *Ampelisca abdita*, were obtained from tidal flats in Bourne Cove, a small inlet in Buzzards Bay, Massachusetts by collecting sediments and sieving them through a 0.5-mm screen. *A. abdita* were collected by flotation from the air/water interface (Gentile *et al.*, 1987). The animals were transferred to 3-L jars containing approximately 5 to 7 cm of collection site sediment in aerated ambient seawater. The amphipods were gradually acclimated under static seawater conditions at 1-3°C per day to the test temperature of 20°C. During acclimation, they were fed *Skeletonema sp.* (1.0×10^7 cells per mL) at the rate of 200 mL of algae per 3-L jar daily. Temperature, dissolved oxygen, salinity, and pH were measured in alternating jars daily during acclimation.

Test Procedures. Dense populations of native *Ampelisca abdita* had been previously observed at many locations in San Francisco Bay (Chapman *et al.*, 1987; Hopkins, 1986) Therefore, sediments were press-sieved wet through 2-mm mesh in an attempt to remove any native animals. If additional amphipods or tubes were observed in the samples, they were removed. Approximately 12 h prior to the initiation of the test, 200 mL (about 4 cm) of the test sediment was placed into the exposure chambers with flowing, gently aerated seawater. Test animals were sieved from the holding sediments. Twenty healthy amphipods of uniform size were placed into each exposure chamber. Moribund or outsized animals were replaced. Test animals were either subadults or females to avoid the natural mortality of males associated with reproductive activity. The test organisms were not fed during the 10-d exposure. The exposure chambers were 1-L mason jars with a 2-cm diameter overflow hole covered with a 0.5-mm mesh Nitex screen near the top. An inverted 9-cm finger bowl with a 2-cm diameter hole functioned as a lid. Air delivery and seawater delivery tubes were fixed through the hole in the lid and positioned to minimize sediment disturbance. Inflowing filtered seawater was delivered via an intermittent flow system at a rate of about 18 turnovers per vessel per day. The 90 percent volume replacement time was estimated to be approximately 3 h according to the method of Sprague, 1973.

Tests under static exposure conditions similar to those used with the *R. abronius* test were set up for aliquots from 3 of the 15 stations. A capillary tube was inserted through each lid for air delivery.

The exposure chambers were monitored daily for dead and emerged amphipods. Dead animals were removed and the number recorded. Additionally, the number of emerged animals (on the sediment or water surface) and molts were recorded daily for each test chamber and the molts were removed. At the end of the 10-d exposure, all sediments were sieved through a 0.5-mm mesh screen. All survivors were enumerated and those unaccounted for were counted as dead. In order to minimize sample storage time, two batches of samples were tested: The first batch consisting of sample numbers 1, 2, 3, 4, 5, 6, 7, 8, and 9; the second consisting of sample numbers 10, 11, 12, 13, 14, and 15. Static and flow-through tests were performed concurrently in the same manner on samples from the amphipod collection site (Bourne Cove) which were regarded as control samples.

Water temperature and salinity were measured daily in the batch controls and maintained at 20 ± 1°C and 31 to 34 ppt, respectively. Deionized water was added to all samples in a batch if the salinity in the respective batch controls reached 34 ppt. The dissolved oxygen concentration and pH were measured each day in one of the five replicates of each sample on a rotating basis so that these parameters were measured twice in each replicate during the 10-d exposures. Based upon all of the measurements, the dissolved oxygen concentration and pH ranged from 6.2 to 8.2 mg/L and 7.3 to 8.3, respectively.

Sediment Elutriate Toxicity Test with Embryos of the Mussel *Mytilus edulis*

This toxicity test was developed for use in Puget Sound (Chapman and Morgan, 1983) and has been used in many environmental surveys (Chapman *et al.*, 1987; Tetra Tech, 1985; Williams *et al.*, 1986).

Animal collections. Adult mussels (*M. edulis*) were collected from Deep Cove, Indian Arm, British Columbia. Mussels were placed in a 70-L polypropylene conditioning tray to permit

gonadal maturation, and were thermally conditioned for 4 weeks in unfiltered seawater at 14 ± 1°C. The mussels were fed a daily diet of a marine diatom culture (*Phaeodactylum tricornutum*). Prior to spawning, 30 mussels were stored moist at 5°C for 24 hours.

Spawning was induced by placing the chilled mussels in individual Pyrex™ dishes containing 250 mL of 1 µm filtered seawater at 20°C. Fertilization was accomplished within 1 h of spawning initiation by combining eggs and sperm in a 1-L Nalgene beaker. The fertilized eggs were then washed through a 250 µm Nitex screen to remove excess gonadal material and suspended in 2 L of filtered seawater at incubating temperature 20°C. The embryos were kept suspended prior to testing by frequent agitation with a perforated plunger. When microscopic examination of fertilized eggs revealed the formation of polar bodies, triplicate counts were made of the number of eggs in 1.0 mL samples of a 1:99 dilution of the homogeneous egg suspension.

Elutriate Preparation. Sediment toxicity tests were conducted in clean, distilled water-rinsed 1-L polyethylene bottles. Twenty grams (g) (wet weight (ww)) of sediment was added to each bottle and the volume brought up to 1 L with filtered seawater (30 ppt salinity) to make a final concentration in all containers of 20 g (ww) of sediment per liter of seawater. The sediments were suspended by vigorous shaking for 10 seconds and were allowed to settle at incubation temperature for 1 hour prior to adding the embryos. No additional agitation was provided after inoculation.

Test Procedures. Toxicity testing was conducted following the standardized procedures of Chapman and Morgan (1983), updated by Chapman and Becker (1986). Within 2 hours after fertilization, approximately 15,000 developing mussel embryos were inoculated by automatic pipette into each container, resulting in a concentration of about 15 per mL. The containers were covered and incubated in a temperature-controlled room for 48 hours at 17± 0.5°C under a 14-h light:10-h dark photoperiod. Test vessels were not aerated during the test. After 48 hours, surviving larvae were removed from the water column of each container by automatic pipette. Repeated, gentle mixing with a perforated plunger was used to ensure that the larvae were homogeneously suspended prior to removal of a 7-mL aliquot. The bottom sediments were not disturbed during the subsampling as bivalve larvae are pelagic and do not associate with the benthos until metamorphosis occurs. Previous experience has shown that larvae found in the sediments invariably are dead. Live larvae were transferred to 8-mL screw-cap glass vials and preserved in 5 percent buffered formalin. The preserved samples (equal in volume to that containing at least 100 larvae in controls) were examined in Sedgewick-Rafter cells under 100 times magnification. As bivalve larvae sink after preservation (ASTM, 1985), half of the water was discarded from the vials before examining the residual volume containing the larvae. Control sediments collected off West Beach in Puget Sound, Washington (the collection site for the amphipod *Rhepoxynius abronius* test animals) were tested in the same manner.

Normal and abnormal prodissoconch I larvae were enumerated to determine percent survival and percent abnormality. Percent survival in the 15 samples was determined as the number of normal and abnormal prodissoconch I larvae surviving in each test container relative to the number surviving in the seawater control, which was assigned a survival value of 100 percent. Larvae which failed to transform to the fully shelled, straight-hinged, "D" shaped prodissoconch I stage were considered abnormal. The weighted rather than arithmetic method was used to calculate mean larval abnormality for a given station (including controls) because numbers of larvae vary within treatments and abnormality tends to increase as mortality increases (ASTM, 1985). This method involves multiplying the percent abnormal value for each replicate by the ratio between the percent abnormals in the replicate and the total percent abnormals for all five replicates.

Parallel reference toxicant bioassays (in clean seawater without sediment) were conducted using sodium pentachlorophenate (NaPCP). A 100 ppm stock solution of NaPCP was prepared in a 0.04 mol solution of sodium hydroxide using anhydrous grade pentachlorophenol (Sigma Chemicals), following procedures described in Niimi and McFadden (1982). Bioassay concentrations were prepared in duplicate by volumetric dilution

of the NaPCP stock solution with filtered seawater. The concentrations of NaPCP tested were: 10, 32, 56, 100, and 180 ug/L.

Salinity, dissolved oxygen, and pH levels initially were adjusted in each container to 30 ppt, 8.2 mg/L and 7.8, respectively. These parameters were measured again in each container at the termination of the toxicity test.

Sediment Elutriate Toxicity Test with Embryos of the Urchin *Strongylocentrotus purpuratus*

Elutriates of samples from all 15 stations were tested for effects on development and echinochrome pigment content of the embryos of the purple sea urchin (*Strongylocentrotus purpuratus*). Echinochrome pigment synthesis appears to be affected by abnormal embryonic development and this end-point has been shown to be sensitive, less variable, and quicker than the morphological examinations (Bay *et al.*, 1983). Embryos from one station at each of the sites also were examined microscopically for the presence of cytologic and cytogenetic (mitotic) abnormalities. In addition, concurrent testing of elutriates from one station at each site was conducted to determine egg fertilization success. Additional 48-h tests on elutriates from these five stations were conducted with embryos from two additional urchin species, the white urchin (*Lytechinus pictus*) and the green urchin (*Strongylocentrotus drobachiensis*). Most aspects of this toxicity test have been developed and applied in analyses of primarily water or effluent samples (Oshida *et al.*, 1981; Dinnel *et al.*, 1982; Dinnel and Stober, 1987).

Elutriate preparation. For each replicate tested, a 70-mL aliquot of sediment was washed through a 1-mm mesh screen to remove large organisms, tubes, and debris. A total of 280 mL of laboratory seawater (collected off Redondo Beach, California) was added to the sample (including screening water) to produce a sample dilution of 1:4 (v/v). The sediment/water mixture then was placed in a 400-mL glass beaker and stirred overnight at 17°C with a 60-rpm teflon/glass paddle. Each sample was allowed to settle for 60 min after stirring. The supernatant was then poured into centrifuge bottles and centrifuged at 2,000 times gravity (G) for 5 min to precipitate suspended particulates. The supernatant was carefully decanted and returned to its respective 400-mL beaker. From this volume, a 10-mL aliquot was removed and used in the sperm cell toxicity testing and a 220-mL aliquot was used in tests of embryos for the other end-points. A total of 220 mL of the elutriates was used in the 400-mL beakers for the embryo exposures.

Animal collection. Intertidal adult urchins were collected from Point Dume, in northern Santa Monica Bay, California. Release of the eggs and sperm from gravid sea urchins was induced by injection of 0.5 mL of 0.5 M KCl into the coelom of each individual. Eggs were shed directly into beakers of chilled seawater and washed twice with seawater before use. Sperm were collected with a minimum of seawater (dry condition) and refrigerated until used.

Test procedures. The sperm cell test followed the procedures of Dinnel *et al.* (1987). It was initiated by adding 0.1 mL of sperm stock solution to each 10-mL elutriate sample. After 60 min exposure, 2,000 eggs were added to each elutriate sample. Each sample was allowed 20 min for fertilization to occur and then preserved with formalin for later examination. The formalized eggs were examined using light microscopy (100 times) and a Sedgewick-Rafter counting chamber. The numbers of fertilized and unfertilized eggs in an aliquot of each sperm exposure sample were counted in which the presence of a well-defined fertilization membrane around the egg was the criterion defining successful fertilization.

The embryo toxicity test methods were modified from the procedures of Oshida *et al.* (1981). Exposure of the embryos to the elutriates was initiated by inoculating each 220-mL sample with 7,500 fertilized eggs. Stirrers then were fitted to each beaker, and the sample with its developing eggs was cultured for 48 hours at 17°C. After 48 hours, a 10-mL subsample was removed from each beaker and preserved for later analysis of percentage normal development. A duplicate sample of embryos was taken from some beakers for the

cytologic/cytogenetic examinations. The embryos in 200 mL of the remaining solution were removed with a plastic screen (44 µm) and extracted for echinochrome pigment measurement.

Microscopic examination was used to determine abnormalities in development of the 48-h embryos. The numbers of embryos in the prism stage that had a normal pyramid shape, a differentiated gut, and well-developed skeletal rods were counted as normal. Embryos exhibiting an unusual pattern of development, such as exogastrulation, blastula filled with cells, or unhatched embryo with abnormal cleavage were classified as abnormal. Embryos that appeared normal, but at a less advanced stage of development (gastrula or earlier) after 48 hours, were counted and classified as retarded. The samples were examined randomly without knowledge of the station identification.

To determine echinochrome pigment content, 48-h embryos that had been removed from 200 mL of the test sample were transferred to a centrifuge tube with seawater and concentrated by centrifugation (1,500 x G for 5 min). The overlying water then was removed by aspiration, the pellet was washed with 95 percent ethanol and re-centrifuged. The ethanol then was removed, and 1 mL of acidified ethanol (5 percent HCl) was added to each tube and mixed to extract the echinochrome. The absorbance of the echinochrome-containing supernatant was measured with a spectrophotometer at 475 nanometer (nm), using the methods of Bay *et al.* (1983).

To determine cytologic/cytogenetic abnormalities, preserved 48-h embryos were placed on a glass microscope slide and stained with aceto-orcein solution for 15 min. A glass coverslip was then placed onto the slide and the embryos were squashed into monolayers. Twenty embryos were examined from each replicate sample. The number of mitoses in each embryo was recorded, and all of the cells in each embryo were examined for micronucleated cells, mitotic (anaphase) aberrations, and cytologic abnormalities, following the criteria of Hose (1985).

Two batches of samples were tested in order to minimize storage of the sediments before testing: the first with samples from the VA, YB, and OA sites; and the second with samples from the TB and SP sites. Each experiment included two controls; a laboratory seawater control from Redondo Beach, California and an elutriate control (laboratory seawater carried through the elutriate preparation steps).

Sediment Pore Water Toxicity Test with the Polychaete *Dinophilus gyrociliatus*

Laboratory bioassay data with spiked sediments indicate that sediment toxicity is more highly correlated with interstitial (pore) water contamination than with total sediment concentrations of toxicants (DiToro, in press). This toxicity test had been developed and applied in bioassays of effluents and single chemicals in water (Carr *et al.*, 1986), but had not been used previously in sediment quality assessments.

Pore water extraction. A 2- to 3-L aliquot of the homogenized sample from each station was transferred to a Zip-Lock bag, labeled, and stored on ice in a cooler or in a refrigerator at approximately 4°C. Sediments were transferred from the container to a pressurized Teflon-lined steel cylinder for extraction of the pore water on the same day that the samples were collected, using the methods of Carr *et al.*, in press. A porous Teflon filter plate and a 0.7 µm porosity borosilicate glass filter were mounted in the base of the cylinder. The system was pressurized with compressed air supplied from a standard SCUBA cylinder. Pressure was applied to the top of the cylinder chamber via a first-stage regulator and manifold, forcing the top plate downward. The pore water samples emitted from the bottom of the cylinder were collected in amber glass bottles with Teflon-lined lids and stored frozen until they were used in the toxicity tests.

Animal collections. A population of *Dinophilus gyrociliatus* cultured in the laboratory was used in the toxicity tests.

Test procedures. Before toxicity tests were conducted, the pore water samples were measured and adjusted, if necessary, to produce water with temperature of 20° ± 1°C, ammonia concentration of <2mg/L, salinity of 25 ± 1 ppt, pH of 8.0 ± 0.2, and dissolved oxygen of ≥ 80 percent saturation (Battelle, 1987a). Following water quality adjustments, the life-cycle toxicity test with *Dinophilus gyrociliatus* was conducted to determine mortality and sublethal reproductive effects (*i.e.*, eggs laid per female), using the procedures of Carr *et al.* (1986; in press; Battelle, 1987b). The tests were conducted in 20-mL Stender dishes with ground glass lids, with 10 mL of pore water per dish. At a minimum, four animals were placed into each dish, following the addition of the pore water. The tests were started with 1- to 2-d old animals. Because the worms reach mature size rapidly, an experienced investigator can easily identify newly released juveniles by their small size. Survival and reproductive data for each chamber were recorded after 1, 4, and 7 days. The reproductive data recorded for each chamber consisted of the total number of female eggs, the number of egg cases, and the number of newly emerged juveniles. All observations and manipulations were performed using a dissecting microscope with fiber optic illumination. The test animals were fed 50 µl of a 0.5 percent spinach food suspension in each dish. Tests were performed in two batches: the first consisting of samples from the TB and SP sites; and the second consisting of the samples from the VA, YB, and OA sites. A control pore water sample from Duxbury Bay, Massachusetts was tested concurrently with each batch of samples.

Sediment Chemical Analyses

Chemical and texture analyses of the sediments were performed by SAIC.

Organic Compounds. The methods were based upon the protocols of the NOAA NS&T Program (MacLeod *et al.*, 1985). A 50-g (ww) sediment sample was divided into aliquots for analyses of organic compounds. Internal standards (to permit assessment of analyte recovery efficiency) were spiked into the sample, which was extracted four times with varying amounts of methanol then dichloromethane. A bottle roller or shaker table was used to mix the sample with the extraction solvents. The combined extracts were concentrated to about 1 mL in a Kuderna-Danish apparatus and solvent-exchanged into hexane in preparation for fractionation.

The concentrated extract was loaded onto a precalibrated chromatography column packed with silica gel, alumina, and granular copper. A first fraction (SA1) was eluted with hexane, the second fraction (SA2) with 50 percent dichloromethane in hexane and the third fraction (SA3) with dichloromethane and methanol. Fraction SA1 (containing saturated hydrocarbons) was concentrated for analysis by gas chromatographic-electron capture detector (GC-ECD). Fraction SA2 (containing aromatic and chlorinated hydrocarbons) initially was concentrated and then loaded onto a precalibrated column packed with Sephadex LH-20. A subfraction (SA2-L1) was eluted with a 6:4:3 mixture of cyclohexane-methanol-dichloromethane. This fraction, containing biogenic material, then was concentrated for portion analysis by GC-ECD. A second subfraction (SA2-L2) was eluted with the same solvent mixture. Fraction SA2-L2 was concentrated again, solvent-exchanged into hexane, further concentrated under a stream of nitrogen, and spiked with an additional internal standard (to allow correction for instrument injection volume fluctuations) in preparation for instrument analysis. Fraction SA3 (containing coprostanol, a natural enteric product selected for analysis as a sewage tracer) was concentrated, solvent-exchanged, concentrated again, and spiked with an additional internal standard as described for the SA2-L2 fraction

Fraction SA2-L2 was analyzed for polynuclear aromatic hydrocarbons (PAHs) by gas chromatographic-flame ionization detector (GC-FID) and for chlorinated hydrocarbons by GC-ECD. If hexachlorobenzene (HCB) was found in SA2-L2, fraction SA1 also was analyzed (for additional HCB) by GC-ECD.

The method detection limits attained in the analyses of organics in sediments are listed in Tables 1 and 2.

Table 1. Limits of detection and quantification for polynuclear aromatic hydrocarbons in surface sediments.

Compound	Sediment	
	MLOD[a]	MLOQ[b]
Naphthalene	0.90	3.0
2-Methylnaphthalene	0.75	2.5
1-Methylnaphthalene	0.90	3.0
Biphenyl	0.75	2.5
2,6-Dimethylnaphthalene	1.20	4.0
Acenaphthene	0.45	1.5
Fluorene	0.30	1.0
Phenanthrene	1.20	4.0
Anthracene	1.65	5.5
1-Methylphenanthrene	2.10	7.0
Fluoranthene	1.65	5.5
Pyrene	1.95	6.5
Benz(a)anthracene	1.50	5.0
Chrysene	1.50	5.0
Benzo(e)pyrene	1.35	4.5
Benzo(a)pyrene	0.90	3.0
Perylene	1.20	4.0
Dibenz(a,h)anthracene	0.90	3.0

[a] MLOD = Method Limit of Detection (ng/g dry weight (dw))
[b] MLOQ = Method Limit of Quantification (ng/g dw)

Table 2. Limits of detection and quantification for pesticides and polychlorinated biphenyls (PCBs) in surface sediments.

Compound	Sediment	
	MLOD[a]	MLOQ[b]
Hexachlorobenzene	0.80	0.26
Lindane (gamma-BHC)	0.13	0.43
Heptachlor	0.09	0.30
Aldrin	0.14	0.46
Heptachlor epoxide	0.14	0.46
Alpha-chlordane	0.10	0.33
Trans-nonachlor	0.10	0.33
Dieldrin	0.16	0.53
Mirex	0.10	0.33
o,p'-DDE	0.26	0.86
p,p'-DDE	0.13	0.45
o,p'-DDD	0.26	0.86
p,p'-DDD	0.26	0.86
o,p'-DDT	0.20	0.66
p,p'-DDT	0.20	0.66
PCBs:		
Dichloro	0.40	1.33
Trichloro	0.20	0.67
Tetrachloro	0.20	0.67
Pentachloro	0.20	0.67
Hexachloro	0.20	0.67
Heptachloro	0.13	0.43
Octachloro	0.13	0.43
Nonachloro	0.20	0.67

[a]MLOD = Method Limit of Detection (ng/g dw)
[b]MLOQ = Method Limit of Quantification (ng/g dw)

Metals. For all elements except mercury, samples were thawed, allowed to warm to room temperature, and then wet-homogenized. Sample aliquots were freeze-dried to a constant dry weight and ground to a homogeneous powder. Approximately 0.2 g of dry powdered sediment was digested overnight with concentrated nitric acid, in capped Teflon centrifuge tubes. Samples were later placed in a 95°C water bath for 2 hours and then autoclaved. After cooling, samples were diluted to 50 mL with Milli-Q™ water and stored in polyethylene bottles until analysis.

Approximately 20-g aliquots were stored frozen in polyethylene bottles for mercury analysis. Wet samples were used for mercury analysis to avoid possible losses during the drying process. Approximately 1-g ww of the sample was weighed into a borosilicate bottle. Next, 5 mL of concentrated HNO_3 and 5 mL of concentrated H_2SO_4 were added. The sample was heated in a 95 percent water bath for 2 hours, cooled, and a saturated solution of $KMNO_4$ was added (approximately 5 mL) until a purple color persisted. The sample was then heated again, cooled, capped, and refrigerated until analysis.

Trace metal concentrations, except mercury and silicon, were analyzed by atomic absorption spectrophotometry using graphite furnace or flame (Table 3). Mercury was analyzed by cold vapor atomic absorption, and silicon was analyzed colorimetrically using an ultraviolet spectrophotometer.

Sediment texture. Sediment texture (grain size) was determined as the percentage (based on dry weight) of gravel, sand, silt, and clay. Coarse and fine fractions initially were separated by wet-sieving. The silt-clay fraction was analyzed by collecting, desiccating, and weighing aqueous aliquots at timed intervals after thorough mixing of the fraction. The sand and gravel fraction, after being dried, was sieved through a 2-mm screen and the weight of gravel and sand subfractions were determined.

Total organic carbon and total inorganic carbon. Total organic carbon (TOC) and total inorganic carbon (TIC) in sediments were analyzed by a modification of United States Environmental Protection Agency (EPA) Method 415.5 (Organic Carbon, Total) and Section 4.8 of the O.I. Corporation Model 700 TOC Analyzer Operating Procedures and Service Manual, which describes the analysis of TIC and TOC on the same aliquot of the sample.

All samples were thawed, allowed to warm to room temperature, and wet-homogenized by stirring. Aliquots with a wet weight of approximately 0.02 g were weighed into precombusted ampules with 1 mL of Milli-Q™ water. TIC was determined by sealing each ampule on the TOC analyzer (0.I. Corporation Model 700). Two mL of 5 percent phosphoric acid was injected into the ampules. The carbon dioxide generated was purged with nitrogen to an infrared detector. The resulting millivolt (mV) reading was converted to micrograms TIC.

TOC was analyzed by removing the ampules from the analyzer and purging with oxygen. One mL of potassium persulfate solution (5 percent $K_2S_20_8$) was added immediately before the ampules were sealed. Samples were digested by heating the ampules in an autoclave. Ampules were then attached to the TOC analyzer ampule-breaking assemblage. Carbon (as carbon dioxide) was purged from the ampule using nitrogen and detected as above. The resulting values were recorded as µg organic carbon.

Table 3. Analytical methods for trace and major elements in sediment samples and limits of detection.

Symbol	Element	Analytical Method	Method Detection Limits
Al	Aluminum	FAA	560
Ag	Silver	GFAA	0.01
As	Arsenic	GFAA	2.9
Cd	Cadmium	GFAA	0.08
Cr	Chromium	GFAA	1.2
Cu	Copper	GFAA	0.77
Fe	Iron	FAA	16
Hg	Mercury	CVAA	0.008
Mn	Manganese	FAA	5.0
Ni	Nickel	GFAA	0.42
Pb	Lead	GFAA	0.28
Sb	Antimony	GFAA	6.2
Se	Selenium	GFAA	6.9
Si	Silicon	COLOR	600
Sn	Tin	GFAA	5.0
Ti	Thallium	GFAA	16
Zn	Zinc	FAA	2.3

GFAA = Graphite Furnace Atomic Absorption
CVAA = Cold Vapor Atomic Absorption
FAA = Flame Atomic Absorption
COLOR = Colorimetric

Benthic Community Analyses

Sample collections. Benthic infaunal samples were collected at all three stations at each of the five sediment sampling sites that were sampled for the chemical and bioassay analyses. Five replicate samples were collected at each station. All collections were made in February 1987 by SAIC. Samples were collected using a modified 0.1 m^2 Van Veen grab. The samples taken for benthos analyses were randomly interspersed among those taken for the chemical/bioassay analyses. They were treated separately and individually and not composited. The samples were sieved in the field using a 1-mm screen. The retained material was fixed in formalin for 48 hours and returned to SAIC, La Jolla, California. Samples were delivered to the laboratory at MEC for processing, identified only by site, station, and replicate designation.

Laboratory processing. Laboratory processing of the samples has been performed thus far for samples from four of the five collection sites; the samples from the OA site were deferred for later analyses. Benthic samples received at MEC were logged onto an inventory data sheet. Container identifications on this sheet were used to track samples from receipt through laboratory processing to computer data input. Once in the laboratory, samples were transferred from formalin to 70 percent alcohol for preservation. The majority of the biogenic debris (worm tubes, *etc.*) in each sample was identified. Organisms were sorted into major and minor taxonomic groups (*e.g.*, crustaceans, echinoderms, molluscs, polychaetes, nemerteans, sipunculids, *etc.*) using stereoscopic dissecting microscopes. A laboratory supervisor reviewed the procedures, including sample sorting, handling, and labeling that were followed by the experienced sorters.

A strict quality assurance/quality control protocol (QA/QC) was followed by SAIC and MEC to insure a degree of sorting thoroughness and efficiency that resulted in ≥95 percent effectiveness. A minimum 10 percent re-sort was conducted on every sample. A statistical procedure, which sets an upper limit to the number of organisms that can be found in a re-sort of a fraction of the sample, was used to determine whether a sample had passed the QA/QC check. The pass criterion was that, at the 95 percent probability level, 95 percent of the organisms in a sample were removed during the original sort. In the first fraction re-sort, 10 percent of the original sample was re-sorted and checked for missed organisms. A sample passed if the number of organisms found did not exceed a predetermined number (this predetermined number is part of a specially developed statistical program designed for this purpose). If the sample failed, a second 10 percent of the sample was re-sorted, and a third if needed. Failure of the third 10 percent necessitated complete re-sorting of the entire sample. The complexity of the present samples, which contained large quantities of byssal threads, amphipod tubes, polychaete tubes, and extensive shell hash, resulted in several complete sample re-sorts. Sample re-sorts were checked daily by the laboratory supervisor.

Following satisfactory completion of QA/QC procedures, the specimens from each sample were distributed to taxonomists. Specialists in the taxonomy of each phyletic group enumerated and identified specimens to the lowest practical taxonomic level. To insure taxonomic consistency and provide QA, 10 percent of all species identifications were checked against reference collection organisms. In addition, 1 percent of the identified specimens were sent out, unlabeled, for taxonomic QA checks. Taxonomic data were entered directly onto computer keypunch sheets, thus precluding transcription errors. Unique National Oceanographic Data Center (NODC) codes were used to identify each taxon.

Biomass was determined for each major taxonomic group. Specimens were placed on a 0.3-mm screen and aspirated for 10 seconds, then placed in tared containers and weighed to 0.01 g on an electronic Sartorius balance. Data were coded directly on keypunch data sheets for entry into the data base.

Data base development. The quality of the data was checked during various stages of handling. Keypunch sheets were examined by laboratory supervisors prior to submission to insure that data sheets were completed and all fields correctly entered. After the data were entered into the computer data base, an error-checking program was used to validate the data entries. All data fields were checked for alphabetic, alphanumeric, or numeric characters, and for acceptable ranges and characteristics. In addition, 10 percent of all data entries were checked manually by data management personnel. Additional 10 percent increments were checked if errors were found, and this interactive process continued until no errors were found or until the entire data set was reviewed. After the QA checks, the data base was considered complete and ready for analysis.

Data analyses. Data were organized for presentation at three different levels and reported in detail in a final contractor report available from NOAA (Barnett *et al.*, 1987). Level 1 data analyses included determinations of the name and number of individuals (abundance) for each species in each replicate grab, and the total number of organisms and total biomass in each replicate grab (*i.e.*, per 0.1 m^2) for the major taxonomic groups. Level 2, the station summary, included the means and standard deviations of the sample data from each of three stations at a site. Level 3, the site summary, included the means and standard deviations calculated for the three stations at each site. Levels 2 and 3 included the means and standard deviations for the following parameters: 1) abundance of each species, 2) biomass of each major taxonomic group, 3) total abundance and total biomass of all biota, and 4) numerical proportion of the most abundant species and taxonomic groups to the total abundance of all biota. Level 3 also included the following community descriptive parameters: 1) the Shannon-Weiner diversity index (H), 2) Pielou's measure of equitability (evenness, J), 3) dominance (D) measured as the complement of equitability (*i.e.*, D=1-J), and 4) species richness (R).

Most station and site summaries, and all analyses, used only species that were considered part of the benthic infauna. Transient, water column, or terrestrial species were excluded.

Data analyses included multivariate cluster analyses and univariate Analysis of Variance (ANOVA) techniques. The multivariate technique employed to examine community differences consisted of classificatory procedures (Clifford and Stephenson, 1975) based on multiple attributes (e.g., species composition). The primary assumption underlying this approach was that optimal areas (habitats) for a particular species within an environment were inhabited by greater abundances of that particular species. Areas with similar species composition (in terms of both types and abundance) were assumed to provide similar physical/chemical microenvironments. Conversely, areas that supported modified or different assemblages of species were assumed to provide altered or different microenvironments.

Two classifications were performed in which entities were grouped by specific common attributes. The sampling stations (entities) were grouped by similarities in species composition (attributes). This is termed the "normal" analysis by Clifford and Stephenson (1975). The "inverse" analysis grouped the species (entities) with respect to their distribution among stations (attributes). Both analyses used only identifiable species that were considered to be important in the benthic infauna. Taxa not used in the analyses included species not part of the benthic infaunal community and rare taxa. A number of rare taxa were found in this study. They carried little classification information (Boesch, 1977), but they could mask much of the information carried by the more common species. To ensure that they did not do so, taxa that did not occur in at least two replicates and at a minimum of two stations were excluded from the analyses.

The classification analyses involved three procedures. The first was a calculation of an inter-entity similarity (distance) matrix using the Bray-Curtis index (Clifford and Stephenson, 1975). In the normal analysis, abundance data were square root-transformed and standardized by species mean. Next, the step-across procedure (Bradfield and Kenkel, 1987; Williamson, 1978) was applied prior to application of the flexible sorting strategy (Lance and Williams, 1967; Clifford and Stephenson, 1975). The third procedure was sorting, by which the entities were clustered into a hierarchical dendrogram. Dendrograms from both the normal and inverse analyses were combined into a two-way coincidence table (Clifford and Stephenson, 1975). The values of relative abundance of each species were replaced by symbols (Smith, 1976) in the body of the two-way table as an aid to presenting the patterns of species distributions.

ANOVA techniques were applied to dominant species, taxonomic groups, and community parameters to support statistically (e.g., with probability levels and confidence limits) the community differences that were found. Station and site differences were assessed using the Student-Newman-Keuls (S-N-K) test (Sokal and Rohlf, 1969).

Differences between sites were tested by contrasts on site means. The site means were calculated by averaging the means of the station within each site. Since six contrasts were performed, the α error rate for each contrast was adjusted, using Bonferroni's equation, to $\mu=0.05/6=0.008$.

The ANOVA and S-N-K tests were applied to: 1) community parameters (including total abundance), number of species, diversity (H), evenness (J), and dominance (I-J); 2) abundance and biomass in five major taxonomic groups, and total biomass; and 3) abundance data for the five numerically dominant species at each station and site. Tests of abundance used log (x+1) transformed data.

Sediment Profiling Photography

Contrary to the other biological tests, this method was applied at sites throughout the estuary. A sediment profiling camera was used to determine a variety of sedimentological and biological properties of surficial sediments at 69 sites. The objective of this analysis was not to evaluate the sensitivity of the test to a range in chemical contamination. Rather, it was to characterize sediment properties, mainly indicative of organic enrichment, throughout the San Francisco Bay estuary. However, 4 of the 69 sampling sites corresponded with those sampled for toxicity testing, chemical analyses, and benthos. Therefore, the data from these four sites are included in this report to facilitate a complete review of all the analyses performed in San Francisco Bay. Details of methods and results for all 69 sites are presented by Revelas *et al.* (1987).

Data acquisition. Field operations were conducted by SAIC with the vessel PROPHECY from 3 through 9 February, 1987. The environments surveyed included shallow fine-grained areas, deep fine- and coarse-grained high energy channel habitats, active and inactive disposal sites, creeks and river mouths, and ports and inner harbors. Five replicate photographs were taken per site.

Navigation and data logging. Navigational control of the survey vessel during this project was provided by the SAIC Integrated Navigation and Data Acquisition System (INDAS). This particular system consisted of a Northstar 6000 LORAN-C receiver interfaced to a Hewlett-Packard Series 200 model 20 microcomputer. A calibration procedure was utilized during this project which resulted in a much more accurate LORAN-C positioning system than is usually possible. In order to calibrate LORAN-C, it was necessary to position the LORAN-C receiver at locations whose positions were known with a high degree of certainty. With the resulting calibration factors applied to the incoming LORAN-C coordinates, the ship's geodetic position was calculated to an accuracy of $\pm$ 20 meters.

REMOTS™ images. REMOTS™ sediment-profile images were taken using a modified Benthos Model 3731 Sediment-Profile camera (Benthos Inc. North Falmouth, Massachusetts). The camera consisted of a wedge-shaped prism with a Plexiglas™ face plate; light was provided by an internal strobe. The back of the prism had a mirror mounted at a 45-degree angle to reflect the profile of the sediment-water interface up to the camera, which was mounted horizontally on the top of the prism. The prism was filled with distilled water, and because the object to be photographed was directly against the face plate, turbidity of the ambient seawater was never a limiting factor. The camera was mounted on a large tube frame and raised and lowered by winch.

REMOTS™ image analyses. REMOTS™ measurements of all physical parameters and some biological parameters were measured directly from the film negatives using a video digitizer and computer image analysis system. Negatives were used for analysis instead of positive prints in order to avoid changes in image density that can accompany the printing of a positive image. Proprietary SAIC software allowed the measurement and storage of data on 22 different variables for each REMOTS™ image obtained.

Apparent redox potential discontinuity depth. Oxic near-surface marine sediments have a higher reflectance value relative to underlying hypoxic or anoxic sediments. This discontinuity is readily apparent in REMOTS™ images and is due to the fact that oxidized surface sediment contains particles coated with ferric hydroxide (an olive color when associated with particles), while the sulphidic sediments below this oxygenated layer are gray to black. The boundary between the colored ferric hydroxide surface sediment and underlying gray to black sediment is called the apparent redox potential discontinuity (RPD) and its apparent depth was determined at each site.

The depth of the apparent RPD in the sediment column is an important time-integrator of dissolved oxygen conditions within sediment pore waters. In the absence of bioturbating organisms, this high reflectance layer (in muds) will typically be 1- to 3-mm thick (Rhoads, 1974). This depth is related to the rate of supply of molecular oxygen (by Fickian diffusion) into the bottom, and the consumption of that oxygen by the sediment and associated microflora. In sediments which have very high sediment-oxygen demand (SOD), the sediment may lack a high reflectance layer even when the overlying water column is aerobic. In the presence of bioturbating macrofauna, the high reflectance layer may be several centimeters thick.

Infaunal successional stage. The mapping of successional stages was based on the theory that organism-sediment interactions follow a predictable sequence after a major seafloor perturbation (Rhoads and Germano, 1982; Rhoads and Boyer, 1982; Maurer *et al.*, 1985; Pearson and Rosenberg, 1978). This theory states that primary succession results in "the predictable appearance of macrobenthic invertebrates belonging to specific functional types following a benthic disturbance." The term "disturbance" includes natural processes, such as seafloor erosion, changes in seafloor chemistry, foraging disturbances which cause major reorganization of the resident benthos, or anthropogenic impacts, such as dredged material or sewage sludge dumping, thermal effluents from power plants, pollution impacts from industrial discharge, *etc.*

The designation of successional status in REMOTS™ images was based on the recognition of two end-member assemblages. Disturbed benthic environments are commonly associated with dense tube aggregations at or near the sediment surface. These appear as small hair-like tube projections at the sediment surface. They are usually spaced 10 or more per linear cm along the imaged sediment surface. These "enrichment" assemblages typically consist of spionid or capitellid polychaete populations and were mapped as Stage I seres. In the absence of further disturbance, these early successional assemblages are eventually replaced by infaunal deposit feeders; the start of this "infaunalization" process was designated arbitrarily as a Stage II sere. These seres were identified as shallow-dwelling bivalves or tubicolous amphipods, such as those belonging to the genus *Ampelisca*. These amphipods were also occasionally densely aggregated at the sediment surface. The other end-member infaunal assemblage (Stage III) was dominated by polychaetes which have larger body sizes, are less abundant, and feed head down several centimeters below the surface (conveyor-belt species). These species were usually not imaged *per se*, but rather the feeding pockets or voids that develop around their head ends could be seen in profile images. Active voids were lenticular in shape and the bottoms of these were typically filled with coarse particles. Inactive voids appeared as "collapsed" or relic structures which were recognizable only by their lenticular shape and coarser grain size. These infaunal stages were typically represented by maldanid or orbiniid polychaetes and mapped as Stage III seres. They were typically present on those parts of the seafloor which did not experience severe, frequent (*i.e.*, several times a year) physical disturbance or organic enrichment. This trophic type is apparently adapted to sediments which are relatively "oligotrophic" (Rice and Rhoads, in press).

The pattern described above for primary succession, or the pattern of changes in benthic community functional types after a radical disturbance or the opening of a new patch in the physical environment for colonization, has been repeatedly documented in REMOTS™ monitoring of severely disturbed areas such as dredged material disposal sites. However, it is also quite common when monitoring "ambient" seafloor areas to detect a combination of successional seres in the same image (*e.g.*, a Stage I on Stage III, or Stage II on Stage III). This designation documents the process of secondary succession, which is usually the result of mild physical disturbances or biological interactions such as competition and predation. Secondary succession is the process of re-establishment of conditions similar to the original community after a temporary disturbance.

REMOTS™ Organism-Sediment Index. A multi-parameter REMOTS™ organism-sediment index (OSI), constructed to characterize habitat quality, was calculated for each site. The REMOTS™ OSI was determined by summing the appropriate subset indices shown in Table 4. The lowest OSI value (-10) was given to those bottoms which had low or no dissolved oxygen in the overlying bottom water, no apparent macrofaunal life, and methane gas present in the sediment. At the other end of the scale, an aerobic bottom with a deeply depressed RPD, evidence of a mature macrofaunal assemblage, and no apparent methane gas bubbles at depth had a REMOTS™ OSI value of +11. Past REMOTS™ surveys had shown the OSI to be an excellent parameter for mapping disturbance gradients in an area and documenting ecosystem recovery after disturbance (see Germano and Rhoads, 1984).

Table 4. Calculation of the REMOTS™ OSI Value

CHOOSE ONE VALUE:

Mean RPD Depth	Index Value
0.00 cm	0
> 0 - 0.75 cm	1
0.76 - 1.50 cm	2
1.51 - 2.25 cm	3
2.26 - 3.00 cm	4
3.01 - 3.75 cm	5
> 3.75 cm	6

CHOOSE ONE VALUE:

Successional Stage	Index Value
Azoic	-4
Stage I	1
Stage I --> II	2
Stage II	3
Stage II --> III	4
Stage III	5
Stage I on III	5
Stage II on III	5

CHOOSE ONE OR BOTH IF APPROPRIATE:

Chemical Parameters	Index Value
Methane Present	-2
No/Low Dissolved Oxygen	-4

REMOTS ORGANISM-SEDIMENT INDEX = Total of above subindices

RANGE: -10 to +11

Fish Hepatic Aryl Hydrocarbon Hydroxylase Activity

Slices <5 mm thick were removed from the posterior liver for the *in-vitro* assay of microsomal enzyme activity. These were immediately frozen on dry ice and transferred within an hour to a freezer maintained at -76°C. One or more liver slices were later used to prepare a microsomal pellet.

These microsomes were assayed for AHH activity using the method of Nebert and Gelboin (1968) as described previously (Spies *et al.*, 1982). A portion of the hepatic microsomes from each fish was re-assayed with 10^{-4}M 7,8-BF. This concentration was determined to cause maximal suppression of AHH activity. A more optimal assay temperature was determined to be 25°C rather than 18 or 37°C. At 25°C, reaction kinetics were linear for 10 min. An Aminco Bowman spectrofluorometer was used to quantify the 3-OH benzo(a)pyrene metabolite. The spectrofluorometer was calibrated with quinine sulfate standards. In addition, a standard of microsomes from 3-methylcholanthrene-induced mice was assayed with each batch of microsomes as a control for assay conditions. Fluoresence values of assays were corrected according to the quinine sulfate standard. Based on duplicate and triplicate assays from seven fish, the mean coefficient of variation was 14.6 percent for AHH activity, and 2 percent for the mean percent change in AHH activity with the addition of the AHH inhibitor, 7,8-BF. Protein concentrations were determined by the method of Lowry *et al.* (1951) using bovine serum albumin (BSA) as the standard. Hepatic AHH specific activities, are reported as picomoles 3-OH-benzo(a)pyrene (B(a)p) milligrams (mg) protein^{-1} min^{-1}.

Fish Reproductive Success

For the November-December collections, a small section of the gonad of each female was removed during necropsy and preserved in Davidson's fixative. Appropriate subsections were taken from female gonads in these samples and made up into paraffin sections at 6 µm, mounted on microscope slides and stained with hematoxylin and eosin. These were later examined to evaluate the predominant egg stages present (Yamamoto, 1956) and for the occurrence of atretic oocytes.

Fish captured in the January-February sampling period were taken live to the LLNL to be spawned. Spawning success of several stages in reproduction was determined.

Fish handling. The spawning methods of Policansky and Sieswierda (1979), the only known procedure for spawning *Platichthys stellatus*, were adopted. After capture by trawl from San Francisco Bay in the winter months, 1 to 3 days were allowed for acclimation to the laboratory seawater system that is maintained at 11 to 13°C and at a salinity of 29 to 30 ppt. The holding aquaria measured 58 x 58 x 47 cm (158.1 L) and two to three females were placed in each aquarium. Males were generally maintained separately. Gonadally mature females were then started on a course of intramuscular injections of freeze-dried pituitaries from spawning carp (Crescent Biochemicals) reconstituted in physiological saline, 1 mg pituitary kg^{-1}d^{-1}. Over 90 percent of females, captured mainly in the months of January and February, responded by eventually spawning. The mean time to spawning in all fish (n=49) captured in previous research and so treated in 1983-1985, was 27 ± 13 days. Females generally spawned between two and five times. Females that had not spawned within 43 days were eliminated from analyses because of the positive relationship observed between numbers of days of injections and hepatic AHH activity after 47 d (Rice *et al.*, in press). It was not always necessary to administer pituitary injections as males, unlike females, were often captured in San Francisco Bay in a condition in which sperm could be stripped from them and with a photoperiod of less than 8 h d^{-1} males came into spawning condition in the laboratory.

Protocol for spawning. As females began to swell, they were observed daily and occasionally picked up to determine if there were signs of eggs in the lower portion of the oviduct. Fish were handled deliberately and gently to minimize stress. From the onset of rapid swelling, it was usually only several days until females had freely flowing eggs.

Many females needed only to be removed from the water and tipped vertically for the weight of the fish to expel eggs from oviduct; other fish required only gently abdominal pressure to start the free flow of eggs. From each of several successive 30-mL aliquots, 10 mL of eggs were removed for the determination of percent floating eggs. A second 10-mL egg aliquot was placed in a damp 400-mL beaker, two drops of sperm stripped within 30 seconds from a male were added and rapidly swirled for 1 to 15 seconds. Approximately 400 mL of sea water were then added to the beaker. A pooled aliquot was made up of the remaining 10 mL in each of the fourth through final egg aliquots. When egg volumes were small, sometimes a portion of the third aliquot would be included in the pooled aliquot. Fertilized egg aliquots were washed free of sperm approximately 20 min after fertilization by a complete exchange of sea water. Usually only one male that met a simple sperm motility test was necessary for the spawning tests as males contribute very little to the variability of fertilization success.

Measures of early reproductive success. Several measures of early reproductive success were determined to facilitate the detection of effects at specific developmental stages. Viable hatch is the proportion of spawned eggs that produce viable larvae. Hatching success is the proportion of spawned eggs that hatch. Fertilization success is the proportion of spawned eggs that are fertilized. In addition to these commonly used measures of survival, it is important to recognize that often large numbers of spawned eggs sink. Floating eggs contain the potentially viable gametes, since sinking eggs are usually not fertilized and do not develop normally. Thus, where

N = total number of eggs spawned,

V = the number of eggs that float (viable eggs),

F = the number of fertilized eggs,

H = the number of eggs that hatched, and

L = the total number of normal larvae,

the following measures of survival through early life history stages were determined:

(1) percent floating eggs	= (V/N) *100
(2) percent fertilization success	= (F/V) *100
(3) percent embryological success	= (H/F) *100
(4) percent normal larvae	= (L/H) *100;

in which the sources of variability for these measures in more than 100 spawnings have been assessed and a standard protocol adopted for spawning and evaluation of developmental success (Spies *et al.*, 1985).

Percent floating eggs was determined volumetrically in a calibrated centrifuge tube approximately 10 min after spawning. Fertilization success was measured at the 4-8 blastomere stage after eggs had been held at 11-12°C for 3 to 4 h following fertilization in the first incubation chamber, a 400-mL beaker. Eggs were scored in five categories: (1) fertilized eggs with even cleavages, (2) fertilized eggs with uneven cleavages, (3) unfertilized eggs with cortical reaction, (4) unfertilized eggs without a cortical reaction, and (5) ill-formed opaque eggs or highly disorganized zygotes. Fertilized eggs were considered to be those in categories 1 and 2. Eggs in category 2 never comprised more than 5 percent of the total. Embryological success and hatching success were determined 80 to 100 hours after fertilization based on the number of fertilized eggs that began incubation in a second

chamber, a 400-mL beaker provided with a screen-covered port that allowed sea water to flow through but retained the eggs. In most cases, between 150 and 200 eggs were used to determine embryological success. This second chamber was held at the same temperature as the first, but was provided with flow-through seawater at the rate of 2 to 3 mL per min.

A major source of variability in egg survival is related to the sequence of eggs in spawning: eggs spawned (= stripped) first do not develop as well as those spawned last and a regular progression of egg quality in the early part of a spawning can be seen as aliquots are taken during the course of a stripping. This phenomenon is a function of egg position within the ovarian lumen after ovulation and may be related to the time between ovulation and stripping. Although we cannot precisely control this source of variability due to differences between females, we have incorporated two procedures into our protocol that minimize its effect. Firstly, the first two to three aliquots (39 mL each) of spawned eggs are not used in estimating reproductive success. Secondly, the second and subsequent spawnings of each female are done at 48-h intervals to standardize as much as possible the time between ovulation and stripping. Since the sources of between-spawn variability are unknown, there was no basis for evaluating or controlling its effect on the outcome of these experiments, we therefore simply averaged the reproductive success measures for all spawnings of each female. Males contribute less than 1 percent to the variability in fertilization success provided they have motile sperm, therefore the main effects of contaminants on egg survival could best be determined by evaluating the spawning females. With these features in the protocol between-female variance for the reproductive success measures from 123 spawnings of 43 females was as follows: 45.3 percent for floating eggs, 48.2 percent for fertilization success, 35.7 percent embryological success, and 16.1 percent for percent normal larvae (Spies and Rice, 1988). We therefore concluded that substantial differences in reproductive success measures could be detected between females with the following procedure:

1. Females that were noticeably hydrated were watched closely and stripped once they had freely flowing eggs. Subsequent spawnings were carried out at 48-h intervals.

2. Eggs were collected in a series of 30-mL aliquots. The number of aliquots varied between two and eight, with five to six being the usual number.

3. From each aliquot two 10-mL portions of eggs were removed to evaluate reproductive success. The remainder of eggs (excluding those from aliquots 1 to 3, or 1 to 2) were combined and 10 mL of eggs taken to produce a pooled aliquot which was independently evaluated for the reproductive success measures.

4. To evaluate percent floating eggs in an aliquot, 10 mL of eggs were placed in a graduated, glass 40-mL centrifuge tube, 30 mL of seawater added, the contents stirred, and after standing for 15 to 30 min, the volume ratios of floating and sinking eggs (V:N) determined.

5. A male which had been determined to have sperm that remained motile for 2 min after stripping was used to fertilize the eggs.

6. To evaluate fertilization success in an aliquot, 10 mL of eggs were placed in a wetted glass 400-mL beaker, 2 drops of sperm added, the contents vigorously stirred, 300 mL of seawater added, and the beaker placed in a seawater table for 20 to 30 min. Floating eggs were then transferred to clean seawater in a second 400-mL beaker with a piece of nytex screen. Fertilization success (F:V) ratio was determined at the 4 to 8 blastomere stage after 3 to 4 h at 11 to 13°C.

7. To determine embryological success and percent normal larvae, 150 to 200 eggs that had been evaluated for fertilization success were transferred to a 500-mL glass beaker provided with a 2 to 3 mL/min flow of seawater and a screened outflow to retain the eggs.

Usually only the pooled aliquot from each spawning was evaluated. Dead eggs and embryos were removed daily and preserved in 10 percent neutral formalin. After 80 to 100 hours, the remaining sample was preserved and H:F and L:H ratios were later determined.

8. In nearly all cases, the pooled aliquot was used to provide a single determination per spawning of each reproductive success measure. The measures of percent floating eggs and percent fertilization success in the serial aliquots were used in the above-mentioned analysis of variance.

9. Females had between two and five spawnings, with most females sacrificed after three spawnings. As mentioned above, the mean values of each measure for all spawnings was used to derive one series of reproductive success values for each female.

Fish Plasma Hormone Analyses

Plasma samples collected in the field from live fish were frozen at -76°C and shipped to Dr. Peter Thomas at the University of Texas for hormone analyses. Estradiol-17B and testosterone were analyzed by radioimmunoassay (RIA) techniques in *P. stellatus*. The estradiol-17B antiserum generated against estradiol-17B -3-carboxymethyl-ether BSA (Radioassay Systems Laboratories) cross-reacted 22.3 percent with 16-ketoestradiol, 2.46 percent with estriol, and 1.32 percent with estrone. The assay could detect 2.5 picograms (pg) estradiol-17B per assay tube. The testosterone antiserum prepared against testosterone-3-BSA (Cambridge Medical Diagnostics) was relatively specific and cross-reacted 28.2 percent with dihydrotestosterone, 17.2 percent with 11-ketotestosterone, and 1.46 percent with androstenedione. The assay could detect 1.25 pg testosterone per assay tube.

Radioimmunoassay for testosterone and estradiol-17B were performed on the same plasma extract. One hundred microliters of plasma were extracted with 2 mL hexane/ethyl acetate (70:30) in 12 X 75 mm borosilicate tubes. Prior to extraction, tritiated testosterone (1,800 counts per min (cpm)) was added to each sample for determination of extraction efficiency. The extract was dried under a stream of nitrogen and reconstituted in 250 mL of gelatin assay buffer (21.2 micromole (mM) phosphate buffer, pH 7.6). Two aliquots (50 mL and 25 mL) of the reconstituted sample were measured in each RIA to test for parallelism. In the estradiol-17B assay, 50 mL of tritiated steroid tracer (approximately 4,000 cpm, Radioassay Systems Laboratories) and 75 mL of antiserum (1 in 23,200 dilution) were added to the samples and the standards. In the testosterone assay, 25 mL of tritiated steroid tracer (approximately 4,000 cpm, Research Products International) and 25 mL of antiserum (1, in 9,000 dilution) were added to the samples and standards. Assay mixtures were incubated overnight at 4°C and bound steroid was separated from free steroid with dextran-coated charcoal.

The intra-assay coefficients of variation (CV) of replicate determinations of estradiol-17B and testosterone in a plasma control pool were 16.8 and 8.3 percent, respectively (estradiol-17B mean 1.14 ng/mL, s.e.m 0.15, N=3; testosterone 2.12 ng/mL, s.e.m 0.04, N=3). Recovery of steroid standards (40-250 pg/tube) added to the control plasma ranged from 94.5 to 119 percent.

Fish Erythrocyte Micronuclei Analyses

The number of micronuclei in peripheral erythrocytes of the fish was determined by the SCCWRP and Occidental College. A total of 158 fish were examined from the two sampling periods.

The micronucleus technique was applied to circulating peripheral erythrocytes in approximately 1 cc of blood removed in a heparinized syringe from the caudal vein. For each fish, three blood smears were prepared immediately with one drop of blood each,

allowed to air dry, and fixed in methanol for 15 min. The blood smears were kept cold (on ice in the field or in a refrigerator in the lab) until they were processed. The smears were stained with May-Grunwald-Giemsa procedure (Preece, 1972) and examined on coded slides under a microscope at high power (1,000 x). One of the three slides was examined for each fish; one of the other two was used if the first was not usable. Two replicate counts of the number of micronucleated erythrocytes per 1,000 cells were made on each smear, and the results reported as the average of the two counts. Two types of micronuclei were reported: detached and attached.

