Near-Field Receiving Water Monitoring of Trace Metals and a Benthic Community Near the Palo Alto Regional Water Quality Control Plant in South San Francisco Bay, California: 2005

U.S. GEOLOGICAL SURVEY

OPEN FILE REPORT 2006-1152

Prepared in cooperation with the
CITY OF PALO ALTO, CALIFORNIA

Menlo Park, California

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Conversion Factors, Abbreviations, and Acronyms

Conversion Factors

Multiply	By	To obtain
foot (ft)	0.3048	meter
gallon (gal)	3.785	liter (L)
inch (in.)	2.54	centimeter
inch (in.)	25,400	micrometer (µm)
micromolar (µM)	molecular weight	micrograms per liter
micron (µm)	1,000,000	meter
mile (mi)	1.609	kilometer
ounce (oz)	28.35	gram (g)
part per million	1	microgram per gram (µg/g)

Temperature in degrees Celsius (º C) is converted to degrees Fahrenheit (º F) with the following equation:

º F = (1.8 x º C) + 32

Abbreviations and Acronyms

Abbreviations and Acronyms	Meaning
CI	Condition Index
ERL	Effects Range-Low
ERM	Effects Range-Median
ICP-OES	Inductively Coupled Plasma-Optical Emission Spectrophotometry
IRMS	Isotopic Ratio Mass Spectrophotometry
MDL	Method Detection Limit
MLLW	Mean Low Low Water
MRL	Method Reporting Level
NIST	National Institute of Standards and Technology
NPDES	National Pollutant Discharge Elimination System
PARWQCP	Palo Alto Regional Water Quality Control Plant
RWQCB	California Regional Water Quality Control Board
SFEI	San Francisco Estuary Institute
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

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Abstract

Trace elements in sediment and the clam *Macoma petalum* (formerly reported as *Macoma balthica* (Cohen and Carlton 1995)), clam reproductive activity and benthic, macroinvertebrate community structure are reported for a mudflat one kilometer south of the discharge of the Palo Alto Regional Water Quality Control Plant in South San Francisco Bay. This report includes data collected for the period January to December 2005, and extends a critical long-term biogeochemical record dating back to 1974. These data serve as the basis for the City of Palo Alto's Near-Field Receiving Water Monitoring Program, initiated in 1994.

Metal concentrations in both sediments and clam tissue during 2005 were consistent with results observed since 1990. Copper and zinc concentrations in sediment and bivalve tissue displayed a continued decrease over the last decade. In 2005, Cu concentrations were at or below the effects range-low (ERL) concentration (34 µg/g) for the entire year, the first time this has been observed. Also, zinc concentrations never exceeded the ERL (150 µg/g). Yearly average concentrations of copper, zinc and silver in *Macoma petalum* for 2005 were some of the lowest recorded since monitoring for metals began in 1975. The concentrations of mercury and selenium in sediments, during April and January 2004, respectively, were the highest values observed for these elements during this study. Later in 2005, concentrations decreased to historic levels. The increase in mercury and selenium in 2004 was not a permanent trend and concentrations of these elements in sediments and clams at Palo Alto remain similar to concentrations observed elsewhere in the San Francisco Bay.

Analyses of the benthic-community structure of a mudflat in South San Francisco Bay over a 31-year period show that changes in the community have occurred concurrent with reduced concentrations of metals in the sediment and in the tissues of the biosentinal clam *Macoma petalum* from the same area. Analysis of the reproductive activity of *M. petalum* shows increases in reproductive activity concurrent with the decline in metal concentrations in the tissues of this organism. Reproductive activity is presently stable with almost all animals initiating reproduction in the fall and spawning the following spring of most years. The community has shifted from being dominated by several opportunistic species to a community where the species are more similar in abundance, a pattern that suggests a more stable

community that is subjected to less stress. In addition, two of the opportunistic species (*Ampelisca abdita* and *Streblospio benedicti*) that brood their young and live on the surface of the sediment in tubes have shown a continual decline in dominance coincident with the decline in metals. *Heteromastus filiformis*, a subsurface polychaete worm that lives in the sediment, consumes sediment and organic particles residing in the sediment, and reproduces by laying their eggs on or in the sediment has shown a concurrent increase in dominance. These changes in species dominance reflect a change in the community from one dominated by surface dwelling, brooding species to one with species with varying life history characteristics. For the first time since its invasion in 1986, the non-indigenous filter-feeding bivalve *Corbula* (*Potamocorbula*) *amurensis* has shown up in small but persistent numbers in the benthic community.

Introduction

Environmental Monitoring

Determining spatial distributions and temporal trends of metals in sediments and benthic organisms is common practice for monitoring environmental contamination. These data can be the basis for inferring ecological implications of metal contamination. Another common method of environmental monitoring is to examine the community structure of sediment dwelling benthic organisms (Simon 2002). Spatial and temporal changes in community structure reflect the response of resident species to environmental conditions, although the underlying cause(s) for the response may be difficult to identify and quantify. Integrating measurements of metal exposure and biological response can provide a more complete view of anthropogenic disturbances and the associated effects on ecosystem health.

Environmental Exposure to Trace Metals

Sediment particles can strongly bind metals, effectively removing them from solution. As a result, sediments may accumulate and retain metals released to the environment. Thus, concentrations of metals in sediments serve as a record of metal contamination in an estuary, with some integration over time. Fluctuations in the record may be indicative of changes in anthropogenic releases of metals into the environment.

Metals in sediments are also indicative of the level of exposure of benthic animals to metals through contact with and ingestion of bottom sediments and suspended particulate materials. However, geochemical conditions of the sediment affect the biological availability of the bound metals. Assimilation of bioavailable sediment-bound metal by digestive processes and the relative contribution of this source of metals relative to metals in the aqueous phase are not well understood. Thus, in order to better estimate bioavailable metal exposures, the tissues of the organisms themselves may be analyzed for trace metals. Benthic organisms concentrate most metals to levels higher than those that occur in solution. Therefore, the record of tissue metal concentrations can be a more sensitive indicator of anthropogenic metal inputs than the sediment record. Different species concentrate metals to different degrees. However, if one species is analyzed consistently, the results can be employed to indicate trace-element exposures to the local food web. For example, silver (Ag), copper (Cu) and selenium (Se) contamination, originally observed in clams (*Macoma petalum* formerly reported as *Macoma balthica* (Cohen and Carlton 1995)) at the Palo Alto mudflat, was later found in diving ducks, snails, and mussels also from that region (Luoma and others, USGS, unpublished data).

Biological Response to Trace Metals

Contaminants can adversely impact benthic organisms at several organizational levels. For example, responses to a pollutant at the cellular or physiological level of an individual can result in changes at the population level, such as reductions in growth, survival and reproductive success. Community level responses to population level impairment can include overall shifts in species abundance favoring metal-tolerant species that can result in changes in predator/prey interactions, and in competition for available resources. Changes in the benthic community can ultimately result in changes at the ecosystem level due to that community's importance in the cycling of carbon in aquatic environments (see Alpine and Cloern 1992 for a local example).

In all aquatic environments, benthic organisms may be exposed to contaminants at all life stages through a variety of routes - sediment, water and food (see Wang and Fisher 1999 for a summary of the potential transport of trace elements through food). Toxicant exposure is related to contaminant concentration as well as duration. Even at low contaminant levels, long-term exposure can impact benthic organisms. The added complexity of synergistic or antagonistic effects between different contaminants and between contaminants and natural stressors makes the determination of causal relationships difficult to identify and quantify, even on a site-specific basis. However, a time-integrated picture of ecosystem response to contaminant loading can be provided by field studies which link changes in exposure at multiple time scales (in this case seasonal to decadal) to changes at individual, population and community level.

RWQCB and NPDES

The California Regional Water Quality Control Board (RWQCB) has prescribed a Self Monitoring Program with its re-issuance of the National Pollutant Discharge Elimination System (NPDES) permits for South San Francisco Bay dischargers. The recommendation includes specific receiving water monitoring requirements.

Since 1994, the Palo Alto Regional Water Quality Control Plant (PARWQCP) has been required to monitor metals and other specified parameters using sediments and the clam *Macoma petalum* at an inshore location in South San Francisco Bay. In addition to the required monitoring, PARWQCP has undertaken monitoring of the benthic community as a whole. The monitoring protocols have been designed to be compatible with or complement the RWQCB's Regional Monitoring Program. Monitoring efforts are being conducted by the U. S. Geological Survey (USGS) and are coordinated with 30 years of previous data collections and investigations by the USGS at this inshore location.

Objectives

The data presented by this study includes trace-metal concentrations in sediments and clams, clam reproductive activity and benthic-community structure. These data, and those collected in earlier studies, (Hornberger and others 2000a; Luoma and others 1991; 1992; 1993; 1995; 1996; 1997; 1998; Wellise and others 1999; David and others 2002; Moon and others 2003; 2004; Shouse and others 2003; 2004; Thompson and others 2002) were used to meet the following objectives:

- Provide data to assess seasonal and annual trends in trace-element concentrations in sediments and clams, reproductive activity of clams and benthic-community structure at a site designated in the RWQCB's Self-Monitoring Program guidelines for PARWQCP

- Present the data within the context of historical changes in South Bay and within the context of other locations in San Francisco Bay published in the international literature
- Coordinate inshore receiving water monitoring programs for PARWQCB and provide data compatible with relevant aspects of the Regional Monitoring Program. The near-field data will augment the Regional Monitoring Program as suggested by the RWQCB
- Provide data that could support other South San Francisco Bay issues or programs, such as development of sediment quality standards.

Approach

Despite the complexities inherent in monitoring natural systems, the adopted approach has been effective in relating changes in near-field contamination to changes in reproductive activity of a clam (Hornberger and others 2000b) and in benthic-community structure (Kennish 1998). This study, with its basis in historical data, provides a context within which future environmental changes can be assessed.

Metal concentrations were monitored in sediments and a resident species, *Macoma petalum*. Analysis of trace-element concentrations in the sediments provides a record of metal contamination to the site. The concentration and bioavailability of sediment-bound metals are affected by hydrology and geochemical factors (Thomson-Becker and Luoma 1985; Luoma and others 1995). Thus, ancillary data, including grain-size distribution, organic carbon, aluminum and iron content of the sediment, regional rainfall, and surface salinity, were collected to interpret seasonal, annual, and inter-annual variation in metal concentrations. The tissue of *Macoma petalum* provides a direct measure of exposure to bioavailable metals.

Biological response of the benthic community to metal exposure was examined at three levels of organization: individual, population, and community. At the individual level, concentrations of metals in the tissues of *Macoma petalum* were compared with physiological indicators. Two common animal responses to environmental stress are reduced reproductive activity and reduced growth. Growth and reproduction in *M. petalum* occur on fairly regular seasonal cycles. Seasonally, a clam of a given shell length will increase somatic tissue weight as it grows during the late winter and spring. Reproductive tissue increases during the early stages of reproduction, and subsequently declines during and after reproduction. These cycles can be followed with the condition index (CI) which is an indicator of the physiological condition of the animal, and specifically is the total soft tissue weight of a clam standardized to shell length. Inter-annual differences in growth and reproduction, expressed in the CI, are influenced by the availability and quality of food, as well as other stressors such as pollutant exposure and salinity extremes. Earlier studies (Hornberger and others 2000b) have shown that reproductive activity of *M. petalum* has increased with declining metal concentrations in animals from this location. Therefore, CI and reproductive activity of *M. petalum* appear to be useful indicators of physiological stress by pollutants at this location, and continue to be monitored for this study.