The degree of nuclear pleomorphism (loss of the usual elliptical shape of the nucleus) was determined for each slide and coded: 1 (<5% of erythrocytes), 2 (5-50%), or 3 (>50%). Severely pleomorphic nuclei had indentations and/or projections. If projection was greater than about one-fourth the nuclear diameter and terminated in a chromatin mass, it was counted as an attached micronucleus.

Fish Hepatic Cytochrome P-450 Analyses

Analyses of cytochrome P-450 enzyme activity were performed on liver microsome samples of individual fish by WHOI. Hepatic microsomes were prepared from pieces of liver that had been frozen on dry ice at the time of collection. Methods for microsome preparation were those in use at the LLNL. In addition, microsomes were prepared from gonad from a selected number of individuals. Samples of microsomes were shipped at various times from the LLNL to WHOI following preparation at Livermore by both LLNL and WHOI staff.

Cytochromes P-450 and b_5. Cytochrome P-450 (extinction coefficient (e) = 91 $mM^{-1}cm^{-1}$) was measured by sodium dithionite difference spectra of CO-treated samples and cytochrome b_5 content (e = 185 $mM^{-1}cm^{-1}$) was determined from NADH difference spectra as previously described (Stegeman *et al.*, 1979). Each cuvette contained approximately 1 mg microsomal protein per mL.

Assays for cytochrome b_5 were usually carried out prior to cytochrome P-450 analysis using dilutions or concentrations like those above. After obtaining an NADH difference spectrum, NADH was balanced in the cuvettes by combining material in sample and reference cuvettes, and adding more NADH. The mix was then treated with CO, re-divided, and the sample reduced by $Na_2S_2O_4$ to determine the cytochrome P-450 content. This procedure not only permitted quantitation of cytochrome b_5, but effectively eliminated interference by b_5 or hemoglobin in the analysis, thereby permitting quantitation of cytochrome P-420. NADH and CO were balanced in all analyses to permit measurement of putative cytochrome P-420, whether or not cytochrome b_5 was analyzed. The degradation or denaturation product of cytochrome P-450, if present, could limit some interpretations.

Ethoxyresorufin O-deethylase. EROD activity was measured by the spectrophotometric method described by Klotz *et al.* (1984). This method directly measures product formation, like the fluorometric analysis described by Burke *et al.* (1985), except that the resorufin is detected by absorbance. The reaction mixture contained 0.1 M Tris-C1, pH 8.0 with 0.1 M NaCl, 2 µM 7-ethoxyresorufin added in methanol, and approximately 100 µg of microsomal protein in a final volume of 0.5 mL. The reaction was initiated by the addition of 0.5 mM NADPH and run at 26°C. The formation of resorufin (e = 73 $mM^{-1}cm^{-1}$) was followed at 572 nm on a Shimadzu UV-260 or a Cary 118C recording spectrophotometer.

Estradiol 2-Hydroxylase. Estradiol 2-hydroxylase activity was routinely assayed by 3H20 release from (2-3H)E2 (Kupfer *et al.*, 1981). Our modified assay (Snowberger and Stegeman, 1987) consisted of microsomes (0.1-0.3 mg/mL), 25µM (2-3H)E2 (16 µCi/µmol), 1 mM EDTA, and 0.3 mM NADPH in 100 mM sodium phosphate buffer, pH 7.4 in a final volume of 200 µL.

The reaction was initiated with NADPH, progressed at 25o for 30 min, and was terminated with 200 µL ice-cold 16 mM CaC12 to aggregate the microsomes. Samples were transferred to test tubes containing dextran-coated charcoal (pellets from 200 µL of 1 percent activated charcoal and 0.5 percent dextran in 10 mM Tris, pH 8.0), vortexed, shaken at 0-5oC for 15 min, and centrifuged at 5,000 G. Aliquots (200-µL) of the supernatant were counted in a Packard Tri-Carb scintillation counter.

Cytochrome P-450E homologue. Immunoblot ("Western" blot) analyses were accomplished with monoclonal antibody (MAb) 1-12-3 against P-450E, the major PAH-induced form isolated from the marine fish scup (Klotz *et al.*, 1983). The characterization of this antibody and its specificity in immunoblotting has been described (Park *et al.*, 1986; Kloepper-Sams *et al.*, 1987). Microsomal samples were incubated in a steaming water bath for 10 min, in 20 mM Tris-HCl, pH 6.8, 1 percent SDS, 13.3 percent glycerol, and 1.7 percent B-mercaptoethanol and bromophenol blue. Proteins were electrophoretically resolved and were transferred onto 0.2 µm nitrocellulose paper essentially as described by Towbin *et al.* (1979). The blots were incubated in 5 percent dry milk in phosphate buffered saline (PBS) for 1 hour at 42°C, and MAb 1-12-3 diluted in PBS for 2 hours at room temperature. They were washed 10 min each in: PBS; 0.5 percent Tween, PBS; and PBS again, and then incubated for 1 hour in PBS with 5 µl-mL^{-1} goat anti-mouse peroxidase-linked IgG. They were washed again as above, and developed in PPB with HRP Color Developer (BioRad) containing 4-chloro-1-naphthol added in cold methanol and 0.02 percent hydrogen peroxide for 20 to 30 min. Stain deposition was measured by densitometric analysis with a soft laser densitometer (Helena Labs., Inc.).

All enzyme analyses were done at least in duplicate; some were done up to 10 replicates. Enzyme assays as well as spectral and immunoblot analyses of P-450 were repeated for samples giving unusual results or results near the limits of detection. Some samples were analyzed three or more times. Repeated analyses showed less than 15 percent variation in the results for any given sample.

Positive control samples. Selected individual *P. stellatus* captured at the BK and SP sites were treated with a known inducer, B-naphthoflavone (BNF). The treatment with BNF was done by R. Spies, and liver microsomes were prepared by WHOI personnel, at the LLNL. Microsomes were prepared from fresh liver, according to methods employed at WHOI. These microsomes were prepared to serve as a positive control, to validate the test methods, and to provide a measure of the degree of response which might be possible in *P. stellatus*.

Fish Chemical Analyses

Residues of chlorinated hydrocarbons in liver were determined at the LLNL using methods similar to those of Ozretich and Schroeder (1986). Briefly, tissues were macerated in pre-cleaned beakers, water was removed by addition of pre-combusted (600°C) anhydrous Na_2SO_4, acetonitrile (UV grade) and an internal standard of 4,4'-dibromoocto-fluorobiphenyl was added, and the mixture was homogenized by a high-speed tissue macerator (Polytron) to produce the first extract. The first extract was decanted after settling and the mixture was extracted twice more, with the final extract clarified by centrifugation. The extracts were combined, and made up to 100 mL and cooled overnight at 4°C. A 50 mL subsample was removed to gravimetrically determine extracted lipids. A second subsample was removed for isolation, identification, and quantification of aromatic compounds of interest (PCB, DDT, and pesticides). Interfering saturated compounds (e.g., alkanes), remaining lipids, and fatty acids were removed by passing the extract through disposable reverse-phase chromatography columns (Baker) with C_{18} and NH_2 solid-phase absorbents. The concentrated extract was analyzed by GC (Hewlett-Packard, 5880) using a ^{65}Ni ECD and a 0.25 mm inside diameter, 30-m fused-silica capillary column internally coated with cross-linked methyl silicone. Chlorinated hydrocarbons of interest were analyzed based on retention times and response factors of authentic external standards

(National Bureau of Standards/NOAA standards). Values of analytical blanks were subtracted and final concentrations were corrected for recovery of internal standards. Analyte identifications were confirmed using a Hewlett Packard Mass Selective Detector (MSD), model 5979, operating in the scan mode. The MSD was interfaced with a Hewlett Packard gas chromatograph, model 5880, equipped with a DB-1 fused-silica capillary column. Instrumental conditions included an ionization voltage of 2800 eV and scan conditions of m/z 45-450 at one scan per second. Selected ion searches were used to obtain ion chromatograms for compounds with known retention indexes that were suspected to be present in the samples. If necessary, the mass spectrum and retention time of an identified peak was retrieved and compared with an authentic standard or to a mass spectrum library to aid identification

The PCBs were identified on the basis of International Union of Pure and Applied Chemists (IUPAC) congener numbers (Ballschmitter and Zell, 1980; Mullin *et al.*, 1984). Since there are many more PCB congeners in contaminated marine environments than we could quantify in this study, 19 major congeners were chosen for analysis. These congeners represent the different degrees of chlorination encountered in aroclor mixtures, are indicative of specific aroclors, or are known to be biologically active. Congeners 18, 87, and 180 were used to estimate the concentrations of Aroclor 1242, 1254, and 1260, respectively (Capel *et al.*, 1985). For example, congener 18 represents 9.38 percent of the total congeners in Aroclor 1242. In order to estimate the concentration of Aroclor 1242, the measured concentration of congener 18 is multiplied by (100/9.38). Congener 87 represents 3.32 percent of the congeners in Aroclor 1254. Congener 180 represents 6.5 percent of the congeners in Aroclor 1260. Congener numbers 66, 87, 118, 128, 153, 180, 195, and 206 are included since they are possible inducers of MFO activity in animals (Clark, 1986). Further, congener numbers 66, 118, 128, 180, 195, and 206 have chlorine atoms in positions 4 and 4' and are thought to be preferentially degraded in marine sediments (Brown *et al.*, 1987). Congener numbers 87, 101, and 187 lack chlorines in the 4 and 4' positions and are included in order to compare 4,4' congeners and non-4,4' congeners. For example, in an unaltered Aroclor 1254, congener 118 is expected to be about 3.5 times more abundant than congener 87 (11.5%/3.3% = 3.5). For Aroclor 1260, the expected proportion of congener 180 to 187 is 2.6. In the past, use of these analytical methods results in 70 percent recoveries being within 50 to 90 percent. Analysis of split samples have produced values within 10 percent of the mean for 80 percent of the chlorinated compounds analyzed (Spies *et al.*, 1988).

Data Analysis Methods

Sediment Toxicity Tests. Three attributes of the candidate toxicity tests were considered to be of primary importance and were evaluated: (1) sensitivity of each end-point to test sediments relative to respective controls, (2) within-sample analytical precision (*i.e.*, low analytical variability among replicates), and (3) total range in biological response to the test samples relative to analytical precision (referred to hereafter as "discriminatory power"). Of less importance, the tests should demonstrate some concordance in response with a range in chemical contaminant concentrations. However, the evaluation of concordance between toxicity results and chemical data assumes that the etiological agents in the environmental sediments are among or co-vary with the chemical analytes that were quantified. This assumption may or may not be correct, since the most sensitive toxicity tests may identify some samples as "toxic" that otherwise would not be suspected as such based upon quantification of a limited number of chemical analytes. Other unquantified chemicals may occur in complex media such as sediments that are equally or more toxic than those that are quantified. Finally, if all tests with similar end-points (*e.g.*, acute toxicity) are responding to related mechanisms of toxicity, toxicity data among the bioassays should demonstrate concordance. Outlier toxicity tests may be responding to only "nuisance" variables or may be insensitive .

All sediment toxicity test data were tested for normality by either the Kolmogorov-Smirnov test (Zar, 1984) or an approximation of the Shapiro and Wilke test. Since all end-points were shown to be non-normally distributed ($0.01 < p < 0.025$), and could not be transformed to a normal distribution, non-parametric tests were used for further data

analyses. Tests of differences in toxicity results (*i.e.*, "sensitivity") were performed two ways to satisfy two objectives. First, because these candidate tests were evaluated for future use in the NS&T Program in which the sampling protocol involves collection of samples at three unreplicated stations per site for chemical analyses, differences in mean results among sites for end-points measured at all stations were of interest. Results of each toxicity test for each site were analyzed by the non-parametric Kruskal-Wallis (K-W) test (α=0.05) for differences between sites and respective controls and among sites. For those tests where significant differences were indicated, a non-parametric equivalent of the Student-Newman-Keuls (S-N-K) multiple comparison test was performed to determine which sites could be differentiated from each other, and a non-parametric equivalent to Dunnett's t-test was performed for differentiating sites from the respective control(s). The data from each of the three stations at each site were used as measures of within-site variance. Cumulative (pooled) results from the five laboratory replicates were used in these determinations of between-site differences. Second, to determine the relative sensitivities of each test to individual samples, each composited sediment sample from each station was regarded as an independent, individual sample and the differences between the samples and respective controls were determined and tallied. In this case, the five replicates tested in the laboratory per treatment were used as measures of within-treatment variability. In the latter statistical tests, no attempts were made to determine geographic patterns in toxicity response, but, rather, to determine sensitivity of each toxicity end-point to individual samples. Differences in results between individual samples and respective controls were tested with the K-W test and Dunnett's t-tests (Wilcoxon and Wilcox, 1964).

In addition to the non-parametric tests, a few parametric tests were performed with the data in an exploratory phase to further characterize patterns in the results. Since these additional procedures used parametric methods, the results cannot be used in any inferential sense, but, rather, provide additional qualitative descriptions of the results.

The standard deviations (SDs) and coefficients of variation (CVs) for the five replicates of each sample were calculated. Then, the averages of the CVs were determined for each of the toxicity end-points to evaluate relative analytical "precision." The difference between the maximum and minimum mean values observed in the samples was divided by the average SD to estimate the discriminatory power, an index that was not biased by the data from the controls. Correlations among toxicity end-points normalized to respective batch controls were determined by Spearman's rank correlation (Spearman, 1904). Spearman's rank correlations were also determined between toxicity and bulk sediment chemical data, in which the metals data were normalized to percent fines and the organics data were normalized to TOC content.

Benthic Community Analyses. The data from the benthos taxonomic analyses and the sediment profiling survey were not completed for all five sediment sampling sites. Therefore, they were not subjected to the same statistical treatments applied to the sediment bioassay data. Methods described on pages 16 through 18 were used to classify sites with the data that were collected.

Measures of Effects in Fish. The biological data from the fish analyses were summarized and listed as means and standard deviations for each site for each sampling episode. The chemical data from the fish were treated similarly. The biological data were evaluated with the Kolmogorov-Smirnov test to determine if they were normally distributed. Differences among sampling sites were tested with the K-W test followed by the non-parametric S-N-K test. Data from the analyses of nuclear pleomorphism in erythrocytes were tested with chi-square. Differences in chemical concentrations among sites were tested with one-way ANOVA. Correlations both among the biological measures and between biological measures and liver contaminant concentrations were determined with Spearman's rank correlation analysis. The range in response of each test among sites, the SD and the CV among the samples at each site, and the maximum range divided by the SD were calculated as indicators of methodological sensitivity.

In addition to the non-parametric tests, a few parametric tests were performed with the data in an exploratory phase to further characterize patterns in the results. Since these

additional procedures used parametric methods, the results cannot be used in any inferential sense, but, rather, provide additional qualitative descriptions of the results.

RESULTS

Sediment Toxicity Test Results

Solid Phase Bioassay with the Amphipod *Rhepoxynius abronius*. Results for three end-points in this bioassay are summarized in Table 5. In the control sediments from the amphipod collection site in Puget Sound, means of 19.6 ± 0.5 and 18.8 ± 1.3 survivors out of 20 (98 and 94 percent, respectively) were observed. Mean survival that was lower than the control means was seen in tests of all the samples. Among the most toxic, as judged by the fewest survivors, were samples 1, 2, 3, 7, 11, 13, and 15 in which 50 percent of the amphipods or fewer survived. Based upon previous experience with this bioassay, these results are indicative of highly toxic sediments. Usually, a result showing less than 75 percent survival is significant relative to controls (Swartz *et al.*, 1985; Mearns *et al.*, 1986), and a result showing fewer than 50 percent survivors is observed only in the most contaminated sites (Swartz *et al.* 1985). Mean survival in sample 1 sediments was roughly one-third that in sample 10 sediments.

Means of 1.0 ± 2.2 and 1.4 ± 1.7 amphipods avoided (emerged from) the control sediments. Mean avoidance of the test sediments was relatively similar to that in controls in only three samples: numbers 3, 6, and 13. Mean avoidance of sediment samples 7, 8, and 9 was roughly 5 times higher than avoidance of controls. However, within-sample variability was relatively high for this end-point. Percent reburial of survivors at the end of the tests was similar in all samples and this end-point was not evaluated further.

Solid Phase Toxicity Test with the Amphipod *Ampelisca abdita*. The toxicity data are presented in Table 6 as both counts and percents of survivors. Occasionally, more than 20 animals were inadvertently initially exposed to the sediments, despite the sieving step performed before the tests to remove native *A. abdita*. Means of 17.2 and 16.0 individuals (86 and 80 percent, respectively) survived the 10-d flow-through test in control sediments. The lowest mean percent survival occurred in samples 1, 2, and 3. Mean percent survival was highest in the SP and TB sediments. In some samples, *i.e.*, those from SP, the amphipods showed higher mean survival than those exposed to the sediment from the amphipod collection site. Mean survival in sample 14 exceeded that for sample 1 by a factor of 1.4. Mean cumulative avoidance of the test sediments under flow-through conditions was highest in the OA sediments followed, in order, by avoidance of Control 1, VA, YB, TB, and SP sediments. Mean avoidance of OA sediments exceeded that of TB by a factor of about 3.

These tests of all 15 samples were performed in flow-through conditions, whereas those with *R. abronius* were performed under static conditions. However, three samples also were tested with *A. abdita* under static conditions identical to those for *R. abronius* to provide a comparable basis for evaluation of the results. Mean survival was slightly lower in sample 1 and controls under static test conditions than in flow-through conditions, but was unchanged in samples 4 and 13.

Elutriate Toxicity Test with Embryos of the Mussel *Mytilus edulis*. Data for the two end-points of this test are summarized in Table 7. Both end-points indicated that the three OA samples were the most toxic of all 15 stations tested. About 94 and 95 percent normal larvae were observed in sediment controls and seawater controls, respectively, compared to a site mean of 75 percent for OA. Relative to the controls, sediments from all stations caused lower percentages of normal development. Also, relative to controls, mean percent survival was lower in embryos exposed to samples from all stations. About 76 and 100 percent of the larvae survived in sediment controls and seawater controls, respectively. As few as 29.2 percent survived in OA samples. Mean percent normal development was roughly 1.3 times lower for sample 3 than for sample 8 and for the sediment control. Mean percent survival was about 2.5 times higher in sample 8 samples and the sediment control than in sample 3.

Table 5. Summary of amphipod *Rhepoxynius abronius* toxicity test results (mean values ± standard deviation[a]).

Site	Sample Number	Number of Survivors[b]	Percent Survival	Avoidance[c]	Reburial[d]	Percent Reburial[e]
OA	1	6.2 ± 2.8	31.0 ± 13.9	3.2 ± 2.6	6.0 ± 2.3	97
	2	7.8 ± 1.6	39.0 ± 8.2	1.6 ± 1.7	7.2 ± 2.0	92
	3	8.8 ± 1.9	44.0 ± 9.6	1.4 ± 1.1	8.8 ± 1.9	100
	Mean (n=3)	7.6 ± 1.3	38.0 ± 6.6	2.1 ± 1.0	7.3 ± 1.4	96
YB	4	14.8 ± 1.9	74.0 ± 9.6	1.8 ± 1.1	14.0 ± 1.6	95
	5	13.4 ± 2.4	67.0 ± 12.0	1.6 ± 2.2	13.0 ± 2.2	97
	6	11.8 ± 1.6	59.0 ± 12.9	1.0 ± 0.7	11.2 ± 2.3	95
	Mean (n=3)	13.3 ± 1.5	66.7 ± 7.5	1.5 ± 0.4	12.7 ± 1.4	95
VA	7	6.2 ± 1.3	31.0 ± 6.5	5.4 ± 4.2	6.2 ± 1.3	100
	8	18.0 ± 1.0	90.0 ± 5.0	7.2 ± 4.1	18.0 ± 1.0	100
	9	16.8 ± 3.5	84.0 ± 16.7	7.4 ± 6.4	16.8 ± 3.5	100
	Mean (n=3)	13.7 ± 4.8	68.3 ± 32.5	6.7 ± 1.1	13.7 ± 6.5	100
SP	10	18.2 ± 1.6	91.0 ± 8.2	3.0 ± 2.0	18.0 ± 1.4	99
	11	9.2 ± 1.3	46.0 ± 6.5	2.6 ± 2.4	9.2 ± 1.3	100
	12	16.6 ± 2.6	83.0 ± 13.0	3.8 ± 3.0	16.6 ± 2.6	100
	Mean (n=3)	14.7 ± 4.8	73.5 ± 24.0	3.1 ± 0.6	14.6 ± 4.7	99
TB	13	5.6 ± 2.7	28.0 ± 13.5	1.4 ± 1.7	5.2 ± 3.0	93
	14	11.0 ± 1.9	55.0 ± 9.3	4.0 ± 2.9	10.6 ± 1.3	96
	15	6.0 ± 1.9	30.0 ± 9.3	5.2 ± 3.4	5.8 ± 1.8	97
	Mean (n=3)	7.5 ± 3.0	37.6 ± 15.0	3.5 ± 1.9	7.2 ± 3.0	96
Control 1		19.6 ± 0.5	98.0 ± 2.7	1.0 ± 2.2	19.6 ± 0.5	100
Control 2		18.8 ± 1.3	94.0 ± 6.5	1.4 ± 1.7	18.4 ± 0.9	98

[a] n = 5 per station; all samples were tested with the Control 1 sample with the exception of VA 07 and VA 08 which were tested with the Control 2 sample.

[b] 20.0 = 100% survival.

[c] Cumulative number of amphipods on the surface per jar per day over the 10-d exposure period (out of a maximum of 20.0).

[d] Number of surviving amphipods able to rebury after 1-hour exposure to control sediment and bioassay water.

[e] Percent reburial = (mean reburial/mean survival) x 100

Table 6. Summary of amphipod *Ampelisca abdita* toxicity test results (mean values ± standard deviation[a])

Site	Sample Number	Initial No. Exposed	No. of Survivors [b] (Flow-through)	Percent Survival	Cumulative Avoidance	No. of Survivors (Static)[c]	% Survivors Static
OA	1	20.0 ± 0	13.2 ± 1.6	66.0 ± 8.2	6.8 ± 1.9	10.2 ± 3.0	51.0 ± 15.2
	2	20.0 ± 0	15.2 ± 1.9	76.0 ± 9.6	6.8 ± 1.9		
	3	20.4 ± 0.1	16.4 ± 1.8	80.3 ± 6.4	4.6 ± 2.3		
	Mean (n=3)	20.1 ± 0.2	14.9 ± 1.6	74.1 ± 7.3	6.1 ± 1.3		
YB	4	20.6 ± 0.9	17.4 ± 2.5	84.2 ± 9.1	3.8 ± 2.2	17.2 ± 1.6	86.0 ± 8.2
	5	20.4 ± 0.9	17.4 ± 1.3	85.3 ± 5.0	3.4 ± 1.3		
	6	22.8 ± 1.6	19.4 ± 0.9	85.6± 9.2	6.0 ± 1.2		
	Mean ·n=3)	21.3 ± 1.3	18.1 ± 1.2	85.0 ± 0.7	4.4 ± 1.4		
VA	7	20.4 ± 0.9	16.6 ± 0.9	81.4 ± 2.2	6.6 ± 4.6		
	8	20.0 ± 0	17.0 ± 1.6	85.0 ± 7.9	4.8 ± 3.7		
	9	20.0 ± 0	17.8 ± 1.3	89.0 ± 6.5	3.2 ± 3.2		
	Mean (n=3)	20.1 ± 0.2	17.1 ± 0.6	85.1 ± 3.8	4.9 ± 1.7		
SP	10	22.0 ± 1.9	20.0 ± 1.7	91.0 ± 3.1	3.2 ± 2.4		
	11	20.0 ± 0	18.2 ± 1.4	91.0 ± 7.4	1.4 ± 1.3		
	12	20.2 ± 0.4	18.6 ± 1.8	92.0 ± 7.6	0.8 ± 0.8		
	Mean (n=3)	20.7 ± 1.1	18.9 ± 0.9	91.3 ± 0.6	1.8 ± 1.2		
TB	13	20.0 ± 0	17.2 ± 1.8	86.0 ± 8.9	2.0 ± 0.7	17.0 ± 3.5	85.0 ± 17.3
	14	20.4 ± 0.9	19.4 ± 0.9	95.2 ± 4.8	1.2 ± 1.1		
	15	20.2 ± 0.4	17.0 ± 1.6	84.1 ± 7.4	3.2 ± 2.9		
	Mean (n=3)	20.2 ± 0.2	17.8 ± 1.2	88.4 ± 5.9	2.1 ± 1.0		
Control	1 [d]	20.0 ± 0	17.2 ± 2.2	86.0 ± 10.8	5.2 ± 2.9	14.0 ± 2.0	70.0 ± 10.0
Control	2 [e]	20.0 ± 0	16.0 ± 2.9	80.0 ± 14.6	2.6 ±2.3	15.2 ± 2.8	76.0 ± 13.9

[a] n=5 replicates per station.
[b] Tests performed under flow-through conditions.
[c] Tests performed under static conditions.
[d] Samples from VA, OA, YB, and Control 1 were tested as the first batch.
[e] Samples from SP, TB, and Control 2 were tested as the second batch.

Table 7. Summary of *Mytilus edulis* mussel larvae toxicity test results (mean values ± standard deviation[a]).

Site	Sample Number	Number of Larvae[b]	Percent Relative Survival[c]	Percent Normal
OA	1	52 ± 16	32.3 ± 10.0	73.1 ± 6.5
	2	60 ± 15	37.6 ± 9.1	79.1 ± 1.9
	3	47 ± 17	29.1 ± 10.7	72.7 ± 7.4
	Mean (n=3)	53 ± 7	33.0 ± 4.3	74.9 ± 3.6
YB	4	77 ± 14	48.2 ± 8.9	84.1 ± 4.2
	5	82 ± 8	51.0 ± 5.2	85.1 ± 3.5
	6	95 ± 25	58.8 ± 15.7	88.1 ± 2.3
	Mean (n=3)	85 ± 9	52.7 ± 5.5	85.8 ± 2.1
VA	7	78 ± 11	48.6 ± 6.5	86.8 ± 1.6
	8	117 ± 19	73.0 ± 12.1	93.4 ± 1.5
	9	104 ± 17	64.4 ± 10.8	90.8 ± 1.3
	Mean (n=3)	100 ± 20	62.0 ± 12.4	90.3 ± 1.3
SP	10	117 ± 32	72.8 ± 19.4	82.4 ± 1.3
	11	76 ± 23	47.2 ± 14.0	85.6 ± 3.1
	12	109 ± 29	68.0 ± 18.3	92.1 ± 1.2
	Mean (n=3)	101 ± 22	62.7 ± 13.6	86.7 ± 4.9
TB	13	71 ± 15	44.2 ± 9.5	80.9 ± 4.7
	13	81 ± 13	50.0 ± 8.0	84.2 ± 4.2
	15	70 ± 18	43.5 ± 11.0	83.6 ± 2.8
	Mean (n=3)	74 ± 6	45.9 ± 3.6	82.9 ± 1.8
Sediment Control 01		122 ± 13	76.0 ± 7.9	93.7 ± 0.7
Seawater Control 01		161 ± 42	100.0 ± 25.9	94.8 ± 1.0

[a] n=5 replicates per station.

[b] Numbers of larvae enumerated at the end of the test, which are used to determine relative survival and percent abnormal larvae.

[c] Survival is calculated relative to the numbers of survivors in the seawater control (=161), which is assigned a value of 100% survival.

Elutriate Toxicity Test with Embryos of the Urchin *Strongylocentrotus purpuratus*. Table 8 presents a summary of results for the various end-points of this test. A range of 84.4 to 87.5 percent of the larvae developed normally among the seawater and sediment controls. Consistently lower normal development was seen in samples from the TB and SP sites. Lowest mean percent normal development occurred in samples 13 and 14. Variability was very high in sample 13 due to the result from one replicate. The highest and lowest values differed by a factor of 1.4.

The mean echinochrome pigment content was highest in tests of sample 14 and lowest in samples 1 and 2, differing by a factor of 1.3. Whereas the percent normal development end-point suggested highest toxicity in samples 13 and 14, the echinochrome pigment end-point suggested the lowest toxicity in those samples (Table 8). Fertilization success of eggs was tested in five samples. It was considerably lower in the batch 01 tests, which included samples 1, 4, and 7 than in the batch 02 tests, which included samples 11 and 13. Fertilization success also was low in batch 01 controls, due to a lower sperm density used in the first batch.

Several end-points representing cytogenetic (mitotic) and cytologic abnormalities in the embryos were recorded for five samples (Table 8). All but one of the end-points indicated highest mean toxicity in sample 1. The lowest mean number of mitoses per larva was for those exposed to sample 1 sediments. Mean percent of the embryos with mitotic (anaphase) aberrations was highest (30 percent) in sample 1 and lowest (8 percent) in sample 13. Mean incidences of micronucleated cells were highest (5 in all the cells of 20 embryos) in sample 1 and lowest (0.6 in 20 embryos) in sample 13. Means of zero to 1.2 micronucleated cells out of those in 20 embryos were recorded in animals exposed to the controls. The mean number of embryos with at least one cytologic abnormality was highest in larvae exposed to sample 11 and lowest in those exposed to sample 13.

The fertilized eggs of the white sea urchin (*Lytechinus pictus)* were exposed to elutriates of three samples (1, 4, and 13). A low yield of eggs was obtained from the laboratory population of urchins, forcing a reduction in the number of eggs added to the beakers. The mean percent normally developed embryos was similar among stations and controls, ranging from a minimum of 53.6 percent in a seawater control to a maximum of 70.1 percent in sample 1 (Appendix A).

The exposures of green sea urchin embryos to the elutriate samples were not successful. Despite obtaining good yields of eggs and satisfactory fertilization percentages, normal embryo development was not obtained. None of the embryos in the control or elutriate samples developed beyond the early cleavage stages of development. Consequently, no usable data were obtained (Appendix A).

Pore Water Toxicity Test with the Polychaete *Dinophilus gyrociliatus.* Mean survival was similar (86 to 100 percent) in all samples and controls (Table 9) and this end-point was not evaluated further. Mean survival of 100 percent occurred in tests of 11 of the 15 samples. Lowest mean egg production (2.9 eggs/female) was observed in polychaetes exposed to sediment pore water from sample 4, followed by that for sample 11. Means of 10.4 eggs per female were produced in seawater controls and 10.0 in pore water controls, similar to the results for tests of samples 13 and 15. Animals in the seawater control and sample 13 produced about 3.6 times more eggs than those exposed to sample 4.

Table 8. Summary of sediment elutriate toxicity test results with purple sea urchin *Strongylocentrotus purpuratus* (means ± standard deviation[a]).

Site	Sample Number	% Normal Embryo Development	Echinochrome Content in Embryos	% Eggs Fertilized	No. Mitoses per Embryo	% Mitotic Aberrations	No. Of Micronucleated cells/20 Embryos	No. Embryos with Cytologic Abnormalities/ 20 Embryos
OA[b]	1	84.7 ± 4.0	0.082 ±.012	50.0 ± 9.6	5.6 ± 1.1	30.1 ± 10.2	5.0 ± 5.5	17± 6
	2	86.6 ± 3.5	0.082 ± .002					
	3	83.7 ± 3.4	0.088 ± .002					
	Mean (n=3)	85.0 ± 1.2	0.084 ± .003					
YB[b]	4	87.3 ± 3.6	0.091 ± .005	66.4 ± 4.5	6.0 ± 1.1	19.7 ± 9.6	2.4 ± 1.8	24 ± 6
	5	87.1 ± 2.0	0.086 ± .007					
	6	83.0 ± 5.2	0.092 ± .002					
	Mean (n=3)	85.8 ± 2.4	0.090 ± .003					
VA[b]	7	85.4 ± 5.8	0.085 ± .007	60.8 ± 9.3	6.2 ± 0.8	21.9 ± 4.3	2.8 ± 1.2	6.4 ± 3
	8	87.8 ± 3.0	0.083 ± .010					
	9	87.7 ± 3.6	0.084 ± .004					
	Mean (n=3)	87.0 ± 1.6	0.084 ± .001					
SP[c]	10	80.5 ± 7.5	0.090 ± .010					
	11	82.7 ± 3.2	0.102 ± .011	81.2 ± 2.6	8.0 ± 1.1	19.8 ± 8.2	3.6 ± 2.1	32 ± 6
	12	83.0 ± 5.3	0.100 ± .011					
	Mean (n=3)	82.1 ± 1.4	0.097 ±.006					
TB[c]	13	63.9 ± 17.0	0.104 ± .006	89.8 ± 3.2	7.6 ± 1.1	8.0 ± 3.0	0.6 ± 0.5	10 ± 2
	14	78.7 ± 8.8	0.109 ± .008					
	15	80.8 ± 7.9	0.101 ± .005					
	Mean (n=3)	74.5 ± 9.2	0.104 ± .004					
Elutriate Control	01[b]	87.4 ± 3.1	0.090 ± .004	50.9 ± 2.4	8.0 ± 0.7	7.0 ± 2.9	1.2 ± 1.9	0.6 ± 0.5
Seawater Control	01[b]	87.5 ± 3.0	0.086 ± .002	35.2 ± 14.8	8.9 ± 0.3	5.6 ± 1.2	0	0.5 ± 0.5
Elutriate Control	02[c]	86.5 ± 5.3	0.101 ± .006	85.1 ± 2.6	8.0 ± 0.5	9.3 ±1.5	0.4 ± 0.5	2 ± 0.9
Seawater Control	02[c]	84.4 ± 0.3	0.096 ± .004	62.5 ± 4.0	9.8 ± 0.4	5.8 ± 1.1	0	0.

[a] n=5 replicates per station

[b] Samples from OA, YB, VA, and 01 Controls were tested as the first batch.

[c] Samples from SP, TB, and 02 Controls were tested as the second batch.

Table 9. Summary of sediment pore water toxicity test results with the polychaete *Dinophilus gyrociliatus* (mean values ± standard deviation[a]).

Site	Sample Number	% Survival[b]	Eggs/female
OA	1	100	8.6 ± 2.3
	2	100	5.7 ± 1.0
	3	100	6.3 ± 1.3
	Mean (n=3)		6.9 ± 1.5
YB	4	100	2.9 ± 1.5
	5	100	6.7 ± 4.2
	6	100	6.7 ± 1.9
	Mean (n=3)		5.4 ± 2.2
VA	7	100	9.0 ± 2.5
	8	96	9.6 ± 1.9
	9	100	6.8 ± 1.9
	Mean (n=3)		8.5 ± 1.5
SP	10	100	9.5 ± 3.4
	11	100	4.5 ± 3.5
	12	96	6.9 ± 1.9
	Mean (n=3)		7.0 ± 2.5
TB	13	100	10.3 ± 1.9
	14	86	9.5 ± 2.2
	15	95	10.1 ± 0.9
	Mean (n=3)		10.0 ± 0.4
Seawater Control 1		100	10.4 ± 3.7
Pore Water Control 1[c]		95	10.4 ± 2.7
Pore Water Control 2[d]		95	9.5 ± 2.9
Pore Water Controls Combined (n=2)		95	10.0 ± 2.7

a n=5 replicates per station.

b Percent survival is based on the actual numbers of animals observed, as sometimes more than four animals/replicate were introduced at the start of a test.

c Samples from TB and SP and Control 1 were tested as the first batch.

d Samples from VA, YB, OA and Control 2 were tested as the second batch.

Physical/Chemical Properties of Sediments.

Sedimentological properties of the samples are summarized in Table 10. Samples 1, 2, 3, 13, 14, and 15 had similar and relatively high clay and TOC content. Clay content was relatively low and sand content was relatively high in samples 7, 8, and 9. The percent gravel content was unusually high in samples 8 and 11. TIC was highest in samples 7 and 8.

Trace Metals in Sediments

Sample numbers 1, 2, and 3 had the highest concentrations of a variety of trace metals, notably, silver, cadmium, copper, mercury, lead, and zinc (Table 11). Many of the elements were nearly an order of magnitude higher in concentration in samples 1, 2, and 3 than in all the others. Relative to the differences in concentrations of these metals between samples 1, 2, and 3 together, and the other 12 samples, the differences in concentrations of metals among the other 12 samples were small. Sample number 8, which had a high gravel content, had relatively low concentrations of many metals, *e. g.*, cadmium, chromium, copper, and mercury. Arsenic was most highly concentrated in samples 7 and 9. Samples 13 and 15 had among the lowest concentrations of silver, arsenic, copper, lead, and zinc, but had among the highest concentrations of chromium and nickel.

Organic Compounds in Sediments

Four classes of organic compounds were markedly more concentrated in samples 1, 2, and 3 than in all the others (Table 12). The concentration of total measured polynuclear aromatic hydrocarbons (ΣPAH) in sample 1 was elevated by a factor of 20 over the concentration observed in sample number 15; ΣDDT was elevated by a factor of 50, total pesticides by a factor of about 40, and ΣPCB by a factor of about 73. All four classes of organic compounds were least concentrated in samples 13, 14, and 15 compared to the others. Relative to samples 1, 2, and 3 and samples 13, 14, and 15; the concentrations of the organic classes were intermediate in samples 4 through 12. The relative concentrations of some organic compounds varied among samples. For example, the ratio of ΣPAH concentrations to ΣDDT concentrations was lower in samples 13, 14, and 15 than in the other samples. Coprostanol concentrations were similar in most of the 15 samples (Appendix B).

Chemical Ratios to Reference

The individual trace metal and organic chemical data were merged to form a cumulative index of overall contamination by the mixtures of quantified chemicals in each sample. Ratios-To-Reference (RTR) values (Chapman *et al.*, 1987) were calculated by dividing the concentrations observed for the various metals and organics in each of the samples by the respective mean values calculated for the three samples (13, 14, and 15) from the rural area, Tomales Bay. Then, averages of these RTR values for each of the samples were calculated. These average ratios indicated that samples 1, 2, and 3 were most contaminated relative to the others; samples 13, 14, and 15 were least contaminated; and samples 4 through 12 were intermediate in contamination.

Table 10. Physical/chemical properties of sediments.

Site	Sample Number	Gravel (Percent)	Sand (Percent)	Silt (Percent)	Clay (Percent)	TOC[a] (µg/g)	TIC[b] (µg/g)
OA	1	1.1	5.7	35.4	57.9	17500	1540
	2	5.8	3.0	28.1	63.1	19100	1080
	3	1.3	10.5	37.8	50.3	18500	1330
	Mean	2.7	6.4	33.8	57.1	18367	1317
YB	4	1.7	6.4	47.8	44.1	10600	668
	5	1.1	4.4	42.1	52.3	11000	730
	6	4.6	1.4	39.0	54.8	12300	869
	Mean	2.5	4.1	43.0	50.4	11300	756
VA	7	3.1	29.9	37.5	29.5	12200	2030
	8	18.3	58.7	12.9	10.4	8130	2630
	9	0.4	23.4	43.7	32.5	10400	770
	Mean	7.3	37.3	31.4	24.1	10243	1310
SP	10	0.0	3.3	48.3	48.4	12800	805
	11	10.3	4.5	42.0	43.2	12300	785
	12	0.0	5.0	46.8	48.2	12100	690
	Mean	3.4	4.3	45.7	46.6	12400	760
TB	13	0.3	1.9	29.0	68.8	19800	1450
	14	0.4	2.1	29.1	68.4	19100	990
	15	7.0	1.8	28.0	63.2	18900	1080
	Mean	2.6	1.9	28.7	66.8	19267	1173

[a] TOC = total organic carbon.

[b] TIC = total inorganic carbon (carbonate).

Table 11. Trace metals concentrations in sediments (ppm dw, unless otherwise specified as percent).

Site	Sample Number	Ag	Al%	As	Cd	Cr	Cu	Fe%	Hg	Mn	Ni	Pb	Sb	Se	Si%	Sn	Ti	Zn
OA	1	1.55	5.84	17.7	1.78	189	187	5.15	8.33	484	138	227	<0.069	<0.62	25.3	<1.7	<0.43	379
	2	1.24	5.69	16.0	1.06	190	167	4.99	1.48	507	134	198	<0.068	<0.61	26.5	<1.7	<0.42	311
	3	1.21	5.43	14.8	1.19	182	159	4.22	2.12	414	130	193	<0.068	<0.61	28.3	<1.7	<0.42	304
	Mean	1.33	5.59	16.2	1.34	187	171	4.79	2.31	468	134	206	n/a	n/a	26.7	n/a	n/a	331
YB	4	0.66	5.83	10.4	0.24	174	41	4.62	0.25	554	101	28	<0.069	<0.62	27.4	<1.7	<0.43	123
	5	0.63	6.02	15.1	0.21	182	60	4.57	0.32	580	111	32	<0.069	<0.62	27.9	<1.7	<0.43	136
	6	0.57	5.85	11.9	0.23	185	55	4.76	0.35	561	119	36	<0.070	<0.63	25.6	<1.7	<0.44	148
	Mean	0.62	5.9	12.5	0.23	180	32	4.65	0.31	595	110	32	n/a	n/a	27.0	n/a	n/a	136
VA	7	0.67	5.27	19.7	0.57	168	54	4.84	0.42	673	110	71	<0.069	<0.62	26.6	<1.7	<0.43	138
	8	0.22	3.16	15.7	0.32	144	35	4.18	0.22	714	82	67	<0.069	<0.62	27.1	<1.7	<0.43	125
	9	0.17	5.46	19.9	0.44	235	35	5.80	0.36	611	167	24	<0.069	<0.62	23.9	<1.7	<0.43	114
	Mean	0.36	4.63	18.4	0.44	182	42	4.94	0.33	666	120	54	n/a	n/a	25.9	n/a	n/a	126
SP	10	0.59	6.31	16.0	0.28	182	59	4.88	0.29	1168	115	28	<0.069	<0.62	26.7	<1.7	<0.43	133
	11	0.73	6.28	17.4	0.30	178	59	4.94	0.23	1213	114	27	<0.069	<0.62	26.8	<1.7	<0.43	137
	12	0.51	6.06	16.3	0.28	178	55	4.89	0.26	1373	119	29	<0.069	<0.62	25.9	<1.7	<0.43	134
	Mean	0.61	6.22	16.6	0.29	179	58	4.90	0.26	1251	116	28	n/a	n/a	26.5	n/a	n/a	135
TB	13	0.20	5.82	13.9	0.43	234	33	5.88	0.38	560	172	20	<0.069	<0.62	23.4	<1.7	<0.43	114
	14	0.53	6.12	18.1	0.47	147	66	5.20	0.51	717	101	40	<0.069	<0.61	27.7	<1.7	<0.42	137
	15	0.19	5.43	14.6	0.40	237	40	5.67	0.44	602	173	20	<0.068	<0.61	23.3	<1.7	<0.43	114
	Mean	0.31	5.79	15.5	0.43	206	46	5.58	0.44	626	149	27	n/a	n/a	24.8	n/a	n/a	122

< = less than detection limit value

Table 12. Summary of sediment organics data (ppb dw).

Site	Sample Number	ΣPAH[a]	ΣDDT[b]	ΣPESTICIDE[c]	ΣPCB[d]
OA	1	6206	69.5	42.0	304.9
	2	5304	149.3	45.0	358.4
	3	4312	71.7	49.6	420.9
	mean	5274	120.0	45.5	361.4
YB	4	1062	25.8	5.8	73.5
	5	1046	20.0	6.2	52.8
	6	1023	17.9	4.5	43.6
	mean	1044	21.2	5.5	56.6
VA	7	535	23.3	9.2	50.8
	8	421	18.2	11.9	53.4
	9	666	29.2	5.8	20.3
	mean	541	23.6	9.0	41.5
SP	10	1320	8.3	4.2	20.6
	11	1449	11.5	4.5	27.0
	12	1432	8.5	4.3	25.6
	mean	1400	9.4	4.3	24.4
TB	13	480	2.1	2.7	10.4
	14	486	0.0	1.2	6.4
	15	349	0.0	0.0	4.2
	mean	438	0.7	1.3	7.0

[a] ΣPAH is a summation of the concentrations of 19 polynuclear aromatic hydrocarbons.

[b] ΣDDT is a summation of the concentrations of six isomers of DDT/DDD/DDE.

[c] ΣPESTICIDE is a summation of the concentrations of nine pesticides other than DDT.

[d] ΣPCB is a summation of the concentrations of nine chlorination levels of polychlorinated biphenyls.

Relative Sensitivity, Precision, and Discriminatory Power of Sediment Toxicity Tests

To determine the relative sensitivity of each toxicity end-point, the non-parametric K-W test followed by non-parametric Dunnett's t-test was performed to determine significant differences between test samples and respective controls. The numbers and proportions of samples in which toxicity was significantly higher than in the respective controls are tallied in Table 13. The end-points of *R. abronius* survival, *M. edulis* abnormal development, and *M. edulis* percent survival indicated toxicity in the most samples (≥ 87%). The end-points of *A. abdita* survival (flow-through conditions), *A. abdita* avoidance, *R. abronius* avoidance, and *S. purpuratus* echinochrome content indicated the least sensitivity (0 to 7% of the samples were indicated as "toxic" relative to controls). Relative to these end-points, those of *D. gyrociliatus* egg production and *S. purpuratus* abnormal development were intermediate in sensitivity. The end-points of mitoses per embryo, mitotic aberrations, and cytologic abnormalities in *S. purpuratus* were recorded in tests of only five samples and indicated sensitivity to a majority of those samples relative to controls.

To determine the relative abilities of the toxicity tests to discriminate among sites as sampled with the NS&T Program protocols, the non-parametric K-W test was performed with the mean data from each site for each of nine end-points. Significant differences in toxicity between the sites and respective controls were indicated for only four toxicity end-points (Table 14). Percent survival among *R. abronius* was low in the sediments from the TB and OA sites, but the non-parametric K-W test did not indicate any significant differences ($p = 0.11$) between the sampling sites and the Puget Sound Control (Table 25). Also, there were no differences in toxicity among the five sites ($p=0.12$). Avoidance of the sediments from VA by *R. abronius* was significantly higher than that for Control sediments. Differences among the five sites were indicated ($p=0.057$), however, site-specific differences could not be identified by non-parametric S-N-K. No differences between sites and controls were indicated with *A. abdita* survival or avoidance, however, significantly lower survival was indicated in SP sediments than in the others. *M. edulis* indicated significantly lower normal development and survival in OA sediments than in the controls and in the other four sites. Percent normal development of *S. purpuratus* indicated TB sediments were significantly more toxic than the controls and the other sites, whereas echinochrome content indicated that TB was least toxic of the five sites. Egg production in *D. gyrociliatus* did not indicate any significant differences.

Results of an ANOVA power analysis of minimum detectable differences are summarized in Table 15. The minimum detectable differences between sites for n=2, n=3, n=4, and n=5 stations sampled per site, based upon the data collected in this evaluation, are compared. For the n=3 scenario, which is the standard NS&T Program protocol, the end-points of *S. purpuratus* echinochrome, *A. abdita* survival, and *M. edulis* survival would be expected to detect the smallest differences between sites. The largest of the minimum detectable distances would be for the end-points of *R. abronius* survival and *S. purpuratus* abnormal development.

Table 13. Results of non-parametric Kruskal-Wallis tests of differences in toxicity between sediment samples and respective controls with np Dunnett's t-test.

Toxicity end-point	P Value[a]	No. of batches	No of [b] comparisons	"Toxic" Samples [c] Number	Percent
R. abronius					
percent survival	.41 & .0001	2	15	0 + 13	87
avoidance	.21 & .12	2	15	0 + 0	0
A. abdita					
percent survival (flow-thru)	.22 & .03	2	15	0 + 1	7
avoidance	.24 & .27	2	15	0 + 0	0
percent survival (static)	.0099	1	4	1	25
M. edulis larvae					
percent abnormal	.0001	1	15	14	93
percent relative survival	.001	1	15	13	87
S. purpuratus larvae					
percent abnormal	.02 & .89	2	15	2 + 0	13
percent abnormal and retarded	.38 & .12	2	15	0 + 0	0
echinochrome content	.11 & .09	2	15	0 + 1	7
percent fertilization	.02 & .05	2	5	0 + 1	20
no. of mitoses per embryo	.04 & .40	2	5	3 + 0	60
percent mitotic aberrations	.11 & .01	2	5	3 + 0	60
micronuclei incidence	.33 & .01	2	5	0 + 1	20
cytologic abnormality	.008 & .04	2	5	3 + 1	80
D. gyrociliatus					
egg production	.04 & .006	2	15	2 + 3	33

[a] P value at which differences were indicated by non-parametric K-W test for each batch of tests.

[b] Indicates total number of comparisons, relative to respective controls, from both batches.

[c] Tested by one-way, np Dunnett's t-test ($\alpha = 0.05$); with "toxic" defined as different (e.g., lower survival) from appropriate control.

Table 14. Results of non-parametric Kruskal-Wallis tests of differences (a) between toxicity test data from five sampling sites and respective controls and (b) among toxicity test data from each of the five sites.

Toxicity Test End Points	Sites indicated as different from respective controls	P Values OA/VA/YB	P Values SP/TB	Sites indicated as not different from others are shown with the same underline --Increasing Toxicity-->	P Values
R. abronius					
Percent survival	—		0.105	SP VA YB OA TB	0.121
Avoidance	VA		0.06	YB OA SP TB VA	0.057
A. abdita					
Percent survival	—	0.10	0.28	SP TB YB VA OA	0.043
Avoidance	—	0.21	0.85	SP TB YB VA OA	0.032
M. edulis					
Percent normal	OA		0.02	VA SP YB TB OA	0.028
Percent relative survival	OA		0.049	VA SP YB TB OA	0.047
S. purpuratus					
Percent normal	TB	0.33	0.08	VA YB OA SP TB	0.027
Echinochrome content	—	0.13	0.21	TB SP YB VA OA	0.021
D. gyrociliatus					
Egg production	—	0.13	0.15	TB VA SP OA YB	0.078

Table 15. Minimum detectable distance between sites, assuming n=2, n=3, n=4, and n=5 stations per site, based upon ANOVA power analysis, where α = 0.05 and power = 90%.

	n = 2	n = 3	n = 4	n = 5
R. abronius				
survival	4.33	3.53	3.06	2.74
avoidance	0.87	0.71	0.62	0.55
A. abdita				
survival	0.23	0.19	0.16	0.14
avoidance	1.46	1.20	1.04	0.93
M. edulis				
percent abnormal	2.00	1.63	1.41	1.26
percent survival	0.49	0.40	0.35	0.31
S. purpuratus				
percent abnormal	2.43	1.99	1.72	1.54
echinochrome	0.19	0.15	0.13	0.12
D. gyrociliatus				
egg production	0.76	0.62	0.53	0.48

A variety of calculations were performed to compare the relative analytical precision and discriminatory power of 15 of the toxicity end-points (Tables 16 and 17). For some end-points (*e.g., R. abronius* avoidance) the degree of within-sample variance differed greatly between samples taken at some sites (*e.g.,* YB samples) (Table 16). For other end-points there was relatively high homogeneity (*e.g., M. edulis* percent normal development in VA sediments). The averages of the SDs and CVs for each toxicity test are compared in Table 10, the latter as an index of precision. Given that the SDs were largely influenced by the units in which the end-points were reported, the CVs are a better basis for comparison. Among all of the end-points, that of percent normal development in *M. edulis* had the lowest average CV (3.9%). Among the other end-points measured in all 15 samples, those of *A. abdita* survival and *S. purpuratus* percent normal development and echinochrome content also had relatively low average CVs. The CVs for the avoidance end-points of *R. abronius* and *A. abdita* were the highest. Among the end-points in the tests with *S. purpuratus* measured in five samples, the incidence of micronuclei was highly variable, and the number of mitoses per embryo and egg fertilization success were the least variable.

The quotients obtained by dividing the total range in mean values by the average SD for each end-point are compared in Table 10. This quotient, the discriminatory power of the test, is intended to identify those end-points with the widest range in response and the lowest analytical variability independent of the use of controls. The discriminatory power was highest with the *M. edulis* percent normal development end-point and the *R. abronius* percent survival end-point. They had 6.5 and 6.1 SDs within the range in response, respectively. Among the other end-points measured in all 15 samples, those of avoidance of sediments by *R. abronius* and *A. abdita* had the lowest discriminatory power and those of *M. edulis* survival, *S. purpuratus* percent normal development and echinochrome content, and *D. gyrociliatus* egg production were intermediate. Among the *S. purpuratus* end-points measured in five samples, that of cytological abnormalities had a relatively high discriminatory power, while the others had relatively low values.

Table 16. Coefficients of variation {(S.D./$\bar{X}$) x 100} for selected end-points of sediment toxicity tests performed with five replicates each of 15 samples.

	R. abronius		*A. abdita*		*M. edulis*		*D. gyrociliatus*	*S. purpuratus*						
Sample	Percent Survival	Avoidance	Percent Survival	Avoidance	Percent Survival	Percent Normal	Egg Production	Percent Normal	Echinochrome Content	Percent Fertilization	Mitotic Rate	Mitotic Aberrations	Micronuclei	Cytologic Abnormalities
OA														
1	44.8	81.3	12.4	27.9	30.9	8.9	26.7	4.7	14.7	19.2	18.6	33.9	110.0	35.3
2	21.0	106.3	12.6	27.9	24.3	2.4	17.5	4.0	2.4					
3	21.8	78.6	8.0	50.0	36.8	10.2	20.6	4.1	2.3					
YB														
4	13.0	61.1	10.8	57.9	18.5	5.0	51.7	4.1	5.5	6.8	18.3	48.7	75.0	25.0
5	17.9	137.5	5.9	38.2	10.2	4.1	62.7	2.3	8.1					
6	21.9	70.0	10.7	20.0	26.7	2.6	28.4	6.3	2.2					
SP														
7	9.0	66.7	3.4	75.0	26.6	1.6	35.8	9.3	11.1					
8	14.1	92.3	8.1	92.8	29.7	3.6	77.8	3.9	10.8	3.2	13.7	41.4	58.3	18.7
9	15.7	78.9	8.3	100.0	26.9	1.3	27.5	6.4	11.0					
VA														
10	21.0	77.8	2.7	69.7	13.4	1.8	27.8	6.8	8.2	15.3	12.9	19.6	42.9	46.9
11	5.6	56.9	9.3	77.1	16.6	1.6	19.8	3.4	12.0					
12	19.9	86.5	7.3	100.0	16.8	1.4	27.9	4.1	4.8					
TB														
13	48.2	121.0	10.3	35.0	21.5	5.8	18.4	26.6	5.8	3.6	20.3	37.5	83.3	20.0
14	16.9	72.5	5.0	91.7	16.0	5.0	23.2	11.2	7.3					
15	31.0	65.4	8.8	90.6	25.3	3.3	8.9	9.8	4.9					
MEAN	21.4	83.5	8.2	63.6	22.6	3.9	31.6	7.1	7.4	9.6	16.8	36.2	73.9	29.2

Table 17. Within-sample precision, range in results, and discriminatory power of 15 toxicity end-points measured in 3, 5, or 15 sediment samples.