At the population level, trends of the dominant benthic species were examined to see if certain species have been more affected than others by environmental change. It has been shown that most taxonomic groups have species that are sensitive to elevated silver (Luoma and others 1995) and that some crustacean and polychaete species are particularly sensitive to elevated sedimentary copper (Morrisey and others 1996, Rygg 1985). Finally, the benthic community was examined for changes in structure (that is, shifts in the species composition of the macroinvertebrate community and abundance of individual species at this site). Prior studies have shown that more opportunistic species are likely to persist in highly disturbed environments (see Nichols and Thompson 1985a). It was hypothesized that a shift in community composition would result from changes in the concentrations of specific metals or in the composite of all contaminants.

Previous analysis of this community has shown no correlation between changes in the community and measured environmental parameters (i.e. salinity, air and water temperature, delta outflow, precipitation, chlorophyll a, sediment total organic carbon, and biological oxygen demand: Shouse 2002). Therefore, the community data was only compared to trace-metal data in this report.

Study Site

The Palo Alto site (PA) is located off of Sand Point on a mudflat on the western shore side of San Francisco Bay (not a slough) (*Figure 1*). The site is one kilometer south of the intertidal discharge point of the PARWQCP. The station is 12 m from the edge of the marsh and 110 cm above mean low low water (MLLW).

The sediment and biological samples from this location reflect a response of the receiving waters to the effluent just beyond the location of discharge. Earlier studies (Thomson and others 1984) have shown that dyes, natural organic materials in San Francisquito Creek and waters in the PARWQCP discharge move predominantly south toward Sand Point and thereby influence the mudflats in the vicinity of Sand Point. Spatial distributions of metal concentrations near the PARWQCP site were described by Thomson and others (1984) (also reported by Hornberger and others 2000a; Luoma and others 1991; 1992; 1993; 1995; 1996; 1997; 1998; Wellise and others 1999; David and others 2002; Moon and others 2003; 2004; Shouse and others 2003; 2004; Thompson and others 2002). Earlier work by Thomson and others (1984) showed that San Francisquito Creek and the Yacht Harbor were minor sources of most trace elements compared to the PARWQCP. The PARWQCP appeared to be the primary source of the elevated metal concentrations at the PA site in the spring of 1980, based upon spatial and temporal trends of Cu, Ag and zinc (Zn) in clams and sediments (Thomson and others 1984; Cain and Luoma 1990). Metal concentrations in sediments and clams (*M. petalum*), especially Cu and Ag, have declined substantially since the original studies as more efficient treatment processes and source control were employed (Hornberger and others 2000b). Frequent sampling each year was necessary to characterize those trends since there was significant seasonal variability (Cain and Luoma 1990; Luoma and others 1985). This report characterizes data for the year 2005, employing the methods described in the succeeding section.

Previous reports (Luoma and others 1995; 1996; 1997; 1998; Wellise and others 1999) also included data for a site in South Bay that that was influenced by discharge from the San Jose/Santa Clara Water Pollution Control Plant (SJ). Samples were collected from this site from 1994 to September 1999. Comparison of data from this site and the Palo Alto site allowed differentiation of local and regional long-term metal trends.

Methods

Sampling Frequency

In dynamic systems such as San Francisco Bay, the environmental effects of anthropogenic stressors are difficult to distinguish from natural seasonal changes. Frequent sampling increases the probability that anthropogenic effects can be identified. Analyses of early data (1974 through 1983; Nichols and Thompson 1985a, 1985b) showed that when differences are small, benthic samples need to be collected at monthly to bimonthly intervals to make the distinction between natural and anthropogenic effects. Therefore, samples were collected, with a few exceptions, on a monthly basis from the exposed mudflat at low tide between January and December 2005. Samples collected in the field included surface sediment, the deposit-feeding clam *M. petalum,* surface water, and sediment cores for community analysis. Surface water, surface sediment and *M. petalum* were not collected during the months of July, August and November. Cores for benthic-community analyses were collected during all months except October and December.

Measurements of Metal Exposure

Sediment

Sediment samples were scraped from the visibly oxidized (brownish) surface layers (top 1-2 cm) of mud. These surface layers represent recently deposited sediments and detritus, or sediments affected by recent chemical reaction with the water column. The sediment also supports microflora and fauna, a nutritional source ingested by *M. petalum.* Sediment samples were immediately taken to the laboratory and sieved through a 100 µm polyethylene mesh with distilled water to remove large grains that might bias interpretation of concentrations. The mesh size was chosen to match the largest grains typically found in the digestive tract of *M. petalum*. All sediment data reported herein were determined from the fraction that passed through the sieve (< 100 µm), termed the silt/clay fraction. Previous studies have shown little difference between metal concentrations in sieved and unsieved sediments when silt/clay type sediment dominates at a site. However, where sand-size particles dominate the bed sediment, differences in metal concentrations can be substantial. Sediments in extreme South San Francisco Bay can vary spatially and temporally in their sand content (Luoma and others 1995; 1996; 1997; 1998; Wellise and others 1999; David and others 2002; Moon and others 2003; 2004 also see SFEI 1997). Where sand content varies, sieving reduces the likelihood that differences in metal concentrations are the result of sampling sediments of different grain size. Some differences between the USGS and the Regional Monitoring Program results (SFEI 1997) reflect the bias of particle size on the latter's data.

To provide a measure of bulk sediment characteristics at a site, and thus provide some comparability with bulk sediment determination such as that employed in the Regional Monitoring Program – San Francisco Estuary Institute (SFEI 1997), the fraction of sediment that did not pass through the sieve (≥100 µm) was determined. This fraction is termed sand fraction. Bulk sediment samples were sieved to determine the percent sand and percent silt/clay (<100 µm) (*Appendix A*). The percentage of the bulk sediment sample composed of sand-sized particles (percent sand) was determined by weighing the fraction of sediment that did not pass through the sieve (≥100 µm), dividing that weight by the total weight of the bulk sample, and multiplying the quotient by 100. The percentage of silt/clay in the sediment was determined similarly by weighing the sediment that passed through the sieve (grain size <100 µm).

The silt/clay fraction was dried at 60º C, weighed, and then subsampled to provide replicates weighing 0.4 to 0.6 gram. These were re-dried (60º C), re-weighed, and then digested by hot acid reflux (10 ml of 16 normal (N) nitric acid) until the digest was clear. This method provides a 'near-total' extraction of metals from the sediment and is comparable with the recommended procedures of the U.S. Environmental Protection Agency (USEPA) and with the procedures employed in the Regional Monitoring Program. It also provides data comparable to the historical data available on San Francisco Bay sediments. While near-total analysis does not result in 100% recovery of all metals, recent comparisons between this method and more rigorous complete decomposition show that trends in the two types of data are very similar (Hornberger and others 1999). After extraction, samples were evaporated until dry, then reconstituted in dilute hydrochloric acid (10 % or 0.6 N). The hydrochloric acid matrix was specifically chosen because it mobilizes silver (Ag) into solution through the creation of Ag-chloro complexes. Sediment extracts were allowed to equilibrate with the hydrochloric acid (minimum of 48 hours) before they were filtered (0.45 µm) into acid-washed polypropylene vials for elemental analysis. Another set of replicate subsamples from the silt/clay fraction were directly extracted with 12 mL of 0.6 N hydrochloric acid (HCl) for 2 hours at room temperature. This partial extraction method extracts metals bound to sediment surfaces and is operationally designed to obtain a crude chemical estimate of bioavailable metal. The extract was pressure filtered (0.45 µm) before elemental analysis.

Organic carbon was determined using a continuous flow isotope ratio mass spectrophotometer (IRMS) (*Appendix A*). Prior to the analysis, sediment samples were acidified with 12 N HCl vapor to remove inorganic carbon.

Water pooled on the surface of the mudflat was collected in a bottle and returned to the lab where it was measured for salinity with a handheld refractometer.

Clam Tissue

Macoma petalum were collected by hand on each sampling occasion. Typically, 60-120 individuals were collected, representing a range of sizes (shell length). As they were collected, the clams were placed into a screw-cap polypropylene container (previously acid-washed) containing site water. These containers were used to transport the clams to the laboratory.

In the laboratory, the clams were removed from the containers and gently rinsed with de-ionized water to remove sediment. A small amount of mantle water was collected from randomly selected clams for the determination of salinity with a refractometer. The salinity of the mantle water and the surface water collected from the site (above) were typically within 1 ppt (‰) of each other. Only surface water values are reported here. Natural sand-filtered seawater (obtained from U.C. Santa Cruz, Long Marine Labs, Santa Cruz, CA) was diluted with de-ionized water to the measured salinity of the site water. Clams were immersed in this water and moved to a constant temperature room (12º C) for 48 hours to allow for the egestion of sediment and undigested material from their digestive tracts. Clams were not fed during this depuration period. After depuration, the clams were returned to the laboratory and further prepared for chemical analysis.

Elemental analysis, excluding mercury and selenium

The shell length of each clam was measured with electronic calipers and recorded digitally. Clams were separated into 1 mm size classes (e.g. 10.0-10.9 mm, 11.0-11.9mm, etc). The soft tissues from all of the individuals within a given size class were dissected from the shell and collected in pre-weighed 20 mL screw-top borosilicate glass vials to form a single composite sample for elemental analysis. The sample for each collection was thus composed of six to ten composites, with each composite consisting of 2 to 19 clams of a similar shell length. The vials were capped with a glass reflux bulb and transferred to convection oven (70ºC). After the tissues were dried to constant weight, they were digested by reflux in sub-boiling 16 N nitric. The tissue digests were then dried and reconstituted in 0.6 N hydrochloric acid for trace-element analysis.

Analysis for mercury and selenium

Samples collected in late winter (January and February), spring (April), and summer (June and September) were analyzed for total mercury (Hg) and selenium (Se). Approximately 40 clams were selected from the collection. The only criterion for selection was that the range of sizes (shell length) within this group was representative of the larger collection. Otherwise the selection of individuals was random. Selected individuals were grouped according to size to form 3-4 composites, each containing a minimum of ~1.25 gram wet weight. To meet this requirement, especially for the smaller clams, the 1-mm size classes were usually combined to form broader size classes (3-4 mm). Once the composites were formed, the clams were dissected as described above, and the soft tissue was placed into pre-weighed 30 mL screw top polycarbonate vials. These vials were closed and transferred to a freezer (-20º C). Once frozen, the samples were freeze-dried. After drying, the samples were shipped to the USGS analytical laboratory in Atlanta, GA where they were prepared and analyzed for selenium and mercury according to the method described by Elrick and Horowitz (1985).