Toxicity End-Point	Sample Size	Average of SDs	Average of CVs (%)	Sample means Maximum	Sample means Minimum	Discriminatory Power[a]
R. abronius						
Percent survival	15	10.3	21.4	91.0	28.0	6.1
Avoidance	15	2.6	83.5	7.4	1.0	2.5
A. abdita						
Percent survival	15	6.9	8.2	95.2	66.0	4.2
Avoidance	15	2.1	63.6	6.8	0.8	2.9
Percent survival (static)	3	13.6	19.9	86.0	51.0	2.6
M. edulis						
Percent normal	15	3.2	3.9	93.4	72.7	6.5
Percent survival	15	11.3	22.6	73.0	29.1	3.9
D. gyrociliatus						
Egg production	15	2.2	31.6	10.3	2.9	3.4
S. purpuratus						
Percent normal	15	5.6	7.1	88.4	63.9	4.4
Echinochrome	15	0.007	7.4	0.109	0.082	3.9
Percent eggs fertilized[b]						
(Batch 1)	3	7.8	13.8	66.4	50.0	2.1
(Batch 2)	2	2.9	3.4	89.8	81.2	3.0
Mitoses per embryo	5	1.0	16.8	8.0	5.6	2.4
Percent mitotic aberrations	5	7.1	36.2	30.1	8.0	3.1
Number of micronuclei	5	2.2	73.9	5.0	0.6	2.0
Cytologic abnormalities	5	4.6	29.2	32.0	6.4	5.6

[a] The result of dividing the difference between the maximum and minimum mean values by the average of the SDs.

[b] Controls indicated that batches 1 and 2 behaved differently.

Correlations Among Sediment Toxicity End-Points

All except two of the end-points (*R. abronius* and *A. abdita* avoidance) are presented in Table 18 such that a high value indicates non-toxicity (e.g., percent survival, percent normal). Therefore, the results of these correlation analyses should be interpreted carefully with regard to the sign (positive or inverse correlations) for these end-points. Three patterns in toxicity responses among the end-points were apparent, based upon the Spearman rank correlation analysis. First, results for the three end-points of *M. edulis* survival and normal development and *R. abronius* survival were relatively highly correlated with each other and not very highly correlated with any others. Second, results for the three end-points of *A. abdita* survival and avoidance and *S. purpuratus* echinochrome content were relatively highly correlated with each other. The pattern of response with the *S. purpuratus* percent normal development end-point contradicted that of *A. abdita* survival and *S. purpuratus* echinochrome content. Third, the results for the end-points of *D. gyrociliatus* egg production and *R. abronius* avoidance were weakly correlated with each other, indicating patterns that contradicted each other. Neither was highly correlated with the results of any of the other end-points. The correlations were strongest among the end-points in the first group and progressively weaker in the second and third groups.

Although the toxicity data were not normally distributed, a parametric Principal Components Analysis among the bioassay end-points was performed in an exploratory mode to determine if there were any patterns in correspondence among the tests. Three factors were identified that explained 44.8 percent, 36.3 percent, and 18.9 percent of the total variability, respectively. The first factor suggested that the *M. edulis* percent normal and percent survival end-points and the *R. abronius* survival end-point had very similar patterns in toxic responses among the 15 samples. The second factor indicated that *A. abdita* survival and avoidance and *S. purpuratus* percent normal and echinochrome content had similar patterns in response. The third factor accounted for little of the total variability and contained the *D. gyrociliatus* reproduction data.

Correlations Between Toxicity and Chemical Results

Results of a Spearman rank analysis of correlations between toxicity test end-points and selected sedimentological variables, chemicals, or chemical classes are listed in Table 19. Trace metal data were normalized to percent fines and organic chemical data were normalized to TOC content. With a total of 190 correlations, the experimental level of significance became 0.05/190 = 0.0003 by the Bonferroni method. None of the correlations were significant at a = 0.0003. Therefore, the results for each toxicity end-point are treated qualitatively. Most of the end-points in Table 19 are presented such that a high value indicates non-toxicity (e.g., % normal, % survival), however, high values for the end-points of avoidance, micronuclei, cytological abnormalities and anaphase aberrations denote toxicity. Therefore, the correlations must be interpreted cautiously with regard to the sign (i.e., positive or negative correlations) for these latter end-points. Some of the end-points that were relatively highly correlated with each other (Table 18) also indicated similar patterns in their correlations with some of the same physical/chemical parameters. First, the toxicity end-points of percent normal development and percent survival of *M. edulis*, percent survival of *R. abronius*, and percent normal development of *S. purpuratus* indicated a similar pattern: they were most strongly inversely correlated with sedimentological factor(s) such as percent silt, percent clay, percent fines, and/or TOC content. The *M. edulis* end-points also were inversely correlated relatively highly with mercury concentration, whereas the *R. abronius* survival data were not very highly correlated with any of the chemical variables. Percent normal *S. purpuratus* data were also relatively highly positively correlated with the concentrations of DDE, other pesticides, zinc, and PCBs. Second, low percent survival and high incidences of avoidance of sediments by *A. abdita* and low echinochrome content of *S. purpuratus* also indicated a similar pattern: they were relatively highly correlated with increasing concentrations of DDE, other pesticides, and PCBs. The correlations between *A. abdita* survival and these chemicals were particularly high. Third, egg production in *D. gyrociliatus* was most inversely correlated with PAHs,

nickel, and percent silt and most positively correlated with Fossil Fuel Relative Index (FFRI). Among the *S. purpuratus* end-points measured in only five samples, the end-points of micronuclei incidence, anaphase aberrations, mitoses per embryo, and fertilization success were relatively highly correlated with one or more classes of organic compounds. In addition, anaphase aberrations were relatively highly correlated with several trace metals. Since the sample sizes for these end-points were relatively small, the apparent correlations between the concentrations of PAHs and the incidences of anaphase aberrations and micronuclei are illustrated graphically in Figures 2 and 3.

Table 18. Spearman rank correlations among toxicity test results for end-points measured in all 15 samples. The toxicity data were normalized to respective batch controls.

	M. edulis % survival	*M. edulis* % normal	*D. gyrociliatus* egg production	R. abronius avoidance	*R. abronius* survival	*A. abdita* % survival	*A. abdita* avoidance	*S. purpuratus* % normal
M. edulis % normal	.950							
D. gyrociliatus egg production	.264	.211						
R. abronius avoidance	.314	.380	.452					
R. abronius survival	.818	.761	-.132	.137				
A. abdita % survival	.468	.414	.150	.166	.239			
A. abdita avoidance	.354	-.273	.270	-.013	-.389	-.704		
S. purpuratus % normal	.261	.307	-.239	.259	.486	-.489	.025	
S. purpuratus echinochrome	-.118	-.171	-.125	-.277	-.279	.500	-.566	-.518

Table 19. Rank correlations among sediment chemistry and toxicity test results for either 15 or 5 samples. Trace metal data have been normalized to percent fines and organic chemical data have been normalized to TOC content. The toxicity data were normalized to respective batch controls.

	M. edulis		*D. gyrociliatus*	*R. abronius*		*A. abdita*		*S. purpuratus*						
	% survival	% normal	Reproduction	Avoidance	Survival	Avoidance	Survival	% normal	Echinochrome Content	Mitoses per embryo	% fertilized	Micronuclei	Cytological abnormalities	Anaphase aberrations
N =	15	15	15	15	15	15	15	15	15	5	5	5	5	5
Σpesticides	-.318	-.246	-.311	-.202	-.007	.515	-.861	.579	-.575	-.8	-.2	-.4	.7	.1
DDE	-.256	-.233	-.345	-.177	.131	.301	-.810	.691	-.567	-.9	.0	.3	.6	.9
"1-Bay" PAHs*	-.286	-.250	-.707	-.390	.154	.132	-.479	.364	-.418	-.7	-.2	.5	.3	.7
"No-Bay" PAHs	-.296	.218	-.175	.163	-.036	.186	-.275	.193	-.582	-.1	-.9	.8	-.1	.5
"2-Bay" PAHs	-.354	-.343	-.721	-.510	.061	.224	-.604	.371	-.368	-.7	-.2	.5	.3	.7
ΣPAHs	-.273	-.214	-.685	-.365	.148	.150	-.402	.277	-.463	-.4	-.6	.8	.1	.6
FFRI**	.393	.332	.575	.463	.161	-.281	.343	.075	.318	.3	.8	-.9	-.2	.7
ΣPCB	-.291	-.264	-.414	-.349	.087	.427	-.865	.587	-.506	-.9	.0	.3	.6	.9
Ag	-.366	-.284	-.316	-.133	-.063	.470	-.745	.422	-.504	-.5	-.6	.7	.5	.9
Cd	-.374	-.334	.288	.352	-.270	.406	-.495	.186	-.415	-.4	-.4	.2	.1	.6
Cr	-.121	.032	.407	.335	-.239	.311	-.304	-.296	-.200	.5	-.2	-.1	.0	-.2
Cu	-.268	-.232	-.143	-.004	-.054	.404	-.554	.289	-.507	-.5	-.6	.7	.5	.9
Hg	-.443	-.490	.332	.149	-.374	.591	-.649	.084	-.386	-.7	.0	-.1	.3	.7
Ni	-.114	.011	.529	.365	-.246	.363	-.304	.189	-.289	.2	.0	-.4	-.3	-.2
Pb	-.161	-.168	-.068	.029	.036	.331	-.639	.432	-.361	-.5	-.6	.7	.5	.9
Zn	-.114	-.029	-.125	.048	.082	.343	-.625	.507	-.500	-.5	-.6	.7	.5	.9
% silt	.368	.386	-.511	-.122	.529	-.401	.250	.146	-.064	.0	.1	.3	.5	.1
% clay	-.496	-.661	.114	-.422	-.579	.145	.114	-.696	.357	-.2	.3	-.5	-.7	-.3
% fines***	.052	-.150	.050	-.422	-.070	-.229	.472	-.629	.349	-.2	.3	-.5	-.7	-.3
TOC	-.635	-.696	.120	-.329	-.721	.279	.073	-.792	.263	.2	-.3	-.1	-.8	-.3

* "Bay" refers to the stereochemistry of the ring structure in which three or more benzene rings form a bay-like indention; this structure has been associated with carcinogenic properties.

** FFRI refers to a Fossil Fuel Relative Index, a ratio measure of petroleum related PAHs; the higher the Index, the greater the proportion of PAHs normally associated with petroleum products versus combustion by-products (Boehm and Farrington, 1984).

*** Percent fines is the summation of percent clay and percent silt.

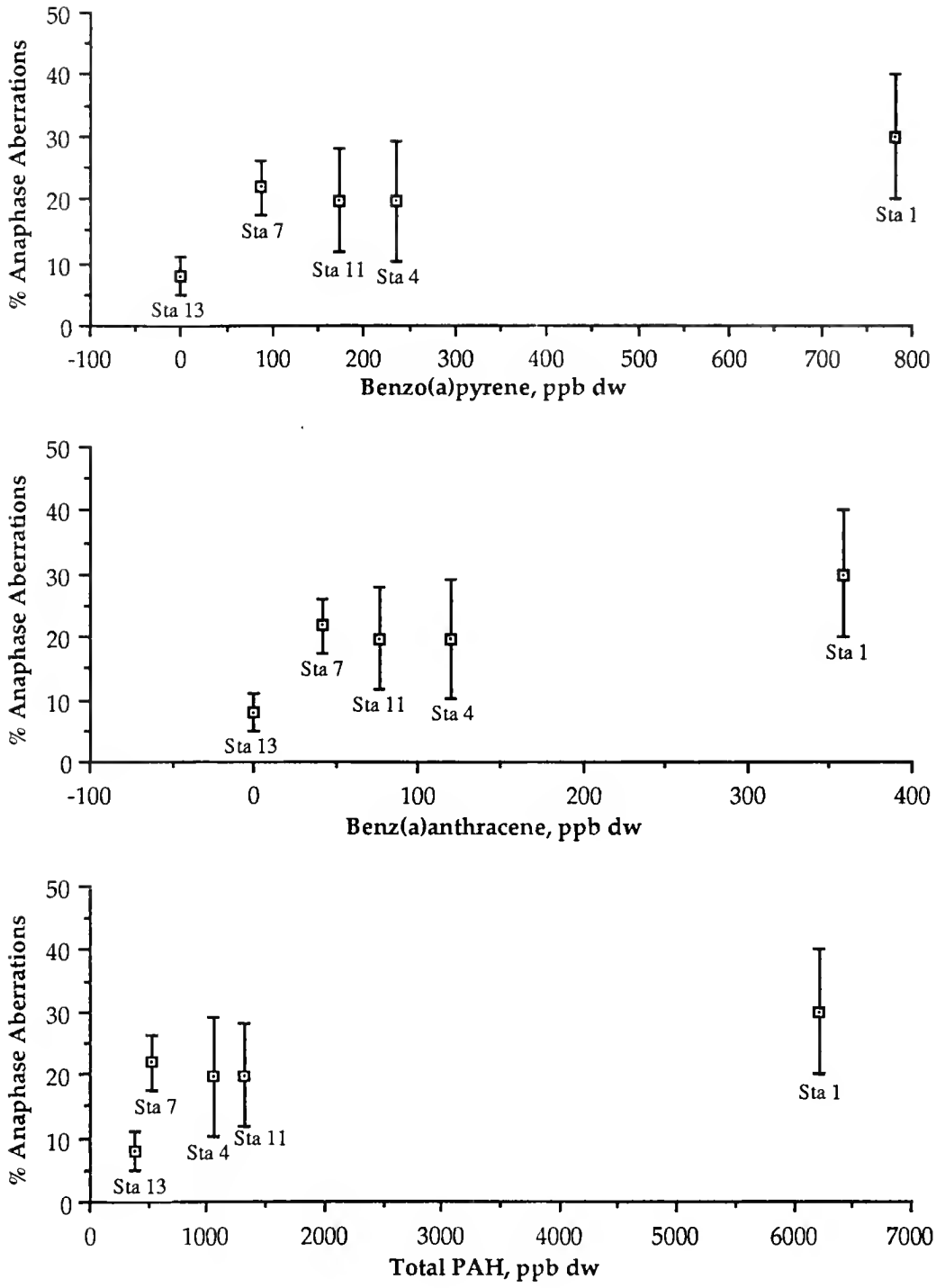

Figure 2. Correspondence between incidence of anaphase aberrations (mean ± standard deviation) in *Strongylocentrotus purpuratus* embryos and concentrations of benzo(a)pyrene, benz(a)anthracene, and tPAH in sediments.

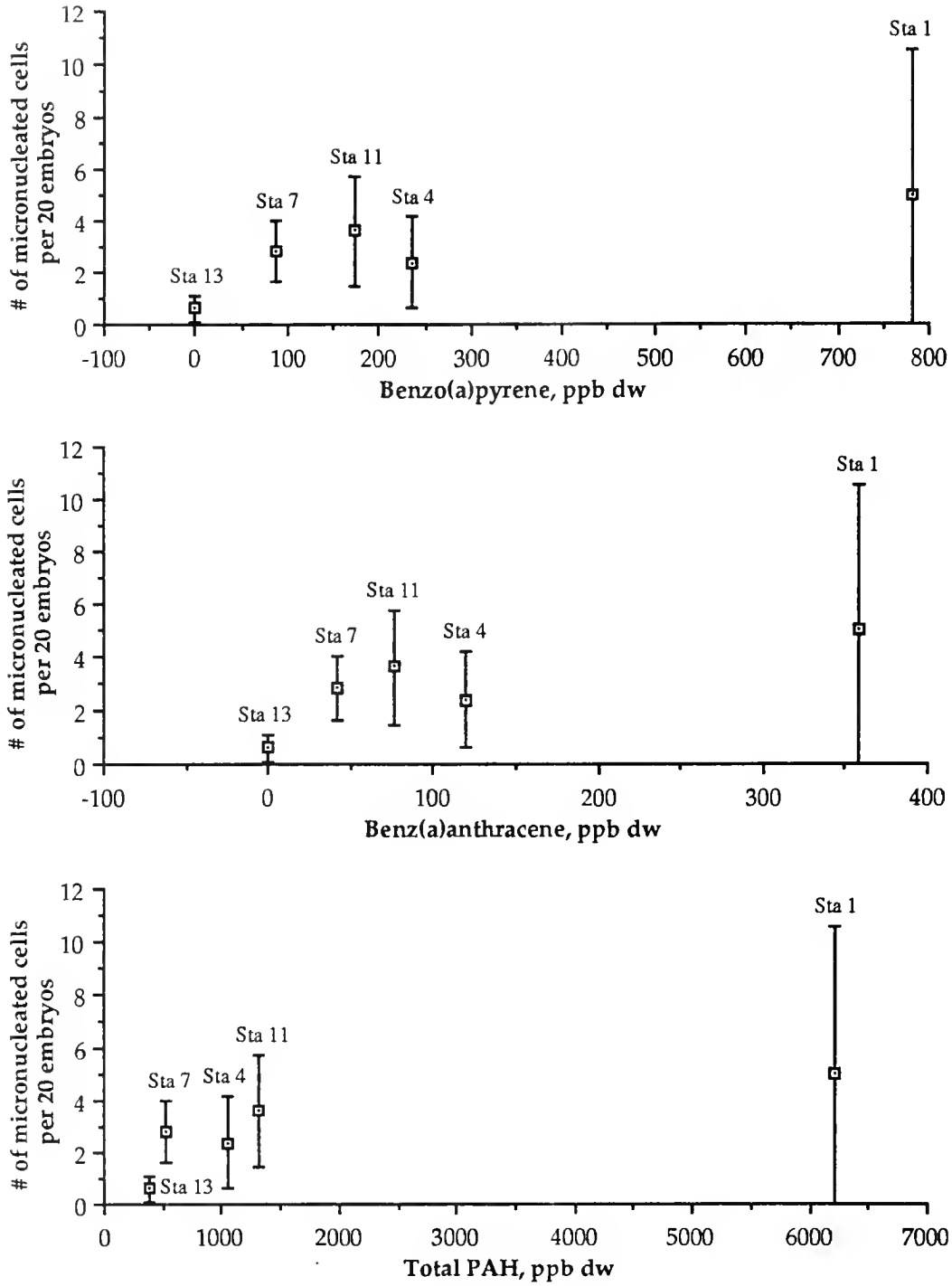

Figure 3. Correspondence between incidence of micronuclei (mean ± standard deviation) in *Strongylocentrotus purpuratus* embryos and concentrations of benzo(a)pyrene, benz(a)anthracene, and tPAH in sediments.

Benthic Community Composition Results

A detailed description of the benthos data is available in the contractor's report to NOAA (Barnett *et al.*, 1987). A summary of selected benthos parameters is listed in Table 20. No data are thus far available for the Oakland site. Among the four sites for which data exist, total abundance was highest at SP and lowest at YB. Species richness was high at TB and lower at all the San Francisco Bay sites: YB, SP, and VA. Dominance was highest at SP, reflecting the abundance of the crustacean *Ampelisca abdita*. Dominance was lowest at station 4 where the abundance of this amphipod was relatively low. Crustaceans dominated the community in abundance at YB and SP, whereas molluscs were dominant at VA and polychaetes were dominant at TB. Mean total biomass was distinctly high at VA and TB, where molluscs and polychaetes were dominants, respectively, and was low at YB and SP where crustaceans predominated.

The amphipod *A. abdita* was the single most abundant organism found at the four sites, occurring in a mean concentration of 3,061 individuals per $0.1m^2$ at SP. At the SP site, the dense population of tubes of *A. abdita* probably influenced the nature of the substrate. This species was also the dominant at YB, but in concentrations roughly an order of magnitude lower than those at SP. The tubes of the abundant polychaete *Asychis elongatus* likely influenced the character of the sediments at YB. Among the four sites, variability in species composition was highest at YB. Molluscs, especially *Mya arenaria*, were dominant in both abundance and biomass at VA, where a significant amount of shell hash was encountered in the sediments. Many polychaetes, especially *Exogone lourei* and the mud-dwelling mussel *Musculista senhousia* were among the most abundant biota at TB where crustaceans were relatively rare. The byssal threads of *M. senhousia* may have provided a haven for some infaunal species at TB.

The dendrogram in Figure 4 produced by Barnett *et al.*, (1987) summarizes the results of a community classification test based upon analyses of community similarity among stations and sites. The community similarity analyses performed on the data for each station produced both normal (by station) and inverse (by species) dendrograms, which were arranged on a single plot on a two-way coincidence diagram. The normal (vertical) dendrogram contains clusters of stations based upon similarity of faunal composition. The (horizontal) inverse dendrogram contains clusters of species that had similar distribution and abundance patterns among stations. The relative abundance of each species is identified by four symbols.

The normal classification analysis identified four major cluster groups of stations, labelled as "site groups" 1, 2, 3, and 4. Site TB (site group 4) was determined to be the most dissimilar among the sites. Next, the dendrogram separated site VA from sites SP and YB. The latter two sites were most similar. Each site group consisted of stations from only one site indicating that faunal similarity was very high at stations within a site compared to similarity among sites.

The inverse classification analysis identified five species groups with similar distribution and abundance patterns among stations. The fauna at site TB was composed almost exclusively of group A species, mainly polychaetes either unique to that site or rarely found at the other sites. Site TB also had some species from groups B and D. The fauna at YB included mainly species from species groups C and D along with species from groups B and E. Species group D was dominant at site SP and group E species were most abundant at site VA. The inverse analysis confirmed the pattern observed with the normal analysis: sites TB and VA were the most dissimilar in faunal composition.

Table 20. Summary of benthic community structure parameters (values are for 0.1m^2 samples)

Site	Sample Number	Total Counts	No. of species	Dominance Index	Crustaceans (% of total)	Molluscs (% of total)	Polychaetes (% of total)	Biomass (g/0.1m^2)	*Ampelisca* (No./0.1m^2)
OA	1	ND							
OA	2	ND							
OA	3	ND							
OA	Mean								
YB	4 (n=5)	263	21.4	0.36	41.4%	24.8%	31.8%	1.1	103.0
YB	5 (n=5)	408	19.6	0.52	69.3%	6.9%	21.5%	2.5	279.0
YB	6 (n=5)	747	19.6	0.73	84.6%	2.4%	12.2%	4.1	629.0
YB	Mean (n=15)	473	20.2	0.54	65.1%	11.4%	18.5%	2.6	337.0
VA	7 (n=5)	1269	17.2	0.60	15.9%	81.2%	2.8%	13.9	105.0
VA	8 (n=5)	720	21.0	0.50	7.6%	71.4%	18.6%	52.6	10.0
VA	9 (n=5)	611	16.2	0.59	9.6%	81.0%	9.4%	3.9	21.0
VA	Mean (n=15)	867	18.1	0.56	11.0%	77.9%	8.7%	23.5	45.0
SP	10 (n=5)	4032	21.4	0.74	81.7%	16.4%	2.0%	5.5	3223.0
SP	11 (n=5)	3188	23.0	0.77	85.4%	11.4%	3.1%	4.3	2678.0
SP	12 (n=5)	3895	19.0	0.80	85.4%	12.6%	2.0%	5	3281.0
SP	Mean (n=15)	3705	21.1	0.77	84.2%	13.5%	2.3%	4.9	3061.0
TB	13 (n=5)	1749	27.8	0.63	0.3%	5.9%	93.7%	42.3	0.4
TB	14 (n=5)	1013	25.6	0.60	0.8%	4.7%	94.1%	23.1	1.0
TB	15 (n=5)	1214	24.6	0.58	0.3%	10.7%	88.5%	40.5	0.2
TB	Mean (n=15)	1326	26.0	0.60	0.5%	7.1%	92.2%	35.3	0.5

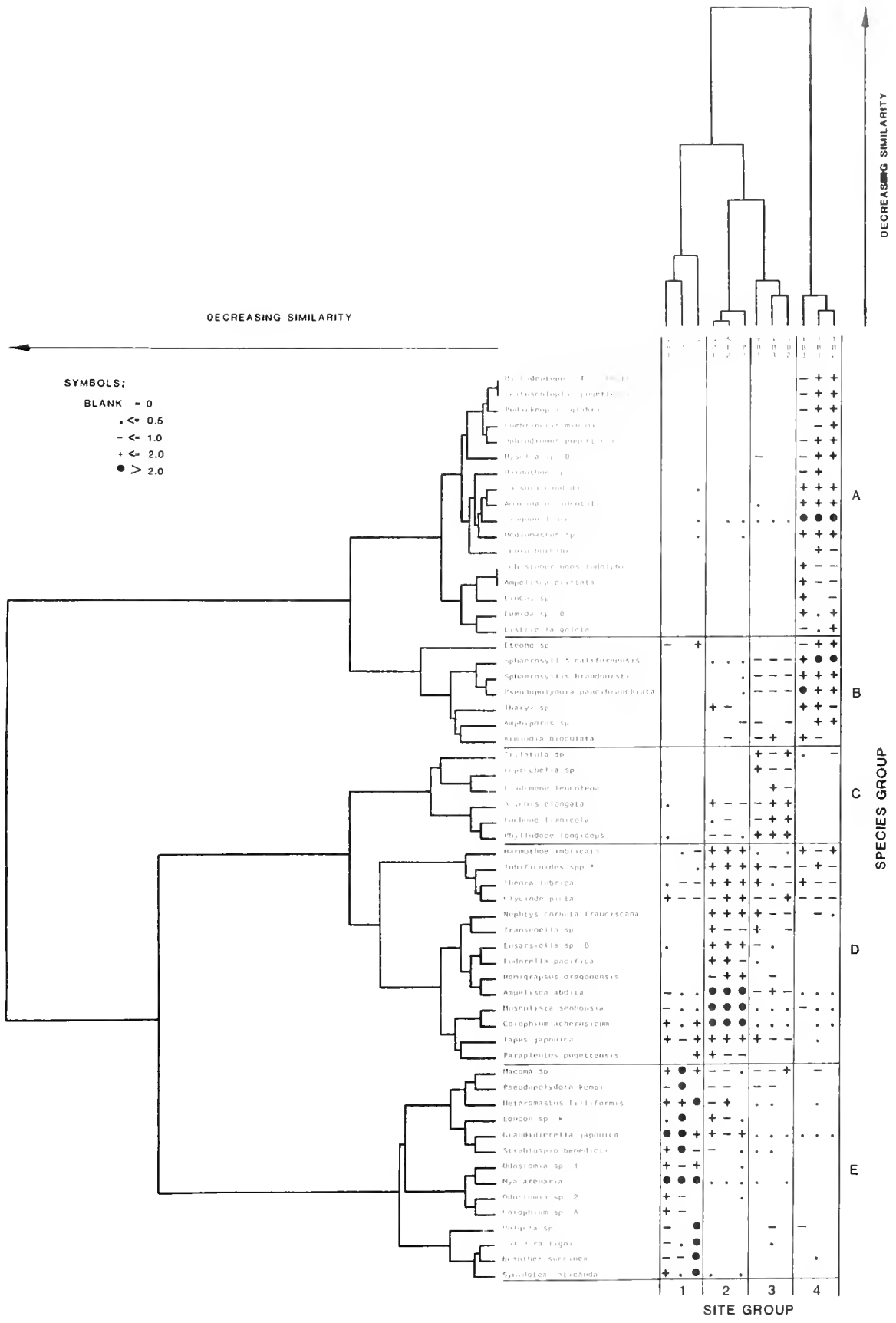

Figure 4. Community classification analysis dendrograms and resultant two-way table. Distances axes are the Bray-Curtis distance values. Symbols in the two-way table represent the abundance values (square root transformed and standardized by the taxon mean); blank = 0, '.'< = 1.5, '..'< 1.0, '+'< = 2.0, '*'> 2.0.

A summary of tests of site differences with ANOVA and S-N-K performed by Barnett *et al.* (1987) is listed in Table 21. The site means were calculated as the averages of the means for the five replicates of the three stations at each site. Significant between-site differences were observed with all the selected parameters. Total counts, crustacean abundance and dominance were significantly higher at the SP site than at the others, and, accordingly, evenness and diversity were significantly lower there. Species richness, total biomass, and abundance of polychaetes/oligochaetes were significantly higher at TB than at the other sites. Mollusc abundance was significantly higher at VA and SP than at TB and YB.

Table 21. Summary of site differences in selected benthic community parameters based upon ANOVA with a S-N-K test on mean or log (x + 1) transformed mean data from the YB, SP, VA, and TB sites. Means connected by the same underline are not significantly different ($\alpha \geq 0.008$)

Total count	SP	TB	VA	YB
site log mean	3.53	3.07	2.58	2.62
Species richness	TB	SP	YB	VA
site mean	26.00	21.13	20.20	18.1
Crustacean abundance	SP	YB	VA	TB
site log mean	3.45	2.41	1.93	0.76
Mollusc abundance	VA	SP	TB	YB
site log mean	2.64	2.59	1.88	1.50
Polychaete/Oligochaete abundance	TB	YB	SP	VA
site log mean	3.03	1.92	1.91	1.77
Total biomass	TB	VA	SP	YB
site mean	35.31	23.48	4.95	2.60
Shannon-Wiener diversity index	YB	TB	VA	SP
site mean	1.39	1.29	1.26	0.70
Pielou evenness measure	YB	VA	TB	SP
site mean	0.46	0.44	0.40	0.23
Dominance index	SP	TB	VA	YB
site mean	0.77	0.60	0.56	0.53

Sediment Profiling Photography Results

A variety of measures of the characteristics of sediments was recorded through use of sediment profiling photography and other means at four of the sites (Table 22). No data were produced for the TB site. The overall intent of these measurements was to determine the degree, if any, of organic enrichment of sediments as indicated by the variety of sedimentological and biological measures.

The sediments were mainly fine-grained (≥ 4 phi; >95% fines) at three of the four sites; they were more coarse at VA. The indices of biological conditions at the sites (Organism-Sediment Index (OSI) and Infaunal Successional Stage) did not indicate the infauna were stressed or recently disturbed at most of the stations within the sites. Some of the stations at the OA site, however, indicated that recent disturbance or organic enrichment may have

occurred there. The OSI was lower and the apparent RPD was smaller there. The depth of the apparent RPD was most shallow at SP and OA, indicative of sediment organic enrichment and deepest at YB. However, contrary to expectation, the TOC and total organic nitrogen (TON) concentrations were the lowest, or among the lowest, at YB. Both TOC and TON were highest at OA. The density of *Clostridium perfringens* spores was over an order of magnitude higher at OA than elsewhere.

Biological Characteristics of Fish Samples: Results

All of the individual data from the fish that were evaluated are listed in Appendix C. They include data on the gender, size, weight, and measures of biological effects.

Fish were located and captured at the BK, OK, VJ, SP, and RR sites in November-December; and at the BK, OK, VJ, and SC sites in January-February. About 15 fish were caught and used for evaluation at each of the five sampling sites in the first sampling (November-December).

Females predominated at all sites, except SP where a nearly equal number of males was obtained in November-December (Table 23). Mature fish were most commonly examined at three of the sites; however, roughly equivalent numbers of immatures were found at the VJ and SP sites. The lengths of the fish were similar at all sites, although SP fish were slightly smaller and those at the RR were slightly larger than those at the other three sites. The relatively high proportion of immature fish at SP was reflected in the small mean length of the fish. The liver/body weight ratios and condition factors were similar among all sites and there was relatively low variability in the data from within the sites. The gonad/body weight ratios, however, showed greater differences among the sites, and were highly variable within sites. Relative to the other sites, the gonads in SP fish, where the most immatures were captured, were smaller. The RR fish which were the largest also had the highest gonad/body weight ratios.

Table 22. Sedimentological and biological properties of sediments determined with sediment profiling photography and supporting measures.

Site	SAIC Station	% fines (4 phi) by wet sieving	Texture major mode by REMOTS™ (Phi)	Organism Sediment Index*	Apparent RPD depth (cm)^	*Clostridium perfringens* counts (no/gm)	TOC mg/g~	TON mg/g'	Benthic Process Features	Infaunal Successional Stage +
OA	33	97.0	>4	+7.2	1.78	21,000	23.89	2.38	Mud Clasts	I,III, III-1 (3)
YB	24	95.3	>4	+9.0	4.23	1,500	11.58	1.25	Mud Clasts	III(5)
SP	4	95.4	>4	+6.2	1.35	1,530	13.71	1.34	Mud Clasts	II, II > III(4)
VA	3	55.6	2 - 1	n/a	n/a	412	15.49	1.23	n/a	n/a

*A multiparameter index based upon sedimentologic and infaunal parameters; high values (≥10) indicate high sediment quality; low values (negative values) indicate high sediment oxygen demand, no macrofauna, and reducing conditions.

^Apparent depth in sediments at which oxic/anoxic discontinuity exists.

~Total organic carbon.

'Total organic nitrogen.

+Apparent stages in succession of infaunal communities where stage I communities are dominated by small surface-dwelling, tube-forming polychaetes and others, stage II communities are dominated by deposit feeders such as Ampelisca abdita, and stage III communities are dominated by large, head-down feeding polychaetes and others. Values in parentheses are the number of replicates associated with each stage.

n/a - data not available.

Table 23. Summary of biological characteristics of starry flounder (*Platichthys stellatus*) from five sites sampled in November-December, 1986; mean ± standard deviation.

Site	Number Males	Number Females	Mature/ Immature Ratio	Standard Length (cm)	Total Body Weight (gm)	Liver/Body Weight x 100	Gonad/Body Weight x 100	Condition Factor ($Wt/L^3 \times 100$)
Berkeley	5	9	10 / 4	31.3 ± 6.3	823 ± 544	1.26 ± 0.34%	2.56 ± 2.58%	2.36 ± 0.14%
Oakland	2	13	10 / 5	32.3 ± 7.3	889 ± 528	1.27 ± 0.50%	2.46 ± 3.29%	2.31 ± 0.27%
Vallejo	5	9	8 / 6	30.2 ± 10.0	683 ± 756	1.43 ± 0.82%	1.39 ± 1.79%	2.04 ± 0.43%
San Pablo	8	6	6 / 8	26.5 ± 4.1	465 ± 209	1.38 ± 0.40%	0.90 ± 0.73%	2.38 ± 0.19%
Russian River	5	11	12 / 4	37.1 ± 4.8	1176 ± 477	1.36 ± 0.42%	2.98 ± 2.31%	2.18 ± 0.18%

Sampling success was significantly reduced during January-February. Only six fish were caught at BK, 12 at SC and only one each at the OK and VJ sites (Table 24). The fish caught at SC were slightly larger and considerably heavier than those at the other sites. However, the condition factors were similar among all the fish. The fish caught in January-February were considerably larger than those caught in November-December.

Table 24. Summary of biological characteristics of mature female (*Platichthys stellatus*) from four sites sampled in January-February, 1987.

Site	Standard Length (cm)	Weight (gm)	Condition Factor (wt. $/L^3$ x 100)
Berkeley (n=6)	39.3 ± 4.8	1462.7 ± 413.4	2.4 ± 0.3%
Oakland (n=1)	43	1748	2.2%
Vallejo (n=1)	39.8	1040	1.6%
Santa Cruz (n=12)	43.5 ± 2.9	2010.2 ± 458.2	2.6 ± 0.3%

Measures of Biological Effects Among Fish: Results

Liver Microsomal Enzyme Activity (Nov-Dec). Aryl hydrocarbon hyroxylase (AHH) activity was highest among fish in November-December from the OK and VJ sites and lowest in fish from the BK and RR sites (Table 25). The biggest difference observed was between samples from the OK and RR sites, where the OK fish had nearly a 5-fold greater mean activity among the males and immatures. A 3-fold difference occurred in mean activity between these two sites for mature females. No major differences occurred in samples treated with the cytochrome P-450E inhibitor, 7,8-benzoflavone.

Plasma Steroid Hormones (Nov-Dec). Testosterone concentrations were among the lowest in fish from BK and among the highest at VJ (Table 25). Patterns in estradiol concentrations in mature males and mature females varied among sites. However, among the immature fish the values in three BK fish were higher than in those at the other sites.

Two of the female fish from the OK site were large (>40 cm), but had no vitellogenic oocytes. Two large females from the VJ site had very little gonadal material and were very thin. Based upon previous experience with this species in San Francisco Bay (Spies, personal communication); these four fish should have had vitellogenic oocytes during this sampling season. However, based upon their apparent condition they likely would not have spawned.

Table 25. Summary of results of analyses of (a) microsomal enzyme activity and (b) plasma steroid hormone analyses in starry flounder (Platichthys stellatus) collected in November-December 1986; means ± standard deviation.

A.

Site	microsomal enzyme activity					
	AHH (all)	AHH w7,8BF (all)	AAH (M,I)	AHH w7,8BF (M,I)	AHH (MF)	AHH w7,8BF (MF)
Berkeley	78.6 ± 37.8 (14)	24.8 ± 15.2 (14)	86 ± 44 (8)	29 ± 17 (8)	68 ± 28 (6)	19 ± 9 (6)
Oakland	287.1 ± 227.5 (15)	51.1 ± 34.8 (14)	363 ± 94 (8)	54 ± 34 (7)	200 ± 145 (7)	48 ± 37 (7)
Vallejo	250.4 ± 248.2 (14)	54.6 ± 37.8 (14)	279 ± 271 (11)	59 ± 41 (11)	147 ± 105 (3)	37 ± 18 (3)
San Pablo Bay	134.2 ± 93.1 (13)	34.2 ± 18.5 (8)	138 ± 96 (12)	33 ± 19 (7)	86 (1)	45 (1)
Russian River	64.7 ± 62.4 (15)	25.0 ± 12.3 (15)	75 ± 45 (5)	30 ± 15 (5)	60 ± 71 (10)	22 ± 11 (10)

B.

Site	Plasma steroids (ug/mL)					
	Testosterone			Estradiol		
	MM	MF	I	MM	MF	I
Berkeley	1.2 ± 0.41 (4)	0.14 ± .06 (6)	0.15 ± 0.19(3)	0.35 ± 0.06 (4)	8.3 ± 5.3 (6)	1.6 ± 1.7 (3)
Oakland	1.6 (1)	0.38 ± 0.35 (5)	0.26 ± 0.26 (5)	0.81 (1)	10.9 ± 10.7 (5)	0.78 ± 0.52 (5)
Vallejo	2.2 ± 1.2 (3)	0.48 ± 0.49 (2)	0.68 ± 0.96 (7)	0.36 ± 0.30 (3)	1.9 ± 1.7 (2)	0.50 ± 0.23 (7)
San Pablo Bay	1.7 ± 1.3 (5)	0.14 (1)	0.75 ± 0.88 (10)	0.27 ± 0.18 (5)	8.7 (1)	0.44 ± 0.23 (10)
Russian River	0.5 ± 0.32 (5)	0.2 ± 0.07 (6)	0.12 ± 0.05 (5)	0.34 ± 0.16 (5)	7.7 ± 4.7 (6)	0.38 ± 0.13 (5)

MF - mature female, MM = mature male; I = immature
AHH = aryl hydrocarbon hydoxylase activity, pmol 3-OH B(a)P/mg protein/min
AHH W7, 8BF = AHH activity with 10-4 M 7,8-benzoflavone added

Liver Microsomal Enzyme Activity/Plasma Steroid Hormones/Reproductive Success (January-February). Differences among sites were difficult to detect with the fish from the second collection, since relatively few fish were caught at each site. AHH activity was similar among fish from the three sites (Table 26). Mean testosterone concentrations in BK fish were about one-third those in SC fish. Estradiol concentrations were similar among sites. There was a consistent pattern of lower measures of reproductive success in fish from BK compared to those from SC. The difference between site means was about three fold for percent embryological success, but within-site variability was high.

Blood Erythrocyte Micronuclei. The mean number of micronucleated erythrocytes in all fish (both sampling periods) was lowest in fish from the coastal sites (SC and RR) compared to those from the four sites in San Francisco Bay (Table 27). The counts were highest in fish from the VJ and BK sites. OK and SP fish had similar mean values. Variability within each site was high, especially in the fish from BK and OK, where the standard deviations exceeded the means. The proportion of fish with zero micronucleated cells was highest in the fish from the SC and RR sites and lowest at the VJ, SP, and BK sites.

In the November-December collection, the mean incidence of micronuclei was distinctly lower in the fish from RR (Table 27). No detached micronuclei were found and 77 percent of the cells had no micronuclei in the RR fish. The highest mean incidences of total and detached micronuclei were in BK, VJ, and SP fish; whereas, the highest mean incidences of attached micronuclei were in OK and BK fish.

The incidence of nuclear pleomorphism (loss of the usual elliptical shape of the nucleus) was also recorded in each fish. The percent of the fish with this condition was highest in fish from BK and OK, lower in fish from SP, and lowest in fish from VJ, SC, and RR (Table 28)

Table 26. Summary of analyses of microsomal enzyme activity, plasma steroid hormone, and reproductive success analyses in starry flounder (*Platichthys stellatus*) collected in January-February, 1987; means ± standard deviation (sample size).

	Reproductive success measures				Plasma steroids at collection (ng/mL)		AHH at spawning
	% floaters	% fertilization	% embryological success	% normal	Testosterone	Estradiol	
Berkeley	56 ± 12 (4)	59 ± 7 (4)	17 ± 13 (4)	83 ± 25 (4)	0.81 ± 0.50 (5)	16 ± 9 (5)	28 (3)
Oakland	56 (1)	70 (1)	28 (1)	73 (1)	1.42 (1)	26 (1)	10 (1)
Santa Cruz	61 ± 20 (6)	66 ± 16 (6)	57 ± 31 (6)	94 ± 6 (6)	2.3 ± 2.2 (12)	18 ± 11 (12)	32 (2)

Table 27 Summary of results of mean counts of micronucleated erythrocytes (per 1000) in blood of *Platichthys stellatus* collected during two seasons (November-December 1986 and January-February 1987) and collected only in November-December 1986 (means ± standard deviation).

Site	N	Total Micronuclei	Detached Micronuclei	Attached Micronuclei	Proportion of fish with zero micronuclei
All Fish					
Berkeley	42	1.9 ± 2.3	0.7 ± 0.7	1.2 ± 2.2	0.12
Oakland	23	1.5 ± 2.1	0.5 ± 0.8	1.0 ± 1.7	0.35
Vallejo	22	2.2 ± 1.5	0.9 ± 1.2	0.5 ± 0.5	0.09
San Pablo Bay	29	1.3 ± 1.2	0.7 ± 0.7	0.6 ± 0.8	0.17
Russian River	29	0.4 ± 0.7	0.1 ± 0.4	0.3 ± 0.4	0.66
Santa Cruz	13	0.6 ± 0.8	0.3 ± 0.3	0.4 ± 0.6	0.46
Nov-Dec					
Berkeley	14	2.4 ± 2.0	1.5 ± 0.8	1.2 ± 1.6	0
Oakland	15	1.6 ± 2.4	0.4 ± 0.3	1.3 ± 2.0	0.40
Vallejo	13	1.8 ± 1.8	1.2 ± 1.5	0.6 ± 0.5	0
San Pablo Bay	12	1.8 ± 1.1	1.2 ± 0.8	0.7 ± 0.4	0
Russian River	15	0.1 ± 0.3	0 ± 0	0.1 ± 0.3	0.77

Table 28. Percent of *P. stellatus* with pleomorphic nuclei (NP). Each fish was rated: 1 if <5% of erythrocytes were pleomorphic; 2 if 5-50% of erythrocytes were pleomorphic; or 3 if >50% of erythrocytes were pleomorphic. N= sample size.

STATION	Percent with NP rating 1	2	3	N
Berkeley	55	29	17	42
Oakland	65	22	13	23
San Pablo Bay	66	31	3	29
Vallejo	64	36	0	22
Santa Cruz	77	23	0	13
Russian River	97	3	0	29

Liver Cytochrome P-450 Activity. Data were produced for a variety of end-points involving the cytochrome P-450 system. Values for many of the end-points were recorded for selected fish from one site (BK) injected with B-naphthoflavone (BNF), a known P-450 inducer, and untreated fish from each of the five collection sites. Total cytochrome P-450 content in nanomoles (nmol) per mg microsomal protein represents the native, active enzyme activity. Mean total P-450 content was about three fold higher in treated fish than in equivalent untreated samples (Table 29). Among the five collection sites, the highest mean values were found in fish at the OK site and the lowest were at the SP and RR sites. The differences in site means were less than twofold.

EROD activity, expressed as both nmol/min/mg microsomal protein and nmol/min/nmol of total P-450, is catalyzed by the P-450 system. About an 11-fold difference in mean EROD activity was observed between BNF-treated and untreated fish, indicating a very high potential for induction in *P. stellatus* (Table 29). Mean EROD activity, as nmol/min/mg protein, was highest among fish from the OK site; about 6 times higher than in RR fish and 4 times higher than in SP fish. When expressed as nmol/min/nmol P-450, the activity in BNF-treated fish was roughly fivefold higher than in untreated fish and the mean activity in OK fish was again highest, exceeding that in the RR fish by 4.5 times.

Content of the apparent homologue of the BNF-, PCB-, PAH-inducible teleost cytochrome P-450E was determined and expressed as picomoles (pM)/mg microsomal protein (Table 29). Mean P-450E content in BNF-treated fish exceeded that in untreated fish by over 15 fold. Mean P-450E content was highest in field collections in the fish from OK and BK and lowest in fish from SP and RR. The mean value for the OK site exceeded that for SP and the RR site by nearly 14 times.

Table 29. Summary of results for total hepatic cytochrome P-450 content, EROD activity, and "P-450E" content in field-sampled *Platichthys stellatus* collected in November-December (means ± SD)

Treatment or site	N	Total P-450[a]	EROD[b]	EROD[c]	P-450E[d]
Experimental					
Control	3	0.135±0.013	0.186±0.097	1.43±0.83	11.1± 8.3
BNF[e]	4	0.326±0.046	2.170±0.787	6.80±2.68	171.4±47.9
Environmental					
Berkeley	14	0.200±0.076	0.121±0.090	0.68±0.51	16.0±26.0
Oakland	15	0.267±0.169	0.259±0.208	1.47±1.02	26.5±23.0
Vallejo	14	0.209±0.101	0.161±0.034	0.62±0.32	3.5 ± 6.7
San Pablo	14	0.168±0.057	0.062±0.030	0.60±0.33	1.9± 1.8
Russian River	15	0.191±0.070	0.044±0.026	0.32±0.17	1.9± 2.1

[a] nM/mg protein
[b] nM/min/mg protein
[c] nM/min/nmol total P-450
[d] pM/mg protein
[e] fish injected with β–naphthoflavone

All of these analyses indicate that the fish at the OK site were exposed to the highest concentrations of P-450 enzyme inducers, including hydrocarbons such as PCBs and PAHs. The BK site ranked second by these measures, followed by VA, SP, and the RR sites. However, the values for BNF-treated fish exceeded those for the OK fish by 1.7 to 8.5 times for the measured end-points, indicating the fish from OK were not exposed to exceptionally high or maximally effective contaminant concentrations.

The mean levels of cytochrome b5 measured in fish from BK, OK, and RR and in fish injected with BNF were similar (Table 30). This measure likely represents the denatured, inactive form of cytochrome P-450. The origin of this degradation is not certain, but could have resulted from the procedures involved in freezing the liver tissue on dry ice. The levels of cytochrome P-420 also were fairly similar among sites. A major pathway of estradiol metabolism in fish is apparently through 2-hydroxylation. Mean measures of estradiol 2-hydroxylase in BK control and BNF-injected fish were essentially identical when expressed as nmol/min/mg protein, but considerably lower in BNF-injected fish when expressed as a function of total native P-450 content (Table 30). Expressed as nmol/min/nmol native P-450, the mean estradiol 2-hydroxylase activity was lowest in the BK and OK fish. The fish used in the experimental evaluation were immature females. Also, all of the SP fish that were analyzed were immature females. The comparable mean values for immature females from the BK, OK, VJ, SP, and RR sites were: 0.126 ± 0.037, 0.213 ± 0.122, 0.246 ± 0.080, 0.299 ± 0.066, and 0.344 ± 0.148 nmol/min/nmol native P-450, respectively. Therefore, these mean values indicated that estradiol hydroxylation was lower in the fish from the two sites (OK and BK) where mean cytochrome P-450 induction was highest. They were highest in the sites (SP and RR) where induction was lowest.

Results of analyses of the few fish caught in the January-February collections are summarized in Table 31. No conclusions can be drawn from the data because of the small sample size. Total cytochrome P-450 activity was very high in SC fish, but a large proportion of that activity was represented by cytochrome P-420, the putative inactive form.

Table 30. Summary of measures of hepatic cytochrome b_5 content, cytochrome P-420 content, percent denatured P-450, and estradiol 2-hyroxylase activity in starry flounder (*Platichthys stellatus*) collected in November and December (Means ± standard deviation).

	N	Cytochrome b_5[a]	N	Cytochrome P-420[a]	N	% Denatured P-450[b]	N	Estradiol 2-OHase[c]	N	Estradiol 2-OHase[d]
Experimental										
Berkeley Control	3	0.044 ± 0.009		ND		ND	3	0.052 ± 0.011	3	0.385 ± 0.071
BNF-injected	4	0.060 ± 0.013		ND		ND	4	0.051 ± 0.018	4	0.165 ± 0.087
Environmental										
Berkeley		ND	9	0.082 ± 0.046	14	29.3 ± 28.5	8	0.016 ± 0.010	8	0.101 ± 0.036
Oakland	13	0.057 ± 0.034	12	0.124 ± 0.138	15	29.3 ± 18.8	12	0.031 ± 0.019	12	0.173 ± 0.107
Vallejo		ND	11	0.104 ± 0.069	14	36.9 ± 23.8	6	0.024 ± 0.012	6	0.246 ± 0.063
San Pablo		ND	12	0.071 ± 0.024	14	38.0 ± 22.0	5	0.038 ± 0.008	5	0.299 ± 0.066
Russian River	10	0.046 ± 0.023	13	0.072 ± 0.033	15	31.9 ± 17.5	10	0.026 ± 0.011	10	0.279 ± 0.184

[a] nmol/mg protein
[b] percentage of total P-450 that appears to be in the P-420 state
[c] nmol/min/mg protein
[d] nmol/min/nmol native P-450

Table 31. Summary of results for total cytochrome P-450 content and EROD activity in *Platichthys stellatus* sampled in January-February 1987.

Treatment or site	N	Total P-450[a]	EROD[b]	EROD[c]
Berkeley	3	0.188 ± .077	0.071 ± 0.011	0.680 ± 0.226
Oakland	1	0.278	0.108	0.103
Santa Cruz	2	0.358 ± 0.138	0.082 ± 0.026	0.915 ± .559

[a] nmol/mg protein

[b] nmol/min/mg protein

[c] nmol/min/nmol total P-450

Relative Sensitivity of Bioeffects Measures in Fish

Very few fish were caught in the January-February collections. The measures of spawning success, therefore, are difficult to interpret. A pattern of decreased success in fish from BK relative to those from outer coastal site at SC is suggested by the data, but the small sample sizes preclude drawing many conclusions. In many years of previous research with this species in San Francisco, significant differences in fertilization success and larval hatching success have been recorded among sites. Fish from the BK and OK sites have generally indicated impaired reproductive success compared to those from SP, SC, and other sites (Spies *et al.*, 1985; Spies and Rice, 1988). The measures of AHH and cytochrome P-450 activities in fish caught in January-February are equally difficult to interpret because of the small sample sizes. The measures of micronuclei in the January-February fish were pooled with those made on November-December fish. Therefore, the discussion of the biological measures in fish will be confined to those performed with fish caught in November and December.

The data from the biological measures of the health of the fish caught in November and December were not normally distributed (Kolmogorov-Smirnov test). Following various transformations of the data, they remained not normally distributed. Therefore, non-parametric statistical tests generally were performed with the fish data.

Based upon the non-parametric K-W test, there were no significant differences among sites in length ($p = 0.106$), weight ($p = 0.113$), GSI ($p = 0.122$), HSI ($p = 0.708$), and liver weight ($p = 0.248$) among females. Among the males, there were differences among sites in these measures: length ($p = 0.014$), weight ($p = 0.010$), GSI ($p = 0.029$), HSI ($p = 0.200$), and liver weight (0.0495). However, non-parametric S-N-K tests could not identify which sites were different. Generally, the fish from the RR site were larger and those from the OK site were smaller than the others.

Both EROD and cytochrome P-450E measurements indicated a similar pattern of relatively high induction of the cytochrome P-450 system in fish, especially immatures, from the BK and OK sites and low induction in fish from the SP, VJ, and RR sites. EROD activity, expressed as either units per mg protein or units per nmol P-450, indicated differences between sites ($p = 0.0004$ and $p = 0.003$, respectively): higher in immature fish from OK than in mature fish from SP, RR, and BK and immatures from RR (Table 32). Mean EROD activities in mature OK fish and immature BK fish were also relatively high, but not significantly different from those at other sites. Cytochrome P-450E activity per mg protein was significantly higher in immature OK fish than in mature fish from RR and SP

($p = 0.0011$). When expressed in proportion to total P-450 content, the P-450E content was greater in immature OK fish than in mature SP, VJ and RR fish.

Mean total P-450 content and P-420 content were highest in fish from OK, but there were no significant differences ($p = .183$ and 0.786, respectively) among sites (Table 32). Also, there were no significant differences ($p = 0.385$) among sites in percent denatured P-450 content. Cytochrome b_5 content did not differ between RR and OK fish (Mann-Whitney, $p = 0.756$).

Two-way ANOVA (performed despite the fact that the data were not normally distributed) indicated there were no differences ($p = 0.09$ to 0.98) in any of the P-450 measurements between sites that were attributable to sex. However, both EROD activity and P-450E content/mg protein in immature fish exceeded those measures in mature fish.

Estradiol 2-hydroxylase activity/mg protein did not differ significantly ($p = 0.94$) among sites. However, estradiol 2-hydroxylase/nmol P-450 content did differ significantly ($p < 0.01$) among sites (Table 32). The average values were lowest in mature BK fish where cytochrome P-450 induction was among the highest and highest in immature fish from SP. Consistent with this pattern was the observation (Table 30) that estradiol 2-hydroxylase activity in fish injected with BNF was about one-half that in untreated fish. This measure was significantly ($p = 0.007$) lower in mature females than in immature females.

AHH activity was generally higher in immature fish than in mature fish. Significant between-site differences in AHH activity were indicated at $p = 0.001$, but non-parametric S-N-K could not distinguish which sites were different. The mean AHH values in fish in which the samples had been exposed to 7,8 benzflavone were generally one-third to one-fifth those of fish not exposed to this P-450 isozyme inhibitor.

Estradiol concentration in plasma was not significantly different among sites ($p = 0.94$) (Table 32). The overall mean value in VJ fish, which were mostly immature, was about one-fifth that in fish from OK which included more matures. Since estradiol suppresses the induction of P-450E, an inverse relationship between estradiol content and P-450E content and EROD activity would be expected. But, this relationship was not obvious with the present data. As would be expected, mature females had higher plasma estradiol concentrations than immatures. Testosterone concentrations also did not differ significantly among sites ($p = 0.40$) (Table 32).

Among the fish caught in November and December, the incidence of total counts of micronuclei in blood erythrocytes was significantly different among sites (non-parametric K-W, $p = 0.0001$). Non-parametric S-N-K indicated that counts were lower in RR than in SP, VJ and BK fish (Table 32). Incidences among the four sites in San Francisco Bay did not differ. Counts of both attached and detached micronuclei were recorded. The incidences of attached micronuclei in all fish did not differ significantly among sites ($p = 0.061$). However, the incidence of detached micronuclei did differ between sites ($p = 0.001$) with the same pattern as observed with total counts. The incidence of both forms did not differ among sites in males. However, total incidence and incidence of detached micronuclei were significantly lower in females from RR than in females from three other sites.

The highest nuclear pleomorphism rating was observed in fish from the Berkeley and Oakland sites (Table 28). There was a significant difference in the incidence of this end-point among fish collected in November-December and January-February from the six sites ($X^2 = 11.07$, $p < 0.001$). Because of the high frequency of zeros for class 3, classes 2 and 3 were combined. Fish from the RR site had the lowest incidence (Table 28). With these fish removed, the incidence was not significantly different at the remaining sites ($X^2 = 2.42$, $df = 4$, $p > 0.50$).

Table 32. Results of non-parametric Kruskal-Wallis tests of differences[a] in biological measures in *Platichthys stellatus* collected at five sites in November and December 1986. Underlines indicate sites that were not different from each other (upper case for mature fish, lower case for immatures).

Biological Measure	(Increasing Toxicity) →
EROD/mg protein	rr SP RR BK sp VJ vj OK bk ok
EROD/nmol P-450	rr RR SP BK VJ sp vj OK bk ok
P-450E/mg protein	SP RR VJ vj rr BK sp OK bk ok
P-450E/nmol P-450	SP VJ RR vj BK rr sp bk OK ok
Total P-450/mg protein	SP RR VJ BK OK
P-420/mg protein	SP RR BK VJ OK
Denatured P-450 (%)	SP VJ RR OK BK
Cytochrome b_5/mg protein[b]	RR OK
Estradiol 2-OH/mg (females)	SP OK RR VJ BK
Estradiol 2-OH/nmol P-450 (females)	BK OK RR VJ SP
AHH	RR SP BK rr bk vj sp OK VJ ok
AHH with 7,8-BF	BK RR bk rr SP vj OK sp ok VJ
Estradiol (mature females)	RR OK BK
Testosterone (males)	VJ SP BK RR
Total Micronuclei	RR OK SP VJ BK
Detached micronuclei	RR OK SP VJ BK
Attached micronuclei	RR OK VJ BK SP

[a] $p \leq 0.05$

[b] Mann-Whitney test

Fish Contaminant Concentrations: Results

Data were produced for individual chlorinated organic compounds in the livers of the fish (normalized to wet weight in Appendix D, normalized to lipid weight in Appendix E). Mean values for sums of the six DDT/DDD/DDE isomers, many pesticides (hexachlorobenzene, lindane, heptachlor, aldrin, heptachlor epoxide, chlordane, transnonachlor, dieldrin, mirex), and tPCBs (based upon sums of the estimated concentrations of Aroclors 1242, 1254, and 1260) are listed in Table 33. The estimates of Aroclor concentrations are based upon the concentrations of only one IUPAC congener each, and, therefore, may not be very accurate estimates. Lipid content of the SC fish was about one-half that of fish from the other sites. Normalized to lipid content, the mean tDDT concentration was highest in fish from the OK, SC, VJ, and BK sites. Total pesticide concentrations, especially dieldrin in two fish, were highest in SC fish and considerably lower and relatively similar among fish from the other sites. Total PCB concentrations were highest in BK and OK fish. PCB concentrations were lowest in SP, RR, and VJ fish.

Of the 74 fish analyzed, 13 had total PCB concentrations that exceeded 10 µg/g lipid weight; all but one were from the BK and OK site (Appendix E). One of those fish from OK also had the highest concentrations of chlordane, transnonachlor, mirex, p,p-DDE, and tDDT of all the fish. One fish from RR had the highest dieldrin concentration (1.53 µg/g lipid weight) of all the fish. One fish each from the BK and OK sites had about 30 µg/g lipid weight tPCB concentrations, roughly three times higher than the site means.

Table 33. Summary of contaminant data for *Platichthys stellatus* liver tissue from six sites (mean ± SD).

Site		ug/g lipid weight		
	g lipid/g liver	Total DDT	Total Pesticides[a]	Total PCBs[b]
Berkeley (n = 14)	0.17 ± 0.08	1.28 ± 0.8	0.45 ± 0.2	9.68 ± 7.7
Oakland (n = 15)	0.14 ± 0.07	1.68 ± 1.7	0.69 ± 0.5	12.48 ± 8.8
Russian River (n = 14)	0.13 ± 0.06	0.92 ± 0.9	0.44 ± 0.5	3.50 ± 2.9
Santa Cruz (n = 4)	0.07 ± 0.03	1.63 ± 0.9	1.77 ± 1.6	6.09 ± 3.0
San Pablo Bay (n = 14)	0.18 ± 0.04	0.92 ± 0.4	0.39 ± 0.2	1.68 ± 1.5
Vallejo (n = 14)	0.14 ± 0.05	1.37 ± 1.2	0.36 ± 0.1	3.45 ± 3.6

[a] Sum of concentrations of lindane, heptachlor, aldrin, heptachlor epoxide, chlordane, transnonachlor, dieldrin, and mirex.

[b] Sum of estimated concentrations of Aroclors 1242, 1254, and 1260.

Table 34 summarizes the results of an analysis of variance of the chemical data from five sampling sites. Although o,p-DDT concentrations were higher at OK than at all other sites and p,p-DDD concentrations were higher in BK, OK and SP fish than in RR fish, there were no significant differences between sites in p,p-DDT, p,p-DDE or in the sum of resolved forms of DDT-type compounds (Table 34). No single DDT isomer accounted for the majority of the variation in the DDT concentration, according to Principal Components Analysis.

Fish from either OK or BK generally had the highest concentrations of many of the pesticides that were quantified (Table 34). Although the lowest concentrations of lindane were in fish from RR, the highest concentrations of heptachlor epoxide were found in those fish. No significant site differences were found in heptachlor or dieldrin concentrations. Aldrin, tDDT, transnonachlor and mirex accounted for 50 percent of the variation among pesticides.

Significantly higher concentrations of Aroclor 1254, Aroclor 1260, and a sum of three aroclors were found in the OK and BK fish. Aroclor 1242, in contrast, was higher in RR fish than in BK fish. About one-third of the PCB congeners (IUPAC 8, 44, 66, 153, 101, 206) accounted for 58 percent of the variance among the PCBs.

Lipid-normalized concentrations of contaminants in liver were generally not related to length or weight of the fish. Also, no significant correlations were apparent between gonad weight, liver weight, GSI and HSI and the concentrations of contaminants. These observations pertained to both the complete collection of November-December fish and to fish collected at individual sites.

No consistent pattern in contamination was apparent for all the quantified chemicals among the sites. Fish from one site with the highest concentrations of one group of compounds did not necessarily have the highest concentrations of the others. For example, fish from the BK and OK sites had the highest tPCB concentrations, but among the lowest concentrations of heptachlor epoxide. Fish from the VJ site had relatively high DDE concentrations, but concentrations of other pesticides in those fish were relatively low. Fish from the RR site were surprisingly contaminated with PCBs relative to those from VJ and SP. However, the RR fish were larger than those from the other sites. The relative similarity in mean contaminant levels between BK and OK reflected the proximity of these two sites to each other. Overall, the fish from the SP, RR, and SC sites were generally the least contaminated, and those from the BK and OK sites were generally the most highly contaminated. Within-site variability was relatively high, as indicated by high standard deviations relative to the means. Some degree of variability in contaminant levels is to be expected in a population of feral fish because of their mobility. However, it is possible that these fish were exposed to and were affected by readily metabolized and nonquantified compounds, such as aromatic hydrocarbons, that may have been partially or wholly responsible for the induction of the biological measures. If the latter case pertained, then a strong correspondence between the biological data and the quantified chemical data would not be expected.

Table 34. Summary of results of 1-way ANOVA for chemical data in *Platichthys stellatus* collected at five sites in November and December 1986. Underlines connect sites that were not different.

	DECREASING CONCENTRATIONS →				
o,p - DDT	OK	BK	SP	VJ	RR
p,p - DDT	BK	OK	RR	SP	VJ
p,p - DDD	OK	BK	SP	VJ	RR
p,p - DDE	RR	VJ	OK	BK	SP
Σ DDT	OK	BK	RR	VJ	SP
Lindane	BK	SP	VJ	OK	RR
Heptachlor	BK	OK	RR	VJ	SP
Heptachlor epoxide	RR	VJ	SP	OK	BK
Transnonachlor	OK	BK	RR	VJ	SP
Dieldrin	OK	RR	BK	SP	VJ
Mirex	OK	RR	VJ	SP	BK
Aroclor 1242	RR	SP	VJ	OK	BK
Aroclor 1254	OK	BK	RR	VJ	SP
Aroclor 1260	OK	BK	RR	VJ	SP
Σ PCB	OK	BK	RR	VJ	SP

Correlations Among Biological Measures in Fish.

Table 35 summarizes the results of a qualitative Spearman rank correlation analysis between measures of length and weight of the fish and the measures of effects. Very few of the correlations were particularly high. Cytochrome P-450E was relatively highly inversely correlated with HSI. Estradiol 2-hydroxylase was relatively highly positively correlated with length, weight, and GSI.

Table 35. Spearman rank correlations between measures of bioeffects in fish and measures of length, weight, GSI, and HSI.

	Standard Length	Weight	GSI	HSI
AHH	-.248	-.238	-.329	-.157
Mean total micronuclei	-.064	-.093	-.032	.140
Cytochrome P-450E	-.272	-.245	-.293	-.574
EROD/mg protein	-.281	-.302	-.276	-.206
EROD/P-450	-.381	-.357	-.331	-.274
Cytochrome P-450	.015	.022	-.069	-.085
Cytochrome P-420	-.004	.022	-.014	.139
Percent denaturated P-450	-.037	-.005	-.012	.101
Total P-450E/total P-450	-.245	-.204	-.248	-.557
Testosterone	-.131	-.148	.112	.335
Estradiol 2-hydroxylase	.415	.478	.507	.264
Total P-450	.076	.074	-.001	.078

Spearman rank correlation analysis among the various measures of effects also did not show many high correlations (Table 36). AHH activity was most highly correlated with EROD activity, as would be expected. Many of the suite of cytochrome P-450 measures (*i.e.*, total P-450, EROD, P-450E) were most highly correlated with each other. The counts of total micronuclei were not very highly correlated with the other measures. Measures of testosterone and estradiol 2-hydroxylase content were not highly correlated with the other measures.

Correlations Among Bioeffects Measures and Contaminant Concentrations in Fish.

None of the biological measures was particularly highly correlated with any of the chemical contaminants in the livers of the fish (Table 37). Total counts of micronuclei were most highly correlated (negatively) with mirex and aldrin concentrations. Cytochrome P-450 and P-450E content and EROD activities were weakly positively correlated with tPCB concentrations. Estradiol 2-hydroxylase activity was relatively highly correlated with dieldrin concentrations. No single chemical or chemical class stood out as consistently being correlated with the biological measures.

Within-Site Variability in Bioeffects Measures in Fish.

Analytical variability, as evaluated with the sediment bioassays, could not be evaluated with the bioeffects measures in fish, since replicate analyses of individual fish were not performed on all the fish with all of the measures. However, within-site variability and between-site discriminatory power can be compared among measures, since all of the measures were performed on the same fish. Within-site variability among fish can be viewed two (opposing) ways. First, if one assumes that individual fish sampled within one area (site) had different histories of exposure to contaminants, then a bioeffects measure that has high within-site variability may simply reflect that variability if the measure is especially sensitive. If, on the other hand, one assumes that the fish sampled in one area (site) are from a relatively homogeneous population and, therefore, all the individuals have had a similar history of contaminant exposure, then a bioeffects measure with high within-site variability may indicate relatively low analytical precision. Unfortunately, *Platichthys stellatus* migrate in and out of San Francisco Bay annually and little is known of the fidelity of the returning adults to specific areas of the estuary. Although Spies *et al.* (1985, 1988) have demonstrated differences in measures of contaminants

in tissues and measures of bioeffects between sites in the bay, they also observed sufficient within-site variability to suggest that all the fish from any one site were not from a distinct population with identical histories of contaminant exposure.

An assortment of natural environmental factors and biological variables can influence within-site variability in the fish bioeffects measures. They could include genotype, gender, degree of maturation, stress preceding capture, stress during capture, and feeding success. Any combination of these and other factors may have contributed to the variability among fish within the sampling sites.

Coefficients of variation in the biological measures performed on fish caught at each site in November and December differed among the measures (Table 38). The measures of total and attached micronuclei had high within-site variation. The analysis for cytochrome P-450E/mg protein also indicated relatively high variation. The coefficients of variation for testosterone, estradiol-2-hydroxylase/mg protein, total cytochrome P-450/mg protein, EROD/mg protein, and AHH with 7,8-BF were relatively small at most sites. Based upon data in Table 31, the chemical data from the BK and SP sites were the least variable. However, there was no apparent pattern of lower within-site variation in the biological measures in the fish from those two sites.

The maximum and minimum site means, the total range in mean values, the average of the SDs, the average of the CVs, and the quotient of dividing the range by the average SD are listed in Table 39. The average CVs were highest for the end-points of attached and total micronuclei and cytochrome P-450E and lowest for total cytochrome P-450 and estradiol-2-hydroxylase/mg protein. The quotients of total range over the average SDs were highest for EROD/mg protein and EROD/nmol P-450. By comparison, these values were relatively low for total P-450, attached micronuclei, and AHH following exposure to 7,8-benzflavone.

Table 36. Spearman rank correlations between measures of bioeffects in fish.

	tP-450 + P-420	Estradiol-2-hydroxy-lase	Testo-sterone	P-450E/ tP-450	% Dena-natured P-450	Cyto-chrome P-420	Cyto-chrome P-450	EROD/ P-450	EROD/ mg	Cyto-chrome P-450E	Total micro-nuclei
AHH	.368	.031	-.061	.267	-.022	.246	.252	.448	.448	.294	.074
Total micronuclei	-.119	-.006	.043	.049	.097	-.09	-.077	.191	.153	.071	
Cytochrome P-450E	.375	-.195	-.073	.896	-.213	.173	.589	.52	.606		
EROD/mg protein	.471	.089	-.063	.505	-.318	.24	.549	.863			
EROD/P-450	.151	.126	-.108	.529	-.094	.043	.214				
Cytochrome P-450	.9	.027	-.102	.363	-.44	.47					
Cytochrome P-420	.779	.032	-.062	-.159	.418						
%denatured P-450	-.04	-.012	-.063	-.328							
P-450E/tP-450	-.012	-.016	-.119								
Testosterone	.017	-.359									
Estradiol 2-hydroxylase	-.109										

Table 37. Spearman rank correlations between measures of biological effects and concentrations of contaminants in fish livers.

	Lindane	Heptachlor	Aldrin	Heptachlor epoxide	Chlordane	Transnona-chlor	Dieldrin	Mirex	ΣDDT	ΣPCB
AHH	.013	-.08	-.048	.081	.082	.133	-.197	.202	.119	-.002
Total micronuclei	-.106	.249	-.417	.107	.27	.283	.173	-.541	.215	.175
Cytochrome P-450E	.239	-.397	-.122	-.037	.062	-.008	-.207	-.011	-.019	.112
EROD/mg protein	.219	-.131	-.232	-.132	.102	.185	-.109	.002	-.009	.224
EROD/tP-450	.382	.102	-.19	.033	.108	.202	-.056	.007	.067	.233
Cytochrome P-450	-.037	-.277	-.281	-.25	-.177	-.063	-.208	-.031	-.169	.089
Cytochrome P-420	.367	.258	-.155	.074	-.132	.091	.027	.246	-.05	.095
% denatured P-450	.198	.148	-.053	.158	.007	.094	-.006	.084	.151	.007
P-450E/tP-450	.065	-.351	-.008	.026	.139	.064	-.098	-.008	.018	.137
Testosterone	-.164	-.197	-.406	-.164	.075	-.013	-.069	-.129	.038	-.082
Estradiol 2-hydroxylase	.046	.175	.136	.127	.016	.211	.416	-.142	.124	.234
tP-450 + P-420	.126	-.202	-.309	-.159	-.306	-.028	-.129	.225	-.174	.09

Table 38. Coefficients of variation [(S.D./$\bar{X}$) x 100] for selected biological measures performed with starry flounder (Platichthys stellatus) collected at five sites in November and December 1986.

Site	AHH	AHH with 7,8-BF	Testosterone (males)	Estradiol (females)	Total Micronuclei	Detached Micronuclei	Attached Micronuclei	Total P-450	EROD/mg protein	EROD/nmol P-450	P-450E/mg protein	Estradiol 2-OH/ mg protein	Estradiol 2-OH/ nmol P-450
Berkeley	48.1	61.3	34.2	63.8	84.2	56.7	134.2	38.0	74.4	75.0	162.5	62.5	133.3
Oakland	79.2	68.1	NA	98.2	147.5	82.5	156.9	63.3	80.3	69.4	86.8	61.3	66.3
Vallejo	99.1	69.2	54.5	89.5	97.8	122.5	81.7	48.3	21.1	51.6	191.4	50.0	27.5
San Pablo Bay	69.4	54.1	76.5	NA	62.8	67.5	62.9	33.9	48.4	55.0	94.7	28.6	17.5
Russian River	96.4	49.2	64.0	61.0	310.0	NA	310.0	36.6	59.1	53.1	110.5	51.7	67.3
AVERAGE	78.4	60.4	57.3	78.1	140.5	82.3	149.1	44.0	56.7	60.8	129.2	50.8	62.4

Table 39. Maximum and minimum site means, total ranges among site means, averages of the site SDs and CVs, and the quotient of dividing the range by the average SD for selected bioeffects measures in *Platichthys stellatus*.

	Maximum Site Mean	Minimum Site Mean	Total Range	Average SD	Average CV	Range/ Average SD
AHH (all fish)	287.1	64.7	222.4	133.8	78.4	1.7
AHH with 7,8-BF (all)	54.6	24.8	29.8	23.7	60.4	1.3
Testosterone (males)	2.2	0.5	1.7	0.8	57.3	2.1
Estradiol (females)	10.9	1.9	9.0	5.6	78.1	1.6
Total micronuclei*	2.4	0.1	2.3	1.5	140.5	1.5
Detached micronuclei*	1.5	0	1.5	0.7	82.3	2.1
Attached micronuclei*	1.3	0.1	1.2	1.0	149.1	1.2
Total P-450	0.267	0.168	0.099	0.095	44.0	1.0
EROD/mg protein	0.259	0.044	0.215	0.078	56.7	2.8
EROD/nmol P-450	1.47	0.32	1.15	0.47	60.8	2.4
P-450E	26.5	1.9	24.6	11.9	129.2	2.1
Estradiol 2-0H'ase/mg protein	0.038	0.016	0.022	0.012	50.8	1.8
Estradiol 2-0H'ase/nmol P-450	0.299	0.101	0.198	0.091	62.4	2.2

* November - December fish

DISCUSSION AND CONCLUSIONS

Sediment Toxicity Tests

Mytilus edulis. The bivalve larvae bioassay was initially developed for use in testing the toxicity of water and effluents, particularly pulp mill wastes in Puget Sound. Its initial use in sediment tests was reported by Chapman and Morgan, 1983. The embryos of oysters were initially used in the tests. The test has been used as a relatively quick and inexpensive indicator of sediment toxicity. Embryos generally can be acquired throughout most of the year, although with more difficulty during the winter. However, since the embryos of both oysters and mussels do not seek and colonize soft-bottom sediments, the test may be most appropriately viewed as an indicator test with less ecological relevance than, say, a solid phase test with an infaunal or epibenthic species. Protocols have been developed for the performance of the test. These protocols (Chapman and Becker, 1986), specify that at least 70 percent of the larvae must survive in seawater controls and that at least 90 percent of the larvae develop normally. These protocols recommended that either oyster larvae or mussel larvae could be used in the tests.

Out of 60 stations sampled in the industrial waterways of Commencement Bay, normal development of oyster larvae was 70 percent or less in samples from 18 (30%) of the stations (Williams *et al.*, 1986). No normal larvae were observed in a test of one of the stations, less than 40 percent were normal in tests of five of the stations. In four samples from a rural reference area, Carr Inlet, mean percent normal development was 87 percent. About 96 percent of the larvae developed normally in seawater controls. In other research conducted in Puget Sound, less than 80 percent normal development was observed in 3 of 10 (30%) stations sampled in Bellingham Bay, 3 of 6 (50%) stations sampled in Everett Inner Harbor, 4 of 4 (100%) stations sampled in the Duwamish Waterway near Seattle, and 6 of 9 (67%) stations sampled in the Commencement Bay waterways (Long, 1985). Mean normal development was less than 40 percent in samples from Islais Waterway, off Port of San Francisco piers 94/96, off Hunters Point, and off Treasure Island tested with oyster or mussel larvae by various investigators (Long *et al.*, 1988). By comparison, mean normal development

of mussel larvae in the present study exceeded 90 percent in both seawater and sediment controls and was less than 75 percent in the OA site sediments. Therefore, in comparison with some samples from highly contaminated waterways elsewhere in San Francisco Bay and in parts of Puget Sound, the samples tested in the present study were not as toxic to mussel larvae.

Mean survival of oyster larvae was less than 50 percent in 8 of 10 (80%) samples from Bellingham Bay, 6 of 6 (100%) samples from Everett Inner Harbor, 4 of 4 (100%) samples from the Duwamish Waterway, and 8 of 9 (89%) samples from the Commencement Bay waterways (Long, 1985). Mean survival of mussel larvae was less than 15 percent in samples from the Islais Waterway, 24 to 50 percent in samples collected off the Alameda Naval Air Station and 50 to 83 percent in samples from the SP site tested in 1985 (Chapman *et al.*, 1987). By comparison, 76 percent of the mussel larvae survived exposure to sediment controls in the present experiment. As few as 29 percent survived in tests of sediments from the OA site. Again, the survival end-point of this test indicated a degree of response that was somewhat less than that observed in other studies of very highly contaminated sediments.

The adult mussels can be induced to spawn year-round as exemplified in this study. The tests were performed in February. However, several investigators have experienced problems, especially with oysters, in attempting to induce bivalves to spawn in the winter (Joe Cummins, US EPA; Paul Dinnel, University of Washington; Peter Chapman, E.V.S. Consultants, personal communications).

The high sensitivity of the *M. edulis* larvae test observed in this evaluation was also reported by Chapman *et al.* (1987) in a previous study in San Francisco Bay in which six toxicity end-points were measured. In that study, the end-points of percent abnormal development and percent survival of *M. edulis* indicated that the most samples, 5 of 9 and 8 of 9, respectively, were "toxic" relative to controls. However, Williams *et al.* (1986) reported that a similar test performed with oyster larvae (*Crassostrea gigas*) was the least sensitive of three that were evaluated. It indicated 35 percent of the samples from Commencement Bay waterways were "toxic" relative to controls, compared to 39 percent for *R. abronius* and 63 percent for a Microtox™ test. In the data reported by Chapman *et al.* (1987), the analytical precision was somewhat lower (average CVs were 25% and 32.5%, respectively, for percent abnormal and percent survival) than in the present evaluation (average CVs of 3.9 and 22.6%, respectively). The positive correlations between the results of this test and the texture and TOC content of the sediments have not been quantified through empirical experimentation. However, similar to the results observed here, Chapman *et al.* (1987) often observed highest toxicity in samples that had the highest percent fines and TOC content, as well as the highest concentrations of toxicants. In this evaluation, fine-grained, organically enriched samples that were apparently not contaminated with the quantified analytes were also toxic to this organism. In conclusion, although the end-point of abnormal development of this test was the most sensitive and had the highest precision and discriminatory power of the five evaluated, it also may be sensitive to "nuisance variables" (Bayne *et al.*, 1988) such as sedimentological properties and/or it may be a sensitive indicator of the toxicity of sediments contaminated with chemicals that are not routinely quantified in chemical analyses.

Similar to the results reported here, the data from the *M. edulis* test and the *R. abronius* test previously have indicated very high concordance with each other (Williams *et al.*, 1986; Chapman *et al.*, 1987).

Rhepoxynius abronius. This test has been developed and evaluated through extensive research (*e.g.*, Swartz *et al.*, 1985). The life history and sensitivity of the animal to many toxicants and sediment types has been described (*e.g.*, Swartz *et al.*, 1985). The species normally burrows in surface sediments and, therefore, is appropriate for use in solid phase tests. Populations in Yaquina Bay, Oregon and off Whidbey Island, Washington have been sampled year-round for use in toxicity tests. The analytical precision of the test has been quantified and compared among five laboratories (Mearns *et al.*, 1986).

In the development of the *R. abronius* test protocols, Swartz *et al.* (1985) observed that with 5 replicates per treatment and 20 amphipods per replicate the test is 75 percent certain of detecting statistical significance ($p<0.05$) if the difference in mean survival between control and test sediments is 2.8. With the mean control survival of 19.0 that they suggest, this difference corresponds with mean survival of 16.2 or less in test sediment, roughly a 15 percent reduction in survival. The relatively high sensitivity of *R. abronius* survival has been reported in previous inter-method comparisons (Swartz *et al.*, 1979, 1985; Williams *et al.*, 1986; Chapman *et al.*, 1987). In an inter-laboratory comparison of the *R. abronius* toxicity test, Mearns *et al.* (1986) found that survival greater than 87 percent clearly indicated sediments were not toxic and survival less than 76 percent clearly classified sediments as toxic. An overall mean of 19.2 ± 1.1 amphipods survived in control sediments. The minimum mean survival was 15.8 ± 2.4 in a sample from Sinclair Inlet near Bremerton, Washington and 3.8 ± 3.1 in a sample spiked with 12 mg/kg cadmium. Mean emergence in control sediments was 0.4 amphipods out of 20. In that comparison, all five laboratories agreed in the ranking of test samples according to survival, emergence, and reburial end-points. At least four of the five laboratories agreed on mean values for the samples for the three end-points. Based upon the results of these two evaluations of the methods, mean survival in test sediments of 15.0 or fewer amphipods may be used as a conservative criterion for classifying a sample as "toxic."

Out of 129 sediment samples from the industrial waterways of Commencement Bay, Washington, 92 (71.3 percent) were "toxic," *i.e.* 15 or fewer survivors (Swartz *et al.*, 1982). Using the same criterion, 6 of 8 samples (75%) were toxic in inner Everett Harbor, Washington; 10 of 17 samples (59%) were toxic in Sinclair Inlet, Washington; and 5 of 10 samples (50%) were toxic off a major combined sewer overflow near Seattle (Battelle, 1986). None of the 15 samples collected at sites on the Palos Verdes shelf and in Santa Monica Bay, California resulted in 15 or fewer survivors (Swartz *et al.*, 1986). Percent survival in sediments collected in 1984 from the Commencement Bay waterways was 25 percent or less in 23 of 60 samples (38.3%) (Williams *et al.*, 1986). There were no survivors in a sample taken near a defunct metal smelter. Low survival of amphipods has been observed in samples from parts of San Francisco Bay (Long *et al.*, 1988). The lowest mean survival rate (34.5%) in two deep cores taken off Hunters Point exceeded the mean (47%) observed in 10 samples from Islais Waterway. A grand mean survival of 11.0 percent was observed in 26 samples from South Bay tested with *R. abronius* (Baumgartner, unpublished manuscript). By comparison with the results from other studies, mean survival in the present study exceeded 75 percent at only 3 of the 15 stations sampled; therefore, 12 of 15 were "toxic," using the criterion stated above.

The average CV reported here (21.4%) was exactly the same as that for data from nine samples reported by Chapman *et al.* (1987) and very similar to that (22.4%) for data from seven samples reported by Mearns *et al.* (1986). Also, the high analytical variance (average CV of 83.5%) for the avoidance end-point observed in this evaluation has been observed elsewhere: 65.7 percent in nine samples (Chapman *et al.*, 1987); and 111.2 percent in seven samples (Mearns *et al.*, 1986).

Despite the correlations observed by Swartz *et al.* (1985) between sediment avoidance by *R. abronius* and the cadmium concentrations and the relatively good agreement among five laboratories in this end-point (Mearns *et al.*, 1986), the avoidance end-point in this evaluation performed relatively poorly. Within-sample variability was very high, between-sample discriminatory power was low, the data did not correlate very highly with chemical concentrations, nor did they correlate with the data from the other tests. Also, the reburial end-point was not responsive at all, corroborating the observation of Swartz *et al.* (1985) that failure to rebury was very rare among survivors of the 10-d tests.

The negative correlations between *R. abronius* survival and both percent clay and TOC content corroborates this relationship demonstrated quantitatively in empirical experiments conducted by DeWitt *et al.* (1988). *R. abronius* normally occurs in well-sorted, fine sands and usually not in muddier sediments. Therefore, some degree of mortality observed in toxicity tests is probably attributable to the presence of fine-grained sediments when such samples are tested DeWitt *et al.* (1988) examined the possible role of particle size on *R. abronius*

mortality and observed, on average, 15 percent lower survival in uncontaminated fine-grained sediments than in uncontaminated coarse-grained sediments. They concluded, however, that particle size is probably just a "super-variable" that is correlated with the actual cause of mortality. The 15 percent effect of grain size, alone, upon survival would not explain the magnitude of the response observed in apparently uncontaminated sediments tested in this evaluation. In conclusion, the test of *R. abronius* survival was among the most sensitive bioassays and had a relatively wide range in response, a relatively high discriminatory power and intermediate precision; however, survival may be influenced by sedimentological variables and the end-points of reburial and avoidance appear to be relatively insensitive and/or highly variable.

Ampelisca abdita. As opposed to *R. abronius,* which is a burrowing species, *A. abdita* forms mud tubes on the surface of fine-grained sediments. This species is indigenous to the New England area, but also has been introduced to San Francisco Bay where it is very abundant (Hopkins, 1986). The development of the *A. abdita* toxicity test has not yet progressed as far as that with *R. abronius.* Initial work with the test animal has indicated that it is not sensitive to uncontaminated fine-grained sediments, that it may be sensitive to coarse-grained sediments, and that it is somewhat less sensitive to contaminated sediments than *R. abronius.*

In an evaluation of dredged material from Black Rock Harbor (BRH), Connecticut, Rogerson *et al.* (1985) observed acute toxicity in only one of ten species that was tested: *Ampelisca abdita.* They calculated a 96-h LC 50 of about 28 percent BRH material. A maximum of 84.8 percent mortality was observed in 50 percent BRH treatments tested for 96 hours. The ability of the test animal to build tubes was also impaired by exposure to all BRH treatments. Variability in test results due to the location of the test animal collection site was observed. In accompanying tests, Scott and Redmond (in press) observed effects of BRH material upon growth rate, egg production, and population growth. They also recorded dose-responsive mortality in chronic 18-, 32-, and 58-day tests. For example, in the 18-day exposures mortality was 9 percent, 98 percent and 100 percent in treatments that were 0 percent BRH/100 percent reference material, 25 percent BRH, and 50 percent BRH, respectively. Recent unpublished tests of sediments from New Bedford Harbor, Connecticut also have shown high toxicity of some samples: Over 90 percent mortality in samples from two sites in the inner harbor in 10-day exposures. In comparison, a maximum of 34 percent mortality was observed among the 15 samples tested in the present study with no dilution.

In the present evaluation, mortalities in the control sediments exceeded those in some of the test samples and probably resulted in the underestimation of the potential sensitivity of this test. As a result, the end-point of survival was relatively insensitive, indicating a significant difference from controls in only 1 of the 15 samples tested; a sample from the Oakland Inner Harbor that was among the most contaminated. The sensitivity of this test, as determined in the present evaluation, may have been greater if the survival of *A. abdita* in the controls had been higher. The concentrations of PCBs and many trace metals were generally more than an order of magnitude higher in Black Rock Harbor sediments (Rogerson et al., 1985) than in those from Oakland Inner Harbor. The toxicity test results with Black Rock Harbor samples varied with the sampling location of the source of test organisms. Dose-dependent responses of *A. abdita* to Black Rock Harbor sediments were corroborated with the positive correlations observed in the present evaluation between toxicity and the concentrations of several classes of organic toxicants. The organism did not indicate sensitivity to fine-grained sediments that apparently were not highly contaminated. In conclusion, the end-point of *A. abdita* survival was less sensitive and had lower discriminatory power than that with *R. abronius,* but had relatively higher analytical precision than that with *R. abronius,* was not highly correlated with sedimentological variables, and was relatively highly correlated with several toxicants. The end-point of avoidance was not sensitive and had low precision and discriminatory power.

Strongylocentrotus purpuratus. Before the present study, the relative sensitivity of sea urchin sperm and embryos to sediments had not been evaluated. However, toxicity tests with urchin or sand dollar sperm and embryos have been evaluated in bioassays of water-borne chemicals and sewage (Dinnel *et al.,* 1982; Dinnel and Stober, 1987; Nacci *et al.,* 1986).

Dinnel *et al.* (1982) found that EC 50 or LC 50 values for silver and endosulfan tested with sperm or embryos of urchins (*Strongylocentrotus droebachiensis*) or sand dollars (*Dendraster excentricus*) were comparable to or slightly higher than those for zooea of crab (*Carcinus maenas*), *Daphnia magna*, embryos of oysters (*Crassostrea virginica*), or rainbow trout (*Salmo gairdneri*).

D. excentricus sperm were observed to be more sensitive to municipal sewage influents and effluents than *C. gigas* embryos (Dinnel and Stober, 1987). In most of the tests, they also found that the sensitivity of *S. droebachiensis* embryo abnormality to sewage exceeded that of fertilization success and mortality of the embryos of the same species and mortality of *Cancer magister* zooea. In aquatic bioassays of organic compounds and trace metals, Nacci *et al.* (1986), observed that the sperm cell test was frequently more sensitive than the embryo test with the urchin *Arbacia punctulata*. Both were generally comparable to the Microtox™ bacterial bioluminescence test in sensitivity; sometimes exceeding it in sensitivity, sometimes not. Both were also generally comparable in sensitivity to bioassays with *Pimephales promelas* (fathead minnow) and *Daphnia magna*.

The utility of cytogenetic/cytologic end-points to augment tests of percent egg fertilization and normal embryo development in *S. purpuratus*) was suggested by Hose *et al.* (1983) and Hose (1985). Generally, as the dose of aqueous B(a)p was increased, the number of mitoses per embryo decreased, the percent of mitoses with cytogenetic abnormalities increased, the number of micronuclei per embryo increased, and cytologic abnormalities increased. Also, the fertilization success and normal embryo development decreased. In addition, Bay *et al.* (1983) proposed use of a test of echinochrome pigment in the urchin bioassay and recorded the sensitivity of this end-point to aqueous copper and lowered salinity.

In a survey of runoff water and sediments near Newport, California, sediment leachates were generally found to be not toxic to *S. purpuratus* fertilization success and embryo development (MBC and SCCWRP, 1980). However, as few as 1.1 percent and 1.6 percent of the embryos developed normally in two of the samples. The end-point of normal embryo development appeared to be more sensitive to the same samples than fertilization success. In an evaluation of prospective dredge material from Los Angeles Harbor, MBL (1982) observed significant reductions in either normal development or fertilization success of *S. purpuratus* or *Lytechinus pictus* exposed to liquid phase samples. Whereas, fertilization success and normal development exceeded 90 percent in seawater controls, they were less than 33 percent in some samples, and significantly different from controls in samples from 9 of 20 stations. In comparison, percent normal development in the present study was below 80 percent in only 2 out of 15 samples. However, fertilization success was 70 percent or lower in three out of five samples and in three out of four controls.

In the present evaluation, the end-points of abnormal development and echinochrome pigment content were not as sensitive as those of abnormal development of *M. edulis* and of *R. abronius*. The increased incidences of cytogenetic abnormalities, micronuclei and cytological abnormalities and the decreased number of mitoses per embryo had been demonstrated to be responsive to benzo(a)pyrene (Hose, 1985). In the present evaluation, most of these end-points were sensitive to many of the samples tested and were correlated with increasing concentrations of many contaminants, including hydrocarbons. However, these end-points were evaluated in only five samples and the analytical variability was relatively high. The pattern in response among the samples indicated by the abnormal development end-point contradicted that indicated by many of the other end-points in the same test and in the *A. abdita* test. This contradiction may be a result of different toxicity mechanisms among these end-points or of unintentional bias in the subjective scoring of embryos as morphologically abnormal versus normal. This contradiction in results has not been observed by the analysts at SCCWRP in previous experience with this test in assessments of complex effluents. In conclusion, it appears that most of the end-points of this test are intermediate in sensitivity, precision, and discriminatory power, but the test should be developed and evaluated further, particularly to refine the mutagenicity and cytological end-points. No test of marine sediment mutagenicity has been widely tested and accepted.

Some compounds in sediments may be mutagenic or promutagenic and their effects probably are undetectable with tests of acute mortality.

Dinophilus gyrociliatus. This species had been used to test the toxicity of dissolved contaminants and effluents. Because of its short life cycle, the species can be used to quickly determine effects upon reproductive success (Carr et al., 1986)

The survival of *D. gyrociliatus* was found to be relatively resistant to Endosulfan and pentachlorophenol, but egg production was observed to be sensitive to complex effluents and pentachlorophenol (Carr *et al.*, 1986). In this evaluation, survival also was insensitive However, egg production was sensitive to about one-third of the samples tested. There are no other sediment toxicity data with which to compare the results of these tests. The end-point of egg production is a biologically meaningful indicator of reproductive success. As expected with a test of pore water, the results were not strongly correlated with those from the tests of the solid phase sediments or elutriates. However, they were relatively highly correlated with the concentrations of PAHs in bulk sediments. The medium that is tested, the pore water, is predicted by equilibrium-partitioning theory to be the controlling exposure medium in the toxicity of sediments to infaunal organisms (DiToro, in press). Laboratory toxicity test results are often more highly correlated with TOC-normalized pore water chemical concentrations than with non-TOC-normalized pore water or bulk sediment chemical data (DiToro, in press). However, since the borosilicate filter used in the pore water extraction method may have removed some of the potentially toxic polar compounds, including organic compounds, this test may have underestimated the pore water toxicity. In conclusion, further testing and evaluation of other pore water extraction methods are needed to increase the sensitivity of this promising test.

Patterns in the Toxicity Data. Three patterns in toxicological response to the samples described above were suggested by the rank correlations among toxicity tests (Table 11) and by correlations with similar chemical or physical variables (Table 12). These patterns were not related to the medium tested (i.e., solid phase, elutriate, pore water), nor to the biological type of end-point. Whereas the toxicity test end-points within each affinity group indicated similar patterns in response, some indicated negative correlations with end-points in other affinity groups. For example, the data from the *M. edulis* percent normal development end-point and the *A. abdita* avoidance end-point were positively correlated and, therefore, contradicted each other. Two end-points of the *S. purpuratus* test, echinochrome content and percent normal development, also contradicted each other. Despite the suggestions derived from the correlations between toxicity and chemical data, the etiological agents for each test are unknown. It is possible that each end-point responded to different physical or chemical properties, including those that were not quantified, in the very complex sediments that were tested. Therefore, until the relationships between these toxicity end-points and specific chemicals are quantified in empirical experimentation, comprehensive assessments of sediment toxicity are best made with multiple end-points.

Many of the toxicity end-points measured in all samples indicated that samples 1, 2, and 3 from Oakland Inner Harbor were among the most toxic samples. As expected, these samples were also the most contaminated since the Oakland Inner Harbor is surrounded by a highly industrialized and urbanized area. However, unexpectedly, several of the end-points (e.g., *M. edulis* and *S. purpuratus* abnormal development and *R. abronius* survival) indicated that samples 13, 14, and 15 collected in Tomales Bay were among the most toxic samples. These unexpected results are not easily explained. The chemical data collected with the toxicity results and chemical analyses of previously collected sediments from the Tomales Bay location suggest that it is not contaminated. Tomales Bay receives no major industrial or municipal wastes and is mostly surrounded by pastures and forests. However, benthos samples collected synoptically with the sediments tested in this evaluation were dominated by relatively hardy polychaetes and molluscs and were nearly devoid of relatively sensitive crustaceans, possibly corroborating the toxicity test results. The model developed by DeWitt et al. (1988) for interpreting the results of measuring *R. abronius* survival in uncontaminated fine-grained sediments does not account, alone, for the degree of toxicity observed or for the multiplicity of end-points that indicated that these sediments

were toxic. Collectively, these chemical, toxicity and benthic community data suggest that some unquantified factor(s) that co-occurred with these fine-grained, organically enriched sediments somehow induced or influenced the biological responses. The data from Tomales Bay corroborate the strength of using multiple indicators such as those included in the Sediment Quality Triad concept (Long and Chapman, 1985; Chapman et al., 1987) in environmental assessments, since the chemical data, if collected alone, would have not suggested that biological effects were likely. However, both the toxicity tests and benthic community data demonstrated that the sediments were relatively inhospitable due to some unknown factor(s).

Benthic Community Composition.

The benthic community composition differed significantly among the four sites for which data are available. All parameters measured or calculated indicated between-site differences. Similarity in composition among stations at each of the four sites was relatively high. However, the degree of chemical contamination at these four sites did not differ remarkably, whereas it was relatively high at the OA site as compared to these four. Because no benthic data are available thus far for the most contaminated site, it is not possible to attribute the observed faunal differences in the benthos among sites to chemical contamination. Nichols (1979) summarized some of the natural factors that may contribute to alterations among benthic communities along with or instead of toxic chemicals in San Francisco Bay. The between-site differences in benthos observed at the four sites may be attributable to "natural" factors as well as the small differences in chemical contamination. The observation of relatively low abundance of crustaceans at the apparently least contaminated site, along with the indication of toxicity of sediments from that site to amphipods, mussel larvae, and urchin larvae suggest that some unquantified factor or characteristic of the TB sediments was toxic to sensitive species. Taxonomic analyses of the benthos from the OA site--where toxicity and contamination were generally highest--will confirm (or refute) the speculation that the benthos there were most affected by pollutants.

In conclusion, the composition of benthic communities differed significantly among sites. This type of analysis is a tool that has been used in many studies of water quality in San Francisco Bay and many other places. The analyses are ecologically relevant, since the organisms are residents, form a major component of the ecosystem, and constitute an *in situ* bioassay of sediment quality. However, the composition of benthic communities is influenced and controlled by many natural factors such as proximity to brood stock, bottom scouring, water temperature and salinity, predation, depth, and sediment texture. Many of these factors probably varied among the sampling sites. Therefore, the differences in composition among the four sites could not be attributed only to the presence of chemical contamination.

Sediment Profiling Photography

The survey of 69 sites with sediment profiling photography provided useful baseline information on sedimentological characteristics of the estuary. The data indicated that the majority of the estuary was not organically enriched. However, some indices of sediment quality developed in the survey of 69 sites indicated poor conditions in selected peripheral harbors and channels. Among the four sites that corresponded with those sampled for measures of toxicity/contamination/benthos, the sediment profiling photography indicated that the OA site was most modified by sewage and organic enrichment. However, these data indicated that the infauna at that site were only minimally stressed. This survey technique has been used in studies of many fjords and estuaries worldwide, especially regarding re-colonization of defaunated sediments or organic enrichment of sediments. In conclusion, sediment profiling photography has been shown in numerous studies, including this one, to provide useful information on sedimentological and biological properties of soft-bottom sediments very quickly.

Measures of Bioeffects in Fish

Micronuclei. Micronuclei are likely formed as a consequence of chromosome breakage or spindle dysfunction during mitosis. Micronuclei occur at background levels in uncontaminated conditions, but at very low incidences. Chromosomal aberrations and micronuclei may have a role in evolutionary changes. However, elevated incidences of micronuclei above background rates have been attributed to x-rays and specific chemicals with mutagenic properties. Therefore, as applied in the context of monitoring marine pollution, this test can be assumed to be responsive to chemicals with specific types of effects, primarily genotoxicity. Although the degree of pollution-related elevation of micronuclei incidence observed in studies of fish and mussels performed thus far are small, the differences between contaminated and uncontaminated conditions are often significant and show a consistent pattern among species. The background frequencies and the degree of elevations in frequencies at sites that are contaminated does not appear to be species specific.

Whereas the enzymatic indicators of effects may respond to toxicants in time scales of days, micronuclei formation may be indicative and integrative of longer term exposures. The lifetime of blood cells may be several months. In a mobile animal, such as *P. stellatus* the measures of micronuclei abundance may be most useful when distinct populations are sampled and compared.

In this evaluation, mean total micronuclei incidence in peripheral erythrocytes in fish caught in November-December ranged from 0.1 per 1,000 at RR to 2.4 per 1,000 at BK. The highest incidences were among fish from the San Francisco Bay sites compared to fish from coastal reference sites. In 27 New England coastal areas, micronucleus frequencies in mature erythrocytes of winter flounder (*Pseudopleuronectes americanus*) ranged from 0.2 per 1,000 at a site at Georges Banks to 5.6 per 1,000 at a site in Long Island Sound. The ratio of the highest and lowest value indicated a 29-fold difference between sites (Table 40), similar to that (24-fold) observed in the present study with *P. stellatus*. Overall mean frequencies in the New York Bight Apex (2.33/1,000, n=39) and throughout Long Island Sound (3.94 per 1,000, n=35) were significantly higher than in offshore areas (*e.g.*, 0.46 per 1,000, n=13 on the mid-Atlantic shelf) (Longwell *et al.*, 1983).

Mean micronuclei frequencies in the cells of the gills of *Mytilus galloprovincialis* ranged from 2.2 per 1,000 to 4.7 per 1,000 at six sites in the Venetian Lagoon, Italy (Brunetti *et al.*, 1988). The highest frequencies were generally found in populations nearest sources of pollutants.

Mean micronuclei incidences in peripheral erythrocytes of *Umbra limi* injected with ethyl methanesulphonate exceeded those in control fish (maximum of 3.71 per 1,000 vs. 0.14 per 1,000), however the test was not dose-responsive (Metcalfe, 1988), possibly due to toxic effects on mitosis (Majone *et al.*, 1987). Repeated injections of benzo(a)pyrene in *Ictalurus nebulosus* resulted in a dose-responsive increase in peripheral erythrocyte micronuclei.

White croaker (*Genyonemus lineatus*) caught in California coastal waters off Dana Point had lower frequencies of micronuclei in peripheral erythrocytes (mean of 0.8 per 1,000, n=28) than those caught in San Pedro Bay (mean of 3.5 per 1,000, n=28) (Hose *et al.*, 1987). Similar studies of kelp bass (*Paralabrax clathratus*) showed that fish from Catalina Island had lower incidences (mean of 0.6 per 1,000, n=15) than fish caught off White Point near a major sewer discharge (mean of 6.8 per 1,000, n=15). The ratios of the maximum and minimum values observed in the studies of these two species was about 4.4- and 11.3-fold, respectively (Table 40), as compared to 24-fold for *P. stellatus* in the present study. Nuclear pleomorphism also was found in those fish with the highest micronuclei frequencies. Though differences in micronuclei frequencies between sites were significant for both species, micronuclei counts were only weakly correlated with concentrations of tDDT and tPCB in the fish livers. Highest frequencies, however, occurred in fish from areas known to have high concentrations of PAHs in sediments.

Relative to many of the other tests performed on the fish, the counts of total micronuclei had relatively high within-site variability (Tables 38 and 39) and a relatively low range/SD (Table 29). Despite the probability that species of fish collected in other studies were exposed to very different water quality and hydrographic conditions, have different biological characteristics, and different sensitivities to toxicants, estimates of within-site variability and range/SD were surprisingly similar (Table 41). Relatively high average CVs among fish caught at each site in the present study also had been observed in other species (Table 41). The ranges/SD were relatively low for this measure in three of the four species for which there are micronuclei data (Table 41).

Table 40. Ratios of highest and lowest mean values for selected biological measures in starry flounder (*Platichthys stellatus*), winter flounder (*Pseudopleuronectes americanus*), Norwegian flounder (*Platichthys flesus*), white croaker (*Genyonemus lineatus*), kelp bass (*Paralabrax clathratus*), deep-sea fish (*Coryphaenoides armatus*), and English sole (*Parophrys vetulus*).

	Platichthys stellatus [a]	*Pseudopleuronectes americanus* [b,c]	*Platichthys flesus* [d]	*Genyonemus lineatus* [e]	*Paralabrax clathratus* [e]	*Coryphaenoides armatus* [f]	*Parophrys vetulus* [g]
AHH (all fish)	4.44		2.69			9.07	9.17
Total micronuclei (Nov-Dec)	24.00	29.00		4.38	11.33		
Total P-450	1.59	1.7	2.94				
EROD/mg protein	5.89		14.02				
EROD/nmol p-450	4.59	3.05				6.60	
P-450E/mg protein	13.95		13.69				

Sources of Data:

[a] present study
[b] Stegeman *et al.*, 1987 for P-450 data
[c] Longwell, 1983 for micronuclei data
[d] Stegeman *et al.*, 1988; Addison and Edwards, 1988
[e] Hose *et al.*, 1987
[f] Stegeman *et al.*, 1986
[g] Varanasi *et al.*, 1986

Table 41. Average CV and range/average SD for total micronuclei counts in *Platichthys stellatus* from San Francisco Bay (present study), *Pseudopleuronectes americanus* from New England (Longwell, 1983), *Genyonemus lineatus* from southern California (Hose *et al.*, 1987), and *Paralabrax clathratus* from southern California (Hose *et al.*, 1987).

	Platichthys stellatus (5 sites, n=12 to 15 fish at each site)	*Pseudopleuronectes americanus* (27 sites, n = 2 to 20 fish at each site)	*Genyonemus lineatus* (2 sites, n = 28 fish at each site)	*Paralabrax clathratus* (2 sites, n = 15 fish at each site)
Average CV	140.5%	81.2%	108.4%	87.5%
Range/average SD	1.4	4.94	0.96	2.17

Micronuclei incidence in fish from all the sites in San Francisco Bay Bay was higher than in fish from coastal reference areas, however, there were no significant differences among sites within San Francisco Bay. Differences among sites in San Francisco Bay could have been expected, since the concentrations of chlorinated organic compounds in the fish differed among sites there. However, the formation of micronuclei may not be responsive to the measured analytes. They may be responsive to compounds such as aromatic hydrocarbons (*e.g.*, B(a)p), which were not quantified in the fish and which are probably readily metabolized to compounds that are not readily quantified. Also, because of its shallow geomorphology and strong water currents, chemical contaminants are readily dispersed throughout the estuary. The concentrations of chemicals rarely show large gradients among the basins of the estuary, but do indicate elevations of most chemicals only in the peripheral harbors and industrial waterways (Long *et al.*, 1988). Therefore, the fish collected at the sites in the estuary may have been exposed to relatively similar concentrations of mutagenic compounds and these concentrations may have been higher than those in fish from outside the estuary. In conclusion, it appears that the incidence of micronuclei is a relatively sensitive measure, that it has been successfully used in several species of marine animals and the data correlated with the concentrations of some organic compounds, but the data are relatively variable among fish captured at the same site.

Cytochrome P-450. The cytochrome P-450 proteins catalyze monooxygenase reactions. They are the enzymes primarily responsible for metabolism or biotransformation of organic pollutants. This metabolism of xenobiotics can result in their inactivation and detoxification or their activation to toxic derivatives. Inactivation can lead to enhanced elimination and tolerance; activation can lead to serious organ dysfunction or pathology. Cytochrome P-450 enzymes are also responsible for both synthesis and degradation of steroid hormones. Aromatic hydrocarbons and chlorinated hydrocarbons, such as PCBs, can induce cytochrome P-450 activity. Cytochrome P-450 exists in different isozymes each having differing functions. One isozyme that has been isolated from fish hepatic microsomes is cytochrome P-450E (Klotz *et al.*, 1983), which appears to be inducible by PAH/PCB-type chemicals. Cytochrome P-450E is likely an important isozyme in conducting EROD activity.