Analytical

Sediment and tissue concentrations of aluminum (Al), chromium (Cr), copper (Cu), iron (Fe), nickel (Ni), silver (Ag), vanadium (V) and zinc (Zn) were determined using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). Mercury (Hg) and Selenium (Se) were determined in both sediment and clam tissues by Hydride Atomic Absorption Spectrophotometry. Analytical results are included in *Appendix B*, *Appendix C*, and *Appendix D*.

Quality Assurance

The polypropylene containers used in the field, depuration containers, glass-reflux bulbs, and all glassware and plastic used for metal analysis were first cleaned to remove contamination. Cleaning consisted of a detergent wash and rinse in de-ionized water, followed with a 1 N nitric-acid wash and thorough rinse in double-deionized water (18 MΩ resistivity). Materials were dried in a dust-free positive pressure environment, sealed, and stored in a dust free cabinet.

Samples prepared for ICP-OES analysis (i.e. all elements except selenium and mercury) were accompanied with procedural blanks and standard reference materials issued by the National Institute of Standards and Technology (NIST). Analysis was preceded with instrument calibration, followed by quality-control checks with prepared quality-control standards before, during (approximately every 10 samples) and after each analytical run. Analyses of reference materials (NIST 2079, San Joaquin soils and NIST 2976, mussel tissue) were consistent for the method and generally were within the range of certified values reported by NIST. Recoveries of Cd, Ni, and Pb in NIST 2976 tend to be less than the certified concentrations (*Appendix E*). Method detection limits (MDL) and reporting levels (MRL) were determined using the procedures outlined by Glaser and others (1981), Childress and others (1999), and USEPA (2004) (*Appendix F*). A full quality-assurance/quality-control plan is available upon request.

A variety of standard reference materials were prepared according to the method used for the determination of selenium and mercury. Observed concentrations fell within the range of certified values for these materials (*Appendix D*).

Other data sources

Precipitation data for San Francisco Bay is reported at San Francisco International Airport and was obtained from the California Data Exchange Center 2005.

Biological Response

Condition Index

The condition index (CI) is a measure of the clam's physiological state derived from the relationship between soft tissue weight and shell length and reported as the soft tissue dry weight (grams) for a clam of a particular shell length (mm). Specifically, for each collection, the relationship between the average shell length and tissue dry weight of the composites was fit with a linear regression, and from that regression the tissue dry weight was predicted for a normalized shell length of 25 mm.

Reproductive Activity

A minimum of 10 clams of varying sizes (minimum of 5 mm) were processed for reproductive activity concurrent with samples for metal analyses. Clams were immediately preserved in 10% formalin at the time of collection. The visceral mass of each clam was removed in the laboratory, stored in 70% ethyl alcohol, and then prepared using standard histological techniques. Tissues were dehydrated in a graded series of alcohol, cleared in toluene (twice for one hour each), and infiltrated in a saturated solution of toluene and Paraplast® for one hour, and two changes of melted Tissuemat® for one hour each. Samples were embedded in Paraplast® in a vacuum chamber and then thin sectioned (10 µm) using a microtome. Sections were stained with Harris' hematoxylin and eosin and examined with a light microscope. Each individual was characterized by size (length in mm), sex, developmental stage, and condition of gonads, thus allowing each specimen to be placed in one of five qualitative classes of gonadal development (previously described by Parchaso, 1993) (*Appendix G*).

Community Analysis

Samples for benthic-community analysis were collected with an 8.5 cm diameter x 20 cm deep hand-held core. Three replicate samples were arbitrarily taken, within a square-meter area, during each sampling date.

Benthic-community samples were washed on a 500 µm screen, fixed in 10% formalin and then later preserved in 70% ethanol. Samples were stained with rose bengal solution. All animals in all samples were sorted to species level where possible (some groups are still not well defined in the bay, such as the oligochaetes), and individuals for each species were enumerated. Taxonomic work was performed in conjunction with a private contractor familiar with the taxonomy of San Francisco Bay invertebrates (Susan McCormick, Colfax, CA) (*Appendix H*). S. McCormick also compared and verified her identifications with previously identified samples.

Results and Discussion

Salinity

Surface water salinity is related to the seasonal weather pattern in Northern California, which is characterized by a winter rainy season defined by months with rainfall amounts greater than 0.25 inches (November through April) and a summer dry season (May through October) (*Figure 2*). The 11 year (1994-2005) average annual rainfall is 24.3 inches. At 30.1 inches, precipitation for 2005 was one of the wettest years within this period (rainfall in 1998 was 30.2 inches). Rainfall during March and April of 2005 was especially greater compared to other years.

Surface-water salinity typically exhibits a seasonal pattern that is generally the inverse of regional rainfall (*Figure 3*, *Table 1*). This pattern was again observed in 2005. The salinity minimum of 16 parts per thousand (ppt) occurred in April, consistent with the late season rainfall, and elevated inflow of freshwater from surface water runoff. Considering the cumulative rainfall for the year, the salinity minimum was not as low as in other years of heavy rainfall (e.g. 1997-98). This could indicate that in 2005 winter salinity was affected more by local runoff than by the large flushing flows from the Sacramento/San Joaquin Rivers. Salinities continually increased during the dry season and reached their maximum (26 ppt) in the fall (September-November).

Sediments

Metal concentrations in surface sediments from Palo Alto typically display an annual periodicity of seasonal patterns. Thomson-Becker and Luoma (1985) suggested that this inter-annual variation is related to changes in the size distribution of sediment particles caused by deposition of fine-grained particles in the winter and their subsequent wind-driven re-suspension in the fall. Thomson-Becker and Luoma showed that the composition of surface sediments was dominated by fine-grained particles - and accompanied by high Al and Fe concentrations - during the period of freshwater input (low salinities through April), reflecting annual terrigenous sediment inputs from runoff. Coarser sediments dominated later in the year because the seasonal diurnal winds progressively winnow the fine sediments into suspension through the summer. This pattern was observed again in 2005 (*Figure 4*, *Appendix A*).

In 2005, the percent of silt/clay in the sediment was at its maximum (95%) in April, coincident with prolonged late season rainfall. Aluminum and Fe concentrations varied with the percentage of silt/clay-sized particles (*Figure 4*, *Table 1*), as described above, reflecting the contribution of clays composed of Al and Fe.

The total organic carbon (TOC) content of the sediments varied modestly during the year, coincident with other sedimentary constituents (*Table 1*). TOC content was highest during the winter (January through April values ranged from 1.44 to 1.48 %), after April declined to a minimum in September (0.89%), and then increased during the early winter to 1.23%, as of December 2005. In light of the most recent data, the exceptionally high value observed in October of 2004 (8.1%) appears to have been an anomalous event.

The metals Cr, Ni and V are highly enriched in some geologic formations within the watershed. In North San Francisco Bay, studies of sediment cores indicated that concentrations of these elements similar to those reported here were derived from natural geologic inputs (Hornberger and others, 1999; Topping and Kuwabara, 2003). Inputs of minerals bearing Cr, Ni, and V appear to vary seasonally as suggested by the variable concentrations of these metals in surface sediments. Typically, maximum concentrations coincide with winter/spring maximums in fine sediments, while minimum concentrations occur during the late summer/fall (*Figure 5*, *Table 2*). The minimum Ni concentration in the fall of 2004 (51.7µg/g in October) and the following winter/spring maximum in 2005 (85.3 µg/g in March) were the lowest seasonal concentrations observed since 1994. Concentrations of Cr and V declined from their maximum concentrations in the winter of 2002/2003 to concentrations similar to those prior to 2003.

Copper concentrations in sediments are shown with sediment guidelines set by the National Oceanic and Atmospheric Administration (Long and others, 1995). Long and others defined values between ERL (Effects Range-Low) and ERM (Effects Range-Median) as concentrations that are occasionally associated with adverse effects (21 - 47% of the time for different metals). Values greater than the ERM were frequently associated with adverse effects

(42% - 93% of the time for different metals). It must be remembered, however, that these effects levels were derived mostly from bioassay data and are not accurate estimates of sediment toxicity. In 2005, Cu concentrations were near or below the effects range-low (ERL) (34 µg/g) for the entire year, the first time this has been observed (*Figure 6*, *Table 2*). Cu concentrations were at their maximum (33-35 µg/g) throughout the winter/spring (January to April). The minimum concentration (21 µg/g) was observed in September. The magnitude of the inter-annual cycle was smaller than in some other years (e.g. 2004). Near-total Cu concentrations appear to have been declining gradually since at least 2000. Over the same period, partial-extractable concentrations have remained relatively constant outside of the typical seasonal variation (*Figure 6*).

For the second consecutive year, near-total and partial-extractable Zn concentrations never rose above the Zn ERL (150 µg/g) (*Figure 7*, *Table 2*). Winter Zn concentrations were the lowest observed during the past three years and were consistent with temporal patterns of Cu and Ni over the same period.

The concentration of partial-extractable Ag in Palo Alto sediments are well below the Ag ERL (1 µg/g), but greater than the established concentration for uncontaminated sediments in San Francisco Bay (Hornberger and others, 1999) (*Figure 8*, *Table 2*). A seasonal pattern in Ag concentrations was well defined in 2005, but no long-term trend in this seasonal pattern is evident in the decade prior to 2005.

Mercury concentrations in sediment during 2005 ranged between 0.26 µg/g (September) to 0.32 µg/g (January to April) (*Figure 9*, *Table 2*). These values were more typical of concentrations observed during the record (1994-2005) and were considerably less than the maximum Hg concentrations observed in 2004. The April 2004 concentration of Hg in the sediment (0.49 µg/g) was the highest observed in this study. Otherwise, Hg concentrations were within the range usually observed within San Francisco Bay (0.2 - 0.4 µg/g).

Selenium concentrations were also less during 2005 than in 2004 (*Figure 9*, *Table 2*.) Concentrations ranged between 0.5 µg/g (February) to 0.3 µg/g (June and September). The annual mean concentration for the year was 0.38 ± 0.04 µg/g (*Table 2*), only slightly lower than the overall mean for the entire record (0.40 µg/g).

Clam Tissue

Metal concentrations in the soft tissues of *Macoma petalum* reflect the combined metal exposures from water and food. Exposures to Cu and Ag at Palo Alto are of special interest due to the high tissue concentrations observed at this site in the past relative to other South Bay locations (*Figure 10* and *Figure 11*, *Table 3* and *Table 4*, respectively). During the period 1977 – 1987, the range in annual concentrations of Cu and Ag were 95-287 and 45-106 µg/g, respectively. Since 1987, concentrations have been considerably lower: 24-71 µg Cu /g and 2-20 µg Ag/g. Annual mean concentrations of Cu and Ag for 2005 were, respectively, 26 ± 2 and 1.8 ± 0.3 µg/g, the lowest concentrations (Cu concentrations were comparable in 1991) observed during the record.