The background or uninduced levels of cytochrome P-450 activity have been measured in a variety of fish and invertebrates. For example, Stegeman and Kloepper-Sams (1987) reported levels ranging from 0.10 to 0.91 nmol/mg protein in mussels, crustaceans, fish, and rats. Average cytochrome P-450 content in four species of untreated fish ranged from 0.11 to 0.50 nmol/mg protein (James and Bend, 1980). In the latter study, exposure to 3-methylcholanthrene or 1,2,3,4-dibenzanthracene resulted in minimal or no change in total cytochrome P-450 content. In the present study, the lowest mean level of total P-450 content

was 0.135 nmol/mg protein in the *P. stellatus*, very similar to results in other species and phyla.

Induction of cytochrome P-450 content by injection of the fish in the present study with BNF indicated a large potential for response in the *Platichthys stellatus*. Relative to controls, BNF-injected fish showed a 2.4-fold increase in mean total P-450 content. In contrast, *Pseudopleuronectes americanus* injected with BNF showed an increase in mean total P-450 content of 1.3-fold over that of controls (Stegeman *et al.*, 1987). Similarly, mean EROD activity (units/min/nmol total P-450) increased 4.8-fold in BNF-treated *P. stellatus* relative to controls, whereas EROD activity in BNF-treated *P. americanus* changed 1.6-fold relative to controls. EROD activity in the deep-sea fish *Coryphaenoides armatus* averaged 1.175 ± 0.310 nmol/nmol P-450 in fish from the Hudson Canyon off New York and 0.178 ± 0.050 nmol/nmol P-450 in fish from the Carson Canyon off Newfoundland (Stegeman *et al.*, 1986).

Mean liver microsomal cytochrome P-450 content ranged from 0.18 ± 0.05 to 0.53 ± 0.11 nmol/mg protein in *Platichthys flesus* sampled at four sites in Langesundfjord, Norway (Stegeman *et al.*, 1988). This range corresponded to roughly a 3-fold difference among sites. A difference of about 14-fold (from 3.5 ± 1.6 to 47.9 ± 18.7 pmol/min/mg protein) in the activity of the P-450E isozyme between the fish from the reference and contaminated sites indicated that the fish were highly induced at the contaminated site. Mean EROD activity in the same fish increased roughly 14-fold (from 39 ± 19 to 547 ± 236 pmoles/min/mg protein) between the reference site and the most contaminated site. All three of the responses (total P-450, P-450E, and EROD) paralleled the gradient in contamination reported by Addison and Edwards, 1988. All three appeared to be responsive to high molecular weight hydrocarbons (PAHs and PCBs) measured at the sites. None of the three was particularly responsive to the low molecular weight hydrocarbons in mesocosm exposures tested concurrently with analyses of feral fish. The pattern of EROD response in the Norwegian flounder (*Platichthys flesus*) recorded by Stegeman *et al.* (1988) using spectrophotometric methods was confirmed in the same fish by Addison and Edwards (1988) using fluorometric methods. With the latter methods, a 13.2-fold difference in EROD activity (range = 91 ± 41 to 1,206 ± 462 pmol/min/mg protein) was observed.

The difference in mean total P-450 content in feral fish between the sites with the highest and lowest mean values was 1.6-fold in *P. stellatus* (present study), 1.7-fold in *P. americanus* (Stegeman *et al.*, 1987), and 2.9-fold in *P. flesus* (Stegeman *et al.*, 1988) (Table 40). The difference in mean EROD activity (units/min/nmol total P-450) between the highest and lowest sites was 4.6-fold in *P. stellatus*, 3.05-fold in *P. americanus* and 14.0-fold in *P. flesus*. The difference in mean P-450E content among sites was 13.9-fold in *P. stellatus* and 13.7-fold in *P. flesus*.

The averages of the CVs and the ranges per average SD for four end-points are compared among three species of feral flatfish in Table 42. These species of fish were likely exposed to different water quality conditions in different geographic areas and were collected in studies with different methods and research objectives. For all five end-points, the average CVs and ranges/SDs were fairly similar among the three species, despite the differences in species and geography. The average CV for cytochrome P-450E content in *P. stellatus* was particularly high. The range per average SD was very consistent for the measures of EROD/mg protein among the three species. The average CVs were also very similar among the three species for AHH activity.

Table 42. Average CV and range/average SD for biochemical measures in *Platichthys stellatus* (present study), *Platichthys flesus* (Stegeman *et al.*, 1988; Addison and Edwards, 1988), and *Pseudopleuronectes americanus* (Stegeman *et al.*, 1987).

	Platichthys stellatus (5 sites, n =14 to 15 fish per site)	*Platichthys flesus* (4 sites, n = 10 to 12 fish per site)	*Pseudopleuronectes americanus* (4 sites, n = 8 to 18 fish per site)
Total P-450/mg protein			
Average CV	44.0%	26.8%	11.8%
Range/average SD	1.0	4.0	4.3
EROD/mg protein			
Average CV	56.7%	69.2%	21.0%
Range/average SD	2.8	2.4	2.6
EROD/nmol P-450			
Average CV	60.8%	71.7%	19.9%
Range/average SD	2.4	1.2	1.6
P-450E/mg protein			
Average CV	129.2%	52.7%	
Range/average SD	2.1	3.0	NA
AHH (pmol/B(a)P/min/mg protein)			
Average CV	78.4%	63.4%	48.3%*
Range/average SD	1.7	1.3	1.2

*units were reported as nmol/B(a)p/min/mg protein

It is apparent that the *P. stellatus* cytochrome P-450 system is highly responsive to exposures to organic compounds. Total P-450, EROD, and P-450E activities were highest in fish from the BK and/or OK sites which were located nearest known sources of potentially P-450-inducing contaminants. These end-points indicated differences in response both among the sites in the estuary and between sites within and outside the estuary. Experience with the *P. stellatus* confirmed the patterns in response observed with *P. americanus* and scup in New England and flounder in Norway. It is also apparent that these end-points are excellent specific indicators of exposure to high molecular weight hydrocarbons in the environment. The markedly different values obtained from highly induced fish versus fish from reference areas facilitates determinations of site-to-site differences.

In either laboratory exposures or in feral fish, the suite of total P-450/EROD/P-450E end-points appear to respond to contaminants similarly among the species tested thus far. While the P-450 suite of tests may indicate the successful response of fish to xenobiotics, and may not necessarily reflect an adverse effect upon the longevity or fecundity of the animal, the tests, nevertheless, are indicators of exposure to contaminants that may not be quantifiable otherwise and that may cause subtle adverse effects. In conclusion, the suite of total P-450/EROD/P-450E measures appears to be very sensitive, correlated with some contaminant data, relatively low in variability among fish from the same site and over a similar range in response among species.

Aryl Hydrocarbon Hydroxylase. Mixed-function oxygenase (MFO) enzymes are important, primarily in the liver, in detoxifying xenobiotics and steroid hormones. Relatively insoluble componds are converted into water-soluble metabolites, which may be excreted or further conjugated and, then, excreted in the urine or bile. Potent inducers of the MFO enzymes include polycyclic aromatic hydrocarbons, PCBs, and petroleum. MFO enzymes include AHH enzymes which were assayed in the present evaluation using benzo(a)pyrene as a substrate. In previous studies of *P. stellatus* in the San Francisco Bay, relatively high AHH activities were observed in samples most highly contaminated with chlorinated hydrocarbons. Mean AHH activities in fish collected in 1983-1984 from the BK, OK, and SP sites sampled in the present evaluation were 95, 54, and 51 units (pmol 3-OH B(a)p/min/mg protein), respectively (Spies *et al.*, 1985). AHH activities were not suppressed in BK fish during gametogenesis (presumably, in response to exposure to organic contaminants), whereas they were suppressed in SP fish. The effects of AHH-mediated perturbations in the regulation of steroid hormones during and after gametogenesis is unknown, but could be significant in fish reporduction. In San Francisco Bay, high hepatic xenobiotic concentrations and high hepatic AHH activity in *P. stellatus* were negatively correlated with several measures of spawning success suggesting a cause-effect relationship. Some individual fish from the BK and OK sites had AHH activities of over 300 units (Spies *et al.*, 1985).

The mean AHH activities (147 to 363 units) recorded in the present study in fish from OK and VJ and in males and immatures at SP were higher than expected, based upon experience from previous studies of the same species. The large difference (*e.g.*, 363 vs. 86 units in males and immatures) in activities between OK and BK fish also was unexpected, since the sites are near each other and in previous research the differences in AHH activities between these sites had not been as large.

Compared to *P. stellatus*, mean AHH activities in *P. americanus* from four sites in New England were relatively high (450 to 770 pmol B(a)p metabolites/min/mg protein) and uniform. There was a strong correlation between EROD and AHH activities in fish from the Buzzards Bay site (Stegeman *et al.*, 1987). Hepatic AHH activity in English sole (*Parophrys vetulus*) ranged from 36 to 330 pmol/mg protein/min in fish from a rural area, Discovery Bay, known to be uncontaminated with aromatic hydrocarbons (Varanasi *et al.*, 1986). Fish from another area in Puget Sound with higher aromatic hydrocarbon concentrations had hepatic AHH activities that ranged from 330 to 570 pmol/mg protein/min. A strong positive correlation was observed in hepatic AHH activity and concentration of specific isozymes of cytochrome P-450. In a subsequent study, Johnston *et al.* (1988) reported a range of 72 to 492 pmol/mg/min in mean AHH activity in *P. vetulus* from Puget Sound sites, corresponding to a 6.8-fold difference between sites. A range of 33.5 ± 21.2 to 90.2 ± 52.2 pmol B(a)p hydroxylase/min/mg protein was reported by Addison and Edwards (1988) for *P. flesus* sampled along a pollution gradient in Langesundfjord, Norway. This range corresponded to a 2.7-fold difference between the least and most induced fish. Nearly a 4-fold difference in response in the same species was recorded following exposure to a dilution series of oil and copper in mesocosm basins.

Hepatic AHH activity in untreated sheepshead (*Archosargus probatocephalus*), flounder (*Paralichthyes lethostigma*), stingray (*Dasyatis sabina*) and skate (*Raja erinacea*) averaged 3100 ± 1800, 250 ± 90, 770 ± 390 and 180 ± 180 units (50 pmol 3-hydroxybenzo(a)pyrene/min/mg protein), respectively (James and Bend, 1980). Hepatic AHH activity was inducible with exposure to 3-methylcholanthrene or 1,2,3,4-dibenzanthrene, resulting in an increase in activity of over an order of magnitude in the same species. AHH activity in liver microsomes of the deep-sea fish *Coryphaenoides armatus* averaged 408 ± 170 units (pmol/min/nmol P-450) in samples from the Hudson Canyon off New York and 0.045 ± 0.010 units in samples from the Carson Canyon off Newfoundland (Stegeman *et al.*, 1986). PCB concentrations in the fish livers were roughly 8 times higher in the Hudson Canyon than in the Carson Canyon.

Gender-specific and species-specific differences in AHH activities were observed in sanddabs collected in Southern California (Spies *et al.*, 1982). Specific activities were usually higher in males and about an order of magnitude higher in *Citharichthys sordidus* than in *C. stigmaeus*. Fish collected during the winter had lower activities than those

collected in the summer. Body size and AHH activity were usually not significantly correlated. AHH activity and hepatic P-450 content were significantly correlated. Fish that were fed oil and/or PCB showed significant increases in AHH activity relative to controls. Fish caught in areas near sources of contaminants or near natural oil seeps always had higher AHH activities than those caught in Monterey Bay, a relatively uncontaminated embayment.

In conclusion, it appears that AHH activity was less sensitive than some of the other measures, that within-site variability was relatively moderate, that the measure is responsive to exposure to hydrocarbons, and that it may be influenced by gender, species, stage of gametogenesis, and seasons. Fish exposed to hydrocarbons often demonstrate a distinct difference in activity relative to fish from uncontaminated areas. AHH measurements complement other measures of the cytochrome P-450 system and are often correlated with them.

Reproductive Success. Since all steps in steroid synthesis and metabolism are regulated by MFO enzymes, the potential exists in any of these steps to interfere with the proper quantities or timing of synthesis or metabolism of steroid hormones. Interference may be expressed as measures of the concentrations of precursor hormones or the concentrations of the hormones themselves or of the percent of reproductive products that survive to various stages in development. In the present evaluation, the concentrations of two steroid hormones were measured and selected fish were spawned to determine fertilization, hatching and embryological success. The measures of steroid hormone content and fertilization/ hatching/embryological success are important indicators of reproductive condition and success. They have been used successfully in other studies. However, in this evaluation the steroid hormone measures were relatively insensitive and the sample size available for the fertilization/hatching/ embryological success tests was too small to provide useful data.

Summary Comparative Evaluation.

Each of the biological tests is compared in a subjective rating matrix in Table 43. The biological end-points are compared with five criteria for which data were collected in the present evaluation. These five criteria are a subset of the original eight that were initially used to select the biological measures for evaluation. Sediment profiling photography was omitted, since it was performed to determine geographic patterns in the San Francisco Bay estuary, not to compare its performance with the other tests. The sample sizes for the reproductive success end-points were too small to evaluate their performance and the benthos analyses are incomplete.

The 'sensitive' criterion reflected the ability of the biological test to determine differences either between a test sample and respective controls (sediment tests) or between two sampling sites (fish tests). The sediment toxicity tests were rated a "yes" for sensitive if the end-point indicated that one or more of the samples was significantly more toxic than respective controls (Table 13). The measures of fish health were rated a "yes" for sensitive if one or more of the sites were indicated as significantly different than other sites (Table 32). Both the sediment and fish tests rated a "yes" for the "correlated with toxicants" criterion of the rank correlations with toxic chemicals were equal to or exceeded .500 in Tables 19 and 39, respectively. Similarly, both sediment and fish tests generally rated a "yes" for the "not correlated with nuisance variables" criterion if the ranked correlations were less than 500 in Tables 19 and 35, respectively. The sediment and fish tests rated "yes" for the "low analytical variability" criterion if the average CVs were ≤30 percent (Table 17) and ≤75 percent (Table 39), respectively. The sediment and fish tests rated a "yes" for the "high discriminatory power" criterion if the quotients of the range over the average SD were >3.0 (Table 17) and >2.0 (Table 39), respectively. All of these yes/no thresholds were arbitrarily selected and the ratings for many of the tests could change if different values had been selected.

Among the sediment toxicity tests, all but the end-points of avoidance by the two amphipods were sensitive to at least one of the samples tested. *R. abronius* survival, and *M. edulis* abnormal development and survival were the most sensitive end-points. The

benthic communities indicated significant differences between all sites. Most of the cytochrome P-450 end-points and two of the micronuclei end-points indicated differences between sites, and, therefore, rated yes's for the "sensitive" criterion.

Half of the sediment toxicity end-points rated a "yes" for the "correlated with toxicants" criterion, including those of *A. abdita* survival, *D. gyrociliatus* reproduction and *S. purpuratus* echinochrome content and cytogenetic/mitotic abnormalities. None of the fish tests were very highly correlated with the concentrations of chemicals in the fish livers. Since no benthos data are available for the most contaminated site, correlation analyses have not yet been performed.

Again, half of the sediment toxicity end-points rated a "yes" for not being correlated with nuisance variables (grain size and TOC). The benthos data have not yet been tested for correlations with sedimentological factors. The AHH, micronuclei, steroid hormone, and most of the P-450 end-points were not correlated with length, weight, or organ weight of the fish. However, HSI was inversely correlated with P-450E content and P-450E/total P-450; while estradiol 2-hydroxylase was positively correlated with GSI.

The two avoidance end-points in the amphipod tests had very high analytical variability and rated a "no" in Table 43 for the "low analytical variability" criterion. The average CVs of two of the *S. purpuratus* cytogenetic/mitotic end-points were very high, while those of two others were relatively low. One or more of the AHH, P-450 and hormone end-points had relatively high variability among fish at the sites while the others had low variability. All of the micronuclei end-points had relatively high variability among fish at sampling sites.

The avoidance end-points in the amphipod tests and some of the *S. purpuratus* cytogenetic/mitotic end-points had relatively low discriminatory power. *R. abronius* survival and *M. edulis* percent normal end-points had the highest values among the sediment toxicity tests. Discriminatory power of the AHH end-points was relatively low. The discriminatory power of most of the P-450 end-points exceeded a value of 2.0. The testosterone concentration end-point had a relatively high discriminatory power, while that of estradiol content did not. The discriminatory power of the detached micronuclei end-point exceeded 2.0, whereas those of total and attached micronuclei did not.

Table 43. Subjective rating of each biological test end-point with regard to five performance criteria (see accompanying text for an explanation of the criteria).

		Sensitive	Correlated with toxicants	Not correlated with nuisance variables	Low analytical variability	High discriminatory power
Sediments						
R. abronius	survival	yes	no	no	yes	yes
	avoidance	no	no	yes	no	no
A. abdita	survival	yes	yes	yes	yes	yes
	avoidance	no	yes	yes	no	no
M. edulis	abnormalities	yes	no	no	yes	yes
	survival	yes	no	no	yes	yes
S. purpuratus	abnormalities	yes	no	no	yes	yes
	echinochrome	yes	yes	yes	yes	yes
	cytogenetic/ mitotic	yes	yes	no	?	no
D. gyrociliatus	reproduction	yes	yes	yes	yes	yes
Benthos		yes	nd	nd	nd	nd
Fish						
AHH activity		no	no	yes	?	no
Cytochrome P-450 content/ EROD activity		yes	no	yes	?	yes
Steroid hormone content		no	no	yes	?	?
Reproductive success		nd	nd	nd	nd	nd
Micronuclei		yes	no	yes	no	?

RECOMMENDATIONS

All of the biological measures that were evaluated provided useful information and most should be viewed as candidates for future use. None should be considered as the best, or the worst, but each has distinct strengths and weaknesses. Because the contamination of marine areas near urban centers often results in complex mixtures of chemicals, biological responses to those mixtures would be expected to be equally (or more) complex. Some chemicals may be acutely lethal and a short-term bioassay of sediment could be a useful indicator of the bioavailability and toxicity of those chemicals. Other chemicals may induce subtle changes that are expressed or quantifiable over only long periods of time. Tests of mutagenicity and/or enzymatic response may be useful in evaluating exposure of biota to these chemicals. No single biological measure can be expected to suffice as the sole test of effects of complex mixtures of contaminants. The measures evaluated in the present study should be viewed as a menu of candidates from which a suite of complementary tests can be selected and tailored for use in satisfying specific programmatic and technical objectives. Each measure has certain strengths and weaknesses that should be evaluated in the selection of the specific suite of tests.

- The *Mytilus edulis* larvae test appears to have relatively high sensitiivity, precision, and discriminatory power; it has been sufficiently developed to warrant its use in screening studies of sediment toxicity; but the influence of sediment texture and organic carbon content should be evaluated in controlled laboratory experiments.

- A quick procedure for accurately counting the number of *M. edulis* embryos inoculated into the test chambers at the initiation of the tests should be developed to help reduce the variance in the end-point of survival.

- Many of the whole-embryo *Strongylocentrotus purpuratus* test end-points appear to be less sensitive than those measured with *M. edulis*, but the cytogenetic/mitotic end-points should be evaluated further as indicators of mutagenicity in environmental samples.

- The relatively highly tested and developed *Rhepoxynius abronius* test is very sensitive and the influence of fine-grained sediments upon the organism has been quantified in controlled laboratory expeiments; the test should be used further in assessments of sediment quality.

- The relatively new test with *Ampelisca abdita* appears to be less sensitive than some of the others including that with *R. abronius*, but appears to be particularly suitable for testing the toxicity of fine-grained sediments; it should be used in assessments of sediments known or suspected to be highly contaminated; and a source of non-toxic native sediments should be located for use as controls.

- In both the *R. abronius* and *A. abdita* tests, emphasis should be placed upon the survival end-point; the avoidance end-point has very high within-sample variance, resulting in relatively low sensitivity; and the reburial end-point with *R. abronius* is insensitive and should be discontinued.

- Better methods of extracting sediment pore water that reduce the amount of organic contaminants that are removed from the pore water should be developed to enhance the utility of pore water tests; other tests of reproductive success such as that measured with *Dinophilus gyrociliatus* should.be developed.

- More emphasis should be placed upon the development of sediment toxicity tests in which mutagenicity is determined and in which reproductive success is determined.

- The benthic community samples from the Oakland Inner Harbor site should be analyzed to determine if the composition data confirm the toxicity test data.

- The survey of sediment quality performed in San Francisco Bay with the profiling photography should be repeated at selected sites where it appeared that the sediments and benthic communities were in transition to determine temporal trends.

- The cytochrome P-450 measures and micronuclei counts, together, appear to provide a suite of sensitive indicators of both exposure to and effects of certain hydrocarbons, including those that may be readily metabolized and not detected in fish; the enzymes may reflect recent expsoures to toxicants, whereas the micronuclei may integrate the effects of exposures over periods of several months; they should be used in assessments of marine environmental quality where the presence of hydrocarbons is known or suspected.

- Tests of reproductive success in feral fish should be conducted with additional species (preferably, those that are non-migratory and demersal) in areas suspected of being highly contaminated.

- Biochemical and other analyses that are indicative of reproductive impairment, but are quicker and less expensive than spawning studies, should be tested and evaluated.

- Other comparative evaluations should be conducted as new candidate tests become available.

- Multiple, complementary measures of bioeffects should be applied in comprehensive surveys; the measures chosen should match or be responsive to the types of chemicals known or hypothesized to occur in the study area; and they should be chosen following a comparative evaluation of candidates such as that reported here.

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APPENDIX A

SEDIMENT TOXICITY TEST DATA

Individual sediment toxicity test data from five types of tests performed on five replicates at 15 stations sampled in the San Francisco Bay area. Some columns appear twice where tests were performed in two batches of samples; control values should be compared with data from samples tested in respective batches. *Mytilus edulis* tests were performed in one batch. TB and SP samples were tested with Control 1 samples in the *Dinophilus gyrociliatus* test. VA 2 and VA 3 samples were tested with Control 2 samples in the *Rhepoxynius abronius* test. VA, OA, and YB samples were tested with Control 1 samples in the VA test with *Ampelisca abdita*. VA, OA, and YB samples were tested with Control 1 samples in the test with *Strongylocentrotus purpuratus*. YB and OA samples were tested with Control 1 samples in the white sea urchin (*Lytechinus pictus*) tests and the green sea urchin (*S. droebachiensis*) tests.

			Mussel Larvae				*Dinophilus*				Rhepoxynius		
Site	#	Rep	Total No. Larvae	Percent Survival	No. Abnormal	Percent Abnormal	Reproduction (eggs/female)	Reproduction (eggs/female)	Percent Survival	Cumulative No. Emerge (out of 20)	No. Alive (out of 20)	Percent Survival	No. Failing to Reburrow
OA	*1*	*Mean*	*52*	*32.3%*	*13.4*	*25.8%*	*8.64*		*100.0%*	*3.2*	*6.2*	*31.0%*	*0.2*
		A	46		14	30.4%	6.8			3	5	25%	0
		B	31		10	32.3%	10.2			2	4	20%	0
		C	49		11	22.4%	7.8			0	11	55%	1
		D	60		19	31.7%	6.6			4	6	30%	0
		E	74		13	17.6%	11.8			7	5	25%	0
OA	*2*	*Mean*	*60.4*	*37.5%*	*12.4*	*20.5%*	*5.68*		*100.0%*	*1.6*	*7.8*	*39.0%*	*0.6*
		A	85		15	17.6%	4			0	9	45%	0
		B	54		12	22.2%	6.2			0	6	30%	1
		C	60		13	21.7%	6.6			2	6	30%	1
		D	57		12	21.1%	5.8			4	9	45%	1
		E	46		10	21.7%	5.8			2	9	45%	0
OA	*3*	*Mean*	*46.8*	*29.1%*	*12.4*	*26.5%*	*6.28*		*100.0%*	*1.4*	*8.8*	*44.0%*	*0*
		A	46		10	21.7%	7.8			0	6	30%	0
		B	44		10	22.7%	4.5			1	9	45%	0
		C	35		14	40.0%	6.2			3	10	50%	0
		D	76		19	25.0%	5.5			2	8	40%	0
		E	33		9	27.3%	7.4			1	11	55%	0
SP	*10*	*Mean*	*117*	*72.7%*	*8.6*	*7.4%*		*9.54*	*100.0%*	*3*	*18.2*	*91.0%*	*0.2*
		A	83		7	8.4%		4.8		4	19	95%	0
		B	165		10	6.1%		12.2		4	17	85%	0
		C	96		9	9.4%		13.2		2	20	100%	1
		D	129		9	7.0%		7.5		0	16	80%	0
		E	112		8	7.1%		10		5	19	95%	0
SP	*11*	*Mean*	*75.8*	*47.1%*	*10.6*	*14.0%*		*4.52*	*100.0%*	*2.6*	*9.2*	*46.0%*	*0*
		A	69		11	15.9%		4		1	11	55%	0
		B	63		9	14.3%		5.6		4	8	40%	0
		C	54		10	18.5%		1		6	8	40%	0
		D	113		15	13.3%		10		0	10	50%	0
		E	80		8	10.0%		2		2	9	45%	0
SP	*12*	*Mean*	*109.4*	*68.0%*	*8.6*	*7.9%*		*6.88*	*96.0%*	*3.8*	*16.6*	*83.0%*	*0*
		A	112		11	9.8%		4.2		4	13	65%	0
		B	128		9	7.0%		7.7		5	19	95%	0
		C	68		5	7.4%		6		8	15	75%	0
		D	144		10	6.9%		7.3		2	19	95%	0
		E	95		8	8.4%		9.2		0	17	85%	0
TB	*13*	*Mean*	*71.4*	*44.3%*	*13.6*	*19.0%*		*10.32*	100.0%	*1.4*	*5.6*	*28.0%*	*0.4*
		A	68		12	17.6%		11.6		1	6	30%	0
		B	60		16	26.7%		12.8		2	9	45%	0
		C	84		14	16.7%		10.2		4	2	10%	1
		D	55		8	14.5%		8.5		0	4	20%	0
		E	90		18	20.0%		8.5		0	7	35%	1

			Mussel Larvae				Dinophilus			Rhepoxynius			
Site	#	Rep	Total No. Larvae	Percent Survival	No. Abnormal	Percent Abnormal	Reproduction (eggs/female)	Reproduction (eggs/female)	Per cent Survival	Cumulative No. Emerge (out of 20)	No. Alive (out of 20)	Per cent Survival	No. Failing to Reburrow
TB	*14*	*Mean*	*80.8*	*50.2%*	*12.4*	*15.3%*		*9.5*	*86.0%*	*4.2*	*11*	*55.0%*	*0.4*
		A	73		10	13.7%		11.8		1	13	65%	1
		B	88		12	13.6%		7.2		3	10	50%	0
		C	78		13	16.7%		12		3	9	45%	0
		D	66		15	22.7%		8.5		8	13	65%	1
		E	99		12	12.1%		8		6	10	50%	0
	15	*Mean*	*70.2*	*43.6%*	*11.2*	*16.0%*		*10.14*	*95.0%*	*5.2*	*6*	*30.0%*	*0.2*
		A	55		11	20.0%		10.7		4	6	30%	0
		B	84		12	14.3%		11.2		5	6	30%	0
		C	49		9	18.4%		10.6		11	7	35%	1
		D	74		10	13.5%		9.2		2	8	40%	0
		E	89		14	15.7%		9		4	3	15%	0
VA	*7*	*Mean*	*78.4*	*48.7%*	*10.4*	*13.3%*	*9.02*		*100.0%*	*5.4*	*6.2*	*31.0%*	*0*
		A	84		10	11.9%	9.5			2	5	25%	0
		B	89		13	14.6%	6			8	8	40%	0
		C	80		12	15.0%	6.8			0	6	30%	0
		D	61		8	13.1%	11.8			10	5	25%	0
		E	78		9	11.5%	11			7	7	35%	0
	8	*Mean*	*117.4*	*72.9%*	*7.6*	*6.5%*	*9.6*		*96.0%*				
		A	116		7	6.0%	9.8						
		B	135		6	4.4%	8.5						
		C	85		7	8.2%	9.8						
		D	121		8	6.6%	12.5						
		E	130		10	7.7%	7.4						
	9	*Mean*	*103.6*	*64.3%*	*9.4*	*9.1%*	*6.76*		*100.0%*				
		A	110		9	8.2%	7.2						
		B	125		10	8.0%	3.6						
		C	78		8	10.3%	6.8						
		D	104		9	8.7%	8						
		E	101		11	10.9%	8.2						
YB	*4*	*Mean*	*77.2*	*48.0%*	*11.8*	*15.3%*	*2.86*		*100.0%*	*1.8*	*14.8*	*74.0%*	*0.8*
		A	93		11	11.8%	5.5			1	16	80%	1
		B	80		13	16.3%	2.5			3	17	85%	1
		C	64		13	20.3%	1.8			1	15	75%	2
		D	61		12	19.7%	2			1	12	60%	0
		E	88		10	11.4%	2.5			3	14	70%	0
	5	*Mean*	*82.4*	*51.2%*	*12.2*	*14.8%*	*6.74*		*100.0%*	*1.6*	*13.4*	*67.0%*	*0.4*
		A	90		12	13.3%	0			0	10	50%	0
		B	73		15	20.5%	9			0	14	70%	0
		C	86		14	16.3%	10.8			4	12	60%	0
		D	89		11	12.4%	5.4			0	16	80%	0
		E	74		9	12.2%	8.5			4	15	75%	2

			Mussel Larvae				*Dinophilus*			Rhepoxynius			
Site	#	Rep	Total No. Larvae	Percent Survival	No. Abnormal	Percent Abnormal	Reproduction (eggs/female)	Reproduction (eggs/female)	Percent Survival	Cumulative No. Emerged (out of 20)	No. Alive (out of 20)	Percent Survival	No. Failing to Reburrow
YB	*6*	*Mean*	*94.6*	*58.8%*	*10.8*	*11.4%*	*6.7*		*100.0%*	*1*	*11.8*	*59%*	*0.6*
		A	92		10	10.9%	3.5			1	10	50%	0
		B	135		12	8.9%	8.8			2	9	45%	0
		C	97		11	11.3%	6.8			0	11	55%	0
		D	82		11	13.4%	7.4			1	14	70%	3
		E	67		10	14.9%	7			1	15	75%	0
NaPCP (µg/L)	320	A	2	6.0%	2	100.0%				NaPCP (µg/L)	1	0%	
		B	17		15	88.2%					0.75	0%	
											0.56	0%	
	180	A	37	19.0%	28	75.7%					0.32	0%	
		B	24		20	83.3%					0.18	60%	
											0.1	90%	
	100	A	39	26.0%	23	59.0%							
		B	45	26.0%	24	53.3%					Control	90%	
	56	A	56	32.0%	22	39.3%							
		B	48		23	47.9%							
	32	A	64	45.0%	19	29.7%							
		B	81		21	25.9%							
Seawater Control 1		*Mean*	*161*	*100.0%*	*8.4*	*5.2%*	*10.4*						
		A	202		11	5.4%	7		100.0%				
		B	96		4	4.2%	15.5						
		C	147		10	6.8%	12.5						
		D	192		9	4.7%	7						
		E	168		8	4.8%	9.8						
Seawater Control 2													
Sediment or Elutriate Control 1		*Mean*	*122.4*	*76.0%*	*7.6*	*6.2%*	*10.4*			1			
		A	108		8	7.4%	6.6		95.0%	0	19	95%	0
		B	132		8	6.1%	14.3			0	20	100%	0
		C	139		8	5.8%	10.2			0	20	100%	0
		D	113		7	6.2%	10.6			5	19	95%	0
		E	120		7	5.8%	10.2			0	20	100%	0
Sediment or Elutriate Control 2		*Mean*						9.5					
		A						6	95.0%				
		B						12.2					
		C						10.7					
		D						12					
		E						6.8					

			Rhepoxynius				*Ampelisca*						
			Cumulative	No.		No.	.....	*Flow thru*	.....				
Site	#	Rep	No. Emerged (out of 20)	Alive (out of 20)	Percent Survival	Failing to Reburrow	Initial No. Exposed	No. Alive	Percent Alive	Cumulatve No. Emerged	Initial No. Exposed	No. Alive	Percent Alive
OA	*1*	*Mean*					*20*	*13.2*	*66.0%*	*6.8*			
		A					20	14	70.0%	6			
		B					20	11	55.0%	6			
		C					20	15	75.0%	7			
		D					20	12	60.0%	10			
		E					20	14	70.0%	5			
OA	*2*	*Mean*					*20*	*15.2*	*76.0%*	*6.8*			
		A					20	15	75.0%	4			
		B					20	16	80.0%	9			
		C					20	13	65.0%	8			
		D					20	18	90.0%	6			
		E					20	14	70.0%	7			
OA	*3*	*Mean*					*20.4*	*16.4*	*80.3%*	*4.6*			
		A					20	16	80.0%	4			
		B					20	14	70.0%	3			
		C					20	16	80.0%	7			
		D					20	17	85.0%	2			
		E					22	19	86.4%	7			
SP	*10*	*Mean*									*22*	*20*	*90.9%*
		A									20	19	95.0%
		B									22	20	90.9%
		C									22	19	86.4%
		D									21	19	90.5%
		E									25	23	92.0%
SP	*11*	*Mean*									*20*	*18.2*	*91.0%*
		A									20	16	80.0%
		B									20	18	90.0%
		C									20	20	100.0%
		D									20	18	90.0%
		E									20	19	95.0%
SP	*12*	*Mean*									*20.2*	*18.6*	*92.0%*
		A									21	21	100.0%
		B									20	20	100.0%
		C									20	17	85.0%
		D									20	17	85.0%
		E									20	18	90.0%
TB	*13*	*Mean*									*20*	*17.2*	*86.0%*
		A									20	19	95.0%
		B									20	16	80.0%
		C									20	15	75.0%
		D									20	19	95.0%
		E									20	17	85.0%

			Rhepoxynius				Ampelisca						
			Cumulative	No.		No.	..... Flow thru						
Site	#	Rep	No. Emerged (out of 20)	Alive (out of 20)	Per cent Survival	Failing to Reburrow	Initial No. Exposed	No. Alive	Percent Alive	Cumulatve No. Emerged	Initial No. Exposed	No. Alive	Percent Alive
TB	*14*	*Mean*									*20.4*	*19.4*	*95.2%*
		A									20	19	95.0%
		B									20	20	100.0%
		C									22	20	90.9%
		D									20	18	90.0%
		E									20	20	100.0%
	15	*Mean*									*20.2*	*17*	*84.1%*
		A									20	15	75.0%
		B									21	18	85.7%
		C									20	16	80.0%
		D									20	17	85.0%
		E									20	19	95.0%
VA	*7*	*Mean*					*20.4*	*16.6*	*81.4%*	*6.6*			
		A					20	16	80.0%	11			
		B					20	16	80.0%	2			
		C					22	18	81.8%	12			
		D					20	16	80.0%	4			
		E					20	17	85.0%	4			
	8	*Mean*	*7.2*	*18*	*90.0%*	*0*	*20*	*17*	*85.0%*	*4.8*			
		A	6	17	85%	0	20	17	85.0%	10			
		B	4	17	85%	0	20	19	95.0%	6			
		C	11	19	95%	0	20	16	80.0%	5			
		D	3	19	95%	0	20	18	90.0%	3			
		E	12	18	90%	0	20	15	75.0%	0			
	9	*Mean*	*7.4*	*16.8*	*84.0%*	*0*	*20*	*17.8*	*89.0%*	*3.2*			
		A	18	11	55%	0	20	18	90.0%	1			
		B	8	18	90%	0	20	19	95.0%	1			
		C	6	17	85%	0	20	16	80.0%	5			
		D	2	19	95%	0	20	17	85.0%	1			
		E	3	19	95%	0	20	19	95.0%	8			
YB	*4*	*Mean*					*20.6*	*17.4*	*84.2%*	*3.8*			
		A					20	17	85.0%	3			
		B					20	17	85.0%	6			
		C					22	21	95.5%	3			
		D					20	14	70.0%	1			
		E					21	18	85.7%	6			
	5	*Mean*					*20.4*	*17.4*	*85.3%*	*3.4*			
		A					20	16	80.0%	2			
		B					20	18	90.0%	4			
		C					20	18	90.0%	5			
		D					22	19	86.4%	4			
		E					20	16	80.0%	2			

			Rhepoxynius				*Ampelisca*						
			Cumulative	No.		No.	.....	*Flow thru*					
Site	#	Rep	No. Emerged (out of 20)	Alive (out of 20)	Percent Survival	Failing to Reburrow	Initial No. Exposed	No. Alive	Percent Alive	Cumulatve No. Emerged	Initial No. Exposed	No. Alive	Percent Alive
YB	*6*	*Mean*					*22.8*	*19.4*	*85.6%*	*6*			
		A					24	18	75.0%	5			
		B					24	20	83.3%	6			
		C					23	20	87.0%	8			
		D					20	20	100.0%	5			
		E					23	19	82.6%	6			
			NaPCP (µg/L)	1	0%								
				0.75	0%								
				0.56	0%								
				0.32	0%								
				0.18	60%								
				0.1	90%								
				Control	90%								
Seawater Control 1		*Mean*											
		A											
		B											
Seawater Control 2		*Mean*											
		A											
		B											
Sediment or		*Mean*						17.2	86.0%	5.2			
Elutriate Control 1		A					20	19	95.0%	8			
		B					20	18	90.0%	8			
		C					20	16	80.0%	4			
		D					20	14	70.0%	5			
		E					20	19	95.0%	1			
Sediment or		*Mean*	1.4									16	80.0%
Elutriate Control 2		A	4	20	100%	1					20	15	75.0%
		B	1	19	95%	0					20	18	90.0%
		C	0	17	85%	0					20	14	70.0%
		D	0	20	100%	1					20	13	65.0%
		E	2	18	90%	0					20	20	100.0%

		Ampelisca			*-- Purple Sea Urchin --*					
		Flow thru		*Static*	*.. Sperm Test ..*			*.. Sperm Test ..*		
Site	#	Rep	Cumulative No. Emerged	No. Alive	No. Fertile	No. Unfertile	Percent Unfertile	No. Fertile	No. Unfertile	Percent Unfertile
OA	*1*	*Mean*		10.2	*133*	*137*	50.7%			
		A		9	97	159	62.1%			
		B		6	148	91	38.1%			
		C		12	130	103	44.2%			
		D		14	161	210	56.6%			
		E		10	128	123	49.0%			
OA	*2*	*Mean*								
		A								
		B								
		C								
		D								
		E								
OA	*3*	*Mean*								
		A								
		B								
		C								
		D								
		E								
SP	*10*	*Mean*	*3.2*							
		A	4							
		B	1							
		C	2							
		D	7							
		E	2							
SP	*11*	*Mean*	*1.4*					*226*	*52*	18.8%
		A	2					168	47	21.9%
		B	0					267	68	20.3%
		C	3					254	45	15.1%
		D	0					212	46	17.8%
		E	2					229	53	18.8%
SP	*12*	*Mean*	*0.8*							
		A	1							
		B	0							
		C	2							
		D	1							
		E	0							
TB	*13*	*Mean*	2	17				*230*	*27*	10.5%
		A	3	18				202	17	7.8%
		B	2	20				212	22	9.4%
		C	2	12				262	31	10.6%
		D	1	15				204	17	7.7%
		E	2	20				269	49	15.4%

		Ampelisca			-- Purple Sea Urchin --					
		Flow thru		Static	.. Sperm Test ..			.. Sperm Test ..		
Site	#	Rep	Cumulatve No. Emerged	No. Alive	No. Fertile	No. Unfertile	Percent Unfertile	No. Fertile	No. Unfertile	Per cent Unfertile
TB	*14*	*Mean*	*1.2*							
		A	2							
		B	0							
		C	0							
		D	2							
		E	2							
	15	*Mean*	*3.2*							
		A	3							
		B	1							
		C	3							
		D	8							
		E	1							
VA	*7*	*Mean*			*171*	*103*	37.6%			
		A			111	125	53.0%			
		B			247	105	29.8%			
		C			97	76	43.9%			
		D			176	92	34.3%			
		E			222	119	34.9%			
	8	*Mean*								
		A								
		B								
		C								
		D								
		E								
	9	*Mean*								
		A								
		B								
		C								
		D								
		E								
YB	*4*	*Mean*		17.2	*173*	*88*	33.7%			
		A		16	199	117	37.0%			
		B		20	195	90	31.6%			
		C		17	135	87	39.2%			
		D		16	165	79	32.4%			
		E		17	170	66	28.0%			
	5	*Mean*								
		A								
		B								
		C								
		D								
		E								

Site	#	Rep	*Ampelisca* Flow thru Cumulative No. Emerged	*Ampelisca* Flow thru Static No. Alive	*Purple Sea Urchin* Sperm Test No. Fertile	*Purple Sea Urchin* Sperm Test No. Unfertile	*Purple Sea Urchin* Sperm Test Percent Unfertile	*Purple Sea Urchin* Sperm Test No. Fertile	*Purple Sea Urchin* Sperm Test No. Unfertile	*Purple Sea Urchin* Sperm Test Percent Unfertile
YB	*6*	*Mean*								
		A								
		B								
		C								
		D								
		E								
Seawater Control 1		*Mean*			48	150.5				
		A			36	141				
		B			60	160				
Seawater Control 2		*Mean*						154	103.5	
		A						159	80	
		B						150	127	
Sediment or Elutriate Control 1		*Mean*		14	*132.4*	*124.2*	*49.1%*			
		A		16	110	96	46.6%			
		B		12	188	164	46.6%			
		C		16	173	130	42.9%			
		D		12	100	114	53.3%			
		E		14	91	117	56.3%			
Sediment or Elutriate Control 2		*Mean*	2.6	15.2				*226.8*	*39.6*	*14.9%*
		A	1	14				211	59	21.9%
		B	1	17				262	43	14.1%
		C	6	12				196	45	18.7%
		D	4	14				221	35	13.7%
		E	1	19				244	16	6.2%

			... 48 hr Development ...					Purple Sea Urchin ... 48 hr Development ...					
Site	#	Rep	No. Normal	No. Retarded	No. Abnormal	Percent Abnormal	Percent Abnml.+ Rtd	No. Normal	No. Retarded	No. Abnormal	Per cent Abnormal	Percent Abnml.+ Rtd.	Echino. Absorbance
OA	*1*	*Mean*	*184.6*	*11.4*	*22.2*	*10.1%*	*15.4%*						*0.0816*
		A	219	9	23	9.2%	12.7%						0.08
		B	175	11	14	7.0%	12.5%						0.091
		C	182	12	22	10.2%	15.7%						0.095
		D	175	17	33	14.7%	22.2%						0.076
		E	172	8	19	9.5%	13.6%						0.066
OA	*2*	*Mean*	*185.6*	*7.8*	*19.8*	*9.5%*	*13.4%*						*0.082*
		A	152	15	13	7.2%	15.6%						0.082
		B	145	3	25	14.5%	16.2%						0.081
		C	194	11	23	10.1%	14.9%						0.08
		D	187	9	19	8.8%	13.0%						0.081
		E	250	1	19	7.0%	7.4%						0.086
OA	*3*	*Mean*	*204*	*12.8*	*27.2*	*11.4%*	*16.6%*						*0.0876*
		A	215	21	23	8.9%	17.0%						0.088
		B	194	18	26	10.9%	18.5%						0.089
		C	162	6	36	17.6%	20.6%						0.088
		D	224	15	28	10.5%	16.1%						0.084
		E	225	4	23	9.1%	10.7%						0.089
SP	*10*	*Mean*						*215.8*	*25.6*	*24.6*	*9.9%*	*19.5%*	
		A						257	28	14	4.7%	14.0%	
		B						146	20	46	21.7%	31.1%	
		C						235	13	20	7.5%	12.3%	
		D						229	35	15	5.4%	17.9%	
		E						212	32	28	10.3%	22.1%	
SP	*11*	*Mean*						*218*	*21.6*	*24.6*	*9.2%*	*17.3%*	
		A						246	28	22	7.4%	16.9%	
		B						221	22	41	14.4%	22.2%	
		C						218	21	28	10.5%	18.4%	
		D						174	17	14	6.8%	15.1%	
		E						231	20	18	6.7%	14.1%	
SP	*12*	*Mean*						*230.5*	*21*	*2350.0%*	*8.7%*	*16.9%*	
		A						171	25	19	8.8%	20.5%	
		B						295	11	22	6.7%	10.1%	
		C						*0*	*0*	*0*	*0*	dropped	
		D						184	25	26	11.1%	21.7%	
		E						272	23	27	8.4%	15.5%	
TB	*13*	*Mean*						*160.2*	*25.8*	*67*	*26.2%*	*36.1%*	
		A						188	17	57	21.8%	28.2%	
		B						159	22	53	22.6%	32.1%	
		C						224	18	32	11.7%	18.2%	
		D						108	56	133	44.8%	63.6%	
		E						122	16	60	30.3%	38.4%	

			... 48 hr Development ...					Purple Sea Urchin ... 48 hr Development ...					
Site	#	Rep	No. Normal	No. Retarded	No. Abnormal	Percent Abnormal	Percent Abnml.+ Rtd.	No. Normal	No. Retarded	No. Abnormal	Percent Abnormal	Percent Abnml. + Rtd.	Echino. Absorbance
TB	*14*	*Mean*						*201.8*	*15.4*	*36.8*	*14.5%*	*21.3%*	
		A						206	14	45	17.0%	22.3%	
		B						214	21	67	22.2%	29.1%	
		C						274	20	39	11.7%	17.7%	
		D						82	16	18	15.5%	29.3%	
		E						233	6	15	5.9%	8.3%	
	15	*Mean*						*213.4*	*23.2*	*27.8*	*10.4%*	*19.2%*	
		A						203	31	24	9.3%	21.3%	
		B						230	23	45	15.1%	22.8%	
		C						244	5	18	6.7%	8.6%	
		D						208	18	17	7.0%	14.4%	
		E						182	39	35	13.7%	28.9%	
VA	*7*	*Mean*	*192.4*	*6.8*	*25.4*	*11.4%*	*14.6%*						*0.085*
		A	180	9	15	7.4%	11.8%						0.086
		B	162	5	45	21.2%	23.6%						0.083
		C	146	9	17	9.9%	15.1%						0.083
		D	236	11	28	10.2%	14.2%						0.096
		E	238	0	22	8.5%	8.5%						0.077
	8	*Mean*	*215.8*	*6.2*	*21.8*	*9.0%*	*11.6%*						*0.083*
		A	226	5	15	6.1%	8.1%						0.084
		B	173	9	23	11.2%	15.6%						0.083
		C	234	4	23	8.8%	10.3%						0.09
		D	216	7	24	9.7%	12.6%						0.091
		E	230	6	24	9.2%	11.5%						0.067
	9	*Mean*	*187.8*	*5.6*	*20.8*	*9.5%*	*12.3%*						*0.0842*
		A	234	3	37	13.5%	14.6%						0.085
		B	149	5	11	6.7%	9.7%						0.082
		C	139	6	18	11.0%	14.7%						0.081
		D	188	11	23	10.4%	15.3%						0.082
		E	229	3	15	6.1%	7.3%						0.091
			939										
YB	*4*	*Mean*	*213.8*	*10*	*20.8*	*8.6%*	*12.6%*						*0.091*
		A	193	17	23	9.9%	17.2%						0.088
		B	235	3	18	7.0%	8.2%						0.088
		C	247	17	21	7.4%	13.3%						--
		D	208	8	25	10.4%	13.7%						0.099
		E	186	5	17	8.2%	10.6%						0.089
	5	*Mean*	*214.6*	*10.6*	*20.8*	*8.5%*	*12.8%*						*0.0864*
		A	207	13	21	8.7%	14.1%						0.077
		B	218	7	15	6.3%	9.2%						0.096
		C	191	10	24	10.7%	15.1%						0.082
		D	231	14	20	7.5%	12.8%						0.087
		E	226	9	24	9.3%	12.7%						0.09

			Purple Sea Urchin										
			... 48 hr Development ...					... 48 hr Development ...					
Site	#	Rep	No. Normal	No. Retarded	No. Abnormal	Percent Abnormal	Percent Abnml.+ Rtd	No. Normal	No. Retarded	No. Abnormal	Percent Abnormal	Percent Abnml.+ Rtd.	Echino. Absorbance
YB	*6*	*Mean*	*197.4*	*14.4*	*25.2*	*10.8%*	*17.0%*						*0.0922*
		A	213	15	22	8.8%	14.8%						0.091
		B	145	18	30	15.5%	24.9%						0.091
		C	210	13	37	14.2%	19.2%						0.095
		D	199	14	21	9.0%	15.0%						0.093
		E	220	12	16	6.5%	11.3%						0.091
Seawater Control 1		*Mean*	224	15.5	16.5	6.4%	12.5%						
		A	234	15	19	7.1%	12.7%						
		B	214	16	14	5.7%	12.3%						
Seawater Control 2		*Mean*						265	26.5	22.5	7.2%	15.6%	0.086
		A						275	22	21	6.6%	13.5%	0.088
		B						255	31	24	7.7%	17.7%	0.084
Sediment or Elutriate Control 1		*Mean*	*245.4*	*10.8*	*25*	*8.6%*	*12.7%*						
		A	253	19	36	11.7%	17.9%						
		B	215	9	17	7.1%	10.8%						
		C	202	14	16	6.9%	12.9%						
		D	246	11	18	6.5%	10.5%						
		E	311	1	38	10.9%	11.1%						
Sediment or Elutriate Control 2		*Mean*						*265*	*22.2*	*19.8*	*6.4%*	*13.6%*	*0.09*
		A						253	33	27	8.6%	19.2%	0.088
		B						278	30	31	9.1%	18.0%	0.083
		C						287	8	15	4.8%	7.4%	0.085
		D						232	26	14	5.1%	14.7%	0.089
		E						274	14	12	4.0%	8.7%	0.105

--Purple Sea Urchin --

Site	#	Rep	Echino. Absorbance	Anaphase abberations No. Normal	Anaphase abberations No. Abnormal	Anaphase abberations Percent Abnormal	Anaphase abberations No. Normal	Anaphase abberations No. Abnormal	Anaphase abberations Percent Abnormal	No. Micro-nuclei/20 Embryo	No. w/1 Cytologic Abnormality	Mean Mitoses/ Embryo
OA	*1*	*Mean*		*26.2*	*10.4*	*30.1%*				*5*	*3.4*	*5.62*
		A		23	14	37.8%				3	2	6.0
		B		44	6	12.0%				1	3	6.0
		C		24	15	38.5%				3	8	5.5
		D		26	9	25.7%				2	3	6.8
		E		14	8	36.4%				16	1	3.8
OA	*2*	*Mean*										
		A										
		B										
		C										
		D										
		E										
OA	*3*	*Mean*										
		A										
		B										
		C										
		D										
		E										
SP	*10*	*Mean*	*0.0896*									
		A	0.098									
		B	0.072									
		C	0.091									
		D	0.092									
		E	0.095									
SP	*11*	*Mean*	*0.1022*				*40.2*	*9.8*	*19.8%*			
		A	0.099				36	7	16.3%			
		B	0.104				37	12	24.5%			
		C	0.119				57	15	20.8%			
		D	0.09				27	12	30.8%			
		E	0.099				44	3	6.4%			
SP	*12*	*Mean*	*0.09975*									
		A	0.11									
		B	0.103									
		C	*.012*contam									
		D	0.085									
		E	0.101									
TB	*13*	*Mean*	*0.104*									
		A	0.104				36	5	12.2%			
		B	0.103				39	2	4.9%			
		C	0.114				64	8	11.1%			
		D	0.101				41	3	6.8%			
		E	0.098				52	3	5.5%			

-- *Purple Sea Urchin* --

Site	#	Rep	Echino. Absorbance	*Anaphase abberations* No. Normal	No. Abnormal	Percent Abnormal	*Anaphase abberations* No. Normal	No. Abnormal	Percent Abnormal	No. Micro-nuclei/20 Embryo	No. w/1 Cytologic Abnormality	Mean Mitoses/ Embryo
TB	*14*	*Mean*	*0.1092*									
		A	0.106									
		B	0.099									
		C	0.118									
		D	0.107									
		E	0.116									
	15	*Mean*	*0.1014*									
		A	0.098									
		B	0.099									
		C	0.096									
		D	0.105									
		E	0.109									
VA	*7*	*Mean*		*29.4*	*8.4*	*21.9%*				*2.8*	*6.4*	*6.24*
		A		36	9	20.0%				2	8	7.1
		B		23	8	25.8%				4	7	5.2
		C		24	5	17.2%				3	3	6.4
		D		31	7	18.4%				1	3	5.5
		E		33	13	28.3%				4	11	7.0
											32	31.2
	8	*Mean*										
		A										
		B										
		C										
		D										
		E										
	9	*Mean*										
		A										
		B										
		C										
		D										
		E										
YB	*4*	*Mean*		*29.4*	*6*	*19.7%*				*2.4*	*4.8*	*5.96*
		A		37	4	9.8%				0	4	6.5
		B		20	9	31.0%				4	9	5.2
		C		47	4	7.8%				1	3	8.0
		D		12	5	29.4%				5	2	4.2
		E		31	8	20.5%				2	6	5.9
											24	29.8
	5	*Mean*										
		A										
		B										
		C										
		D										
		E										

-- *Purple Sea Urchin* --

Site	#	Rep	Echino. Absorbance	*Anaphase abberations* No. Normal	No. Abnormal	Percent Abnormal	*Anaphase abberations* No. Normal	No. Abnormal	Percent Abnormal	No. Micro-nuclei/ 20	No. w/1 Cytologic Abnormality	Mean Mitoses/ Embryo
YB	*6*	*Mean*										
		A										
		B										
		C										
		D										
		E										
Seawater Control 1		*Mean*	0.095	42	2.5	5.6%					0.5	8.9
		A	0.092	43	2	4.4%				0	1	9.2
		B	0.099	41	3	6.8%				0	0	8.6
Seawater Control 2		Mean					56.5	3.5	5.9%			
		A					59	3	4.8%			
		B					54	4	6.9%			
Sediment or Elutriate Control 1		*Mean*	*0.101*	46.2	3.6	7.1%				1.20	0.50	8.0
		A	0.085	39	3	7.1%				5	1	6.7
		B	0.121	51	2	3.8%				0	1	8.6
		C	0.098	43	2	4.4%				0	0	8.5
		D	0.109	51	5	8.9%				0	1	8.2
		E	0.092	47	6	11.3%				1	0	7.8
Sediment or Elutriate Control 2		*Mean*					45.2	4.6	9.3%			
		A					50	6	10.7%			
		B					56	4	6.7%			
		C					42	4	8.7%			
		D					35	4	10.3%			
		E					43	5	10.4%			

Site	#	Rep	No. Micronuclei/20 Embryo	No. w/1 Cytologic Abnormality	Mean Mitoses/ Embryo	White Sea Urchin — 48hr Development — No. Normal	No. Retarded	No. Abnormal	Green Sea Urchin — No. Normal	No. Abnormal
OA	*1*	*Mean*				*26.4**	*0.6**	*10.4**	*0**	*333.5**
		A				25	8	10	0	304
		B				35	1	11	0	363
		C				30	0	8		
		D				23	1	13		
		E				19	1	10		
OA	*2*	*Mean*								
		A								
		B								
		C								
		D								
		E								
OA	*3*	*Mean*								
		A								
		B								
		C								
		D								
		E								
SP	*10*	*Mean*								
		A								
		B								
		C								
		D								
		E								
SP	*11*	*Mean*	*3.6*	*6.4*	*7.98*					
		A	4	6	8.4					
		B	2	9	8.4					
		C	7	6	8.5					
		D	4	9	5.8					
		E	1	2	8.8					
SP	*12*	*Mean*								
		A								
		B								
		C								
		D								
		E								
TB	*13*	*Mean*	*0.6*	*2*	*7.64*					
		A	1	1	7.6	66**	2**	26**	0**	514**
		B	1	2	6.8	73	12	34	0	450
		C	0	2	9.4	69	11	44		
		D	0	2	6.6	102	2	42		
		E	1	3	7.8	60	6	27		

Site	#	Rep	No. Micronuclei/20 Embryo	No. w/1 Cytologic Abnormality	Mean Mitoses/ Embryo	White Sea Urchin — 48hr Development — No. Normal	No. Retarded	No. Abnormal	Green Sea Urchin — No. Normal	No. Abnormal
TB	*14*	*Mean*								
		A								
		B								
		C								
		D								
		E								
	15	*Mean*								
		A								
		B								
		C								
		D								
		E								
VA	*7*	*Mean*								
		A								
		B								
		C								
		D								
		E								
	8	*Mean*								
		A								
		B								
		C								
		D								
		E								
	9	*Mean*								
		A								
		B								
		C								
		D								
		E								
YB	*4*	*Mean*				*21.5**	*0.4**	*10.8**	*0**	*269**
		A				26	0	10	0	251
		B				22	0	8	0	287
		C				25	0	3		
		D				21	1	14		
		E				18	1	19		
	5	*Mean*								
		A								
		B								
		C								
		D								
		E								

Site	#	Rep	No. Micronuclei/20 Embryo	No. w/1 Cytologic Abnormality	Mean Mitoses/ Embryo	White Sea Urchin — 48hr Development — No. Normal	No. Retarded	No. Abnormal	Green Sea Urchin — No. Normal	No. Abnormal
YB	*6*	*Mean*								
		A								
		B								
		C								
		D								
		E								
Seawater Control 1		*Mean*				18*	0*	15*	0*	265*
		A				23	0	16	0	256
		B				13	0	14	0	274
Seawater Control 2		*Mean*	0	0	9.8	62.5**	2.5**	31.5**	0**	517**
		A	0	0	9.4	48	1	26	0	546
		B	0	0	10.2	77	4	37	0	488
Sediment or Elutriate Control 1		*Mean*				20.6	0.6	13.2	0*	112*
		A				13	1	16	0	49
		B				21	1	8	0	175
		C				29	0	14		
		D				20	0	10		
		E				20	1	18		
Sediment or Elutriate Control 2		*Mean*	0.4	2	8.0	57.2	5.8	34.4	0**	472**
		A	0	3	8.4	75	9	42	0	455
		B	1	3	7.9	33	5	42	0	488
		C	0	1	8.2	61	9	34		
		D	1	1	7.1	68	3	34		
		E	0	2	8.2	49	3	20		

APPENDIX B

SEDIMENT PHYSICAL AND CHEMICAL DATA

Individual chemical and physical/chemical data from sediments sampled at 15 stations in the San Francisco Bay area. Concentrations of organic compounds are expressed as µg/kg (ppb) dry weight, coprostanol as ug/g (ppm), trace metals as mg/kg (ppm) dry weight or percent for aluminum, iron, and silicon.