Intra-annual variations in metal concentrations in clam soft tissues display a consistent seasonal signal, with fall/winter maxima and spring/summer minima, although it is common for the amplitude of this seasonal cycle to vary from year to year. For example, the winter maxima and the magnitude of seasonal Cu and Ag concentrations were greater between 1994 and 1996 than in subsequent years (*Figure 12*, *Figure13*). The magnitude of the decline in Cu and Ag concentrations during the spring/summer of 2005 was comparable to previous years; however, the subsequent increase in tissue concentrations was not as great as in previous years and as of

December, concentrations were only about half the maximum values observed in 2004. These trends most likely reflect the interaction of the changing exposure regime of the site (the long term decline in metal concentrations) with the annual growth cycle of *M. petalum* (Cain and Luoma 1990).

As with Cu and Ag, tissue concentrations of Cr (*Figure 14*, *Table 5*), Ni (*Figure 15*, *Table 5*) and Zn (*Figure 16*, *Table 5*) also exhibited seasonal cycles. The seasonal cycles of Cr and Ni were very similar in terms of their timing and magnitude throughout the record (1994 - 2005). Neither element exhibited a clear temporal trend (either decreasing or increasing) in concentration. Maximum concentrations occurred in the winter of 1996-1997, while 2000 – 2002 was a period of relatively low winter-maximum concentrations. In 2003, concentrations increased somewhat and have remained relatively comparable through 2005. In addition to the typical seasonal pattern, Zn concentrations exhibited a slight long-term decline in concentration. During 1994-1997, Zn concentrations were notably higher throughout the year when compared to subsequent years. The winter maximum for 2004-05 was somewhat less than the previous two winters, but was comparable to the winter of 2001-02. Wellise and others (1999) observed that seasonal and inter-annual patterns of Cr, Ni, and Zn in *M. petalum* at Palo Alto were generally similar to those from the San Jose site, suggesting that regional-scale processes may be more important than treatment plant inputs in controlling the bioavailability of these elements.

Mercury concentrations in *M. petalum*, like Zn, have trended slightly lower since 1994 (*Figure 17*). The highest concentrations observed during the record occurred in September 1994 (0.53 µg/g) and during the winters of 1995 (0.48 µg/g) and 1996 (0.47 µg/g). The seasonal (summer/fall) low concentration in 1995 (0.33 – 0.37 µg/g) was the highest recorded, also. Concentrations declined after 1996, and since then they have fluctuated seasonally between 0.12 and 0.42 µg/g and averaged 0.26 ± 0.08 µg/g.

Selenium concentrations in *M. petalum* vary seasonally like other elements (*Figure 18*, *Table 5*). Long-term trends in the data are not evident. However, the annual maximum concentrations (during summer/fall) have increased somewhat since 2002. Concentrations in 2005 appear consistent with this more recent feature.

The condition index for *M. petalum* at Palo Alto extends back to 1988 (*Figure 19*). As previously discussed, the data fluctuate seasonally in relation to growth and reproductive cycles, and annual cycles differ in magnitude. For example, the maximum value in the CI during 1994-1999 was generally less than preceding or succeeding years. The CI during 2005 was generally comparable to the previous five years.

Reproduction of Macoma petalum

Earlier studies (Hornberger and others 2000b; Shouse and others 2004) found that low reproductive activity in *M. petalum* in the late 1970s was related to highly elevated concentrations of silver in the soft tissues. This finding has implications for the reproductive success of the population. Following the decline in tissue concentrations of Ag (and Cu) in the 1980s, reproductive activity improved (*Figure 20*) . Furthermore, the low reproductive activity observed during the late 1970s has not been observed during the entire period of reduced metal exposures. Data for 2005 show that *M. petalum* continues to be highly reproductive relative to the 1970's with a high percentage of the animals being reproductively active at any one time and with normal seasonal cycling of reproduction beginning in fall and spawning occurring during the following spring (see *Appendix G* for detailed reproduction data for 2005).

Benthic Community

The simplest metrics that are used in assessing environmental stress on biological communities are estimates of species diversity and total animal abundance. Species diversity, as estimated by a time series of number of species for each month, trended upward in 2005 *(Figure 22)*. However, total animal abundance does not show the same trend *(Figure 23)*. The difficulty with these types of metrics is that they do not consider the possibility that one species can take the place of another. Depending on the characteristics of the new species, the community structure and function may change as a result of this exchange of species. The details of changes in species composition are important because they may reflect the relative ability of species to accommodate environmental stress and redistribute site resources.

Three common bivalves (*Macoma petalum*, *Mya arenaria*, and *Gemma gemma*) did not show any consistent trend over the 29-year period *(Figure 24*, *Figure 25*, and *Figure 26*). In all cases, there was significant seasonal and inter-annual variability in species abundances. There were, however, six species that did show trends in their abundance throughout the study. The first, *Ampelisca abdita*, a small crustacean that lives above the surface of the mudflat in a tube built from selected sediment particles showed a general decline in both the annual average abundances and annual maximum abundances (seasonal peaks in abundance; *Figure 27*). The second species to showed a significant trend was the small polychaete worm *Streblospio benedicti*, which also builds a tube above the surface of the mudflat. As with *A. abdita*, *S. benedicti* exhibited a decline in annual maximum abundances as well as annual average abundances *(Figure 28)*. The small burrowing crustacean *Grandiderella japonica*, a deposit feeder, initially showed a declining trend through the 1980's followed by increasing seasonal maximum abundances in recent years *(Figure 29)*. *Neanthes succinea*, a burrowing polychaete that feeds on surface deposits and scavenges, similarly showed an initial decrease in annual maximum abundances through the 1980's, followed by an increase in both annual average abundances and annual maximum abundances *(Figure 30)*. Two species showed an increase in abundance within the time series. The first was the polychaete worm *Heteromastus filiformis (Figure 31)*, a deposit feeding, burrowing species that lives deep in the sediment (usually 5-20 cm below the surface of the mudflat). Abundance increased sharply in 1985 and then partially receded in the late 1980's. Abundances since 2000 have remained higher than in the late 1970's. The second was an introduced species, *Nippoleucon hinumensis*, a small burrowing crustacean, which appeared in the dataset in 1988 *(Figure 32)* was introduced into the bay in 1986 (Cohen and Carlton 1995). *Corbula amurensis*, a non-indigenous filter feeding bivalve, first appeared in the benthic community as more than a rare species in April 2005 and persisted into November 2005 (Appendix H).

As stated earlier, multivariate analyses of population data of the dominant species with environmental parameters did not reveal any relationships, except with the concentration of silver and copper in the sediment and in the tissue of *Macoma petalum* (using data as reported by David and others 2002). Therefore, this update will only consider those metals (recent data, 2002 through 2003, taken from Moon and others 2004). This comparison can be made by plotting the metals and individual species together over the period of the study. The worm *H. filiformis* has increased in abundance with the decrease in silver and copper through time *(Figure 33)*. Because the natural spatial variability (that is, the large standard deviations around the monthly means) and seasonal variability of invertebrate abundance and metal concentration can be quite large, the annual average abundances for *H. filiformis* and annual average metal concentrations are shown *(Figure 34)* and *(Figure 35)*. To interpret these plots, we must first examine the life history characteristics of this species and determine if there is some mechanism by which this organism could be responding to a decrease in silver or copper in the environment. *H. filiformis* has continual tissue contact with the sediment both at the exterior of its body, as well as within its body, due to its lifestyle of burrowing through the sediment and consuming a diet of mud and organic particles. In addition, this is one of the few species in the present community that reproduces exclusively by laying its eggs in the sediment. The larvae hatch after two to three days and spend two to three days in the plankton before settling back to the mud as juvenile worms (Rasmussen 1956). One hypothesis as to why *H. filiformis* increased in abundance may be that either the adult worms or the eggs are less stressed in the present environment. Because of its mode of reproduction and short planktonic larval period, this species is not likely to move into an area quickly after the environment becomes acceptable. Therefore, it is not possible to identify either the identity of the metal or the threshold concentration of the metal to which the animal is responding without laboratory tests. However, other investigators have shown that silver can adversely affect reproduction in invertebrates and that adult *H. filiformis* can tolerate high levels of copper (Ahn and others1995). The gradual increase in *H. filiformis* abundance through 1984 may be a response to the gradual reduction of metals in the environment or may indicate that it took several years for the population to build up in the area. The large abundance increase in 1985 and 1986, followed by a decline and leveling out of abundance, may be an example of the "boom and bust" principle whereby a species rises to levels too high for the habitat to support, and then declines in abundance until it levels out to a habitat-supportable abundance (Begon and others 1986). It is unclear, based on only eight years of data since the early 1990's, if this species has established a stable abundance.

The two species that have declined in abundance coincident with the decline in metals, the crustacean *A. abdita (Figure 36*, *Figure 37* and *Figure 38)* and the worm *S. benedicti (Figure 39, Figure 40*, and *Figure 41)* have very similar life history characteristics. Both species live on the surface of the sediment in tubes that are built from sediment particles, are known as opportunistic and are thus capable of rapid increase in population size and distribution, brood their young, and produce young that are capable of either swimming or settling upon hatching. It is unclear why these species have become less competitive in the present day environment, but their very low numbers in the last several years indicate that there is a major shift in the community as both species were numerically very dominant in the benthic community in the 1970's and 1980's. Unlike *A. abdita* and *S. benedicti*, there has been no significant decline in the abundance of *G. gemma (Figure 42, Figure 43*, *and Figure 44)* the small clam that reproduces by brooding their young and lives on the sediment surface. All three species are suspension feeders and thus consume water borne particles, although *S. benedicti* may also deposit feed.

Summary

Long-term Observations

Since 1974, USGS personnel have monitored and conducted basic research on the benthic sediments and biological community in the vicinity of the discharge of the Palo Alto Regional Water Quality Control Plant (PARWQCP). The time series presented here updated previous findings (Luoma and others 1991; 1992; 1993; 1995; 1996; 1997; 1998; Wellise and others 1999; David and others 2002; Moon and others 2003; 2004; 2005, Shouse and others 2003; 2004; Thompson and others 2002) with additional data from January 2005 through December 2005, to create a record spanning 32 years. This long-term dataset includes sediment chemistry, tissue concentrations of metals, condition index and reproductive activity in *Macoma petalum*, and population dynamics of benthic-invertebrate species. The time series encompasses the period when exceptionally high concentrations of copper and silver were found in *M. petalum* (1970's) and the subsequent period when those concentrations declined. The sustained record of biogeochemical data at this site provides a rare opportunity to examine the biological response to metal contamination within this ecosystem.

Studies during the 1970's showed that sediments and *Macoma petalum* at the Palo Alto site contained highly elevated levels of metals, especially Ag and Cu, as a result of metal-containing effluent being discharged from the PARWQCP to South Bay. In the early 1980's, the point-source metal loading from the nearby Palo Alto Regional Water Quality Control Plant was significantly reduced as a result of advanced treatment of influent and source mitigation. Coincident with declines in metal loadings, concentrations of metals in the sediment and in the clam *M. petalum* (serving as a biomonitor of metal exposures) also declined as previously described by Hornberger and others (2000). Hornberger and others found a significant correlation between metal loadings (Cu) and tissue concentrations in *M. petalum*. They also showed that metal levels in sediments and clams respond relatively quickly to changes in metal loading; the reduction in metal loadings by the PARWQCP resulted in a reduction in metal concentrations in both the sediment and *M. petalum* within a year.