Site	Station	Lab sample #	% dry wt	% Gravel	% Sand	% Silt	% Clay	% Recovery	Hexachloro-benzene	Lindane
OA	1	AAB 734	34.7	1.1	5.7	35.4	57.9	50.7	0.0	1.2
	2	AAB 735	32.2	5.8	3.0	28.1	63.1	43.2	0.0	1.9
	3	AAB 736	38.6	1.3	10.5	37.8	50.3	30.0	0.0	0.0
	mean		35.2	2.7	6.4	33.8	57.1	41.3	0.0	1.1
YB	4	AAB 849	35.0	1.7	6.4	47.8	44.1	82.7	0.0	0.0
	5	AAB 850	37.2	1.1	4.4	42.1	52.3	57.1	0.0	0.0
	6	AAB 851	34.4	4.6	1.4	39.0	54.8	76.2	0.0	0.0
	mean		35.5	2.5	4.1	43.0	50.4	72.0	0.0	0.0
VA	7	AAB 846	50.0	3.1	29.9	37.5	29.5	86.5	0.8	0.0
	8	AAB 847	63.5	18.3	58.7	12.9	10.4	87.3	1.4	0.0
	9	AAB 848	49.4	0.4	23.4	43.7	32.5	72.4	0.0	0.0
	mean		54.3	7.3	37.3	31.4	24.1	82.1	0.7	0.0
SP	10	AAB 852	36.9	0.0	3.3	48.3	48.4	85.8	0.0	0.0
	11	AAB 853	39.8	10.3	4.5	42.0	43.2	74.5	0.0	0.0
	12	AAB 854	39.8	0.0	5.0	46.8	48.2	96.8	0.0	0.0
	mean		38.8	3.4	4.3	45.7	46.6	85.7	0.0	0.0
TB	13	AAB 855	35.0	0.3	1.9	29.0	68.8	57.6	0.0	1.2
	14	AAB 856	36.3	0.4	2.1	29.1	68.4	65.2	0.0	0.0
	15	AAB 857	34.9	7.0	1.8	28.0	63.2	113.0	0.0	0.0
	mean		35.4	2.6	1.9	28.7	66.8	78.6	0.0	0.4

Site	Station	Heptachlor	Aldrin	Heptachlor Epoxide	opDDE	a Chlordane	trans-Nonachlor	Dieldrin	ppDDE	opDDD	ppDDD
OA	1	0.0	0.0	0.0	0.0	13.9	7.6	17.8	12.0	0.0	50.4
	2	0.0	1.1	0.0	0.0	13.2	7.0	19.1	11.5	5.4	60.1
	3	0.0	0.0	0.0	0.0	15.9	9.1	23.7	0.0	0.0	58.9
	mean	0.8	0.4	0.0	0.0	14.3	7.9	20.2	7.8	1.8	56.5
YB	4	0.0	0.0	0.0	0.0	0.0	0.0	5.8	2.6	1.4	17.1
	5	0.0	0.0	0.0	0.0	0.0	0.0	6.2	1.9	1.0	14.5
	6	0.0	0.0	0.0	0.0	0.0	0.0	4.5	1.4	0.0	12.3
	mean	0.0	0.0	0.0	0.0	0.0	0.0	5.5	2.0	0.8	14.6
VA	7	0.0	0.7	0.0	0.0	2.0	0.0	5.7	2.5	3.1	15.8
	8	0.0	1.9	0.0	0.0	2.0	0.0	6.6	2.2	2.4	13.6
	9	0.0	0.0	0.0	0.0	0.0	0.0	5.8	1.1	2.3	16.2
	mean	0.0	0.9	0.0	0.0	1.3	0.0	6.0	1.9	2.6	15.2
SP	10	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.5	6.4
	11	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.5	8.2
	12	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.0	0.0	6.9
	mean	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.0	0.3	7.2
TB	13	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.3	1.8
	14	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0
	15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	mean	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.1	0.6

Site	Station	opDDT	ppDDT	Mirex	Naphthalene	2Methylnaph-thalene	1Methylnaph-thalene	Biphenyl	2,6-Dimethylnaph-thalene
OA	1	0.0	7.1	1.5	105.0	0.0	0.0	0.0	0.0
	2	0.0	72.3	2.7	83.0	0.0	0.0	0.0	0.0
	3	0.0	12.8	0.9	76.0	0.0	0.0	0.0	0.0
	mean	0.0	30.7	1.7	88.0	0.0	0.0	0.0	0.0
YB	4	0.0	4.7	0.0	46.0	0.0	0.0	0.0	0.0
	5	0.0	2.6	0.0	37.0	23.0	0.0	0.0	0.0
	6	0.0	4.2	0.0	40.0	25.0	0.0	0.0	0.0
	mean	0.0	3.8	0.0	41.0	16.0	0.0	0.0	0.0
VA	7	0.0	1.9	0.0	17.0	13.0	9.0	0.0	0.0
	8	0.0	0.0	0.0	84.0	24.0	13.0	0.0	5.0
	9	0.0	9.6	0.0	155.0	27.0	19.0	0.0	0.0
	mean	0.0	3.8	0.0	85.3	21.3	13.7	0.0	1.7
SP	10	0.0	1.4	0.0	25.0	21.0	12.0	0.0	0.0
	11	0.0	2.8	0.0	30.0	21.0	14.0	10.0	0.0
	12	0.0	1.6	0.0	25.0	9.0	4.0	0.0	0.0
	mean	0.0	1.9	0.0	26.7	17.0	10.0	3.3	0.0
TB	13	0.0	0.0	0.0	31.2	58.2	40.1	17.2	39.3
	14	0.0	0.0	0.0	26.0	70.0	44.0	16.0	33.0
	15	0.0	0.0	0.0	25.0	48.0	28.0	15.0	31.0
	mean	0.0	0.0	0.0	27.4	58.7	37.4	16.1	34.4

Site	Station	Acenapthene	Trimethylnaph-thalene	Fluorene	Phenanthrene	Anthracene	1Methylphenan-threne
OA	1	0.0	0.0	56.0	461.0	164.0	92.0
	2	0.0	0.0	0.0	249.0	250.0	136.0
	3	0.0	0.0	0.0	273.0	104.0	104.0
	mean	0.0	0.0	19.0	327.0	173.0	110.0
YB	4	0.0	0.0	0.0	173.0	47.0	0.0
	5	0.0	0.0	0.0	129.0	39.0	0.0
	6	0.0	0.0	0.0	115.0	29.0	0.0
	mean	0.0	0.0	0.0	139.0	38.3	0.0
VA	7	0.0	0.0	0.0	57.0	14.0	0.0
	8	0.0	0.0	4.0	22.0	6.0	0.0
	9	0.0	0.0	0.0	44.0	12.0	0.0
	mean	0.0	0.0	1.3	41.0	10.7	0.0
SP	10	0.0	0.0	10.0	82.0	22.0	12.0
	11	0.0	0.0	12.0	96.0	26.0	13.0
	12	0.0	0.0	5.0	87.0	13.0	<
	mean	0.0	0.0	9.0	88.3	20.3	12.5
TB	13	0.0	0.0	0.0	108.9	0.0	0.0
	14	0.0	0.0	0.0	101.0	0.0	0.0
	15	0.0	0.0	0.0	76.0	0.0	0.0
	mean	0.0	0.0	0.0	95.3	0.0	0.0

Site	Station	Fluoranthene	Pyrene	B(a)anthracene	Chrysene	Benzo(e)pyrene	Benzo(a)pyrene	%Recovery	Perylene
OA	1	1055.0	1460.0	358.0	545.0	678.0	783.0	124.0	313.0
	2	764.0	854.0	393.0	647.0	677.0	836.0	101.6	314.0
	3	618.0	726.0	317.0	497.0	541.0	667.0	84.7	238.0
	mean	812.3	1013.0	356.0	563.0	632.0	762.0	103.4	289.0
YB	4	0.0	0.0	119.0	142.0	155.0	235.0	66.3	146.0
	5	0.0	0.0	105.0	135.0	154.0	235.0	83.6	143.0
	6	0.0	0.0	103.0	120.0	154.0	237.0	78.7	171.0
	mean	0.0	0.0	109.0	132.3	154.3	235.7	76.2	153.3
VA	7	0.0	160.0	42.0	66.0	71.0	88.0	87.2	0.0
	8	46.0	74.0	21.0	29.0	38.0	47.0	168.0	0.0
	9	0.0	158.0	41.0	60.0	64.0	84.0	34.8	0.0
	mean	15.3	130.7	34.7	51.7	57.7	73.0	96.7	0.0
SP	10	204.0	268.0	77.0	105.0	119.0	172.0	76.2	156.0
	11	207.0	283.0	91.0	118.0	142.0	198.0	79.3	169.0
	12	247.0	336.0	83.0	121.0	148.0	193.0	100.7	155.0
	mean	219.3	295.7	83.7	114.7	136.3	187.7	85.4	160.0
TB	13	49.9	42.7	0.0	28.8	0.0	0.0	33.3	63.2
	14	53.0	44.0	0.0	33.0	0.0	0.0	54.3	65.7
	15	33.0	26.0	0.0	25.0	0.0	0.0	43.5	41.6
	mean	45.3	37.6	0.0	28.9	0.0	0.0	43.7	56.8

Site	Station	DB[ah]anthra-cene	tPAH	2Cl-biphenyl	3Cl-biphenyl	4Cl-biphenyl	5Cl-biphenyl	6Cl-biphenyl
OA	1	136.0	6206.0	0.0	6.5	93.0	60.0	82.7
	2	101.0	5304.0	0.0	7.9	81.0	65.2	97.4
	3	151.0	4312.0	0.0	6.2	124.1	78.6	115.4
	mean	129.0	5274.0	0.0	6.9	99.4	67.9	98.5
YB	4	0.0	1062.0	0.0	2.0	3.6	0.7	0.4
	5	47.0	1046.0	0.0	6.5	13.1	15.5	23.9
	6	30.0	1023.0	0.0	4.7	8.1	6.2	12.1
	mean	25.7	1043.7	0.0	4.4	8.3	7.5	12.1
VA	7	0.0	535.0	0.1	6.9	11.7	15.4	12.5
	8	8.0	421.0	0.0	16.9	12.0	7.9	11.2
	9	0.0	666.0	0.0	1.1	3.8	4.7	7.2
	mean	2.7	540.7	0.0	8.3	9.2	9.3	10.3
SP	10	35.0	1320.0	0.0	3.3	4.6	3.3	4.7
	11	20.0	1449.0	0.0	3.8	6.6	2.9	6.2
	12	6.0	1431.0	0.0	2.5	4.2	2.8	6.3
	mean	20.3	1400.0	0.0	3.2	5.1	3.0	5.7
TB	13	0.0	479.5	0.0	5.0	1.7	1.6	1.5
	14	0.0	485.7	0.0	3.1	1.4	0.0	0.0
	15	0.0	348.6	0.0	1.9	1.0	0.0	0.0
	mean	0.0	437.9	0.0	3.3	1.4	0.5	0.5

Site	Station	7Cl-biphenyl	8Cl-biphenyl	9Cl-biphenyl	10Cl-biphenyl	tPCB	Coprostanol	Ag	Al%
OA	1	41.2	18.6	2.9	0.0	304.9	4900	1.55	5.64
	2	65.2	34.4	7.4	0.0	358.5	9600	1.24	5.69
	3	66.2	25.8	4.5	0.0	420.9	140	1.21	5.43
	mean	57.5	26.3	4.9	0.0	361.4	4880	1.33	5.59
YB	4	0.4	0.6	0.0	0.0	73.5	3000	0.66	5.83
	5	22.2	4.6	0.0	0.0	52.8	2000	0.63	6.02
	6	9.6	2.1	0.0	0.0	43.6	2900	0.57	5.85
	mean	10.7	2.4	0.0	0.0	56.6	2633	0.62	5.90
VA	7	4.3	0.0	0.0	0.0	50.9	87	0.67	5.27
	8	5.4	0.0	0.0	0.0	53.5	87	0.22	3.16
	9	3.5	0.0	0.0	0.0	20.3	72	0.18	5.46
	mean	4.4	0.0	0.0	0.0	41.6	82	0.36	4.63
SP	10	3.2	0.0	0.0	0.0	20.6	2200	0.60	6.31
	11	5.4	1.6	0.0	0.0	27.0	1100	0.73	6.28
	12	5.8	2.8	0.0	0.0	25.6	6400	0.51	6.06
	mean	4.8	1.5	0.0	0.0	24.4	3233	0.61	6.22
TB	13	0.0	0.0	0.0	0.0	10.4	ND	0.20	5.82
	14	0.0	0.0	0.0	0.0	6.4	4600	0.54	6.12
	15	0.0	0.0	0.0	0.0	4.2	3500	0.19	5.43
	mean	0.0	0.0	0.0	0.0	7.0	2700	0.31	5.79

Site	Station	As	Cd	Cr	Cu	Fe%	Hg	Mn	Ni	Pb	Sb	Se	Si%	Sn
OA	1	17.7	1.78	189	187	5.15	3.33	484	138	227.00	<.069	<.62	25.3	<1.7
	2	16.0	1.06	190	167	4.99	1.48	507	134	198.00	<.068	<.61	26.5	<1.7
	3	14.8	1.19	182	159	4.22	2.12	414	130	193.00	<.068	<.61	28.3	<1.7
	mean	16.2	1.34	187	171	4.79	2.31	468	134	206.00	<.69	<.62	26.7	<1.7
YB	4	10.4	0.24	174	42	4.62	0.26	554	101	28.20	<.069	<.62	27.4	<1.7
	5	15.1	0.21	182	60	4.57	0.32	580	111	31.70	<.069	<.62	27.9	<1.7
	6	11.9	0.24	185	55	4.76	0.35	651	119	35.90	<.070	<.63	25.6	<1.7
	mean	12.5	0.23	180	52	4.65	0.31	595	110	31.93	<.69	<.62	27.0	<1.7
VA	7	19.7	0.57	168	55	4.84	0.42	673	110	71.20	<.069	<.62	26.6	<1.7
	8	15.7	0.32	144	35	4.18	0.22	714	82	66.80	<.069	<.62	27.1	<1.7
	9	19.9	0.44	235	35	5.80	0.37	611	167	23.80	<.069	<.62	23.9	<1.7
	mean	18.4	0.44	182	42	4.94	0.34	666	120	53.93	<.69	<.62	25.9	<1.7
SP	10	16.0	0.28	182	59	4.88	0.29	1168	115	27.60	<.069	<.62	26.7	<1.7
	11	17.4	0.31	178	59	4.94	0.23	1213	114	27.50	<.069	<.62	26.8	<1.7
	12	16.3	0.28	178	55	4.89	0.26	1373	119	29.00	<.069	<.62	25.9	<1.7
	mean	16.6	0.29	179	58	4.90	0.26	1251	116	28.03	<.69	<.62	26.5	<1.7
TB	13	13.9	0.43	234	33	5.88	0.38	560	172	20.40	<.069	<.62	23.4	<1.7
	14	18.1	0.48	147	66	5.20	0.51	717	101	40.50	<.069	<.61	27.7	<1.7
	15	14.6	0.40	237	40	5.67	0.44	602	173	20.10	<.068	<.61	23.3	<1.7
	mean	15.5	0.44	206	46	5.58	0.44	626	149	27.00	<.69	<.62	24.8	<1.7

Site	Station	Tl	Zn
OA	1	<.43	379
	2	<.42	311
	3	<.42	304
	mean	<.43	331
YB	4	<.43	123
	5	<.43	136
	6	<.44	148
	mean	<.43	136
VA	7	<.43	138
	8	<.43	125
	9	<.43	114
	mean	<.43	126
SP	10	<.43	133
	11	<.43	137
	12	<.43	134
	mean	<.43	135
TB	13	<.43	114
	14	<.42	137
	15	<.43	114
	mean	<.43	122

APPENDIX C

MEASURES OF EFFECTS DATA FOR *P. STELLATUS*

Individual data from measures of effects in *P. stellatus*.

Site	Sample No.	Date	Sex	Maturity	Std. Length	Condition factor (w/lxlxl)	Liver wt. (g)	Gonad wt. (g)	Total wt. (g)	Wt/Length
Berkeley	5120	Nov	M	mat	26	2.51	4.7	1.4	442	17
Berkeley	5121	•	•	•	•	•	•	•	•	•
Berkeley	5122	•	•	•	•	•	•	•	•	•
Berkeley	5123	•	•	•	•	•	•	•	•	•
Berkeley	5124	•	•	•	•	•	•	•	•	•
Berkeley	5125	•	•	•	•	•	•	•	•	•
Berkeley	5126	Nov	F	mat	30.5	2.35	7.9	31.2	666	21.84
Berkeley	5127	Nov	F	immat	30	2.44	5.9	6.8	658	21.93
Berkeley	5128	•	•	•	•	•	•	•	•	•
Berkeley	5129	•	•	•	•	•	•	•	•	•
Berkeley	5130	Nov	F	immat	28.5	2.24	4.1	4.3	416	15.7
Berkeley	5131	•	•	•	•	•	•	•	•	•
Berkeley	5132	•	•	•	•	•	•	•	•	•
Berkeley	5133	Nov	M	mat	29	2.27	7.1	12.2	554	19.1
Berkeley	5134	•	•	•	•	•	•	•	•	•
Berkeley	5135	Nov	F	mat	40.5	2.36	20	41.2	1566	38.67
Berkeley	5136	Nov	F	mat	38.4	2.47	27	92.6	1397	36.38
Berkeley	5137	Nov	F	immat	26.5	2.34	4.3	4.5	438	16.45
Berkeley	5138	•	•	•	•	•	•	•	•	•
Berkeley	5139	Nov	F	mat	44	2.38	35.3	165	2027	46.07
Berkeley	5140	Nov	M	mat	32	2.42	12	14	792	24.75
Berkeley	5141	•	•	•	•	•	•	•	•	•
Berkeley	5142	Nov	M	mat	28	2.28	5.7	1.8	500	17.86
Berkeley	5143	•	•	•	•	•	•	•	•	•
Berkeley	5144	•	•	•	•	•	•	•	•	•
Berkeley	5145	•	•	•	•	•	•	•	•	•
Berkeley	5146	Nov	M	immat	23	2.26	2.9	0.5	275	11.96
Berkeley	5147	•	•	•	•	•	•	•	•	•
Berkeley	5148	•	•	•	•	•	•	•	•	•
Berkeley	5149	Nov	F	immat	26.5	2.11	3.5	2.3	393	14.83
Berkeley	5150	Nov	F	mat	37.4	2.68	24	73	1403	37.51
Vallejo	5151	Nov	F	immat	20.5	2.38	2.2	0.8	205	10
Vallejo	5152	Nov	F	immat	29.5	1.57	3.4	3.3	402	13.63
Vallejo	5153	Nov	F	immat	35.4	0.94	16.8	27.9	417	11.78
Vallejo	5154	Nov	M	immat	23	2.13	2.9	1.6	259	11.28
San Pablo Bay	5155	Nov	F	mat	35.4	2.26	16.8	27.9	1002	28.31
San Pablo Bay	5156	Nov	M	mat	24.6	2.39	5.1	2.6	356	14.47
San Pablo Bay	5157	Nov	M	mat	26	2.33	6.7	4	409	15.73
San Pablo Bay	5158	Nov	M	immat	27	2.26	6.6	4.4	444	16.44
San Pablo Bay	5159	Nov	M	immat	20.5	2.24	1.9	0.1	193	9.41
San Pablo Bay	5160	Nov	F	immat	25.5	2.44	4.8	2.3	405	15.88
San Pablo Bay	5161	Nov	F	immat	26	2.65	5.2	2.3	466	17.92
San Pablo Bay	5162	•	•	•	•	•	•	•	•	•
San Pablo Bay	5163	Nov	F	immat	24	2.77	4	2.5	383	15.96
San Pablo Bay	5164	Nov	M	mat	24	2.59	7.9	7.1	358	14.92
San Pablo Bay	5165	Nov	M	immat	26.5	2.23	8	6.7	415	15.66
Oakland	5166	Nov	F	mat	41	2.07	17.8	17.5	1428	34.83
Oakland	5167	Nov	F	immat	25.7	2.39	3.9	2.4	406	15.8
Oakland	5168	Nov	F	immat	34.2	2.2	9.6	6.3	881	25.78
Oakland	5169	Nov	M	immat	25	2.17	2.9	1	339	13.56
Oakland	5170	•	•	•	•	•	•	•	•	•
Oakland	5171	Nov	F	mat	38.5	2.72	39.9	112	1553	40.34
Oakland	5172	Nov	F	mat	35.2	2.39	13	28.7	1043	29.63
Oakland	5173	•	•	•	•	•	•	•	•	•
Oakland	5174	•	•	•	•	•	•	•	•	•
Oakland	5175	•	•	•	•	•	•	•	•	•
Oakland	5176	Nov	F	immat	34.8	2.15	8.5	8.7	905	26.01
San Pablo Bay	5177	•	•	•	•	•	•	•	•	•
San Pablo Bay	5178	•	•	•	•	•	•	•	•	•

Site	Sample No.	Date	Sex	Maturity	Std. Length	Condition factor (w/lxlxl)	Liver wt. (g)	Gonad wt. (g)	Total wt. (g)	Wt/Length
San Pablo Bay	5179	•	•	•	•	•	•	•	•	•
San Pablo Bay	5180	•	•	•	•	•	•	•	•	•
San Pablo Bay	5181	•	•	•	•	•	•	•	•	•
San Pablo Bay	5182	Nov	F	Immat	29	2.41	6.3	2.9	587	20.24
San Pablo Bay	5183	•	•	•	•	•	•	•	•	•
San Pablo Bay	5184	•	•	•	•	•	•	•	•	•
San Pablo Bay	5185	Nov	F	immat	28.5	2.42	5.3	3.8	560	19.65
San Pablo Bay	5186	•	•	•	•	•	•	•	•	•
San Pablo Bay	5187	•	•	•	•	•	•	•	•	•
San Pablo Bay	5188	•	•	•	•	•	•	•	•	•
San Pablo Bay	5189	•	•	•	•	•	•	•	•	•
San Pablo Bay	5190	•	•	•	•	•	•	•	•	•
San Pablo Bay	5191	Nov	M	immat	20.6	2.35	2	0.9	205	9.95
San Pablo Bay	5192	•	•	•	•	•	•	•	•	•
San Pablo Bay	5193	•	•	•	•	•	•	•	•	•
San Pablo Bay	5194	•	•	•	•	•	•	•	•	•
San Pablo Bay	5195	Nov	M	immat	33	2.04	12	0.6	733	22.21
San Pablo Bay	5196	•	•	•	•	•	•	•	•	•
Vallejo	5197	•	•	•	•	•	•	•	•	•
Vallejo	5198	Nov	M	mat	31.8	2	11.1	3.5	642	20.19
Vallejo	5199	•	•	•	•	•	•	•	•	•
Vallejo	5200	Nov	M	mat	25.8	2.35	5.6	2.5	404	15.66
Vallejo	5201	Nov	F	mat	51	1.65	39.7	71.7	2192	42.98
Vallejo	5202	Nov	F	immat	53	1.78	13.9	35.9	2657	50.13
Vallejo	5203	Nov	M	mat	25.7	2.26	6.3	2.3	384	14.94
Vallejo	5204	Nov	F	immat	24.6	2.38	3.5	1.3	355	14.43
Vallejo	5205	Nov	F	mat	30.2	2.58	9.7	14.4	712	23.58
Vallejo	5206	•	•	•	•	•	•	•	•	•
Vallejo	5207	Nov	F	immat	24.5	2.18	3.5	1.6	317	12.94
Vallejo	5208	Nov	F	immat	24.8	2.06	3.5	2	314	12.86
Vallejo	5209	Nov	M	mat	23.5	2.32	4.1	3.1	301	12.81
Vallejo	5210		•	•	•	•	•	•	•	•
Vallejo	5211	•	•	•	•	•	•	•	•	•
Vallejo	5212	•	•	•	•	•	•	•	•	•
Oakland	5213	Nov	F	mat	33.6	2.42	13.7	23.3	918	27.32
Oakland	5214	•	•	•	•	•	•	•	•	•
Oakland	5215	Nov	F	immat	22.3	1.95	2.6	1.1	216	9.69
Oakland	5216	Nov	F	mat	37.5	2.65	27	64	1397	37.25
Oakland	5217	Nov	F	immat	22	2.22	1.9	1.2	236	10.73
Oakland	5218	Nov	F	mat	42.4	1.88	14.7	20	1431	33.75
Oakland	5219	Nov	F	immat	28	2.2	3.5	2.5	482	17.21
Oakland	5220	Nov	M	mat	23.5	2.74	4.3	3.1	358	15.15
Oakland	5221	Nov	F	mat	41	2.52	31.5	212	1740	42.44
Russian River	5222	Nov	F	mat	44	2.4	40.8	173	2047	46.52
Russian River	5223	Nov	F	mat	42.3	2.27	35	113	1715	40.54
Russian River	5224	Nov	F	mat	38.5	2.01	16.8	32.8	1146	29.77
Russian River	5225	Nov	F	mat	36	2.31	17.2	40.8	1076	29.89
Russian River	5226	Nov	F	immat	33.5	2.24	11.3	7.3	842	25.13
Russian River	5227	Nov	F	immat	37.5	1.77	9.3	6.3	932	24.85
Russian River	5228	Nov	F	immat	28	2.03	4.6	3.2	445	15.89
Russian River	5229	Nov	M	mat	38.5	2.09	15.1	29.5	1191	30.94
Russian River	5230	Nov	F	immat	33.5	2.19	8.1	3.2	824	24.6
Russian River	5231	Nov	F	immat	31	2.1	7.3	4	627	20.23
Russian River	5232	Nov	M	mat	40.5	1.95	18.6	37	1293	31.93
Russian River	5233	Nov	M	mat	32.5	2.3	9.4	22.2	790	24.31
Russian River	5234	Nov	M	mat	37.5	2.4	7.4	35.2	1267	33.79
Russian River	5235	•	•	•	•	•	•	•	•	•
Russian River	5236	Nov	M	mat	35	2.35	13.3	19.4	1007	28.77
Russian River	5237	•	•	•	•	•	•	•	•	•

Site	Sample No.	Date	Sex	Maturity	Std. Length	Condition factor (w/lxlxl)	Liver wt. (g)	Gonad wt. (g)	Total wt. (g)	Wt/Length
Russian River	5238	•	•	•	•	•	•	•	•	•
Russian River	5239	•	•	•	•	•	•	•	•	•
Russian River	5240	•	•	•	•	•	•	•	•	•
Russian River	5241	•	•	•	•	•	•	•	•	•
Russian River	5242	•	•	•	•	•	•	•	•	•
Russian River	5243	•	•	•	•	•	•	•	•	•
Russian River	5244	•	F	mat	46	2.2	43.5	93.8	2141	46.54
Russian River	5245	•	F	mat	40	2.31	•	80	1477	36.93
Russian River	5246	•	•	•	•	•	•	•	•	•
Russian River	5247	•	•	•	•	•	•	•	•	•
Russian River	5248	•	•	•	•	•	•	•	•	•
Russian River	5249	•	•	•	•	•	•	•	•	•
Russian River	5250	•	•	•	•	•	•	•	•	•
Russian River	5251	•	•	•	•	•	•	•	•	•
Russian River	5252	•	•	•	•	•	•	•	•	•
Berkeley	5253	Jan.	F	mat	43	2.436	•	•	1937	45.05
Berkeley	5254	Jan.	F	mat	31.5	•	•	•	•	•
Berkeley	5255	Jan.	F	mat	35.7	2.824	•	•	1285	35.99
Berkeley	5256	Jan.	•	•	•	•	•	•	•	•
Berkeley	5257	Jan.	F	mat	43	•	•	•	•	•
Berkeley	5258	Jan.	•	•	•	•	•	•	•	•
Berkeley	5260	Jan.	•	•	•	•	•	•	•	•
Berkeley	5261	Jan.	•	•	•	•	•	•	•	•
Berkeley	5263	Jan.	F	mat	39	2.331	•	•	1415	36
Vallejo	5264	Jan.	F	mat	39.8	•	•	•	•	•
Vallejo	5265	Jan.	•	•	•	•	•	•	•	•
Vallejo	5266	Jan.	•	•	•	•	•	•	•	•
Oakland	5267	Jan.	•	•	•	•	•	•	•	•
Oakland	5268	Jan.	F	mat	43	2.199	•	•	1748	40.65
Oakland	5269	Jan.	•	•	•	•	•	•	•	•
Santa Cruz	5275	Jan.	F	mat	49	•	•	•	•	•
Santa Cruz	5276	Jan.	F	mat	41.2	2.202	•	•	1540	37.38
Santa Cruz	5278	Jan.	F	mat	42.5	•	•	•	•	•
Santa Cruz	5279	Jan.	F	mat	43.2	•	•	•	•	•
Santa Cruz	5280	Jan.	F	mat	41.3	•	•	•	•	•
Santa Cruz	5311	Jan.	F	mat	40	2.65	•	•	1696	42.4
Santa Cruz	5312	Jan.	F	mat	40	•	•	•	•	•
Santa Cruz	5313	Jan.	•	•	•	•	•	•	•	•
Santa Cruz	5314	Jan.	F	mat	45.5	•	•	•	•	•
Santa Cruz	5315	Jan.	F	mat	43.5	•	•	•	•	•
Santa Cruz	5316	Jan.	F	mat	42.8	3.022	•	•	2369	55.35
Santa Cruz	5317	Jan.	F	mat	48.5	•	•	•	•	•
Santa Cruz	5318	Jan.	F	mat	44	2.86	•	•	2436	55.36
Berkeley	5319	Jan.	F	mat	43	2.376	•	•	1889	43.93
Berkeley	5320	Jan.	•	•	•	•	•	•	•	•

Site	Sample No.	Date	Liver/Body wt x 100	Gonad/Body wt x 100	GSI gonad wt./ (total wt - gonad wt) x 1,000	HSI liver wt./(total wt - liver wt) x 1,000
Berkeley	5120	Nov	1.06	0.32	3.18	10.63
Berkeley	5121	•	•	•	•	•
Berkeley	5122	•	•	•	•	•
Berkeley	5123	•	•	•	•	•
Berkeley	5124	•	•	•	•	•
Berkeley	5125	•	•	•	•	•
Berkeley	5126	Nov	1.19	4.68	49.15	11.86
Berkeley	5127	Nov	0.9	1.03	10.44	8.97
Berkeley	5128	•	•	•	•	•
Berkeley	5129	•	•	•	•	•
Berkeley	5130	Nov	0.99	1.03	10.44	9.86
Berkeley	5131	•	•	•	•	•
Berkeley	5132	•	•	•	•	•
Berkeley	5133	Nov	1.28	2.2	22.52	12.82
Berkeley	5134	•	•	•	•	•
Berkeley	5135	Nov	1.28	2.63	27.02	12.77
Berkeley	5136	Nov	1.93	6.63	70.99	19.33
Berkeley	5137	Nov	0.99	1.03	10.43	9.88
Berkeley	5138	•	•	•	•	•
Berkeley	5139	Nov	1.74	8.14	88.61	17.41
Berkeley	5140	Nov	1.52	1.77	17.99	15.15
Berkeley	5141	•	•	•	•	•
Berkeley	5142	Nov	1.14	0.36	3.61	11.4
Berkeley	5143	•	•	•	•	•
Berkeley	5144	•	•	•	•	•
Berkeley	5145	•	•	•	•	•
Berkeley	5146	Nov	1.05	0.18	1.82	10.55
Berkeley	5147	•	•	•	•	•
Berkeley	5148	•	•	•	•	•
Berkeley	5149	Nov	0.89	0.59	5.89	8.91
Berkeley	5150	Nov	1.71	5.2	54.89	17.11
Vallejo	5151	Nov	1.07	0.39	3.92	10.73
Vallejo	5152	Nov	0.85	0.82	8.28	8.48
Vallejo	5153	Nov	4.03	6.69	71.7	40.29
Vallejo	5154	Nov	1.12	0.62	6.22	11.2
San Pablo Bay	5155	Nov	1.68	2.78	28.64	16.77
San Pablo Bay	5156	Nov	1.43	0.73	7.36	14.33
San Pablo Bay	5157	Nov	1.64	0.98	9.88	16.38
San Pablo Bay	5158	Nov	1.49	0.99	10.01	14.86
San Pablo Bay	5159	Nov	0.98	0.05	0.52	9.84
San Pablo Bay	5160	Nov	1.19	0.57	5.71	11.85
San Pablo Bay	5161	Nov	1.12	0.49	4.96	11.16
San Pablo Bay	5162	•	•	•	•	•
San Pablo Bay	5163	Nov	1.04	0.65	6.57	10.44
San Pablo Bay	5164	Nov	2.21	1.98	20.23	22.07
San Pablo Bay	5165	Nov	1.93	1.61	16.41	19.28
Oakland	5166	Nov	1.25	1.23	12.41	12.46
Oakland	5167	Nov	0.96	0.59	5.95	9.61
Oakland	5168	Nov	1.09	0.72	7.2	10.9
Oakland	5169	Nov	0.86	0.29	2.96	8.55
Oakland	5170	•	•	•	•	•
Oakland	5171	Nov	2.57	7.21	77.72	25.69
Oakland	5172	Nov	1.25	2.75	28.3	12.46
Oakland	5173	•	•	•	•	•
Oakland	5174	•	•	•	•	•
Oakland	5175	•	•	•	•	•
Oakland	5176	Nov	0.94	0.96	9.71	9.39
San Pablo Bay	5177	•	•	•	•	•
San Pablo Bay	5178	•	•	•	•	•

Site	Sample No.	Date	Liver/Body wt x 100	Gonad/Body wt x 100	GSI gonad wt./ (total wt - gonad wt) x 1,000	HSI liver wt./(total wt - liver wt) x 1,000
San Pablo Bay	5179	•	•	•	•	•
San Pablo Bay	5180	•	•	•	•	•
San Pablo Bay	5181	•	•	•	•	•
San Pablo Bay	5182	Nov	1.07	0.49	4.96	10.73
San Pablo Bay	5183	•	•	•	•	•
San Pablo Bay	5184	•	•	•	•	•
San Pablo Bay	5185	Nov	0.95	0.68	6.83	9.46
San Pablo Bay	5186	•	•	•	•	•
San Pablo Bay	5187	•	•	•	•	•
San Pablo Bay	5188	•	•	•	•	•
San Pablo Bay	5189	•	•	•	•	•
San Pablo Bay	5190	•	•	•	•	•
San Pablo Bay	5191	Nov	0.98	0.44	4.41	9.76
San Pablo Bay	5192	•	•	•	•	•
San Pablo Bay	5193	•	•	•	•	•
San Pablo Bay	5194	•	•	•	•	•
San Pablo Bay	5195	Nov	1.64	0.08	0.82	16.37
San Pablo Bay	5196	•	•	•	•	•
Vallejo	5197	•	•	•	•	•
Vallejo	5198	Nov	1.73	0.55	5.48	17.29
Vallejo	5199	•	•	•	•	•
Vallejo	5200	Nov	1.39	0.62	6.23	13.86
Vallejo	5201	Nov	1.81	3.27	33.82	18.11
Vallejo	5202	Nov	0.52	1.35	13.7	5.23
Vallejo	5203	Nov	1.64	0.6	6.03	16.41
Vallejo	5204	Nov	0.99	0.37	3.68	9.86
Vallejo	5205	Nov	1.36	2.02	20.64	13.62
Vallejo	5206	•	•	•	•	•
Vallejo	5207	Nov	1.1	0.5	5.07	11.04
Vallejo	5208	Nov	1.11	0.64	6.41	11.15
Vallejo	5209	Nov	1.36	1.03	10.41	13.62
Vallejo	5210		•	•	•	•
Vallejo	5211	•	•	•	•	•
Vallejo	5212	•	•	•	•	•
Oakland	5213	Nov	1.49	2.54	26.04	14.92
Oakland	5214	•	•	•	•	•
Oakland	5215	Nov	1.2	0.51	5.12	12.04
Oakland	5216	Nov	1.93	4.58	48.01	19.33
Oakland	5217	Nov	0.81	0.51	5.11	8.05
Oakland	5218	Nov	1.03	1.4	14.17	10.27
Oakland	5219	Nov	0.72	0.52	5.21	7.16
Oakland	5220	Nov	1.21	0.87	8.78	12.08
Oakland	5221	Nov	1.81	12.18	138.74	18.1
Russian River	5222	Nov	1.99	8.45	92.32	19.93
Russian River	5223	Nov	2.04	6.59	70.54	20.41
Russian River	5224	Nov	1.45	2.86	29.46	14.49
Russian River	5225	Nov	1.6	3.79	39.41	15.99
Russian River	5226	Nov	1.34	0.87	8.75	13.42
Russian River	5227	Nov	1	0.68	6.81	9.98
Russian River	5228	Nov	1.03	0.72	7.24	10.34
Russian River	5229	Nov	1.27	2.48	25.4	12.68
Russian River	5230	Nov	0.98	0.39	3.9	9.83
Russian River	5231	Nov	1.16	0.64	6.42	11.64
Russian River	5232	Nov	1.44	2.86	29.46	14.39
Russian River	5233	Nov	1.19	2.81	28.91	11.9
Russian River	5234	Nov	0.58	2.78	28.58	5.84
Russian River	5235	•	•	•	•	•
Russian River	5236	Nov	1.32	1.93	19.64	13.21
Russian River	5237	•	•	•	•	•

Site	Sample No.	Date	Liver/Body wt x 100	Gonad/Body wt x 100	GSI gonad wt./ (total wt - gonad wt) x 1,000	HSI liver wt./(total wt - liver wt) x 1,000
Russian River	5238	•	•	•	•	•
Russian River	5239	•	•	•	•	•
Russian River	5240	•	•	•	•	•
Russian River	5241	•	•	•	•	•
Russian River	5242	•	•	•	•	•
Russian River	5243	•	•	•	•	•
Russian River	5244	•	2.03	4.38	45.82	20.32
Russian River	5245	•	0	5.42	57.27	0
Russian River	5246	•	•	•	•	•
Russian River	5247	•	•	•	•	•
Russian River	5248	•	•	•	•	•
Russian River	5249	•	•	•	•	•
Russian River	5250	•	•	•	•	•
Russian River	5251	•	•	•	•	•
Russian River	5252	•	•	•	•	•
Berkley	5253	Jan.	•	•	•	•
Berkley	5254	Jan.	•	•	•	•
Berkley	5255	Jan.	•	•	•	•
Berkley	5256	Jan.	•	•	•	•
Berkley	5257	Jan.	•	•	•	•
Berkley	5258	Jan.	•	•	•	•
Berkley	5260	Jan.	•	•	•	•
Berkley	5261	Jan.	•	•	•	•
Berkley	5263	Jan.	•	•	•	•
Vallejo	5264	Jan.	•	•	•	•
Vallejo	5265	Jan.	•	•	•	•
Vallejo	5266	Jan.	•	•	•	•
Oakland	5267	Jan.	•	•	•	•
Oakland	5268	Jan.	•	•	•	•
Oakland	5269	Jan.	•	•	•	•
Santa Cruz	5275	Jan.	•	•	•	•
Santa Cruz	5276	Jan.	•	•	•	•
Santa Cruz	5278	Jan.	•	•	•	•
Santa Cruz	5279	Jan.	•	•	•	•
Santa Cruz	5280	Jan.	•	•	•	•
Santa Cruz	5311	Jan.	•	•	•	•
Santa Cruz	5312	Jan.	•	•	•	•
Santa Cruz	5313	Jan.	•	•	•	•
Santa Cruz	5314	Jan.	•	•	•	•
Santa Cruz	5315	Jan.	•	•	•	•
Santa Cruz	5316	Jan.	•	•	•	•
Santa Cruz	5317	Jan.	•	•	•	•
Santa Cruz	5318	Jan.	•	•	•	•
Berkley	5319	Jan.	•	•	•	•
Berkley	5320	Jan.	•	•	•	•

Site	Sample No.	Date	AHH activity pmol/mg/min	AHH with 7,8-BF pmol/mg/min	Egg Stage	Testosterone ng/ml	Vitellogenin ug/P/ml	Estradiol ng/ml
Berkeley	5120	Nov	50	11	0	1.17	-	0.3
Berkeley	5121	•	•	•	0	•	-	•
Berkeley	5122	•	•	•	0	•	-	•
Berkeley	5123	•	•	•	0	•	-	•
Berkeley	5124	•	•	•	0	•	-	•
Berkeley	5125	•	•	•	0	•	-	•
Berkeley	5126	Nov	41	13	4	0.14	19.43	6.81
Berkeley	5127	Nov	42	9	0	0.1	2.86	1.03
Berkeley	5128	•	•	•	0	•	-	•
Berkeley	5129	•	•	•	0	•	-	•
Berkeley	5130	Nov	111	43	0	0.1	2.67	3.38
Berkeley	5131	•	•	•	0	•	-	•
Berkeley	5132	•	•	•	0	•	-	•
Berkeley	5133	Nov	114	50	0	1.29	2.55	0.44
Berkeley	5134	•	•	•	0	•	-	•
Berkeley	5135	Nov	103	35	4	0.14	10.9	7.98
Berkeley	5136	Nov	96	24	5	0.07	14.16	5.8
Berkeley	5137	Nov	39	13	0	0.09	2.98	1.28
Berkeley	5138	•	•	•	0	•	-	•
Berkeley	5139	Nov	49	17	5	0.24	20.83	11.47
Berkeley	5140	Nov	37	13	0	1.63	4.07	0.34
Berkeley	5141	•	•	•	0	•	-	•
Berkeley	5142	Nov	86	16	0	0.64	3.21	0.33
Berkeley	5143	•	•	•	0	•	-	•
Berkeley	5144	•	•	•	0	•	-	•
Berkeley	5145	•	•	•	0	•	-	•
Berkeley	5146	Nov	165	50	0	0.28	4.46	0.08
Berkeley	5147	•	•	•	0	•	-	•
Berkeley	5148	•	•	•	0	•	-	•
Berkeley	5149	Nov	89	39	0	•	-	•
Berkeley	5150	Nov	79	14	5	0.12	20.52	16.77
Vallejo	5151	Nov	97	39	0	0.11	3.68	0.72
Vallejo	5152	Nov	33	11	0	0.09	2.05	0.28
Vallejo	5153	Nov	56	18	0	2.58	2.98	0.32
Vallejo	5154	Nov	170	23	0	1.37	2.82	0.26
San Pablo Bay	5155	Nov	86	45	0	0.14	12.58	8.71
San Pablo Bay	5156	Nov	5	1.4	0	1.56	3.52	0.58
San Pablo Bay	5157	Nov	193	44	0	1.6	3.76	0.2
San Pablo Bay	5158	Nov	•	•	0	1.48	3.1	0.22
San Pablo Bay	5159	Nov	83	39	0	0.17	3.02	0.13
San Pablo Bay	5160	Nov	163	•	0	0.12	1.74	0.73
San Pablo Bay	5161	Nov	98	•	0	0.06	1.35	0.58
San Pablo Bay	5162	•	•	•	0	•	-	•
San Pablo Bay	5163	Nov	126	•	0	0.65	1.58	0.67
San Pablo Bay	5164	Nov	49	•	0	3.67	1.51	0.2
San Pablo Bay	5165	Nov	80	•	0	2.82	4.34	0.49
Oakland	5166	Nov	356	31	1	•	-	•
Oakland	5167	Nov	178	111	0	0.12	4.07	1.58
Oakland	5168	Nov	587	45	1	0.21	3.29	1.01
Oakland	5169	Nov	209	•	0	•	-	•
Oakland	5170	•	•	•	0	•	-	•
Oakland	5171	Nov	40	24	5	0.19	17.57	1.72
Oakland	5172	Nov	166	31	4	•	-	•
Oakland	5173	•	•	•	0	•	-	•
Oakland	5174	•	•	•	0	•	-	•
Oakland	5175	•	•	•	0	•	-	•
Oakland	5176	Nov	615	46	1	0.73	0.98	0.58
San Pablo Bay	5177	•	•	•	0	•	-	•
San Pablo Bay	5178	•	•	•	0	•	-	•

Site	Sample No.	Date	AHH activity pmol/mg/min	AHH with 7,8-BF pmol/mg/min	Egg Stage	Testosterone ng/ml	Vitellogenin ug/P/ml	Estradiol ng/ml
San Pablo Bay	5179	•	•	•	0	•	-	•
San Pablo Bay	5180	•	•	•	0	•	-	•
San Pablo Bay	5181	•	•	•	0	•	-	•
San Pablo Bay	5182	Nov	266	60	0	0.12	1.66	0.63
San Pablo Bay	5183	•	•	•	0	•	-	•
San Pablo Bay	5184	•	•	•	0	•	-	•
San Pablo Bay	5185	Nov	193	23	0	0.13	1.96	0.53
San Pablo Bay	5186	•	•	•	0	•	-	•
San Pablo Bay	5187	•	•	•	0	•	-	•
San Pablo Bay	5188	•	•	•	0	•	-	•
San Pablo Bay	5189	•	•	•	0	•	-	•
San Pablo Bay	5190	•	•	•	0	•	-	•
San Pablo Bay	5191	Nov	337	42	0	1.22	-	0.23
San Pablo Bay	5192	•	•	•	0	•	-	•
San Pablo Bay	5193	•	•	•	0	•	-	•
San Pablo Bay	5194	•	•	•	0	•	-	•
San Pablo Bay	5195	Nov	66	20	0	0.74	1.81	0.15
San Pablo Bay	5196	•	•	•	0	•	-	•
Vallejo	5197	•	•	•	0	•	-	•
Vallejo	5198	Nov	449	134	0	•	-	•
Vallejo	5199	•	•	•	0	•	-	•
Vallejo	5200	Nov	74	41	0	2.27	1.88	0.27
Vallejo	5201	Nov	268	58	4	0.13	8.61	3.13
Vallejo	5202	Nov	94	27	1	0.82	-	0.69
Vallejo	5203	Nov	958	79	0	2.24	1.81	0.64
Vallejo	5204	Nov	381	112	0	0.07	1.81	0.8
Vallejo	5205	Nov	79	26	4	•	-	•
Vallejo	5206	•	•	•	0	•	-	•
Vallejo	5207	Nov	437	72	0	0.09	2.03	0.48
Vallejo	5208	Nov	157	33	0	0.47	-	0.67
Vallejo	5209	Nov	252	91	0	3.44	1.66	0.12
Vallejo	5210		•	•	•	•	•	•
Vallejo	5211	•	•	•	0	•	-	•
Vallejo	5212	•	•	•	0	•	-	•
Oakland	5213	Nov	443	102	4	0.18	13.4	8.57
Oakland	5214	•	•	•	0	•	-	•
Oakland	5215	Nov	773	93	0	0.09	0.91	•
Oakland	5216	Nov	148	28	5	0.97	12.13	19.59
Oakland	5217	Nov	380	27	0	0.18	0.68	0.37
Oakland	5218	Nov	160	103	1	0.14	1.13	0.26
Oakland	5219	Nov	88	40	0	0.08	1.28	0.37
Oakland	5220	Nov	75	16	0	1.62	1.58	0.81
Oakland	5221	Nov	89	19	6	0.41	18.49	24.16
Russian River	5222	Nov	234	28	7	0.3	13.62	10.24
Russian River	5223	Nov	31	16	7	0.21	16.09	9.12
Russian River	5224	Nov	31	12	5	0.1	3.38	1.08
Russian River	5225	Nov	17	12	5	0.27	15.12	2.74
Russian River	5226	Nov	107	46	0	0.04	2.89	0.5
Russian River	5227	Nov	57	22	0	0.11	3.3	0.33
Russian River	5228	Nov	130	41	0	0.14	3.46	0.33
Russian River	5229	Nov	137	46	0	0.35	3.87	0.18
Russian River	5230	Nov	15	9	0	0.15	2.8	0.22
Russian River	5231	Nov	65	31	0	0.14	3.13	0.53
Russian River	5232	Nov	33	28	0	0.42	3.54	0.29
Russian River	5233	Nov	7	12	0	0.37	3.05	0.21
Russian River	5234	Nov	56	30	0	1.07	2.8	0.57
Russian River	5235	•	•	•	0	•	-	•
Russian River	5236	Nov	32	24	0	0.28	2.31	0.44
Russian River	5237	•	•	•	0	•	-	•