Biological responses to metal inputs to South Bay were assessed at different levels of organization. These responses are interpreted within the appropriate temporal context. Because metal exposures were already high when the study began, interpretations are based on observed changes in biological attributes as metal inputs declined. In general, discernable responses at the organism level (i.e. reproductive activity, a manifestation of a cellular or physiological change) to metal exposure may occur within a relatively short time, while population and community level responses take longer to develop. Stable changes in the benthic community may take a relatively long period of time to be expressed because of the normally high degree of intra-annual variability of benthic-community dynamics, which reflects the cumulative response to natural and anthropogenic disturbances. It is therefore critical that sampling frequency and duration be conducted at temporal scales appropriate to characterize the different biological responses.

During the first 10 years of this study, when the metal concentrations were high and declining, the benthic community was composed of non-indigenous, opportunistic species that dominated due to their ability to survive the many physical disturbances on the mudflat (Nichols and Thompson 1985a, 1985b). These disturbances included sediment erosion and deposition, and aerial exposure at extreme low tides, in addition to less well defined stresses. The possible effects of metal exposure as a disturbance factor were not considered in the analyses by Nichols and Thompson as the decline in metal concentrations in *Macoma petalum* and sediment had just begun.

However, data collected throughout the period of declining metal exposure have revealed biological responses. Reproductive activity improved within a year or two of reduced metal exposure, and responses at the population and community levels were observed afterward. Identification of these responses was possible because the frequency of sampling allowed long-term trends related to metal contamination to be identified within the context of repeating seasonal cycles and unrelated inter-annual variation.

2005

In 2005, Cu and Ag concentrations in sediments and the soft tissues of clam *M. petalum* were as low as anytime during the record (that is, since 1974). This is at least partly attributable to the reduced loading of these metals from the treatment plant which was achieved in the 1990s and has been maintained thereafter. For many other elements of regulatory interest, including Cr, V, Ni, and Zn, regional scale factors appeared to influence sedimentary and bioavailable concentrations. Other variables such as precipitation and accelerated erosion of salt marsh banks in recent years, that may influence the seasonal and year to year patterns in sedimentary and tissue concentrations, should still be investigated.

The long-term dataset demonstrates various adverse impacts of contaminants on benthic organisms. Decreasing particulate concentrations of trace metals in the local environment have benefited resident populations of invertebrates, as evidenced by increased reproductive activity in the clam *Macoma petalum* that has been sustained though 2005. The abundances of individual species showed little variability during 2005. This reflects a more stable community in the absence of metal stressors. All dominant species in the community, with the exception of *Gemma gemma*, have abundances similar to those seen in previous years. The lower abundances exhibited by *G. gemma* in 2004 were found elsewhere in the long-term data set, and could be due to a number interdependent factors. The interpretation that shifts in species abundance at Palo Alto were a response to decreasing contaminants continue to be supported by the most recent sediment and community data.

Value of Long-Term Monitoring

This study highlights the importance of long-term ecosystem monitoring. The decadal time series produced during the course of sustained efforts at this site have made it possible to describe trends, identify previously undocumented phenomena, and pose otherwise unrecognized hypotheses that have guided past detailed explanatory studies and can guide future studies. Monitoring studies cannot always unambiguously determine the causes of trends in metal concentrations or benthic-community structure. The strength and uniqueness of this study is the integrated analysis of metal exposure and biological response at intra- and inter-annual time scales over multiple decades. Changes and trends in community structure that may be related to anthropogenic stressors, as was seen in this study, can only be established with a concerted and committed effort of sufficient duration and frequency of sampling. Such rare field designs allow biological responses to natural stressors to be characterized and separated from those introduced by man. Through interpreting time series data, it has been possible to separate anthropogenic effects from natural annual and inter-annual variability. The data from the recent record (that is, within the past decade) increasingly appear to be indicative of an integrated regional ecological baseline with indicators of metal contamination, and greater physiological well-being of aquatic life and benthic-community structure. Changes are occurring in the South Bay watershed. For example, implementation is beginning in the South Bay Salt Ponds Restoration Program; with unknown implications (positive or negative) for all of South Bay. Nannotechnologies, many of which include metal-based products in forms for which we have no experience, are beginning to take hold in consumer products. The long-term, detailed, integrated ecological baseline that has been established at this sampling site will be uniquely valuable in assessing the response of the South Bay environment as our dynamic activities in the watershed continue to change.

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Figures

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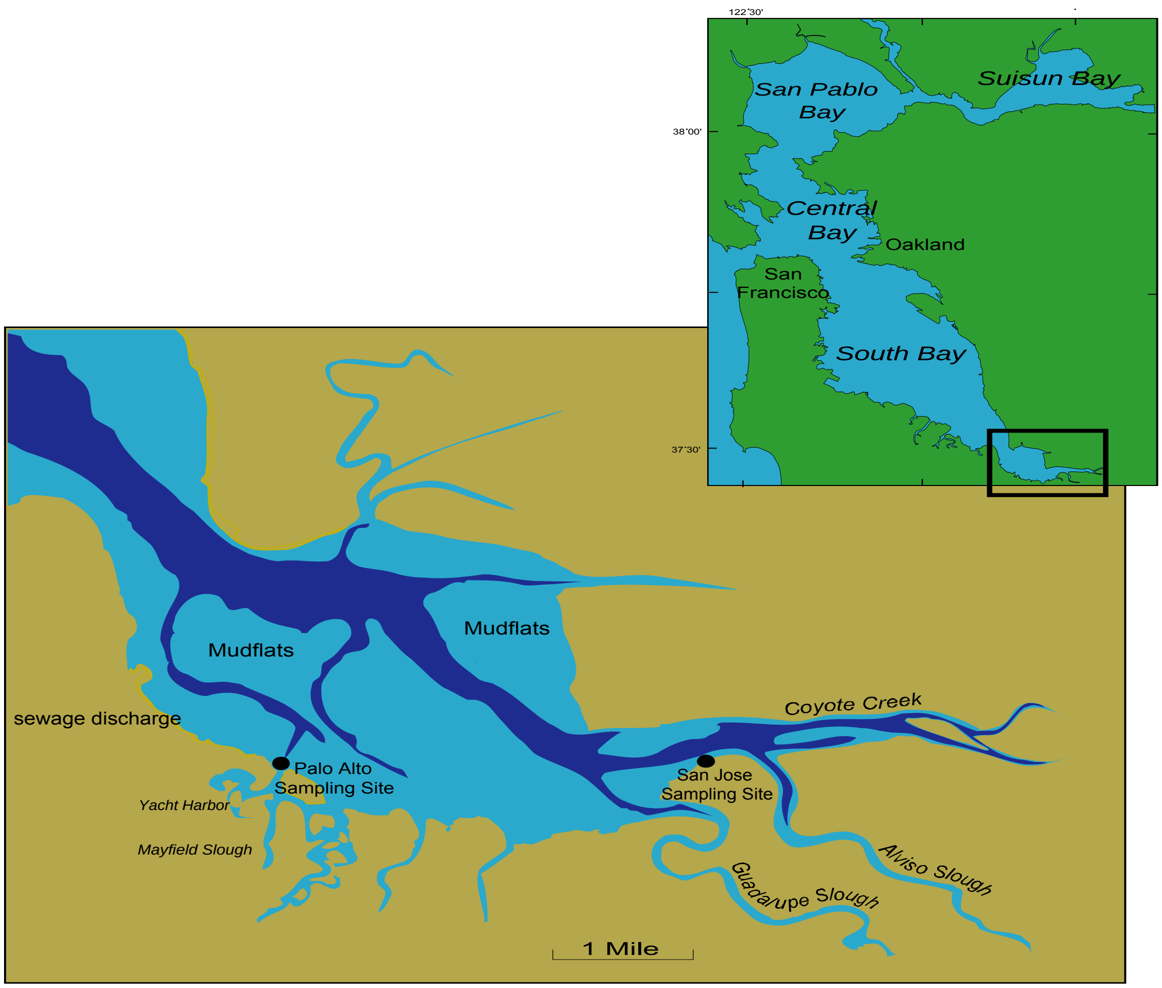


Figure 1. Location of the Palo Alto sampling site in South San Francisco Bay.

The intertidal zone is shaded light blue, subtidal in dark blue, and shoreline in brown. Effluent from the Palo Alto Regional Water Quality Control Plant is discharged approximately 1 mile north/west of the sampling site. The San Jose sampling site (inactive) also is shown for reference.

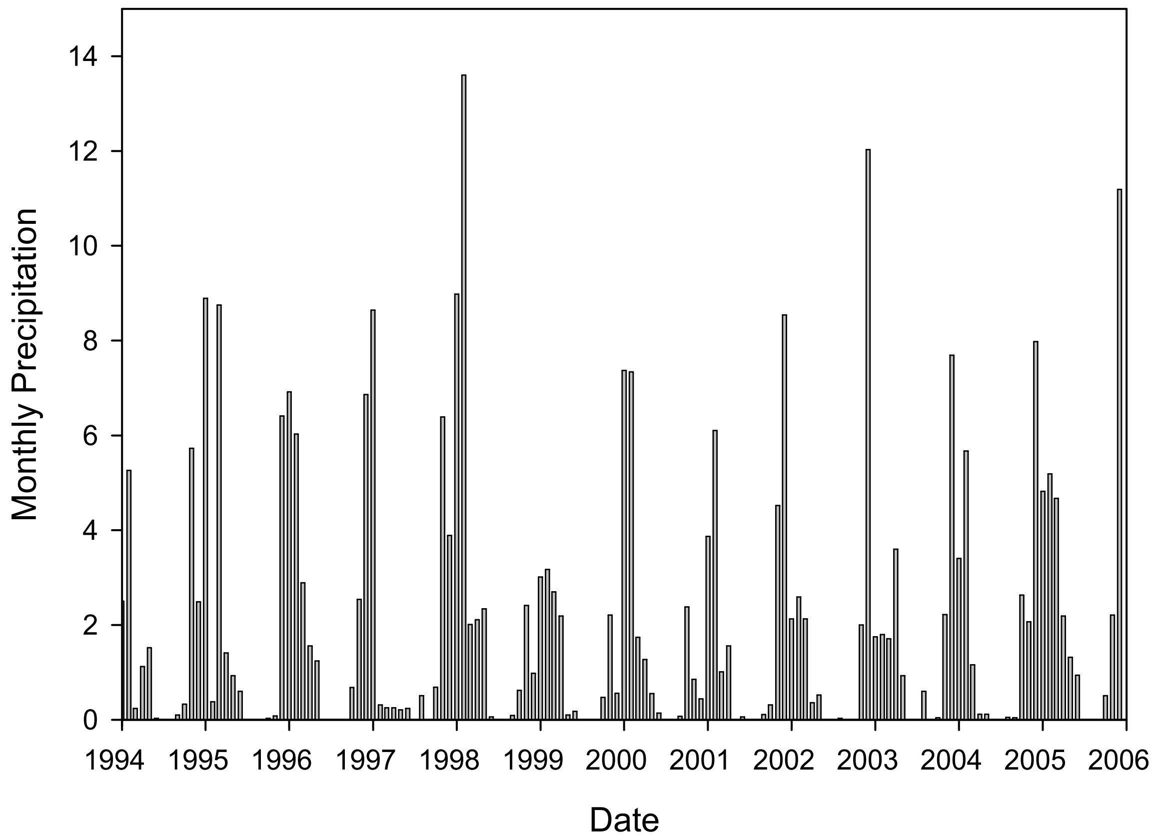


Figure 2. Precipitation

Data from San Mateo gauge station is for period from 1994 through 2005. Precipitation is in inches.

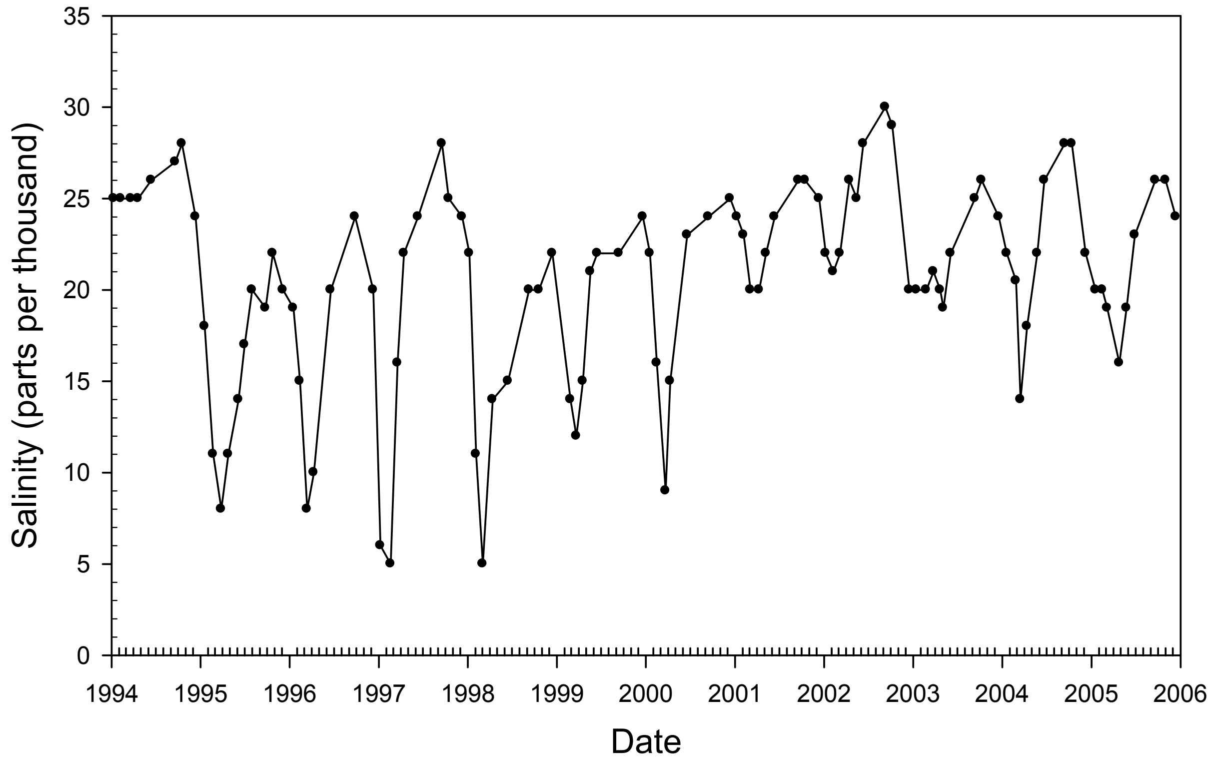


Figure 3. Water column salinity

Data from Palo Alto site is for period from 1994 through 2005.

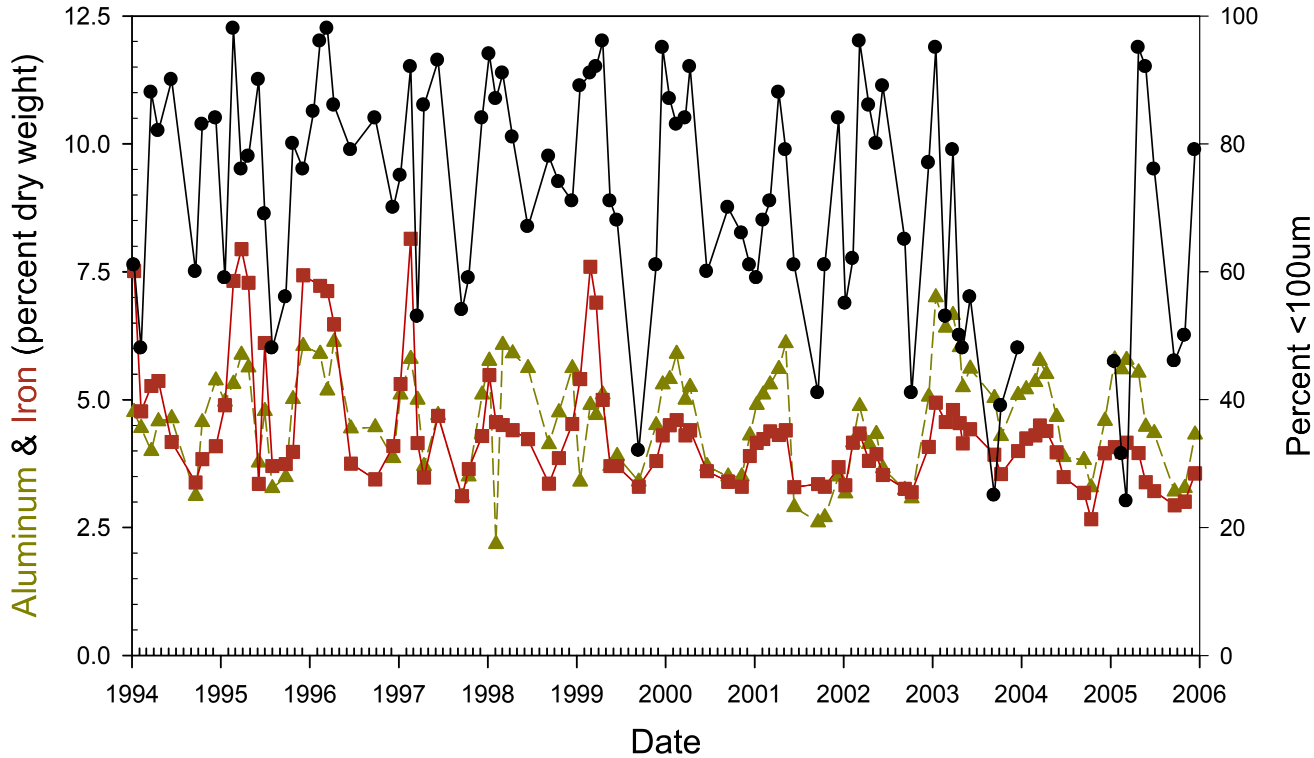


Figure 4. Aluminum, iron and silt/clay in sediments

Data are for the period from 1994 through 2005. Percent aluminum (▲), iron (■) and silt/clay (●) extracted by near-total digest. Data for percent fines for 2004 contain unquantifiable biases due to errors in sample processing, and therefore have been censored. Data for 2004 are shown in Appendices A-2 and A-3 for qualitative purposes only.

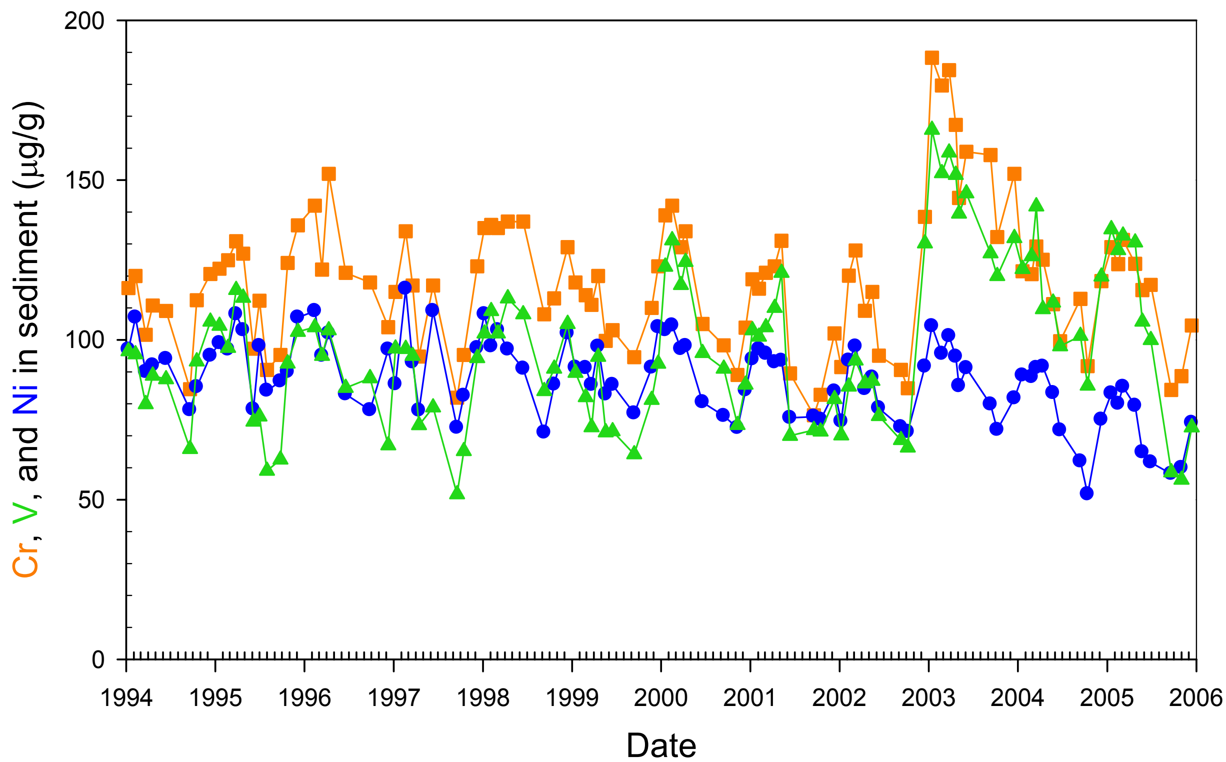


Figure 5. Chromium, nickel and vanadium in sediments

Data are for the period from 1994 through 2005. Concentrations of chromium (Cr) (■), nickel (Ni) (●) and vanadium (V) (▲) extracted by near-total digest.