Site	Sample No.	Date	AHH activity pmol/mg/min	AHH with 7,8-BF pmol/mg/min	Egg Stage	Testosterone ng/ml	Vitellogenin ug/P/ml	Estradiol ng/ml
Russian River	5238	•	•	•	0	•	-	•
Russian River	5239	•	•	•	0	•	-	•
Russian River	5240	•	•	•	0	•	-	•
Russian River	5241	•	•	•	0	•	-	•
Russian River	5242	•	•	•	0	•	-	•
Russian River	5243	•	•	•	0	•	-	•
Russian River	5244	•	19	18	5	0.17	19.25	11.14
Russian River	5245	•	•	•	6	0.18	9.04	12.19
Russian River	5246	•	•	•	•	•	•	•
Russian River	5247	•	•	•	•	•	•	•
Russian River	5248	•	•	•	•	•	•	•
Russian River	5249	•	•	•	•	•	•	•
Russian River	5250	•	•	•	•	•	•	•
Russian River	5251	•	•	•	•	•	•	•
Russian River	5252	•	•	•	•	•	•	•
Berkeley	5253	Jan.	27	8	0	0.47	-	20
Berkeley	5254	Jan.	•	•	•	•	•	•
Berkeley	5255	Jan.	0	0	0	1.3	-	25
Berkeley	5256	Jan.	•	•	•	•	•	•
Berkeley	5257	Jan.	•	•	•	•	•	•
Berkeley	5258	Jan.	•	•	•	•	•	•
Berkeley	5260	Jan.	•	•	•	•	•	•
Berkeley	5261	Jan.	•	•	•	•	•	•
Berkeley	5263	Jan.	57	20	0	1.09	•	19
Vallejo	5264	Jan.	•	•	•	•	•	•
Vallejo	5265	Jan.	•	•	•	•	•	•
Vallejo	5266	Jan.	•	•	•	•	•	•
Oakland	5267	Jan.	•	•	•	•	•	•
Oakland	5268	Jan.	10	8	0	1.42	•	26
Oakland	5269	Jan.	•	•	•	•	•	•
Santa Cruz	5275	Jan.	•	•	•	•	•	•
Santa Cruz	5276	Jan.	63	13	0	0.21	•	11
Santa Cruz	5278	Jan.	•	•	•	•	•	•
Santa Cruz	5279	Jan.	•	•	•	•	•	•
Santa Cruz	5280	Jan.	•	•	•	•	•	•
Santa Cruz	5311	Jan.	•	•	0	2.76	•	9.1
Santa Cruz	5312	Jan.	•	•	•	•	•	•
Santa Cruz	5313	Jan.	•	•	•	•	•	•
Santa Cruz	5314	Jan.	•	•	•	•	•	•
Santa Cruz	5315	Jan.	•	•	•	•	•	•
Santa Cruz	5316	Jan.	•	•	0	1.41	-	50
Santa Cruz	5317	Jan.	•	•	•	•	•	•
Santa Cruz	5318	Jan.	•	•	0	1.49	•	15
Berkeley	5319	Jan.	•	•	0	1.09	•	17
Berkeley	5320	Jan.	•	•	•	•	•	•

Site	Sample No.	Date	Micronuclei (cnts/1,000cells) Detached	Attached	Nuclear Pleomorphism Rating *	Cytochrome P450 nmol/mg	Cytochrome b5 nmol/mg
Berkeley	5120	Nov	2	0	2	0.23	•
Berkeley	5121	•	0	0	1	•	•
Berkeley	5122	•	0	1	2	•	•
Berkeley	5123	•	0.5	0.5	1	•	•
Berkeley	5124	•	1.5	0.5	2	•	•
Berkeley	5125	•	0.5	0	1	•	•
Berkeley	5126	Nov	1.5	0	1	•	•
Berkeley	5127	Nov	2	0	1	0.22	•
Berkeley	5128	•	0.5	2	2	•	•
Berkeley	5129	•	0.5	1	1	•	•
Berkeley	5130	Nov	3	3.5	3	0.21	•
Berkeley	5131	•	0	0.5	1	•	•
Berkeley	5132	•	0.5	0	1	•	•
Berkeley	5133	Nov	1.5	5.5	3	0.16	•
Berkeley	5134	•	0	0	1	•	•
Berkeley	5135	Nov	1	1.5	2	0.12	•
Berkeley	5136	Nov	1	2.5	3	0.09	•
Berkeley	5137	Nov	0	0.5	1	0.24	•
Berkeley	5138	•	0.5	5	3	•	•
Berkeley	5139	Nov	1	0.5	2	0.12	•
Berkeley	5140	Nov	0.5	0	1	0.21	•
Berkeley	5141	•	1.5	0.5	1	•	•
Berkeley	5142	Nov	1.5	0.5	1	0.15	•
Berkeley	5143	•	0	0.5	1	•	•
Berkeley	5144	•	0	0	1	•	•
Berkeley	5145	•	0.5	0	1	•	•
Berkeley	5146	Nov	0	0.5	1	0.13	•
Berkeley	5147	•	1	0	1	•	•
Berkeley	5148	•	0	1.5	2	•	•
Berkeley	5149	Nov	0.5	1	1	0.14	•
Berkeley	5150	Nov	2	0.5	2	0.11	•
Vallejo	5151	Nov	0	1.5	2	0.109	•
Vallejo	5152	Nov	2	0.5	2	0.038	•
Vallejo	5153	Nov	1	1	2	0.119	•
Vallejo	5154	Nov	1	1.5	1	0.165	•
San Pablo Bay	5155	Nov	0.5	0.5	1	0.27	•
San Pablo Bay	5156	Nov	1.5	0.5	2	0.066	•
San Pablo Bay	5157	Nov	1	0	1	0.114	•
San Pablo Bay	5158	Nov	1	1	1	0.12	•
San Pablo Bay	5159	Nov	1.5	1	1	0.071	•
San Pablo Bay	5160	Nov	3	1.5	2	0.056	•
San Pablo Bay	5161	Nov	-	26.9	-	0.089	•
San Pablo Bay	5162	•	0	0.5	1	•	•
San Pablo Bay	5163	Nov	-	0	-	0.104	•
San Pablo Bay	5164	Nov	1.5	1	1	0.076	•
San Pablo Bay	5165	Nov	0.5	0.5	1	0.042	•
Oakland	5166	Nov	1	3.5	2	0.146	0.045
Oakland	5167	Nov	0	0	1	0.228	0.038
Oakland	5168	Nov	0.5	0.5	2	0.114	0.028
Oakland	5169	Nov	0.5	2.5	2	0.21	•
Oakland	5170	•	0.5	0	1	•	•
Oakland	5171	Nov	0	0.5	1	0.072	0.102
Oakland	5172	Nov	0	0	1	0.19	0.03
Oakland	5173	•	0.5	0	1	•	•
Oakland	5174	•	0.5	0	1	•	•
Oakland	5175	•	0	0	1	•	•
Oakland	5176	Nov	1	0	1	0.213	0.102
San Pablo Bay	5177	•	0.5	0	1	•	•
San Pablo Bay	5178	•	0	0	1	•	•

Site	Sample No.	Date	Micronuclei (cnts/1,000cells) Detached	Attached	Nuclear Pleomorphism Rating *	Cytochrome P450 nmol/mg	Cytochrome b5 nmol/mg
San Pablo Bay	5179	•	1.5	1.5	2	•	•
San Pablo Bay	5180	•	0	0	1	•	•
San Pablo Bay	5181	•	0.5	0	1	•	•
San Pablo Bay	5182	Nov	1	0.5	1	0.149	•
San Pablo Bay	5183	•	0.5	0	1	•	•
San Pablo Bay	5184	•	0.5	3.5	2	•	•
San Pablo Bay	5185	Nov	0	0.5	2	0.091	•
San Pablo Bay	5186	•	0	1	1	•	•
San Pablo Bay	5187	•	1	0.5	2	•	•
San Pablo Bay	5188	•	0	0	1	•	•
San Pablo Bay	5189	•	0	0.5	1	•	•
San Pablo Bay	5190	•	0.5	2	3	•	•
San Pablo Bay	5191	Nov	0.5	1	2	0.127	•
San Pablo Bay	5192	•	0	0	2	•	•
San Pablo Bay	5193	•	0	0	1	•	•
San Pablo Bay	5194	•	0	0.5	1	•	•
San Pablo Bay	5195	Nov	2	0	1	0.236	•
San Pablo Bay	5196	•	0.5	0.5	2	•	•
Vallejo	5197	•	0	0	1	•	•
Vallejo	5198	Nov	0.5	0	1	0.211	•
Vallejo	5199	•	0.5	0.5	2	•	•
Vallejo	5200	Nov	0	0.5	1	0.15	•
Vallejo	5201	Nov	0.5	0	1	0.098	•
Vallejo	5202	Nov	5.5	1.5	1	0.048	•
Vallejo	5203	Nov	1.5	0.5	2	0.195	•
Vallejo	5204	Nov	2	0.5	1	0.2	•
Vallejo	5205	Nov	0	0.5	1	0.083	•
Vallejo	5206	•	0	1.5	2	•	•
Vallejo	5207	Nov	-	-	-	0.161	•
Vallejo	5208	Nov	0.5	0	1	0.095	•
Vallejo	5209	Nov	1.5	0.5	2	0.217	•
Vallejo	5210		0	0	1	•	•
Vallejo	5211	•	1.5	0	2	0.149	•
Vallejo	5212	•	0.5	0	1	•	•
Oakland	5213	Nov	1	3.5	3	0.241	0.028
Oakland	5214	•	0	1.5	1	•	•
Oakland	5215	Nov	0	1.5	1	0.171	0.049
Oakland	5216	Nov	1	7	3	0.091	0.015
Oakland	5217	Nov	0	0	1	0.12	0.031
Oakland	5218	Nov	0.5	0	2	0.256	0.078
Oakland	5219	Nov	0	0	1	0.21	0.099
Oakland	5220	Nov	0	0	1	0.11	•
Oakland	5221	Nov	0	0	1	0.15	0.102
Russian River	5222	Nov	0	0	1	0.185	0.04
Russian River	5223	Nov	0	0	1	0.144	0.033
Russian River	5224	Nov	0	0	1	0.107	0.028
Russian River	5225	Nov	0	0	1	0.112	0.034
Russian River	5226	Nov	0	0	1	0.088	0.027
Russian River	5227	Nov	0	0	1	0.126	0.057
Russian River	5228	Nov	0	1	1	0.154	0.104
Russian River	5229	Nov	-	-	-	0.23	•
Russian River	5230	Nov	0	0	1	0.038	0.039
Russian River	5231	Nov	0	0	1	0.128	0.039
Russian River	5232	Nov	0	0.5	1	0.17	•
Russian River	5233	Nov	0	0.5	1	0.1	•
Russian River	5234	Nov	0	0	1	0.1	•
Russian River	5235	•	0	0	1	•	•
Russian River	5236	Nov	0	0	1	0.19	•
Russian River	5237	•	0	0.5	1	•	•

Site	Sample No.	Date	Micronuclei (cnts/1,000cells)		Nuclear Pleomorphism	Cytochrome	Cytochrome b5
			Detached	Attached	Rating *	P450 nmol/mg	nmol/mg
Russian River	5238	•	0	0	1	•	•
Russian River	5239	•	1	1	1	•	•
Russian River	5240	•	0	0.5	1	•	•
Russian River	5241	•	0.5	0	1	•	•
Russian River	5242	•	1	1.5	1	•	•
Russian River	5243	•	1.5	1	2	•	•
Russian River	5244	•	0	0	1	0.06	0.059
Russian River	5245	•	0	0	1	•	•
Russian River	5246	•	0	0	1	•	•
Russian River	5247	•	0	0	2	•	•
Russian River	5248	•	0	0.5	1	•	•
Russian River	5249	•	0	0.5	1	•	•
Russian River	5250	•	0	0	1	•	•
Russian River	5251	•	0	1	1	•	•
Russian River	5252	•	0	0	1	•	•
Berkley	5253	Jan.	0	0.5	3	0.075	0.012
Berkley	5254	Jan.	0	1	2	•	•
Berkley	5255	Jan.	0.5	11	3	•	0.013
Berkley	5256	Jan.	0.5	0	1	•	•
Berkley	5257	Jan.	0	1.5	3	•	•
Berkley	5258	Jan.	0	0	2	•	•
Berkley	5260	Jan.	0	0.5	1	•	•
Berkley	5261	Jan.	0.5	0	1	•	•
Berkley	5263	Jan.	-	-	-	0.151	0.025
Vallejo	5264	Jan.	0	0.5	1	•	•
Vallejo	5265	Jan.	0.5	0	1	•	•
Vallejo	5266	Jan.	0	0.5	1	•	•
Oakland	5267	Jan.	0	0	1	•	•
Oakland	5268	Jan.	3.5	0.5	3	0.1	0.006
Oakland	5269	Jan.	1	1.5	2	•	•
Santa Cruz	5275	Jan.	0	0	1	•	•
Santa Cruz	5276	Jan.	0.5	0.5	1	0.122	0.021
Santa Cruz	5278	Jan.	0.5	1.5	2	•	•
Santa Cruz	5279	Jan.	0.5	1	1	•	•
Santa Cruz	5280	Jan.	1	0	1	•	•
Santa Cruz	5311	Jan.	0	0	1	•	•
Santa Cruz	5312	Jan.	0	0.5	1	•	•
Santa Cruz	5313	Jan.	0.5	0	2	•	•
Santa Cruz	5314	Jan.	0	0	1	0.076	0.09
Santa Cruz	5315	Jan.	0	0	1	•	•
Santa Cruz	5316	Jan.	0	0	1	•	•
Santa Cruz	5317	Jan.	0	0	1	•	•
Santa Cruz	5318	Jan.	0.5	1.5	2	•	•
Berkley	5319	Jan.	0.5	0.5	2	•	•
Berkley	5320	Jan.	1.5	0.5	2	•	•

Site	Sample No.	Date	Cytochrome P420 nmol/mg	%Denatured P450 (T450/420)	Cytochrome P-450E pmol/mg	P450E/ P450 x100	EROD nmol/min/mg
Berkeley	5120	Nov	•	0	84.1	36.6	0.172
Berkeley	5121	•	•	•	•	•	•
Berkeley	5122	•	•	•	•	•	•
Berkeley	5123	•	•	•	•	•	•
Berkeley	5124	•	•	•	•	•	•
Berkeley	5125	•	•	•	•	•	•
Berkeley	5126	Nov	0.02	100	•	•	•
Berkeley	5127	Nov	•	0	53.5	24.3	0.149
Berkeley	5128	•	•	•	•	•	•
Berkeley	5129	•	•	•	•	•	•
Berkeley	5130	Nov	•	0	54	25.7	0.231
Berkeley	5131	•	•	•	•	•	•
Berkeley	5132	•	•	•	•	•	•
Berkeley	5133	Nov	•	0	10	6.2	0.148
Berkeley	5134	•	•	•	•	•	•
Berkeley	5135	Nov	0.06	33	1.5	0.8	0.001
Berkeley	5136	Nov	0.1	50	1	0.5	•
Berkeley	5137	Nov	•	0	3.8	1.6	0.17
Berkeley	5138	•	•	•	•	•	•
Berkeley	5139	Nov	0.061	30	•	•	•
Berkeley	5140	Nov	0.181	46	4.2	1.1	0.23
Berkeley	5141	•	•	•	•	•	•
Berkeley	5142	Nov	0.079	35	2.5	1.1	0.24
Berkeley	5143	•	•	•	•	•	•
Berkeley	5144	•	•	•	•	•	•
Berkeley	5145	•	•	•	•	•	•
Berkeley	5146	Nov	0.08	38	1.6	0.8	0.124
Berkeley	5147	•	•	•	•	•	•
Berkeley	5148	•	•	•	•	•	•
Berkeley	5149	Nov	0.05	28	6.5	3.5	0.17
Berkeley	5150	Nov	0.11	50	1.7	0.8	0.054
Vallejo	5151	Nov	0.106	49	1.7	0.8	0.057
Vallejo	5152	Nov	0.04	51	•	•	0.014
Vallejo	5153	Nov	•	0	0.2	0.2	0.06
Vallejo	5154	Nov	0.043	21	2.6	1.2	0.127
San Pablo Bay	5155	Nov	•	0	•	•	0.049
San Pablo Bay	5156	Nov	0.1	60	•	•	0.062
San Pablo Bay	5157	Nov	0.08	41	•	•	0.031
San Pablo Bay	5158	Nov	0.05	29	3.1	1.8	0.131
San Pablo Bay	5159	Nov	0.09	56	4.9	3	0.032
San Pablo Bay	5160	Nov	0.04	41	2.8	2.9	0.064
San Pablo Bay	5161	Nov	0.06	40	2.9	2	0.089
San Pablo Bay	5162	•	•	•	•	•	•
San Pablo Bay	5163	Nov	0.05	32	3.2	2.1	0.072
San Pablo Bay	5164	Nov	0.05	40	•	•	0.027
San Pablo Bay	5165	Nov	0.1	70	•	•	0.039
Oakland	5166	Nov	0.044	23	15	7.9	0.14
Oakland	5167	Nov	0.14	38	45	12.2	0.547
Oakland	5168	Nov	0.07	38	33	18	0.244
Oakland	5169	Nov	0.083	28	21	7.2	0.125
Oakland	5170	•	•	•	•	•	•
Oakland	5171	Nov	0.048	40	1.8	1.5	0.055
Oakland	5172	Nov	0.194	50	9	2.3	0.107
Oakland	5173	•	•	•	•	•	•
Oakland	5174	•	•	•	•	•	•
Oakland	5175	•	•	•	•	•	•
Oakland	5176	Nov	0.106	33	36.7	11.4	0.356
San Pablo Bay	5177	•	•	•	•	•	•
San Pablo Bay	5178	•	•	•	•	•	•

Site	Sample No.	Date	Cytochrome P420 nmol/mg	%Denatured P450 (T450/420)	Cytochrome P-450E pmol/mg	P450E/ P450 x100	EROD nmol/min/mg
San Pablo Bay	5179	•	•	•	•	•	•
San Pablo Bay	5180	•	•	•	•	•	•
San Pablo Bay	5181	•	•	•	•	•	•
San Pablo Bay	5182	Nov	0.11	71	1.8	0.7	0.078
San Pablo Bay	5183	•	•	•	•	•	•
San Pablo Bay	5184	•	•	•	•	•	•
San Pablo Bay	5185	Nov	•	0	3.1	3.4	0.044
San Pablo Bay	5186	•	•	•	•	•	•
San Pablo Bay	5187	•	•	•	•	•	•
San Pablo Bay	5188	•	•	•	•	•	•
San Pablo Bay	5189	•	•	•	•	•	•
San Pablo Bay	5190	•	•	•	•	•	•
San Pablo Bay	5191	Nov	0.06	32	4.8	2.6	0.096
San Pablo Bay	5192	•	•	•	•	•	•
San Pablo Bay	5193	•	•	•	•	•	•
San Pablo Bay	5194	•	•	•	•	•	•
San Pablo Bay	5195	Nov	0.06	20	•	•	0.059
San Pablo Bay	5196	•	•	•	•	•	•
Vallejo	5197	•	•	•	•	•	•
Vallejo	5198	Nov	0.107	34	1.9	0.6	0.073
Vallejo	5199	•	•	•	•	•	•
Vallejo	5200	Nov	0.084	36	2.2	0.9	0.04
Vallejo	5201	Nov	0.199	67	0.04	0.01	0.05
Vallejo	5202	Nov	0.055	56	•	•	0.014
Vallejo	5203	Nov	•	0	•	•	0.141
Vallejo	5204	Nov	•	0	8	4	0.245
Vallejo	5205	Nov	0.063	43	•	•	0.048
Vallejo	5206	•	•	•	•	•	•
Vallejo	5207	Nov	0.144	70	25	12.2	0.145
Vallejo	5208	Nov	0.054	36	0.2	0.1	0.115
Vallejo	5209	Nov	0.251	54	6.3	1.4	0.109
Vallejo	5210		•	•	•	•	•
Vallejo	5211	•	0.11	71	1.8	0.7	0.078
Vallejo	5212	•	•	•	•	•	•
Oakland	5213	Nov	0.54	69	34.6	4.4	0.248
Oakland	5214	•	•	•	•	•	•
Oakland	5215	Nov	0.082	32	•	•	0.667
Oakland	5216	Nov	0.05	35	0.5	3.5	0.046
Oakland	5217	Nov	•	0	26	21.7	0.232
Oakland	5218	Nov	0.087	25	52	15.2	0.349
Oakland	5219	Nov	•	0	82	39	0.61
Oakland	5220	Nov	0.046	29	14	9	0.118
Oakland	5221	Nov	•	0	0.3	1.8	0.035
Russian River	5222	Nov	0.093	33	4.2	1.5	0.099
Russian River	5223	Nov	•	0	0.8	0.6	0.064
Russian River	5224	Nov	0.02	16	1.3	1	0.056
Russian River	5225	Nov	0.134	54	•	•	0.06
Russian River	5226	Nov	0.054	38	5	3.5	0.043
Russian River	5227	Nov	0.111	47	0.3	0.1	0.055
Russian River	5228	Nov	•	0	5.8	3.7	0.063
Russian River	5229	Nov	0.09	28	4	1.2	0.054
Russian River	5230	Nov	0.059	62	•	•	0.002
Russian River	5231	Nov	0.085	40	•	•	0.021
Russian River	5232	Nov	0.05	23	2.9	1.3	0.033
Russian River	5233	Nov	0.08	44	•	•	0.018
Russian River	5234	Nov	0.04	28	•	•	0.01
Russian River	5235	•	•	•	•	•	•
Russian River	5236	Nov	0.082	30	3	1.1	0.033
Russian River	5237	•	•	•	•	•	•

Site	Sample No.	Date	Cytochrome P420 nmol/mg	%Denatured P450 (T450/420)	Cytochrome P-450E pmol/mg	P450E/ P450 x100	EROD nmol/min/mg
Russian River	5238	•	•	•	•	•	•
Russian River	5239	•	•	•	•	•	•
Russian River	5240	•	•	•	•	•	•
Russian River	5241	•	•	•	•	•	•
Russian River	5242	•	•	•	•	•	•
Russian River	5243	•	•	•	•	•	•
Russian River	5244	•	0.033	35	•	•	•
Russian River	5245	•	•	•	•	•	•
Russian River	5246	•	•	•	•	•	•
Russian River	5247	•	•	•	•	•	•
Russian River	5248	•	•	•	•	•	•
Russian River	5249	•	•	•	•	•	•
Russian River	5250	•	•	•	•	•	•
Russian River	5251	•	•	•	•	•	•
Russian River	5252	•	•	•	•	•	•
Berkley	5253	Jan.	0.144	66	•	•	0.063
Berkley	5254	Jan.	•	•	•	•	•
Berkley	5255	Jan.	0.101	100	•	•	-
Berkley	5256	Jan.	•	•	•	•	•
Berkley	5257	Jan.	•	•	•	•	•
Berkley	5258	Jan.	•	•	•	•	•
Berkley	5260	Jan.	•	•	•	•	•
Berkley	5261	Jan.	•	•	•	•	•
Berkley	5263	Jan.	0.094	38	•	•	0.079
Vallejo	5264	Jan.	•	•	•	•	•
Vallejo	5265	Jan.	•	•	•	•	•
Vallejo	5266	Jan.	•	•	•	•	•
Oakland	5267	Jan.	•	•	•	•	•
Oakland	5268	Jan.	0.178	64	•	•	0.103
Oakland	5269	Jan.	•	•	•	•	•
Santa Cruz	5275	Jan.	•	•	•	•	•
Santa Cruz	5276	Jan.	0.138	53	•	•	0.063
Santa Cruz	5278	Jan.	•	•	•	•	•
Santa Cruz	5279	Jan.	•	•	•	•	•
Santa Cruz	5280	Jan.	•	•	•	•	•
Santa Cruz	5311	Jan.	•	•	•	•	•
Santa Cruz	5312	Jan.	•	•	•	•	•
Santa Cruz	5313	Jan.	•	•	•	•	•
Santa Cruz	5314	Jan.	0.39	84	•	•	0.1
Santa Cruz	5315	Jan.	•	•	•	•	•
Santa Cruz	5316	Jan.	•	•	•	•	•
Santa Cruz	5317	Jan.	•	•	•	•	•
Santa Cruz	5318	Jan.	•	•	•	•	•
Berkley	5319	Jan.	•	•	•	•	•
Berkley	5320	Jan.	•	•	•	•	•

Site	Sample No.	Date	EROD/p450 nmol/min/nmol P450	Estradiol 2-OHase nmol/min/mg
Berkeley	5120	Nov	0.76	-
Berkeley	5121	•	•	•
Berkeley	5122	•	•	•
Berkeley	5123	•	•	•
Berkeley	5124	•	•	•
Berkeley	5125	•	•	•
Berkeley	5126	Nov	•	0.015
Berkeley	5127	Nov	0.68	-
Berkeley	5128	•	•	•
Berkeley	5129	•	•	•
Berkeley	5130	Nov	0.91	0.035
Berkeley	5131	•	•	•
Berkeley	5132	•	•	•
Berkeley	5133	Nov	0.94	-
Berkeley	5134	•	•	•
Berkeley	5135	Nov	0.02	0.01
Berkeley	5136	Nov	•	0.011
Berkeley	5137	Nov	0.71	0.025
Berkeley	5138	•	•	•
Berkeley	5139	Nov	•	0.008
Berkeley	5140	Nov	1.12	-
Berkeley	5141	•	•	•
Berkeley	5142	Nov	1.61	-
Berkeley	5143	•	•	•
Berkeley	5144	•	•	•
Berkeley	5145	•	•	•
Berkeley	5146	Nov	0.96	-
Berkeley	5147	•	•	•
Berkeley	5148	•	•	•
Berkeley	5149	Nov	1.24	0.015
Berkeley	5150	Nov	0.47	0.007
Vallejo	5151	Nov	0.52	-
Vallejo	5152	Nov	0.38	0.01
Vallejo	5153	Nov	0.5	0.016
Vallejo	5154	Nov	0.77	-
San Pablo Bay	5155	Nov	0.14	-
San Pablo Bay	5156	Nov	0.94	•
San Pablo Bay	5157	Nov	0.28	•
San Pablo Bay	5158	Nov	1.09	•
San Pablo Bay	5159	Nov	0.45	•
San Pablo Bay	5160	Nov	1.12	0.018
San Pablo Bay	5161	Nov	1	0.031
San Pablo Bay	5162	•	•	•
San Pablo Bay	5163	Nov	0.69	0.038
San Pablo Bay	5164	Nov	0.35	-
San Pablo Bay	5165	Nov	0.39	-
Oakland	5166	Nov	0.96	0.012
Oakland	5167	Nov	2.39	0.041
Oakland	5168	Nov	2.14	0.015
Oakland	5169	Nov	0.6	-
Oakland	5170	•	•	•
Oakland	5171	Nov	0.75	-
Oakland	5172	Nov	0.56	0.018
Oakland	5173	•	•	•
Oakland	5174	•	•	•
Oakland	5175	•	•	•
Oakland	5176	Nov	1.67	0.038
San Pablo Bay	5177	•	•	•
San Pablo Bay	5178	•	•	•

Site	Sample No.	Date	EROD/p450 nmol/min/nmol P450	Estradiol 2-OHase nmol/min/mg
San Pablo Bay	5179	•	•	•
San Pablo Bay	5180	•	•	•
San Pablo Bay	5181	•	•	•
San Pablo Bay	5182	Nov	0.53	0.032
San Pablo Bay	5183	•	•	•
San Pablo Bay	5184	•	•	•
San Pablo Bay	5185	Nov	0.48	0.022
San Pablo Bay	5186	•	•	•
San Pablo Bay	5187	•	•	•
San Pablo Bay	5188	•	•	•
San Pablo Bay	5189	•	•	•
San Pablo Bay	5190	•	•	•
San Pablo Bay	5191	Nov	0.76	-
San Pablo Bay	5192	•	•	•
San Pablo Bay	5193	•	•	•
San Pablo Bay	5194	•	•	•
San Pablo Bay	5195	Nov	0.25	-
San Pablo Bay	5196	•	•	•
Vallejo	5197	•	•	•
Vallejo	5198	Nov	0.35	-
Vallejo	5199	•	•	•
Vallejo	5200	Nov	0.17	-
Vallejo	5201	Nov	0.52	0.026
Vallejo	5202	Nov	0.29	-
Vallejo	5203	Nov	0.773	-
Vallejo	5204	Nov	1.22	-
Vallejo	5205	Nov	0.57	0.018
Vallejo	5206	•	•	•
Vallejo	5207	Nov	0.9	0.044
Vallejo	5208	Nov	1.21	0.03
Vallejo	5209	Nov	0.5	-
Vallejo	5210		•	•
Vallejo	5211	•	0.53	•
Vallejo	5212	•	•	•
Oakland	5213	Nov	1.03	0.017
Oakland	5214	•	•	•
Oakland	5215	Nov	3.9	0.039
Oakland	5216	Nov	0.51	0.014
Oakland	5217	Nov	1.93	0.01
Oakland	5218	Nov	1.36	0.048
Oakland	5219	Nov	2.9	0.051
Oakland	5220	Nov	1.07	-
Oakland	5221	Nov	0.25	0.069
Russian River	5222	Nov	0.53	0.032
Russian River	5223	Nov	0.44	0.013
Russian River	5224	Nov	0.52	0.011
Russian River	5225	Nov	0.53	0.014
Russian River	5226	Nov	0.49	0.034
Russian River	5227	Nov	0.43	0.031
Russian River	5228	Nov	0.41	0.046
Russian River	5229	Nov	0.33	-
Russian River	5230	Nov	0.05	0.021
Russian River	5231	Nov	0.16	0.027
Russian River	5232	Nov	0.19	-
Russian River	5233	Nov	0.18	-
Russian River	5234	Nov	0.1	-
Russian River	5235	•	•	•
Russian River	5236	Nov	0.17	•
Russian River	5237	•	•	•

Site	Sample No.	Date	EROD/p450 nmol/min/nmol P450	Estradiol 2-OHase nmol/min/mg
Russian River	5238	•	•	•
Russian River	5239	•	•	•
Russian River	5240	•	•	•
Russian River	5241	•	•	•
Russian River	5242	•	•	•
Russian River	5243	•	•	•
Russian River	5244	•	•	0.06
Russian River	5245	•	•	•
Russian River	5246	•	•	•
Russian River	5247	•	•	•
Russian River	5248	•	•	•
Russian River	5249	•	•	•
Russian River	5250	•	•	•
Russian River	5251	•	•	•
Russian River	5252	•	•	•
Berkley	5253	Jan.	0.84	-
Berkley	5254	Jan.	•	•
Berkley	5255	Jan.	-	•
Berkley	5256	Jan.	•	•
Berkley	5257	Jan.	•	•
Berkley	5258	Jan.	•	•
Berkley	5260	Jan.	•	•
Berkley	5261	Jan.	•	•
Berkley	5263	Jan.	0.52	-
Vallejo	5264	Jan.	•	•
Vallejo	5265	Jan.	•	•
Vallejo	5266	Jan.	•	•
Oakland	5267	Jan.	•	•
Oakland	5268	Jan.	0.103	-
Oakland	5269	Jan.	•	•
Santa Cruz	5275	Jan.	•	•
Santa Cruz	5276	Jan.	0.52	-
Santa Cruz	5278	Jan.	•	•
Santa Cruz	5279	Jan.	•	•
Santa Cruz	5280	Jan.	•	•
Santa Cruz	5311	Jan.	•	•
Santa Cruz	5312	Jan.	•	•
Santa Cruz	5313	Jan.	•	•
Santa Cruz	5314	Jan.	1.31	-
Santa Cruz	5315	Jan.	•	•
Santa Cruz	5316	Jan.	•	•
Santa Cruz	5317	Jan.	•	•
Santa Cruz	5318	Jan.	•	•
Berkley	5319	Jan.	•	•
Berkley	5320	Jan.	•	•

APPENDIX D

CHEMICAL DATA (ug/kg wet weight) FOR *P. STELLATUS*

Individual chemical data for each *P. stellatus* sample collected from six sites in the San Francisco Bay area (ug/kg ww).

Site	MSB	opDDE	ppDDE	opDDD	ppDDD	opDDT	ppDDT	tDDT	HCB
BERKELEY									
BK	5120	ND	45.14	*	10.98	ND	ND	56.12	ND
BK	5126	0.85	78.47	*	30.34	ND	ND	109.65	ND
BK	5127	ND	117.19	*	ND	11.42	ND	128.60	ND
BK	5130	ND	132.24	*	ND	ND	3.60	135.84	ND
BK	5133	ND	389.65	*	189.67	ND	16.81	596.14	ND
BK	5135	ND	137.26	*	35.21	ND	ND	172.47	ND
BK	5136	ND	330.45	*	148.57	ND	64.36	543.38	0.59
BK	5137	ND	124.83	*	57.44	ND	6.33	188.60	ND
BK	5139	ND	153.70	*	108.03	ND	58.57	320.30	ND
BK	5140	ND	135.74	*	ND	ND	3.65	139.39	ND
BK	5142	2.33	160.87	*	125.15	ND	ND	288.35	ND
BK	5146	ND	113.76	*	43.12	ND	ND	156.88	ND
BK	5149	ND	184.61	*	75.33	ND	10.21	270.16	ND
BK	5150	ND	199.26	*	143.00	ND	ND	342.26	ND
BK	5253	ND	120.35	*	21.71	ND	ND	142.06	ND
BK	5255	ND	43.13	*	11.82	ND	ND	54.94	ND
BK	5263	ND	98.56	*	27.49	ND	ND	126.05	ND
BK	5319	ND	4.67	*	41.78	ND	27.18	73.63	ND
			142.77		71.31	11.42	23.84	249.34	
AVERAGE=		1.59	142.77		71.31	11.42	23.84	213.60	0.59
STD DEV		1.04	93.53		57.19		24.55	155.16	0.00
OAKLAND									
OK	5166	ND	175.41	*	112.24	39.83	ND	327.48	ND
OK	5167	ND	135.83	*	70.01	ND	5.28	211.12	ND
OK	5168	ND	135.34	*	153.46	ND	22.37	311.17	ND
OK	5169	8.36	126.11	*	133.91	105.70	ND	374.08	ND
OK	5171	1.07	167.25	*	107.98	ND	58.28	334.57	ND
OK	5172	ND	101.19	*	70.37	ND	ND	171.56	ND
OK	5176	1.12	18.94	*	6.27	ND	ND	26.33	ND
OK	5213	ND	114.43	*	97.27	3.50	14.95	230.15	ND
OK	5215	ND	25.06	*	19.34	ND	ND	44.39	ND
OK	5216	ND	244.01	*	108.29	ND	ND	352.30	ND
OK	5217	ND	382.52	*	51.02	52.66	9.74	495.94	ND
OK	5218	ND	40.37	*	14.87	ND	ND	55.24	ND
OK	5219	ND	69.21	*	26.27	ND	ND	95.48	ND
OK	5220	1.44	44.01	*	39.82	ND	ND	85.28	ND
OK	5221	2.42	13.40	*	97.31	ND	18.95	132.07	0.94
OK	5268	ND	81.46	*	39.73	ND	ND	121.18	ND
AVERAGE=		2.88	117.16		71.76	50.42	21.59	210.52	0.94
STD DEV		3.11	95.62		45.42	42.32	19.00	140.98	
RUSSIAN R									
RR	5222	40.42	82.82	*	ND	ND	ND	123.24	ND
RR	5223	ND	ND	*	35.17	ND	9.27	44.44	ND
RR	5224	ND	10.41	*	3.90	ND	2.60	16.92	ND
RR	5225	ND	132.67	*	7.70	ND	ND	140.37	ND
RR	5227	ND	72.00	*	3.60	ND	ND	75.60	ND
RR	5228	ND	36.83	*	ND	ND	ND	36.83	ND
RR	5229	ND	58.88	*	10.01	ND	ND	68.89	ND
RR	5230	2.00	172.03	*	17.72	ND	ND	191.76	ND
RR	5231	ND	ND	*	7.63	ND	10.89	18.51	ND

Site	MSB	opDDE	ppDDE	opDDD	ppDDD	opDDT	ppDDT	tDDT	HCB
RR	5232	ND	162.67	*	3.44	ND	ND	166.12	ND
RR	5233	ND	36.74	*	2.63	ND	ND	39.38	ND
RR	5234	ND	157.60	*	1.02	ND	ND	158.62	ND
RR	5236	ND	ND	*	ND	ND	40.99	40.99	ND
RR	5244	2.28	195.45	*	31.70	ND	6.63	236.07	ND
AVERAGE=		14.90	178.91		14.93	ND	14.08	96.98	ND
STD DEV		22.10	64.32		11.88		15.37	71.32	
SANTA CRUZ									
SC	5276	ND	148.05	*	27.81	8.11	2.83	186.80	ND
SC	5311	17.52	11.62	*	47.13	14.08	37.46	127.81	ND
SC	5316	25.61	25.96	*	23.14	ND	45.83	120.54	ND
SC	5318	ND	2.02	*	4.05	3.56	19.90	29.52	ND
AVERAGE=		21.56	46.91		25.53	8.58	26.50	116.17	ND
STD DEV		5.72	68.14		17.69	5.28	19.13	64.94	ND
SAN PABLO									
SP	5155	2.21	74.68	*	45.30	ND	1.94	124.12	ND
SP	5156	2.88	112.33	*	82.59	8.60	6.22	212.62	ND
SP	5157	2.05	116.85	*	55.52	ND	4.76	179.19	ND
SP	5158	1.71	76.40	*	55.51	ND	ND	133.61	ND
SP	5159	2.46	39.63	*	8.26	ND	ND	50.35	ND
SP	5160	4.42	83.48	*	85.93	ND	ND	173.84	ND
SP	5161	2.39	38.69	*	33.81	ND	ND	74.90	ND
SP	5163	ND	84.74	*	46.68	ND	ND	131.42	ND
SP	5164	ND	56.44	*	ND	ND	12.06	68.51	ND
SP	5165	3.79	247.30	*	165.18	ND	5.63	421.91	ND
SP	5182	2.67	22.08	*	123.21	ND	20.76	168.72	ND
SP	5185	ND	119.29	*	106.99	ND	9.93	236.21	ND
SP	5191	3.16	113.25	*	69.13	ND	ND	185.53	ND
SP	5195	ND	171.94	*	18.23	ND	ND	190.16	ND
AVERAGE=		2.77	96.94		68.95	8.60	8.76	167.94	ND
STD DEV		0.83	58.70		43.81		6.26	91.54	ND
VALLEJO									
VJ	5151	ND	105.96	*	48.14	ND	ND	154.10	ND
VJ	5152	4.71	419.75	*	94.37	ND	7.02	525.85	ND
VJ	5153	ND	61.11	*	43.13	0.96	2.17	107.38	ND
VJ	5154	ND	91.05	*	36.30	ND	2.79	130.15	ND
VJ	5198	ND	102.28	*	44.10	ND	ND	146.38	ND
VJ	5200	6.25	111.72	*	ND	ND	ND	117.97	ND
VJ	5201	ND	39.96	*	9.06	0.61	ND	49.63	ND
VJ	5202	ND	231.16	*	4.27	ND	ND	235.43	ND
VJ	5203	1.61	115.75	*	70.27	7.30	7.17	202.10	ND
VJ	5204	ND	43.44	*	36.27	ND	7.48	87.19	ND
VJ	5205	3.06	94.43	*	57.75	1.63	ND	156.87	ND
VJ	5207	4.02	73.30	*	26.98	ND	ND	104.29	ND
VJ	5208	3.04	71.50	*	33.41	ND	ND	107.94	ND
VJ	5209	1.03	112.83	*	60.85	ND	1.27	175.99	ND
AVERAGE=		3.39	119.59		43.45	2.62	4.65	164.38	ND
STD DEV		1.79	97.91		24.21	3.15	2.86	114.44	ND

Site	MSB	lindane	heptachlor	aldrin	heptepox	chlordane	transnonachlor
BERKELEY							
BK	5120	4.72	ND	ND	1.41	ND	6.76
BK	5126	7.26	0.66	ND	1.36	2.92	13.41
BK	5127	10.62	2.50	ND	ND	15.10	30.77
BK	5130	ND	16.31	ND	ND	8.65	30.60
BK	5133	6.12	ND	1.49	5.48	10.11	65.69
BK	5135	4.63	12.61	ND	3.52	2.18	17.21
BK	5136	8.77	40.33	ND	8.74	7.53	37.26
BK	5137	20.95	ND	ND	2.25	13.39	26.36
BK	5139	ND	1.61	ND	4.75	4.37	19.89
BK	5140	ND	ND	0.27	2.58	2.49	16.95
BK	5142	15.92	26.66	1.43	4.86	10.87	33.89
BK	5146	ND	16.70	ND	5.77	4.14	16.03
BK	5149	ND	ND	ND	ND	10.07	25.96
BK	5150	8.64	28.09	ND	6.60	8.64	41.95
BK	5253	ND	47.41	2.55	12.60	ND	ND
BK	5255	ND	14.86	3.55	8.57	ND	4.61
BK	5263	ND	ND	4.80	ND	0.30	8.31
BK	5319	ND	ND	ND	13.67	3.29	8.50
AVERAGE=		9.74	18.89	2.35	5.87	6.94	23.77
STD DEV		5.45	15.44	1.64	3.87	4.47	15.57
OAKLAND							
OK	5166	ND	ND	ND	7.32	8.71	40.01
OK	5167	11.20	ND	ND	4.64	7.60	53.34
OK	5168	19.72	ND	ND	5.95	8.86	36.33
OK	5169	ND	ND	ND	11.88	12.48	24.48
OK	5171	ND	ND	0.64	6.78	4.79	23.97
OK	5172	ND	ND	ND	ND	7.37	15.85
OK	5176	ND	1.24	0.69	ND	0.62	2.54
OK	5213	4.90	ND	ND	2.22	4.94	33.72
OK	5215	ND	10.47	3.66	2.16	1.09	6.39
OK	5216	2.80	ND	ND	3.65	12.70	41.77
OK	5217	ND	ND	ND	ND	21.63	71.82
OK	5218	ND	16.96	4.19	ND	0.93	10.31
OK	5219	ND	ND	ND	ND	2.65	10.78
OK	5220	5.68	ND	4.90	1.30	3.97	13.66
OK	5221	ND	ND	ND	13.23	3.80	24.16
OK	5268	ND	8.19	ND	0.46	0.13	6.68
AVERAGE=		8.86	9.21	2.82	5.42	6.39	25.99
STD DEV		6.82	6.49	2.01	4.18	5.68	19.16
RUSSIAN R							
RR	5222	ND	9.98	12.14	24.22	2.81	7.79
RR	5223	ND	67.69	ND	ND	ND	5.30
RR	5224	6.91	ND	ND	ND	5.10	3.42
RR	5225	ND	ND	ND	8.81	0.70	ND
RR	5227	ND	ND	10.40	1.20	ND	3.20
RR	5228	ND	ND	3.83	ND	ND	5.51
RR	5229	ND	3.06	3.65	ND	0.66	1.73
RR	5230	ND	ND	6.61	28.87	ND	11.54
RR	5231	ND	ND	ND	ND	2.05	8.23

Site	MSB	lindane	heptachlor	aldrin	heptepox	chlordane	transnonachlor
RR	5232	ND	7.85	ND	ND	ND	2.68
RR	5233	ND	ND	ND	0.27	0.49	2.30
RR	5234	ND	1.50	ND	2.67	1.28	7.11
RR	5236	ND	ND	ND	ND	2.43	8.16
RR	5244	ND	ND	ND	1.17	1.72	8.59
AVERAGE=		6.91	18.02	30.31	12.15	1.92	9.05
STD DEV			27.98	3.83	11.99	1.45	3.02
SANTA CRUZ							
SC	5276	ND	5.84	5.60	0.30	2.23	3.84
SC	5311	ND	ND	ND	6.82	5.43	14.53
SC	5316	ND	ND	ND	25.39	3.59	3.44
SC	5318	ND	ND	ND	ND	ND	2.68
AVERAGE=		ND	5.84	5.60	10.84	3.75	6.12
STD DEV		ND			13.02	1.61	5.62
SAN PABLO							
SP	5155	0.72	ND	ND	2.18	5.39	8.09
SP	5156	6.15	18.20	2.30	4.20	9.98	15.48
SP	5157	7.18	ND	ND	6.24	5.78	15.96
SP	5158	6.98	ND	ND	4.17	5.33	11.29
SP	5159	5.15	ND	ND	6.20	1.54	3.78
SP	5160	5.28	ND	ND	6.87	13.74	21.31
SP	5161	2.05	ND	ND	4.84	4.74	9.61
SP	5163	ND	ND	ND	ND	5.53	12.75
SP	5164	ND	ND	1.84	2.61	20.84	20.69
SP	5165	17.64	ND	ND	9.49	29.62	65.12
SP	5182	8.58	6.82	ND	ND	11.67	16.11
SP	5185	ND	ND	ND	ND	4.96	ND
SP	5191	ND	2.85	2.41	3.57	5.60	18.51
SP	5195	1.31	1.57	1.01	1.40	1.96	13.78
AVERAGE=		6.11	7.36	1.89	4.71	9.05	17.88
STD DEV		4.84	7.56	0.64	2.36	7.83	15.04
VALLEJO							
VJ	5151	ND	4.36	ND	2.71	6.60	27.56
VJ	5152	ND	ND	1.56	1.71	13.42	46.85
VJ	5153	1.84	1.35	3.04	2.12	7.06	17.02
VJ	5154	ND	ND	ND	ND	8.89	16.84
VJ	5198	ND	ND	1.54	2.09	5.92	16.21
VJ	5200	12.82	6.30	3.82	0.64	10.47	17.47
VJ	5201	ND	ND	ND	2.33	1.43	ND
VJ	5202	1.52	13.44	ND	ND	ND	5.37
VJ	5203	ND	ND	ND	1.36	11.27	16.61
VJ	5204	14.07	0.89	ND	8.11	2.69	5.12
VJ	5205	15.88	ND	ND	28.08	7.15	13.02
VJ	5207	ND	ND	ND	0.91	8.18	9.41
VJ	5208	ND	ND	ND	1.73	5.47	11.26
VJ	5209	ND	2.67	1.26	5.45	14.18	17.81
AVERAGE=		9.23	4.84	2.24	4.77	7.90	16.97
STD DEV		6.97	4.67	1.12	7.64	3.77	10.75

	Site	MSB	dieldrin	mirex	Total Pesticide	8	18	28	52	44
BERKELEY										
	BK	5120	10.06	ND	10262.95	ND	ND	ND	11.12	3.95
	BK	5126	15.22	ND	10292.82	ND	ND	3.97	8.80	ND
	BK	5127	29.06	ND	10342.06	ND	ND	ND	19.61	ND
	BK	5130	28.22	0.90	10344.67	ND	ND	ND	33.54	7.55
	BK	5133	63.27	ND	10418.16	ND	ND	15.48	47.36	3.19
	BK	5135	20.01	ND	10330.17	ND	ND	ND	20.80	ND
	BK	5136	63.58	ND	10438.80	ND	ND	13.68	44.35	2.13
	BK	5137	22.99	1.62	10361.56	ND	ND	ND	18.32	ND
	BK	5139	30.75	ND	10339.37	ND	ND	13.18	23.79	40.57
	BK	5140	26.41	ND	10328.69	ND	ND	3.89	14.26	ND
	BK	5142	47.00	ND	10424.62	ND	ND	ND	33.26	ND
	BK	5146	21.69	ND	10356.33	ND	ND	7.65	16.15	8.64
	BK	5149	40.88	2.30	10377.20	ND	ND	6.75	33.29	20.66
	BK	5150	57.42	15.76	10467.09	ND	ND	18.92	47.03	3.39
	BK	5253	9.37	18.96	10596.89	ND	ND	14.93	48.51	2.20
	BK	5255	9.17	ND	10550.77	ND	22.71	ND	ND	ND
	BK	5263	20.21	2.29	10561.91	6.93	3.58	13.35	18.79	8.33
	BK	5319	115.29	ND	10778.74	ND	ND	3.33	ND	ND
	AVERAGE=		35.03	6.97	10420.71	6.93	13.15	10.47	27.44	10.06
	STD DEV		26.59	8.13	129.39		13.53	5.48	13.68	12.06
OAKLAND										
	OK	5166	45.89	ND	10433.93	ND	ND	ND	ND	ND
	OK	5167	27.35	9.96	10448.07	ND	ND	6.41	38.90	9.42
	OK	5168	41.69	ND	10448.54	ND	ND	ND	28.11	10.88
	OK	5169	59.78	26.02	10472.64	ND	ND	ND	65.69	ND
	OK	5171	41.07	ND	10419.26	ND	ND	13.25	33.89	10.12
	OK	5172	23.71	39.76	10430.69	12.28	ND	ND	ND	ND
	OK	5176	2.80	1.68	10361.56	4.20	ND	ND	5.45	ND
	OK	5213	30.71	ND	10502.48	12.94	ND	6.15	22.29	ND
	OK	5215	12.11	38.57	10504.44	ND	ND	2.48	11.49	2.85
	OK	5216	44.68	ND	10537.60	ND	ND	16.03	20.62	ND
	OK	5217	18.67	31.70	10577.81	ND	ND	ND	14.56	9.56
	OK	5218	7.96	6.58	10482.94	ND	ND	3.02	ND	ND
	OK	5219	10.13	24.91	10486.47	ND	ND	ND	13.38	27.13
	OK	5220	ND	ND	10469.51	5.98	ND	ND	14.68	ND
	OK	5221	141.35	ND	10625.48	ND	7.64	ND	24.73	ND
	OK	5268	33.46	ND	10584.92	ND	ND	12.16	17.03	ND
	AVERAGE=		36.09	22.40	10486.65	8.85	7.64	8.50	23.91	11.66
	STD DEV		33.36	14.66	68.29	4.41		5.30	15.62	8.11
RUSSIAN R										
	RR	5222	ND	ND	10500.94	24.20	ND	ND	ND	ND
	RR	5223	115.45	ND	10634.43	ND	74.35	ND	ND	ND
	RR	5224	66.61	ND	10530.03	ND	ND	ND	ND	20.88
	RR	5225	ND	ND	10459.50	ND	ND	27.58	ND	ND
	RR	5227	ND	2.00	16.80	6.00	ND	ND	ND	3.60
	RR	5228	0.82	18.68	10484.85	23.61	2.49	ND	1.15	4.60
	RR	5229	0.08	ND	10467.18	ND	ND	ND	5.65	ND
	RR	5230	ND	ND	10507.02	19.89	ND	ND	27.25	ND
	RR	5231	91.72	10.70	10574.70	ND	ND	ND	ND	ND

Site	MSB	dieldrin	mirex	Total Pesticide	8	18	28	52	44
RR	5232	5.33	4.61	10484.48	ND	ND	15.37	26.56	ND
RR	5233	ND	ND	10469.05	ND	5.57	ND	18.78	ND
RR	5234	ND	23.17	10503.74	ND	3.42	ND	19.66	ND
RR	5236	76.00	ND	10558.60	ND	ND	ND	10.89	ND
RR	5244	5.09	7.64	10512.21	ND	ND	ND	ND	ND
AVERAGE=		45.14	18.23	9764.54	35.32	21.46	21.47	15.71	23.94
STD DEV		47.37	8.25	2806.00	8.72	30.60	7.17	15.88	18.89
SANTA CRUZ									
SC	5276	ND	ND	10569.80	4.27	ND	ND	ND	5.29
SC	5311	311.30	ND	10960.07	ND	ND	ND	ND	13.24
SC	5316	104.87	19.22	10788.51	ND	ND	ND	ND	ND
SC	5318	20.15	7.54	10666.38	ND	ND	9.14	ND	ND
AVERAGE=		145.44	13.38	10746.19	4.27	ND	9.14	ND	9.27
STD DEV		149.75	8.25	168.34		ND		ND	5.62
SAN PABLO									
SP	5155	20.01	ND	10346.39	ND	ND	ND	11.90	ND
SP	5156	34.04	1.71	10404.06	ND	ND	ND	26.73	9.03
SP	5157	24.05	2.45	10375.67	ND	2.72	ND	20.06	ND
SP	5158	19.38	ND	10363.15	ND	ND	ND	13.47	ND
SP	5159	8.42	7.52	10350.61	ND	ND	ND	ND	3.31
SP	5160	27.79	ND	10394.99	ND	ND	ND	10.57	ND
SP	5161	28.79	ND	10372.03	ND	6.99	ND	ND	ND
SP	5163	19.62	ND	10363.90	ND	ND	ND	9.49	ND
SP	5164	21.69	ND	10395.68	ND	ND	ND	ND	ND
SP	5165	55.93	ND	10507.80	ND	ND	ND	30.70	ND
SP	5182	103.35	7.72	10518.25	ND	5.01	ND	44.58	ND
SP	5185	42.54	ND	10417.50	ND	ND	28.73	ND	21.25
SP	5191	18.48	ND	10433.43	ND	16.94	ND	29.84	ND
SP	5195	7.97	ND	10418.99	4.04	ND	ND	27.34	6.45
AVERAGE=		30.86	4.85	10404.46	4.04	7.91	28.73	22.47	10.01
STD DEV		24.39	3.21	53.00		6.26		11.36	7.85
VALLEJO									
VJ	5151	17.77	3.36	10364.37	ND	ND	4.42	33.38	7.36
VJ	5152	26.13	ND	10393.67	4.43	5.11	4.21	36.36	8.13
VJ	5153	13.95	5.43	10357.81	ND	6.80	ND	6.49	ND
VJ	5154	22.48	ND	10356.22	ND	ND	36.66	28.49	ND
VJ	5198	18.37	5.80	10445.93	2.08	2.04	ND	28.59	6.02
VJ	5200	28.49	ND	10480.01	ND	6.37	ND	45.30	7.56
VJ	5201	2.22	8.51	10416.50	ND	ND	ND	ND	ND
VJ	5202	1.03	ND	10425.36	ND	ND	ND	ND	33.15
VJ	5203	26.80	ND	10462.05	ND	ND	ND	32.65	ND
VJ	5204	6.96	ND	10445.83	ND	ND	ND	ND	1.30
VJ	5205	13.80	ND	10487.93	ND	ND	ND	49.90	ND
VJ	5207	11.73	ND	10444.23	ND	ND	ND	ND	ND
VJ	5208	8.84	ND	10443.30	ND	ND	11.94	22.52	ND
VJ	5209	15.16	ND	10474.53	ND	2.16	ND	37.77	1.30
AVERAGE=		15.27	5.78	10428.41	3.26	4.50	14.31	32.15	9.26
STD DEV		8.74	2.12	44.89	1.66	2.27	15.33	12.09	10.92