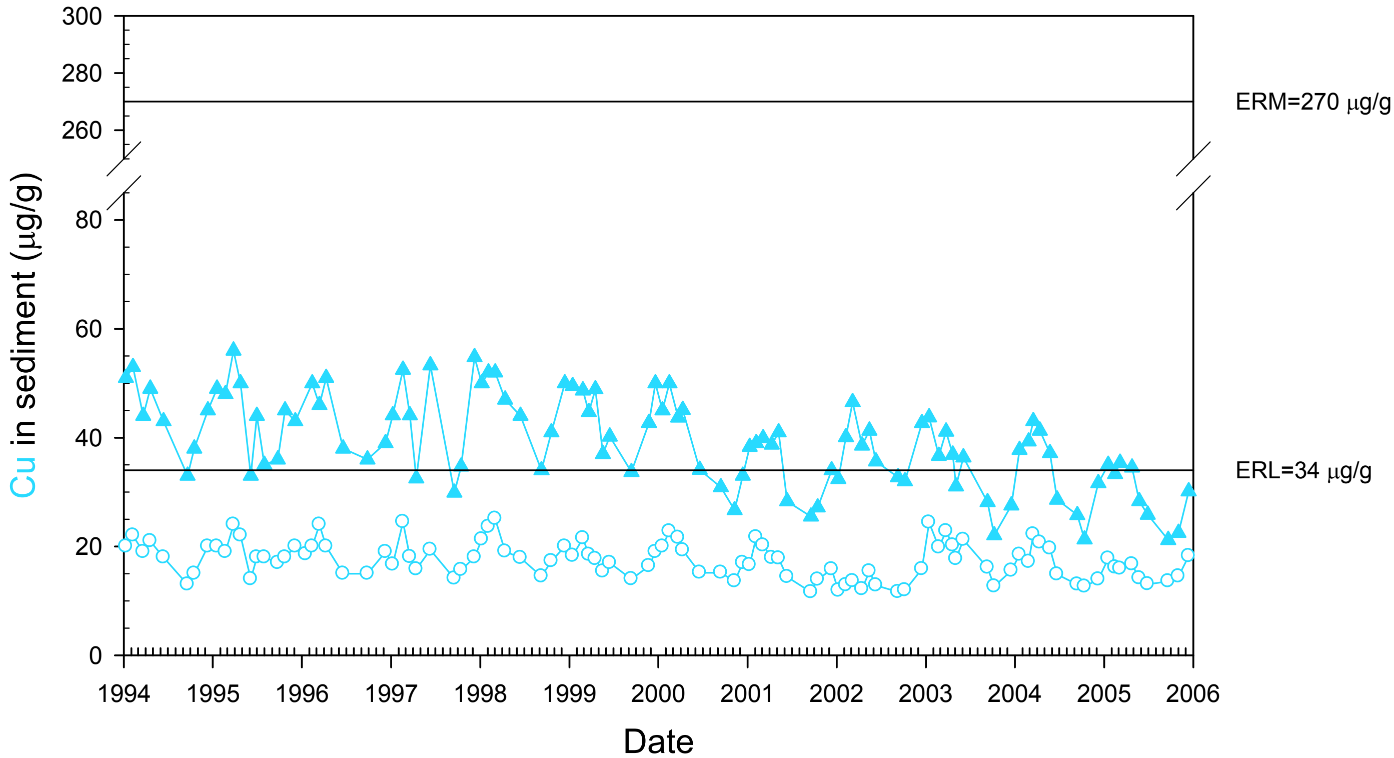


Figure 6. Copper in sediments

Data are for the period from 1994 through 2005. Near-total (▲) and partial-extractable (○) copper.

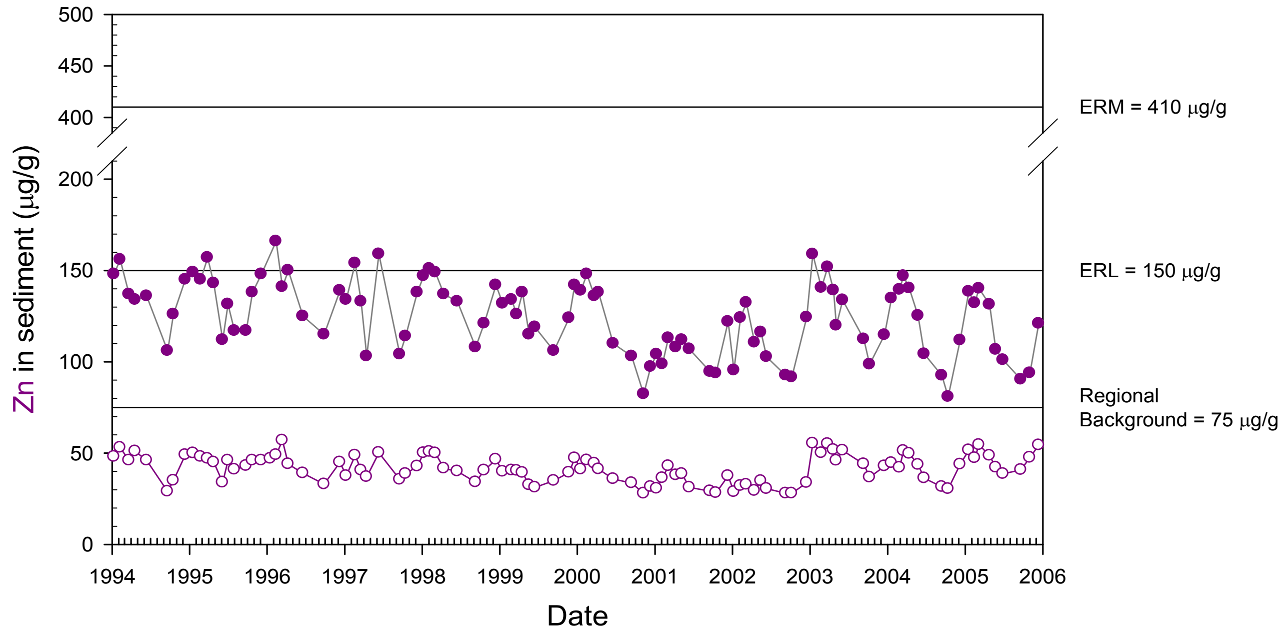


Figure 7. Zinc in sediments

Data are for the period from 1994 through 2005. Near-total (●) and partial-extractable (○) zinc.

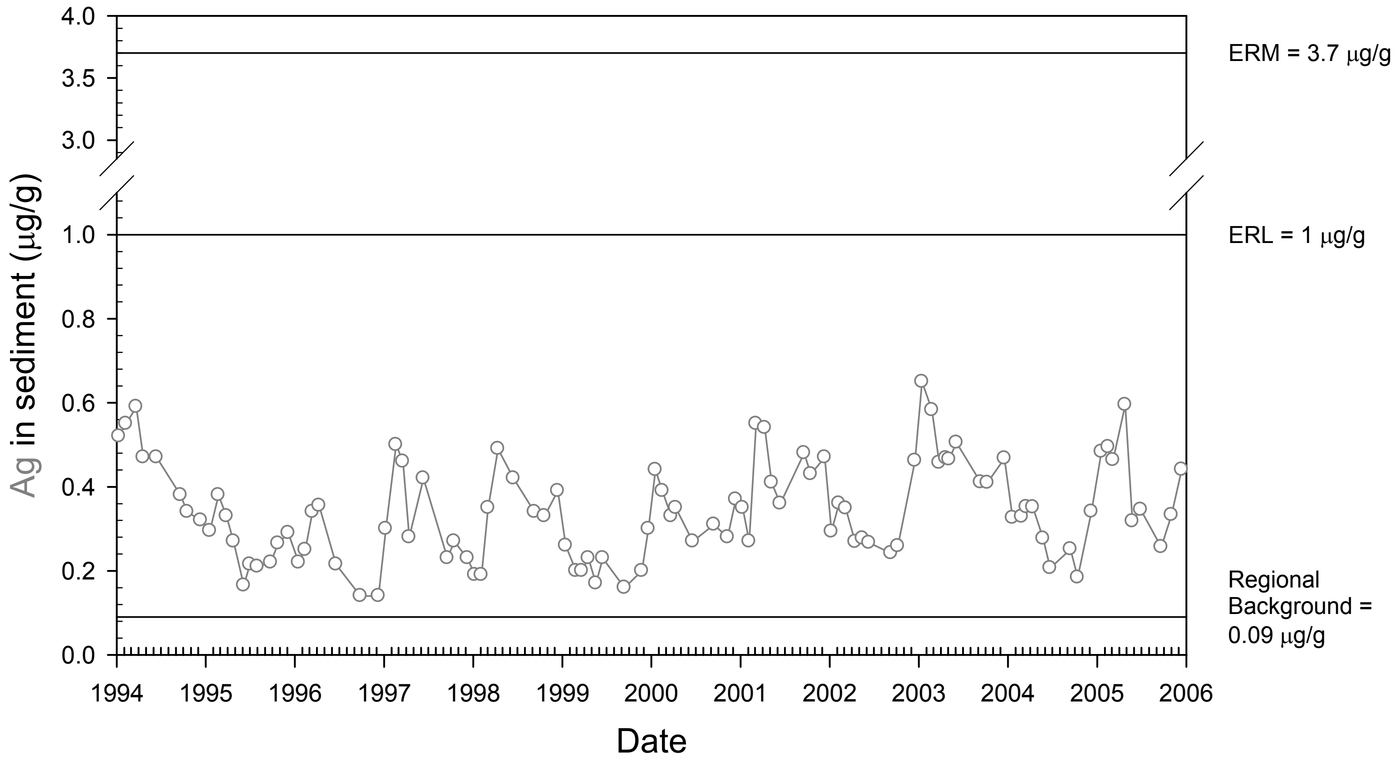


Figure 8. Silver in sediments

Data are for the period from 1994 through 2005. Data represent partial-extractable silver (treatment with 0.6 N hydrochloric acid).