	Site	MSB	66	101	opDDD/77	118	105	153	138	126	187
BERKELEY											
	BK	5120	ND	8.57	15.75	11.75	5.08	31.39	34.65	ND	11.54
	BK	5126	ND	14.92	26.72	21.15	5.26	43.56	42.71	ND	16.47
	BK	5127	0.21	22.37	21.39	41.67	14.18	71.25	76.02	ND	17.82
	BK	5130	ND	26.35	32.06	40.30	18.71	97.90	92.24	ND	40.63
	BK	5133	11.76	87.44	150.16	192.45	34.47	356.07	331.61	ND	136.69
	BK	5135	2.69	36.07	23.89	54.39	8.80	115.27	105.55	ND	53.71
	BK	5136	10.22	77.04	60.58	132.92	21.79	246.48	209.09	ND	118.06
	BK	5137	ND	18.46	7.76	26.38	7.72	60.68	63.21	ND	32.00
	BK	5139	39.22	35.84	27.39	85.22	16.36	121.95	119.05	ND	54.53
	BK	5140	0.80	24.74	18.40	51.66	9.15	77.61	73.06	ND	32.29
	BK	5142	52.19	65.17	66.45	124.32	24.15	235.03	227.59	ND	143.09
	BK	5146	ND	15.49	16.84	22.69	11.70	64.95	57.52	ND	17.95
	BK	5149	ND	26.95	25.24	50.22	18.69	87.32	99.16	ND	37.91
	BK	5150	57.72	46.48	41.85	111.78	20.95	142.54	127.00	ND	62.40
	BK	5253	5.19	56.55	17.13	83.89	14.92	80.47	46.70	ND	35.51
	BK	5255	ND	ND	20.02	ND	9.64	46.00	23.48	ND	31.83
	BK	5263	8.18	34.09	28.69	57.32	11.89	93.12	76.51	ND	33.85
	BK	5319	ND	34.93	ND	64.92	11.57	101.99	101.45	ND	60.94
	AVERAGE=		18.82	37.15	35.31	69.00	14.72	115.20	105.92	ND	52.07
	STD DEV		22.10	22.51	33.35	47.97	7.49	83.71	78.08	ND	40.13
OAKLAND											
	OK	5166	ND	70.10	50.87	104.42	39.05	195.73	163.34	ND	77.69
	OK	5167	ND	87.78	50.87	176.53	27.61	224.22	222.08	ND	81.89
	OK	5168	ND	57.97	45.54	179.13	24.97	291.52	243.38	ND	155.54
	OK	5169	ND	43.91	36.86	39.88	34.26	47.30	94.54	ND	19.85
	OK	5171	5.27	49.58	39.36	99.67	19.37	146.71	132.73	1.80	64.78
	OK	5172	ND	17.52	27.13	24.02	43.08	ND	ND	ND	52.18
	OK	5176	2.03	6.57	7.09	11.37	1.66	19.96	16.96	ND	16.42
	OK	5213	ND	79.19	30.53	ND	46.60	320.73	269.50	ND	ND
	OK	5215	ND	12.90	26.38	22.30	7.06	55.61	59.03	ND	28.18
	OK	5216	ND	28.18	19.80	71.16	22.40	141.58	135.72	ND	50.42
	OK	5217	1.30	15.35	ND	59.64	6.45	147.16	112.30	ND	10.18
	OK	5218	0.36	9.94	32.78	31.44	8.69	67.28	60.20	ND	39.12
	OK	5219	ND	12.56	13.54	35.33	8.60	50.40	68.60	ND	27.73
	OK	5220	3.70	15.70	33.03	ND	22.42	36.83	33.28	ND	11.48
	OK	5221	20.21	63.00	ND	70.67	8.76	67.80	107.46	ND	67.40
	OK	5268	ND	42.45	34.05	66.11	11.99	95.83	79.39	ND	53.96
	AVERAGE=		5.48	38.29	31.99	70.83	20.81	127.24	119.90	1.80	50.45
	STD DEV		7.43	27.07	12.85	53.25	14.20	94.39	76.00		37.47
RUSSIAN R											
	RR	5222	1.32	10.34	108.00	5.61	6.46	13.46	6.42	ND	6.70
	RR	5223	ND	ND	11.79	16.62	32.74	16.61	34.89	ND	23.38
	RR	5224	ND	ND	ND	14.76	22.83	19.17	18.67	ND	13.06
	RR	5225	ND	ND	5.80	8.60	ND	11.14	ND	ND	19.33
	RR	5227	0.40	0.80	ND	27.60	ND	27.60	17.60	ND	5.60
	RR	5228	ND	9.47	4.48	4.53	4.02	8.57	14.46	ND	ND
	RR	5229	ND	6.48	58.84	2.15	2.89	4.62	2.81	ND	10.97
	RR	5230	ND	19.19	25.34	20.34	13.44	38.34	12.64	14.26	20.92
	RR	5231	ND	5.51	8.10	14.95	3.57	27.85	23.34	ND	12.36

Site	MSB	66	101	opDDD/77	118	105	153	138	126	187
RR	5232	ND	ND	18.78	ND	6.99	11.56	4.95	ND	7.25
RR	5233	ND	9.45	62.05	22.26	9.98	23.44	13.19	ND	174.61
RR	5234	ND	12.84	8.83	13.05	3.27	13.08	7.72	ND	4.21
RR	5236	ND	ND	ND	6.96	118.11	27.49	9.70	ND	3.11
RR	5244	0.36	18.66	12.12	22.59	7.79	65.04	52.34	ND	60.94
AVERAGE=		10.20	19.32	33.42	20.18	19.34	44.28	32.41	14.26	32.67
STD DEV		32.66	29.23	33.02	28.86	39.06	36.97	34.96		61.75
SANTA CRUZ										
SC	5276	0.22	13.02	19.64	17.24	2.70	19.20	18.13	ND	9.00
SC	5311	ND	14.34	10.51	16.48	75.70	24.92	15.90	ND	8.52
SC	5316	ND	17.45	47.43	13.94	3.71	10.10	8.11	ND	12.16
SC	5318	ND	3.53	ND	3.40	17.09	2.91	3.85	ND	ND
AVERAGE=		0.22	12.09	25.86	12.77	24.80	14.28	11.50	ND	9.89
STD DEV			6.00	19.23	6.40	34.56	9.73	6.67	ND	1.98
SAN PABLO										
SP	5155	13.46	10.09	11.35	13.59	5.98	29.38	2.67	ND	12.81
SP	5156	11.11	17.65	25.19	48.71	12.18	41.73	ND	ND	13.80
SP	5157	15.82	15.78	16.55	35.45	8.92	44.49	53.77	ND	15.67
SP	5158	ND	14.00	14.92	26.58	6.91	40.00	37.74	ND	14.77
SP	5159	ND	8.70	8.05	1.99	3.93	9.45	ND	ND	20.26
SP	5160	ND	18.78	17.52	2.63	11.10	18.59	23.84	ND	10.17
SP	5161	ND	10.38	14.80	ND	21.88	31.59	17.49	ND	7.72
SP	5163	ND	12.90	20.04	8.90	10.97	23.12	ND	ND	13.60
SP	5164	2.40	ND	13.07	1.45	10.29	15.99	28.10	ND	7.91
SP	5165	ND	25.53	33.79	57.07	15.94	52.94	58.31	ND	18.35
SP	5182	ND	5.96	ND	20.65	41.02	31.00	31.21	ND	21.59
SP	5185	ND	15.42	1.24	8.95	ND	9.73	24.64	ND	12.03
SP	5191	ND	17.76	16.41	30.13	13.24	22.61	41.41	ND	13.49
SP	5195	ND	13.19	10.91	15.51	0.95	40.53	23.46	ND	17.38
AVERAGE=		10.70	14.32	15.68	20.89	12.56	29.37	31.15	ND	14.25
STD DEV		5.85	5.08	7.95	17.91	10.07	13.43	16.00	ND	4.18
VALLEJO										
VJ	5151	ND	13.63	ND	ND	11.32	27.45	33.07	ND	10.78
VJ	5152	ND	31.51	34.00	48.38	11.51	84.72	75.08	ND	29.37
VJ	5153	ND	9.90	15.13	10.77	2.07	18.60	19.91	ND	3.48
VJ	5154	ND	17.12	27.38	7.77	17.76	23.64	42.10	ND	7.68
VJ	5198	ND	16.20	20.58	22.26	6.56	32.80	31.11	ND	14.42
VJ	5200	ND	24.84	32.10	30.58	3.35	28.13	15.72	ND	8.46
VJ	5201	4.07	4.70	8.88	9.76	6.48	10.47	ND	5.11	29.94
VJ	5202	16.09	11.47	11.50	20.44	4.36	20.86	27.54	ND	17.29
VJ	5203	4.00	17.76	48.65	24.20	2.97	22.04	23.56	ND	ND
VJ	5204	0.52	13.00	35.50	16.08	1.78	18.14	15.15	ND	5.73
VJ	5205	ND	13.67	21.47	10.99	1.25	13.56	15.35	ND	4.85
VJ	5207	ND	ND	20.17	13.75	4.35	17.56	6.49	ND	4.76
VJ	5208	ND	10.98	15.12	9.15	10.69	23.55	19.23	ND	5.55
VJ	5209	ND	14.77	ND	15.17	2.44	14.37	19.52	ND	3.99
AVERAGE=		6.17	15.35	24.21	18.41	6.21	25.42	26.45	5.11	11.25
STD DEV		6.82	6.77	11.64	11.27	4.88	18.12	17.30		9.15

	Site	MSB	128	180	170	195	206	209	tPCB	g lipid/ g.liver
BERKELEY										
	BK	5120	2.93	20.11	ND	ND	5.98	0.84	10403.66	0.08
	BK	5126	6.27	40.31	ND	1.74	7.23	4.65	10495.77	0.17
	BK	5127	8.12	49.50	ND	2.82	11.14	0.24	10610.34	0.11
	BK	5130	7.63	47.76	ND	2.98	10.42	2.71	10720.77	0.13
	BK	5133	44.21	236.82	60.30	ND	30.02	18.68	12022.72	0.16
	BK	5135	ND	73.70	ND	ND	8.48	ND	10773.35	0.25
	BK	5136	ND	152.88	ND	ND	2.18	ND	11363.40	0.34
	BK	5137	6.85	41.27	ND	ND	6.70	ND	10563.35	0.18
	BK	5139	14.37	84.07	6.11	ND	4.80	ND	10964.46	0.26
	BK	5140	11.44	52.06	ND	ND	ND	ND	10649.37	0.29
	BK	5142	ND	205.27	ND	ND	59.55	ND	11520.07	0.23
	BK	5146	1.61	26.14	ND	ND	ND	ND	10559.32	0.13
	BK	5149	8.90	52.00	ND	3.60	17.97	10.73	10797.39	0.14
	BK	5150	11.14	88.73	22.79	8.19	18.89	19.61	11149.41	0.28
	BK	5253	6.75	51.18	ND	2.06	ND	0.04	10972.01	0.10
	BK	5255	ND	19.67	ND	0.83	4.05	ND	10688.23	0.14
	BK	5263	5.36	38.84	ND	1.28	2.14	ND	10968.24	0.06
	BK	5319	ND	99.57	ND	2.57	12.06	11.35	11142.69	0.06
	AVERAGE=		10.43	76.66	29.74	2.90	13.44	7.65	10909.14	0.17
	STD DEV		10.71	61.92	27.75	2.17	14.76	7.75	411.79	0.08
OAKLAND										
	OK	5166	15.00	139.98	52.54	ND	ND	ND	11240.70	0.22
	OK	5167	22.76	96.56	7.75	5.15	9.66	1.82	11403.40	0.16
	OK	5168	9.82	234.56	ND	ND	ND	42.71	11660.11	0.18
	OK	5169	17.59	27.21	ND	ND	ND	ND	10765.09	0.09
	OK	5171	13.59	113.63	ND	ND	ND	ND	11085.76	0.31
	OK	5172	29.73	ND	ND	ND	ND	ND	10549.93	0.14
	OK	5176	3.35	10.87	ND	ND	1.84	0.90	10460.67	0.05
	OK	5213	ND	322.18	ND	ND	ND	ND	21996.77	0.17
	OK	5215	5.68	43.19	ND	3.45	ND	16.02	10726.62	0.09
	OK	5216	16.77	106.56	ND	ND	ND	ND	11061.24	0.18
	OK	5217	0.49	55.27	ND	2.81	12.46	ND	10881.52	0.07
	OK	5218	11.28	45.74	ND	ND	1.76	19.55	10767.16	0.05
	OK	5219	6.44	25.07	ND	ND	5.81	11.80	10744.39	0.13
	OK	5220	2.55	16.98	ND	ND	6.86	ND	10643.51	0.12
	OK	5221	11.43	122.16	11.26	6.69	5.79	13.24	11050.25	0.23
	OK	5268	10.61	39.65	ND	ND	5.90	3.87	11008.99	0.11
	AVERAGE=		11.81	93.31	23.85	4.52	6.26	13.74	11627.88	0.14
	STD DEV		7.88	87.30	24.91	1.75	3.60	13.56	2782.99	0.07
RUSSIAN R										
	RR	5222	2.02	4.13	ND	ND	6.34	ND	10639.01	0.14
	RR	5223	ND	32.58	ND	ND	0.60	ND	10689.58	0.23
	RR	5224	8.77	2.76	ND	ND	0.22	ND	10569.12	0.13
	RR	5225	8.85	28.73	ND	ND	16.37	4.17	10580.57	0.07
	RR	5227	2.00	11.60	ND	ND	3.20	ND	79.60	0.04
	RR	5228	ND	ND	ND	ND	1.19	ND	10534.56	0.11
	RR	5229	2.97	ND	ND	ND	3.44	ND	10558.83	0.13
	RR	5230	ND	16.92	ND	0.96	12.78	ND	10702.26	0.06
	RR	5231	9.33	8.91	ND	ND	1.87	0.98	10578.76	0.06

Site	MSB	128	180	170	195	206	209	tPCB	g lipid/ g.liver
RR	5232	3.80	0.64	4.23	ND	18.83	ND	10582.95	0.19
RR	5233	7.45	28.53	ND	ND	1.66	ND	10842.97	0.11
RR	5234	2.22	1.56	0.98	ND	12.19	ND	10571.03	0.21
RR	5236	20.27	62.57	ND	ND	ND	6.32	10737.40	0.20
RR	5244	ND	15.77	ND	ND	6.02	ND	10749.62	0.18
AVERAGE=		9.83	29.05	2.60	0.96	9.69	3.82	9886.88	0.13
STD DEV		36.94	48.14	96.66		53.67	102.61	2824.19	0.06
SANTA CRUZ									
SC	5276	1.85	16.29	ND	ND	1.36	ND	10680.23	0.08
SC	5311	34.11	57.05	ND	ND	0.45	2.23	10895.45	0.11
SC	5316	ND	ND	ND	ND	ND	ND	10744.89	0.05
SC	5318	ND	22.97	ND	ND	ND	ND	10698.89	0.05
AVERAGE=		17.98	32.10	ND	ND	0.91	2.23	10754.86	0.07
STD DEV		22.81	21.86	ND	ND	0.64		97.58	0.03
SAN PABLO									
SP	5155	3.34	18.00	ND	ND	4.79	8.77	10456.13	0.17
SP	5156	5.25	26.62	ND	ND	7.97	ND	10557.98	0.17
SP	5157	4.48	16.07	ND	1.23	5.71	ND	10570.72	0.17
SP	5158	5.61	5.80	ND	ND	ND	ND	10495.80	0.19
SP	5159	66.45	1.83	ND	ND	7.09	ND	10449.06	0.09
SP	5160	6.71	ND	ND	ND	ND	ND	10439.91	0.15
SP	5161	ND	ND	ND	ND	ND	ND	10432.86	0.16
SP	5163	10.71	ND	ND	ND	ND	ND	109.73	0.12
SP	5164	4.06	ND	ND	ND	ND	ND	21076.46	0.16
SP	5165	4.86	26.38	ND	ND	11.31	ND	10665.19	0.23
SP	5182	ND	7.30	ND	ND	ND	3.51	10575.82	0.22
SP	5185	ND	ND	ND	2.25	ND	ND	10494.25	0.23
SP	5191	ND	4.80	69.87	ND	5.65	ND	10664.14	0.22
SP	5195	4.60	13.57	1.09	ND	7.91	ND	10576.92	0.19
AVERAGE=		11.61	13.37	35.48	1.74	7.20	6.14	204.21	0.18
STD DEV		19.38	9.18	48.64	0.72	2.18	3.72	93.83	0.04
VALLEJO									
VJ	5151	5.18	6.24	ND	ND	ND	0.38	10455.19	0.13
VJ	5152	15.32	72.73	ND	2.08	3.73	ND	10770.67	0.16
VJ	5153	1.48	6.90	ND	ND	7.57	ND	10415.11	0.20
VJ	5154	4.33	ND	ND	ND	1.09	6.91	10528.93	0.20
VJ	5198	2.74	9.77	ND	ND	1.74	ND	10592.89	0.15
VJ	5200	ND	14.59	ND	0.67	6.22	ND	10623.90	0.11
VJ	5201	3.84	ND	ND	ND	ND	ND	10485.25	0.11
VJ	5202	10.52	14.93	ND	ND	ND	ND	10592.16	0.05
VJ	5203	8.12	ND	ND	ND	7.15	ND	10597.10	0.17
VJ	5204	ND	ND	ND	ND	0.68	ND	10515.90	0.18
VJ	5205	ND	10.41	ND	ND	0.79	ND	10552.23	0.15
VJ	5207	19.20	12.72	ND	ND	11.52	1.31	10525.83	0.10
VJ	5208	12.36	44.11	0.83	ND	5.63	ND	10607.65	0.07
VJ	5209	ND	10.38	ND	ND	2.59	ND	10542.47	0.18
AVERAGE=		8.31	20.28	0.83	1.38	4.43	2.86	10557.52	0.14
STD DEV		5.89	21.39		1.00	3.49	3.53	86.00	0.05

APPENDIX E

CHEMICAL DATA (ug/kg lipid weight) FOR *P. STELLATUS*

Individual chemical data for each *P. stellatus* sample collected from six sites in the San Francisco Bay area (ug/kg lipid weight).

Site	MSB	opDDE	ppDDE	opDDD	ppDDD	opDDT	ppDDT	HCB	lindane
BK	5120	ND	0.56	*	0.14	ND	ND	ND	0.06
BK	5126	0.01	0.46	*	0.18	ND	ND	ND	0.04
BK	5127	ND	1.07	*	ND	0.10	ND	ND	0.10
BK	5130	ND	1.02	*	ND	ND	0.03	ND	ND
BK	5133	ND	2.44	*	1.19	ND	0.11	ND	0.04
BK	5135	ND	0.55	*	0.14	ND	ND	ND	0.02
BK	5136	ND	0.97	*	0.44	ND	0.19	0.00	0.03
BK	5137	ND	0.69	*	0.32	ND	0.04	ND	0.12
BK	5139	ND	0.59	*	0.42	ND	0.23	ND	ND
BK	5140	ND	0.47	*	ND	ND	0.01	ND	ND
BK	5142	0.01	0.70	*	0.54	ND	ND	ND	0.07
BK	5146	ND	0.88	*	0.33	ND	ND	ND	ND
BK	5149	ND	1.32	*	0.54	ND	0.07	ND	ND
BK	5150	ND	0.71	*	0.51	ND	ND	ND	0.03
BK	5253	ND	1.20	*	0.22	ND	ND	ND	ND
BK	5255	ND	0.31	*	0.08	ND	ND	ND	ND
BK	5263	ND	1.64	*	0.46	ND	ND	ND	ND
BK	5319	ND	0.08	*	0.70	ND	0.45	ND	ND
AVERAGE		0.01	0.83	*	0.41	0.07	0.14	0.00	0.06
OK	5166	ND	0.80	*	0.51	0.18	ND	ND	ND
OK	5167	ND	0.85	*	0.44	ND	0.03	ND	0.07
OK	5168	ND	0.75	*	0.85	ND	0.12	ND	0.11
OK	5169	0.09	1.40	*	1.49	1.17	ND	ND	ND
OK	5171	0.00	0.54	*	0.35	ND	0.19	ND	ND
OK	5172	ND	0.72	*	0.50	ND	ND	ND	ND
OK	5176	0.02	0.38	*	0.13	ND	ND	ND	ND
OK	5213	ND	0.67	*	0.57	0.02	0.09	ND	0.03
OK	5215	ND	0.28	*	0.21	ND	ND	ND	ND
OK	5216	ND	1.36	*	0.60	ND	ND	ND	0.02
OK	5217	ND	5.46	*	0.73	0.75	0.14	ND	ND
OK	5218	ND	0.81	*	0.30	ND	ND	ND	ND
OK	5219	ND	0.53	*	0.20	ND	ND	ND	ND
OK	5220	0.01	0.37	*	0.33	ND	ND	ND	0.05
OK	5221	0.01	0.06	*	0.42	ND	0.08	0.00	ND
OK	5268	ND	0.74	*	0.36	ND	ND	ND	ND
AVERAGE		0.02	0.82	*	0.50	0.35	0.15	0.01	0.06
RR	5222	0.29	0.59	*	ND	ND	ND	ND	ND
RR	5223	ND	ND	*	0.15	ND	0.04	ND	ND
RR	5224	ND	0.08	*	0.03	ND	0.02	ND	0.05
RR	5225	ND	1.90	*	0.11	ND	ND	ND	ND
RR	5227	ND	1.80	*	0.09	ND	ND	ND	ND
RR	5228	ND	0.33	*	ND	ND	ND	ND	ND
RR	5229	ND	0.45	*	0.08	ND	ND	ND	ND
RR	5230	0.03	2.87	*	0.30	ND	ND	ND	ND
RR	5231	ND	ND	*	0.13	ND	0.18	ND	ND
RR	5232	ND	0.86	*	0.02	ND	ND	ND	ND
RR	5233	ND	0.33	*	0.02	ND	ND	ND	ND

Site	MSB	opDDE	ppDDE	opDDD	ppDDD	opDDT	ppDDT	HCB	lindane
RR	5234	ND	0.75	*	0.00	ND	ND	ND	ND
RR	5236	ND	ND	*	ND	ND	0.20	ND	ND
RR	5244	0.01	1.09	*	0.18	ND	0.04	ND	ND
AVERAGE		0.11	1.35	*	0.11	ND	0.11	ND	0.05
SC	5276	ND	1.85	*	0.35	0.10	0.04	ND	ND
SC	5311	0.16	0.11	*	0.43	0.13	0.34	ND	ND
SC	5316	0.51	0.52	*	0.46	ND	0.92	ND	ND
SC	5318	ND	0.04	*	0.08	0.07	0.40	ND	ND
AVERAGE		0.30	0.65	*	0.35	0.12	0.37	ND	ND
SP	5155	0.01	0.44	*	0.27	ND	0.01	ND	0.00
SP	5156	0.02	0.66	*	0.49	0.05	0.04	ND	0.04
SP	5157	0.01	0.69	*	0.33	ND	0.03	ND	0.04
SP	5158	0.01	0.40	*	0.29	ND	ND	ND	0.04
SP	5159	0.03	0.44	*	0.09	ND	ND	ND	0.06
SP	5160	0.03	0.56	*	0.57	ND	ND	ND	0.04
SP	5161	0.01	0.24	*	0.21	ND	ND	ND	0.01
SP	5163	ND	0.71	*	0.39	ND	ND	ND	ND
SP	5164	ND	0.35	*	ND	ND	0.08	ND	ND
SP	5165	0.02	1.08	*	0.72	ND	0.02	ND	0.08
SP	5182	0.01	0.10	*	0.56	ND	0.09	ND	0.04
SP	5185	ND	0.52	*	0.47	ND	0.04	ND	ND
SP	5191	0.01	0.51	*	0.31	ND	ND	ND	ND
SP	5195	ND	0.90	*	0.10	ND	ND	ND	0.01
AVERAGE		0.02	0.55	*	0.39	0.05	0.05	ND	0.03
VJ	5151	ND	0.82	*	0.37	ND	ND	ND	ND
VJ	5152	0.03	2.62	*	0.59	ND	0.04	ND	ND
VJ	5153	ND	0.31	*	0.22	0.00	0.01	ND	0.01
VJ	5154	ND	0.46	*	0.18	ND	0.01	ND	ND
VJ	5198	ND	0.68	*	0.29	ND	ND	ND	ND
VJ	5200	0.06	1.02	*	ND	ND	ND	ND	0.12
VJ	5201	ND	0.36	*	0.08	0.01	ND	ND	ND
VJ	5202	ND	4.62	*	0.09	ND	ND	ND	0.03
VJ	5203	0.01	0.68	*	0.41	0.04	0.04	ND	ND
VJ	5204	ND	0.24	*	0.20	ND	0.04	ND	0.08
VJ	5205	0.02	0.63	*	0.39	0.01	ND	ND	0.11
VJ	5207	0.04	0.73	*	0.27	ND	ND	ND	ND
VJ	5208	0.04	1.02	*	0.48	ND	ND	ND	ND
VJ	5209	0.01	0.63	*	0.34	ND	0.01	ND	ND
AVERAGE		0.02	0.85	*	0.31	0.02	0.03	ND	0.07

Site	MSB	heptachlor	aldrin	heptepox	chlordane	transnonachlor	dieldrin	mirex
BK	5120	ND	ND	0.02	ND	0.08	0.13	ND
BK	5126	0.00	ND	0.01	0.02	0.08	0.09	ND
BK	5127	0.02	ND	ND	0.14	0.28	0.26	ND
BK	5130	0.13	ND	ND	0.07	0.24	0.22	0.01
BK	5133	ND	0.01	0.03	0.06	0.41	0.40	ND
BK	5135	0.05	ND	0.01	0.01	0.07	0.08	ND
BK	5136	0.12	ND	0.03	0.02	0.11	0.19	ND
BK	5137	ND	ND	0.01	0.07	0.15	0.13	0.01
BK	5139	0.01	ND	0.02	0.02	0.08	0.12	ND
BK	5140	ND	0.00	0.01	0.01	0.06	0.09	ND
BK	5142	0.12	0.01	0.02	0.05	0.15	0.20	ND
BK	5146	0.13	ND	0.04	0.03	0.12	0.17	ND
BK	5149	ND	ND	ND	0.07	0.19	0.29	0.02
BK	5150	0.10	ND	0.02	0.03	0.15	0.21	0.06
BK	5253	0.47	0.03	0.13	ND	ND	0.09	0.19
BK	5255	0.11	0.03	0.06	ND	0.03	0.07	ND
BK	5263	ND	0.08	ND	0.00	0.14	0.34	0.04
BK	5319	ND	ND	0.23	0.05	0.14	1.92	ND
AVERAGE		0.11	0.01	0.03	0.04	0.14	0.20	0.04
OK	5166	ND	ND	0.03	0.04	0.18	0.21	ND
OK	5167	ND	ND	0.03	0.05	0.33	0.17	0.06
OK	5168	ND	ND	0.03	0.05	0.20	0.23	ND
OK	5169	ND	ND	0.13	0.14	0.27	0.66	0.29
OK	5171	ND	0.00	0.02	0.02	0.08	0.13	ND
OK	5172	ND	ND	ND	0.05	0.11	0.17	0.28
OK	5176	0.02	0.01	ND	0.01	0.05	0.06	0.03
OK	5213	ND	ND	0.01	0.03	0.20	0.18	ND
OK	5215	0.12	0.04	0.02	0.01	0.07	0.13	0.43
OK	5216	ND	ND	0.02	0.07	0.23	0.25	ND
OK	5217	ND	ND	ND	0.31	1.03	0.27	0.45
OK	5218	0.34	0.08	ND	0.02	0.21	0.16	0.13
OK	5219	ND	ND	ND	0.02	0.08	0.08	0.19
OK	5220	ND	0.04	0.01	0.03	0.11	ND	ND
OK	5221	ND	ND	0.06	0.02	0.11	0.61	ND
OK	5268	0.07	ND	0.00	0.00	0.06	0.30	ND
AVERAGE		0.06	0.02	0.04	0.04	0.18	0.25	0.16
RR	5222	0.07	0.09	0.17	0.02	0.06	ND	ND
RR	5223	0.29	ND	ND	ND	0.02	0.50	ND
RR	5224	ND	ND	ND	0.04	0.03	0.51	ND
RR	5225	ND	ND	0.13	0.01	ND	ND	ND
RR	5227	ND	0.26	0.03	ND	0.08	ND	0.05
RR	5228	ND	0.03	ND	ND	0.05	0.01	0.17
RR	5229	0.02	0.03	ND	0.01	0.01	0.00	ND
RR	5230	ND	0.11	0.48	ND	0.19	ND	ND
RR	5231	ND	ND	ND	0.03	0.14	1.53	0.18
RR	5232	0.04	ND	ND	ND	0.01	0.03	0.02
RR	5233	ND	ND	0.00	0.00	0.02	ND	ND

Site	MSB	hept	aldrin	heptepox	chlordane	transnon	dieldrin	mirex
RR	5234	0.01	ND	0.01	0.01	0.03	ND	0.11
RR	5236	ND	ND	ND	0.01	0.04	0.38	ND
RR	5244	ND	ND	0.01	0.01	0.05	0.03	0.04
AVERAGE		0.14	0.23	0.09	0.01	0.07	0.34	0.14
SC	5276	0.07	0.07	0.00	0.03	0.05	ND	ND
SC	5311	ND	ND	0.06	0.05	0.13	2.83	ND
SC	5316	ND	ND	0.51	0.07	0.07	2.10	0.38
SC	5318	ND	ND	ND	ND	0.05	0.40	0.15
AVERAGE		0.08	0.08	0.15	0.05	0.08	2.01	0.18
SP	5155	ND	ND	0.01	0.03	0.05	0.12	ND
SP	5156	0.11	0.01	0.02	0.06	0.09	0.20	0.01
SP	5157	ND	ND	0.04	0.03	0.09	0.14	0.01
SP	5158	ND	ND	0.02	0.03	0.06	0.10	ND
SP	5159	ND	ND	0.07	0.02	0.04	0.09	0.08
SP	5160	ND	ND	0.05	0.09	0.14	0.19	ND
SP	5161	ND	ND	0.03	0.03	0.06	0.18	ND
SP	5163	ND	ND	ND	0.05	0.11	0.16	ND
SP	5164	ND	0.01	0.02	0.13	0.13	0.14	ND
SP	5165	ND	ND	0.04	0.13	0.28	0.24	ND
SP	5182	0.03	ND	ND	0.05	0.07	0.47	0.04
SP	5185	ND	ND	ND	0.02	ND	0.18	ND
SP	5191	0.01	0.01	0.02	0.03	0.08	0.08	ND
SP	5195	0.01	0.01	0.01	0.01	0.07	0.04	ND
AVERAGE		0.04	0.01	0.03	0.05	0.10	0.17	0.03
VJ	5151	0.03	ND	0.02	0.05	0.21	0.14	0.03
VJ	5152	ND	0.01	0.01	0.08	0.29	0.16	ND
VJ	5153	0.01	0.02	0.01	0.04	0.09	0.07	0.03
VJ	5154	ND	ND	ND	0.04	0.08	0.11	ND
VJ	5198	ND	0.01	0.01	0.04	0.11	0.12	0.04
VJ	5200	0.06	0.03	0.01	0.10	0.16	0.26	ND
VJ	5201	ND	ND	0.02	0.01	ND	0.02	0.08
VJ	5202	0.27	ND	ND	ND	0.11	0.02	ND
VJ	5203	ND	ND	0.01	0.07	0.10	0.16	ND
VJ	5204	0.00	ND	0.05	0.01	0.03	0.04	ND
VJ	5205	ND	ND	0.19	0.05	0.09	0.09	ND
VJ	5207	ND	ND	0.01	0.08	0.09	0.12	ND
VJ	5208	ND	ND	0.02	0.08	0.16	0.13	ND
VJ	5209	0.01	0.01	0.03	0.08	0.10	0.08	ND
AVERAGE		0.03	0.02	0.03	0.06	0.12	0.11	0.04

Site	MSB	8	18	28	52	44	66	101	opDDD/77	118	105
BK	5120	ND	ND	ND	0.14	0.05	ND	0.11	0.20	0.15	0.06
BK	5126	ND	ND	0.02	0.05	ND	ND	0.09	0.16	0.12	0.03
BK	5127	ND	ND	ND	0.18	ND	0.00	0.20	0.19	0.38	0.13
BK	5130	ND	ND	ND	0.26	0.06	ND	0.20	0.25	0.31	0.14
BK	5133	ND	ND	0.10	0.30	0.02	0.07	0.55	0.94	1.20	0.22
BK	5135	ND	ND	ND	0.08	ND	0.01	0.14	0.10	0.22	0.04
BK	5136	ND	ND	0.04	0.13	0.01	0.03	0.23	0.18	0.39	0.06
BK	5137	ND	ND	ND	0.10	ND	ND	0.10	0.04	0.15	0.04
BK	5139	ND	ND	0.05	0.09	0.16	0.15	0.14	0.11	0.33	0.06
BK	5140	ND	ND	0.01	0.05	ND	0.00	0.09	0.06	0.18	0.03
BK	5142	ND	ND	ND	0.14	ND	0.23	0.28	0.29	0.54	0.11
BK	5146	ND	ND	0.06	0.12	0.07	ND	0.12	0.13	0.17	0.09
BK	5149	ND	ND	0.05	0.24	0.15	ND	0.19	0.18	0.36	0.13
BK	5150	ND	ND	0.07	0.17	0.01	0.21	0.17	0.15	0.40	0.07
BK	5253	ND	ND	0.15	0.49	0.02	0.05	0.57	0.17	0.84	0.15
BK	5255	ND	0.16	ND	ND	ND	ND	ND	0.14	ND	0.07
BK	5263	0.12	0.06	0.22	0.31	0.14	0.14	0.57	0.48	0.96	0.20
BK	5319	ND	ND	0.06	ND	ND	ND	0.58	ND	1.08	0.19
AVERAGE		0.04	0.08	0.06	0.16	0.06	0.11	0.21	0.20	0.40	0.09
OK	5166	ND	ND	ND	ND	ND	ND	0.32	0.23	0.47	0.18
OK	5167	ND	ND	0.04	0.24	0.06	ND	0.55	0.32	1.10	0.17
OK	5168	ND	ND	ND	0.16	0.06	ND	0.32	0.25	1.00	0.14
OK	5169	ND	ND	ND	0.73	ND	ND	0.49	0.41	0.44	0.38
OK	5171	ND	ND	0.04	0.11	0.03	0.02	0.16	0.13	0.32	0.06
OK	5172	0.09	ND	ND	ND	ND	ND	0.13	0.19	0.17	0.31
OK	5176	0.08	ND	ND	0.11	ND	0.04	0.13	0.14	0.23	0.03
OK	5213	0.08	ND	0.04	0.13	ND	ND	0.47	0.18	ND	0.27
OK	5215	ND	ND	0.03	0.13	0.03	ND	0.14	0.29	0.25	0.08
OK	5216	ND	ND	0.09	0.11	ND	ND	0.16	0.11	0.40	0.12
OK	5217	ND	ND	ND	0.21	0.14	0.02	0.22	ND	0.85	0.09
OK	5218	ND	ND	0.06	ND	ND	0.01	0.20	0.66	0.63	0.17
OK	5219	ND	ND	ND	0.10	0.21	ND	0.10	0.10	0.27	0.07
OK	5220	0.05	ND	ND	0.12	ND	0.03	0.13	0.28	ND	0.19
OK	5221	ND	0.03	ND	0.11	ND	0.09	0.27	ND	0.31	0.04
OK	5268	ND	ND	0.11	0.15	ND	ND	0.39	0.31	0.60	0.11
AVERAGE		0.06	0.05	0.06	0.17	0.08	0.04	0.27	0.22	0.49	0.14
RR	5222	0.17	ND	ND	ND	ND	0.01	0.07	0.77	0.04	0.05
RR	5223	ND	0.32	ND	ND	ND	ND	ND	0.05	0.07	0.14
RR	5224	ND	ND	ND	ND	0.16	ND	ND	ND	0.11	0.18
RR	5225	ND	ND	0.39	ND	ND	ND	ND	0.08	0.12	ND
RR	5227	0.45	ND	ND	ND	0.09	0.01	0.02	ND	0.18	ND
RR	5228	0.21	0.02	ND	0.01	0.04	ND	0.09	0.04	0.04	0.04
RR	5229	ND	ND	ND	0.04	ND	ND	0.05	0.45	0.02	0.02
RR	5230	0.33	ND	ND	0.45	ND	ND	0.32	0.42	0.34	0.22
RR	5231	ND	ND	ND	ND	ND	ND	0.09	0.13	0.25	0.06
RR	5232	ND	ND	0.08	0.14	ND	ND	ND	0.10	ND	0.04
RR	5233	ND	0.05	ND	0.17	ND	ND	0.09	0.56	0.20	0.09

Site	MSB	8	18	28	52	44	66	101	opDDD/77	118	105
RR	5234	ND	0.02	ND	0.09	ND	ND	0.06	0.04	0.06	0.02
RR	5236	ND	ND	ND	0.05	ND	ND	ND	ND	0.03	0.59
RR	5244	ND	ND	ND	ND	ND	0.00	0.10	0.07	0.13	0.04
AVERAGE		0.27	0.16	0.16	0.12	0.18	0.08	0.15	0.25	0.15	0.15
SC	5276	0.05	ND	ND	ND	0.07	0.00	0.16	0.25	0.22	0.03
SC	5311	ND	ND	ND	ND	0.12	ND	0.13	0.10	0.15	0.69
SC	5316	ND	ND	ND	ND	ND	ND	0.35	0.95	0.28	0.07
SC	5318	ND	ND	0.18	ND	ND	ND	0.07	ND	0.07	0.34
AVERAGE		0.06	ND	0.13	ND	0.13	0.00	0.17	0.36	0.18	0.34
SP	5155	ND	ND	ND	0.07	ND	0.08	0.06	0.07	0.08	0.04
SP	5156	ND	ND	ND	0.16	0.05	0.07	0.10	0.15	0.29	0.07
SP	5157	ND	0.02	ND	0.12	ND	0.09	0.09	0.10	0.21	0.05
SP	5158	ND	ND	ND	0.07	ND	ND	0.07	0.08	0.14	0.04
SP	5159	ND	ND	ND	ND	0.04	ND	0.10	0.09	0.02	0.04
SP	5160	ND	ND	ND	0.07	ND	ND	0.13	0.12	0.02	0.07
SP	5161	ND	0.04	ND	ND	ND	ND	0.06	0.09	ND	0.14
SP	5163	ND	ND	ND	0.08	ND	ND	0.11	0.17	0.07	0.09
SP	5164	ND	ND	ND	ND	ND	0.02	ND	0.08	0.01	0.06
SP	5165	ND	ND	ND	0.13	ND	ND	0.11	0.15	0.25	0.07
SP	5182	ND	0.02	ND	0.20	ND	ND	0.03	ND	0.09	0.19
SP	5185	ND	ND	0.12	ND	0.09	ND	0.07	0.01	0.04	ND
SP	5191	ND	0.08	ND	0.14	ND	ND	0.08	0.07	0.14	0.06
SP	5195	0.02	ND	ND	0.14	0.03	ND	0.07	0.06	0.08	0.00
AVERAGE		0.02	0.04	0.16	0.13	0.06	0.06	0.08	0.09	0.12	0.07
VJ	5151	ND	ND	0.03	0.26	0.06	ND	0.10	ND	ND	0.09
VJ	5152	0.03	0.03	0.03	0.23	0.05	ND	0.20	0.21	0.30	0.07
VJ	5153	ND	0.03	ND	0.03	ND	ND	0.05	0.08	0.05	0.01
VJ	5154	ND	ND	0.18	0.14	ND	ND	0.09	0.14	0.04	0.09
VJ	5198	0.01	0.01	ND	0.19	0.04	ND	0.11	0.14	0.15	0.04
VJ	5200	ND	0.06	ND	0.41	0.07	ND	0.23	0.29	0.28	0.03
VJ	5201	ND	ND	ND	ND	ND	0.04	0.04	0.08	0.09	0.06
VJ	5202	ND	ND	ND	ND	0.66	0.32	0.23	0.23	0.41	0.09
VJ	5203	ND	ND	ND	0.19	ND	0.02	0.10	0.29	0.14	0.02
VJ	5204	ND	ND	ND	ND	0.01	0.00	0.07	0.20	0.09	0.01
VJ	5205	ND	ND	ND	0.33	ND	ND	0.09	0.14	0.07	0.01
VJ	5207	ND	ND	ND	ND	ND	ND	ND	0.20	0.14	0.04
VJ	5208	ND	ND	0.17	0.32	ND	ND	0.16	0.22	0.13	0.15
VJ	5209	ND	0.01	ND	0.21	0.01	ND	0.08	ND	0.08	0.01
AVERAGE		0.02	0.03	0.10	0.23	0.07	0.04	0.11	0.17	0.13	0.04

Site	MSB	153	138	126	187	128	180	170	195	206	209	est 1242
BK	5120	0.39	0.43	ND	0.14	0.04	0.25	ND	ND	0.07	0.01	ND
BK	5126	0.26	0.25	ND	0.10	0.04	0.24	ND	0.01	0.04	0.03	ND
BK	5127	0.65	0.69	ND	0.16	0.07	0.45	ND	0.03	0.10	0.00	ND
BK	5130	0.75	0.71	ND	0.31	0.06	0.37	ND	0.02	0.08	0.02	ND
BK	5133	2.23	2.07	ND	0.85	0.28	1.48	0.38	ND	0.19	0.12	ND
BK	5135	0.46	0.42	ND	0.21	ND	0.29	ND	ND	0.03	ND	ND
BK	5136	0.72	0.61	ND	0.35	ND	0.45	ND	ND	0.01	ND	ND
BK	5137	0.34	0.35	ND	0.18	0.04	0.23	ND	ND	0.04	ND	ND
BK	5139	0.47	0.46	ND	0.21	0.06	0.32	0.02	ND	0.02	ND	ND
BK	5140	0.27	0.25	ND	0.11	0.04	0.18	ND	ND	ND	ND	ND
BK	5142	1.02	0.99	ND	0.62	ND	0.89	ND	ND	0.26	ND	ND
BK	5146	0.50	0.44	ND	0.14	0.01	0.20	ND	ND	ND	ND	ND
BK	5149	0.62	0.71	ND	0.27	0.06	0.37	ND	0.03	0.13	0.08	ND
BK	5150	0.51	0.45	ND	0.22	0.04	0.32	0.08	0.03	0.07	0.07	ND
BK	5253	0.80	0.47	ND	0.36	0.07	0.51	ND	0.02	ND	0.00	ND
BK	5255	0.33	0.17	ND	0.23	ND	0.14	ND	0.01	0.03	ND	1.7295
BK	5263	1.55	1.28	ND	0.56	0.09	0.65	ND	0.02	0.04	ND	.6362
BK	5319	1.70	1.69	ND	1.02	ND	1.66	ND	0.04	0.20	0.19	ND
AVERAGE		0.67	0.61	ND	0.30	0.06	0.44	0.17	0.02	0.08	0.04	.8112
OK	5166	0.89	0.74	ND	0.35	0.07	0.64	0.24	ND	ND	ND	ND
OK	5167	1.40	1.39	ND	0.51	0.14	0.60	0.05	0.03	0.06	0.01	ND
OK	5168	1.62	1.35	ND	0.86	0.05	1.30	ND	ND	ND	0.24	ND
OK	5169	0.53	1.05	ND	0.22	0.20	0.30	ND	ND	ND	ND	ND
OK	5171	0.47	0.43	0.01	0.21	0.04	0.37	ND	ND	ND	ND	ND
OK	5172	ND	ND	ND	0.37	0.21	ND	ND	ND	ND	ND	ND
OK	5176	0.40	0.34	ND	0.33	0.07	0.22	ND	ND	0.04	0.02	ND
OK	5213	1.89	1.59	ND	ND	ND	1.90	ND	ND	ND	ND	ND
OK	5215	0.62	0.66	ND	0.31	0.06	0.48	ND	0.04	ND	0.18	ND
OK	5216	0.79	0.75	ND	0.28	0.09	0.59	ND	ND	ND	ND	ND
OK	5217	2.10	1.60	ND	0.15	0.01	0.79	ND	0.04	0.18	ND	ND
OK	5218	1.35	1.20	ND	0.78	0.23	0.91	ND	ND	0.04	0.39	ND
OK	5219	0.39	0.53	ND	0.21	0.05	0.19	ND	ND	0.04	0.09	ND
OK	5220	0.31	0.28	ND	0.10	0.02	0.14	ND	ND	0.06	ND	ND
OK	5221	0.29	0.47	ND	0.29	0.05	0.53	0.05	0.03	0.03	0.06	.3541
OK	5268	0.87	0.72	ND	0.49	0.10	0.36	ND	ND	0.05	0.04	ND
AVERAGE		0.89	0.83	0.01	0.35	0.08	0.65	0.17	0.03	0.04	0.10	.5666
RR	5222	0.10	0.05	ND	0.05	0.01	0.03	ND	ND	0.05	ND	ND
RR	5223	0.07	0.15	ND	0.10	ND	0.14	ND	ND	0.00	ND	3.4461
RR	5224	0.15	0.14	ND	0.10	0.07	0.02	ND	ND	0.00	ND	ND
RR	5225	0.16	ND	ND	0.28	0.13	0.41	ND	ND	0.23	0.06	ND
RR	5227	0.69	0.44	ND	0.14	0.05	0.29	ND	ND	0.08	ND	ND
RR	5228	0.08	0.13	ND	ND	ND	ND	ND	ND	0.01	ND	.2408
RR	5229	0.04	0.02	ND	0.08	0.02	ND	ND	ND	0.03	ND	ND
RR	5230	0.64	0.21	0.24	0.35	ND	0.28	ND	0.02	0.21	ND	ND
RR	5231	0.46	0.39	ND	0.21	0.16	0.15	ND	ND	0.03	0.02	ND
RR	5232	0.06	0.03	ND	0.04	0.02	0.00	0.02	ND	0.10	ND	ND
RR	5233	0.21	0.12	ND	1.59	0.07	0.26	ND	ND	0.02	ND	.5394

Site	MSB	153	138	126	187	128	180	170	195	206	209	est 1242
RR	5234	0.06	0.04	ND	0.02	0.01	0.01	0.00	ND	0.06	ND	.1737
RR	5236	0.14	0.05	ND	0.02	0.10	0.31	ND	ND	ND	0.03	ND
RR	5244	0.36	0.29	ND	0.34	ND	0.09	ND	ND	0.03	ND	ND
AVERAGE		0.33	0.24	0.11	0.25	0.07	0.22	0.02	0.01	0.07	0.03	1.7216
SC	5276	0.24	0.23	ND	0.11	0.02	0.20	ND	ND	0.02	ND	ND
SC	5311	0.23	0.14	ND	0.08	0.31	0.52	ND	ND	0.00	0.02	ND
SC	5316	0.20	0.16	ND	0.24	ND	ND	ND	ND	ND	ND	ND
SC	5318	0.06	0.08	ND	ND	ND	0.46	ND	ND	ND	ND	ND
AVERAGE		0.20	0.16	ND	0.14	0.25	0.44	ND	ND	0.01	0.03	ND
SP	5155	0.17	0.02	ND	0.08	0.02	0.11	ND	ND	0.03	0.05	ND
SP	5156	0.25	ND	ND	0.08	0.03	0.16	ND	ND	0.05	ND	ND
SP	5157	0.26	0.32	ND	0.09	0.03	0.09	ND	0.01	0.03	ND	.1704
SP	5158	0.21	0.20	ND	0.08	0.03	0.03	ND	ND	ND	ND	ND
SP	5159	0.11	ND	ND	0.23	0.74	0.02	ND	ND	0.08	ND	ND
SP	5160	0.12	0.16	ND	0.07	0.04	ND	ND	ND	ND	ND	ND
SP	5161	0.20	0.11	ND	0.05	ND	ND	ND	ND	ND	ND	.4655
SP	5163	0.19	ND	ND	0.11	0.09	ND	ND	ND	ND	ND	ND
SP	5164	0.10	0.18	ND	0.05	0.03	ND	ND	ND	ND	ND	ND
SP	5165	0.23	0.25	ND	0.08	0.02	0.11	ND	ND	0.05	ND	ND
SP	5182	0.14	0.14	ND	0.10	ND	0.03	ND	ND	ND	0.02	.2428
SP	5185	0.04	0.11	ND	0.05	ND	ND	ND	0.01	ND	ND	ND
SP	5191	0.10	0.19	ND	0.06	ND	0.02	0.32	ND	0.03	ND	.8206
SP	5195	0.21	0.12	ND	0.09	0.02	0.07	0.01	ND	0.04	ND	ND
AVERAGE		0.17	0.18	ND	0.08	0.07	0.08	0.20	0.01	0.04	0.03	.4781
VJ	5151	0.21	0.25	ND	0.08	0.04	0.05	ND	ND	ND	0.00	ND
VJ	5152	0.53	0.47	ND	0.18	0.10	0.45	ND	0.01	0.02	ND	.3403
VJ	5153	0.09	0.10	ND	0.02	0.01	0.03	ND	ND	0.04	ND	.3625
VJ	5154	0.12	0.21	ND	0.04	0.02	ND	ND	ND	0.01	0.03	ND
VJ	5198	0.22	0.21	ND	0.10	0.02	0.07	ND	ND	0.01	ND	.1451
VJ	5200	0.26	0.14	ND	0.08	ND	0.13	ND	0.01	0.06	ND	.6173
VJ	5201	0.10	ND	0.05	0.27	0.03	ND	ND	ND	ND	ND	ND
VJ	5202	0.42	0.55	ND	0.35	0.21	0.30	ND	ND	ND	ND	ND
VJ	5203	0.13	0.14	ND	ND	0.05	ND	ND	ND	0.04	ND	ND
VJ	5204	0.10	0.08	ND	0.03	ND	ND	ND	ND	0.00	ND	ND
VJ	5205	0.09	0.10	ND	0.03	ND	0.07	ND	ND	0.01	ND	ND
VJ	5207	0.18	0.06	ND	0.05	0.19	0.13	ND	ND	0.12	0.01	ND
VJ	5208	0.34	0.27	ND	0.08	0.18	0.63	0.01	ND	0.08	ND	ND
VJ	5209	0.08	0.11	ND	0.02	ND	0.06	ND	ND	0.01	ND	.1281
AVERAGE		0.18	0.19	0.04	0.08	0.06	0.14	0.01	0.01	0.03	0.02	.3424

Site	MSB	est 1254	est 1260	tPCBs
BK	5120	1.2778	3.8656	5.1434
BK	5126	1.0824	3.6473	4.7297
BK	5127	3.2956	6.9208	10.2164
BK	5130	2.697	5.6503	8.3473
BK	5133	10.4643	22.7639	33.2282
BK	5135	1.8928	4.5341	6.4269
BK	5136	3.4011	6.9155	10.3167
BK	5137	1.2751	3.5264	4.8014
BK	5139	2.8515	4.973	7.8246
BK	5140	1.5498	2.7612	4.3111
BK	5142	4.7024	13.7262	18.4286
BK	5146	1.5186	3.0921	4.6107
BK	5149	3.121	5.7123	8.8334
BK	5150	3.4731	4.874	8.3471
BK	5253	7.2985	7.8715	15.17
BK	5255	ND	2.1611	3.8906
BK	5263	8.3117	9.9557	18.9035
BK	5319	9.413	25.5243	34.9373
		.	.	.
AVERAGE		3.978	7.6931	11.5815
		.	.	.
OK	5166	4.1293	9.7855	13.9149
OK	5167	9.5986	9.2822	18.8808
OK	5168	8.6579	20.0422	28.7001
OK	5169	3.8553	4.6499	8.5051
OK	5171	2.7972	5.6376	8.4348
OK	5172	1.4924	ND	1.4924
OK	5176	1.9791	3.3426	5.3217
OK	5213	ND	29.1478	29.1478
OK	5215	2.1553	7.3808	9.5361
OK	5216	3.4395	9.1049	12.5444
OK	5217	7.4122	12.1435	19.5556
OK	5218	5.4704	14.0686	19.539
OK	5219	2.3644	2.9663	5.3307
OK	5220	ND	2.1767	2.1767
OK	5221	2.6731	8.1688	11.196
OK	5268	5.2283	5.5443	10.7726
AVERAGE		4.2869	9.9831	14.8366
RR	5222	.3488	.4532	.8021
RR	5223	.6289	2.1787	6.2537
RR	5224	.9877	.3264	1.3141
RR	5225	1.0695	6.3129	7.3823
RR	5227	1.6	4.5	6.1
RR	5228	.3582	ND	.599
RR	5229	.144	ND	.144
RR	5230	2.9493	4.3377	7.287
RR	5231	2.1675	2.2827	4.4502
RR	5232	ND	.0517	.0517
RR	5233	1.7608	3.9893	6.2894

Site	MSB	est 1254	est 1260	total PCBs
RR	5234	.5406	.1141	.8284
RR	5236	.3026	4.8113	5.1139
RR	5244	1.092	1.3472	2.4393
AVERAGE		1.3217	3.3627	6.406
SC	5276	1.8751	3.1312	5.0062
SC	5311	1.3035	7.9761	9.2797
SC	5316	2.4248	ND	2.4248
SC	5318	.5918	7.0644	7.6562
AVERAGE		1.5318	6.8096	8.3414
SP	5155	.6955	1.6288	2.3242
SP	5156	2.4929	2.4087	4.9016
SP	5157	1.8143	1.4541	3.4389
SP	5158	1.2172	.4693	1.6865
SP	5159	.1925	.3119	.5044
SP	5160	.1524	ND	.1524
SP	5161	ND	ND	.4655
SP	5163	.6455	ND	.6455
SP	5164	.0787	ND	.0787
SP	5165	2.1588	1.7639	3.9227
SP	5182	.8166	.5105	1.5699
SP	5185	.3384	ND	.3384
SP	5191	1.1914	.3356	2.3475
SP	5195	.7102	1.0983	1.8084
AVERAGE		1.0303	1.1659	2.6743
VJ	5151	ND	.7387	.7387
VJ	5152	2.6304	6.991	9.9617
VJ	5153	.4685	.5309	1.3619
VJ	5154	.3379	ND	.3379
VJ	5198	1.2909	1.0023	2.4383
VJ	5200	2.4187	2.0394	5.0753
VJ	5201	.7722	ND	.7722
VJ	5202	3.5573	4.5924	8.1497
VJ	5203	1.2387	ND	1.2387
VJ	5204	.7773	ND	.7773
VJ	5205	.6372	1.0673	1.7045
VJ	5207	1.1962	1.9565	3.1527
VJ	5208	1.1368	9.6916	10.8284
VJ	5209	.7333	.8866	1.7479
AVERAGE		1.1439	2.2277	3.714