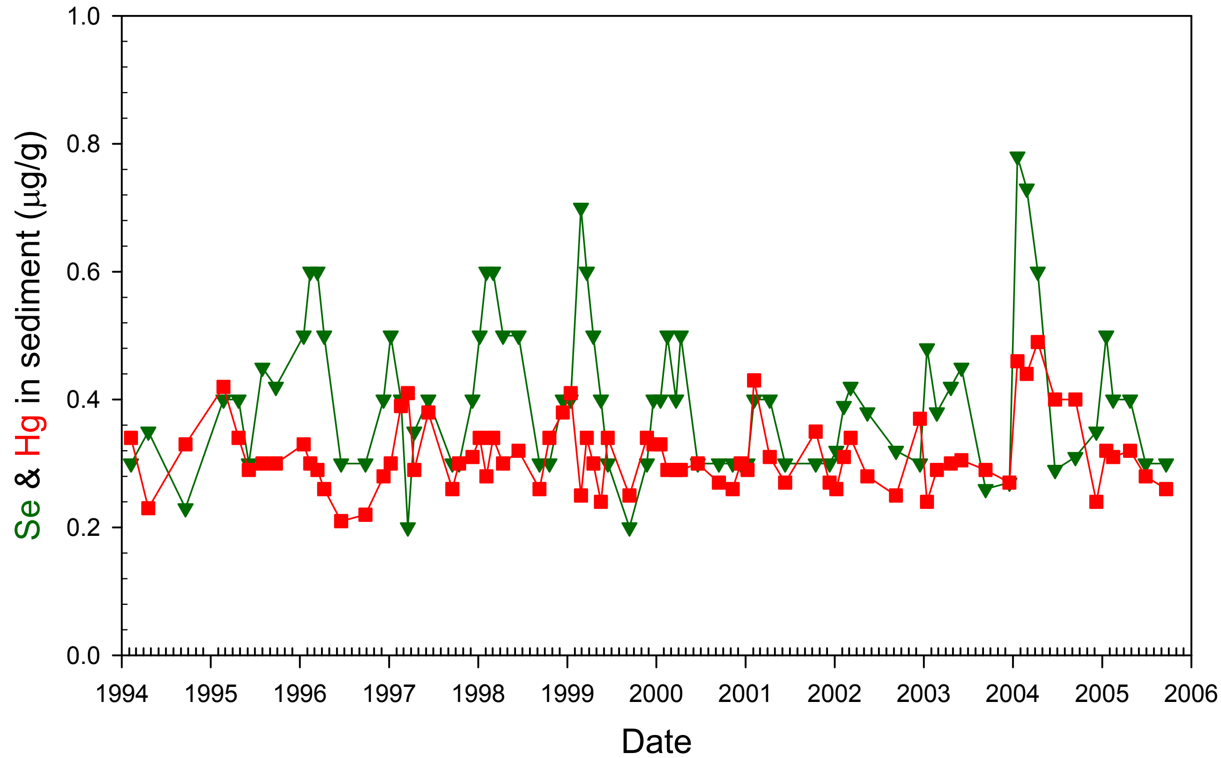


Figure 9. Selenium and mercury in sediments

Data are for the period from 1994 through 2005. Selenium (▼); mercury (■).

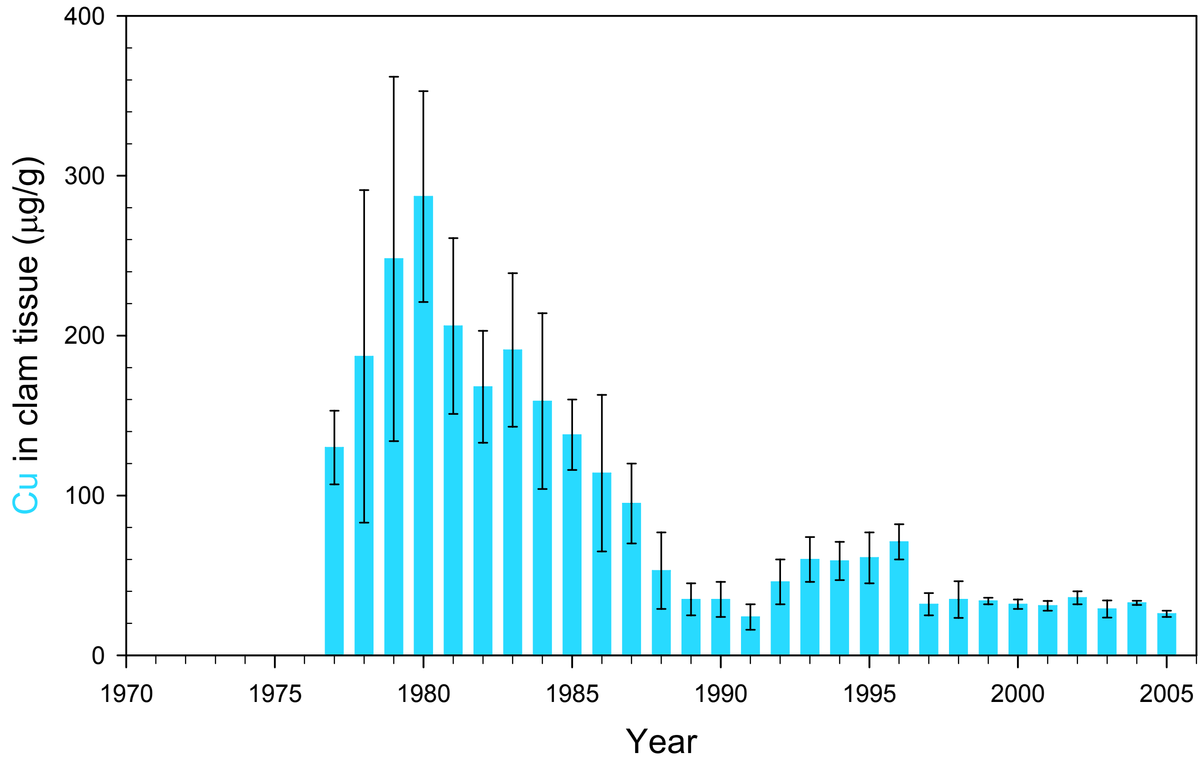


Figure 10. Annual mean copper in *Macoma petalum*

The period of record is from 1977 through 2005. The error bars are the standard error of the mean (SEM).

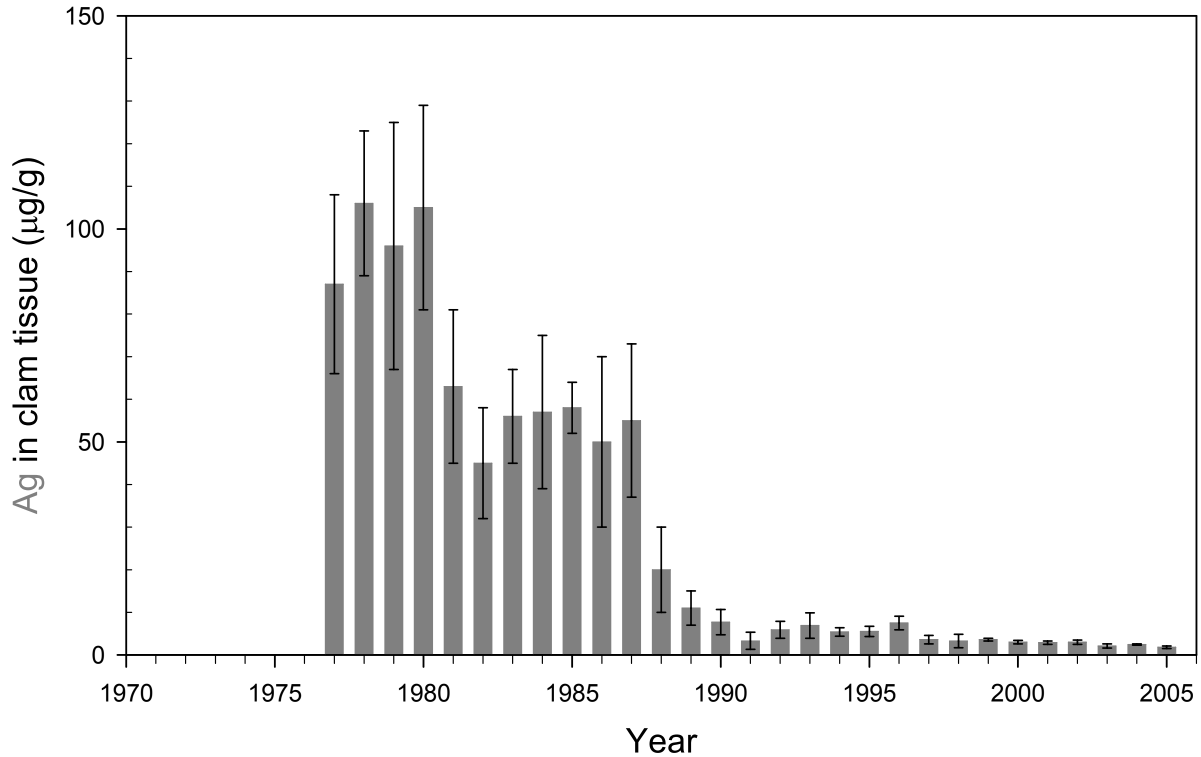


Figure 11. Annual mean silver in *Macoma petalum*

The period of record is from 1977 through 2005. The error bars are the standard error of the mean (SEM).

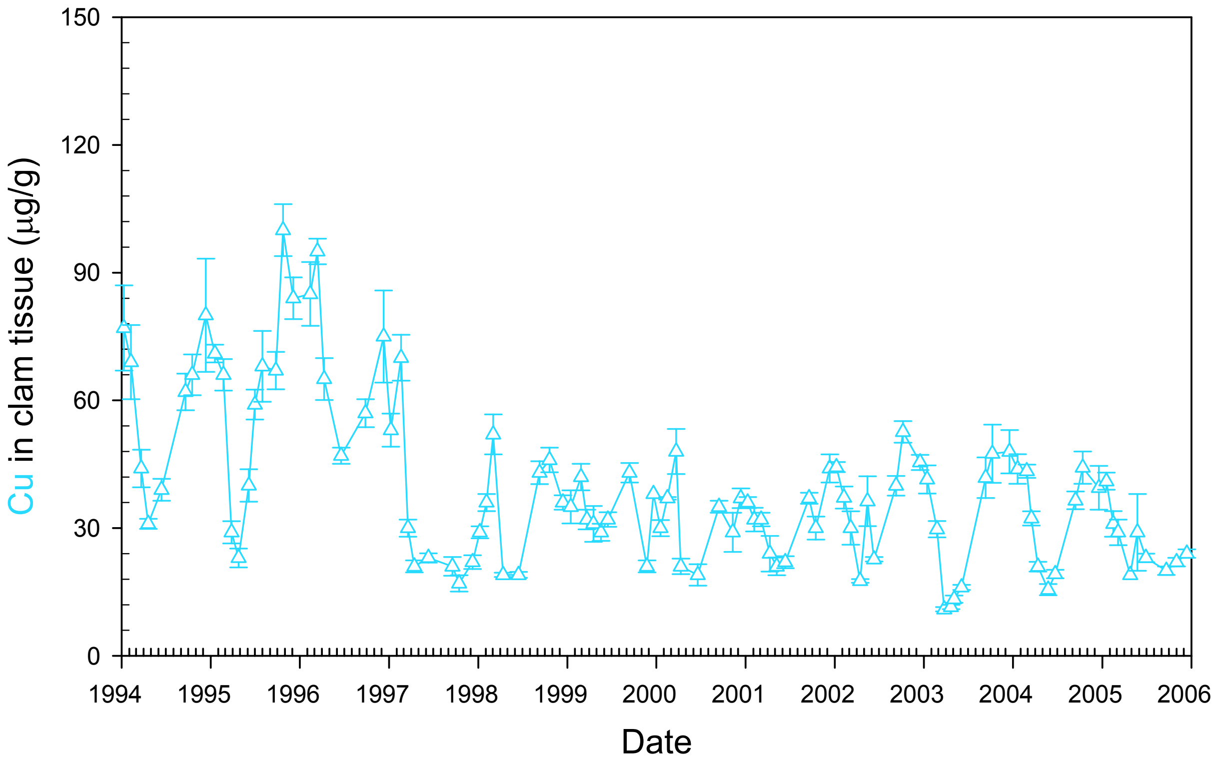


Figure 12. Copper in *Macoma petalum*

Each value is the mean concentration for the sample collected on a given date. The error bar is the standard error of the mean (SEM).

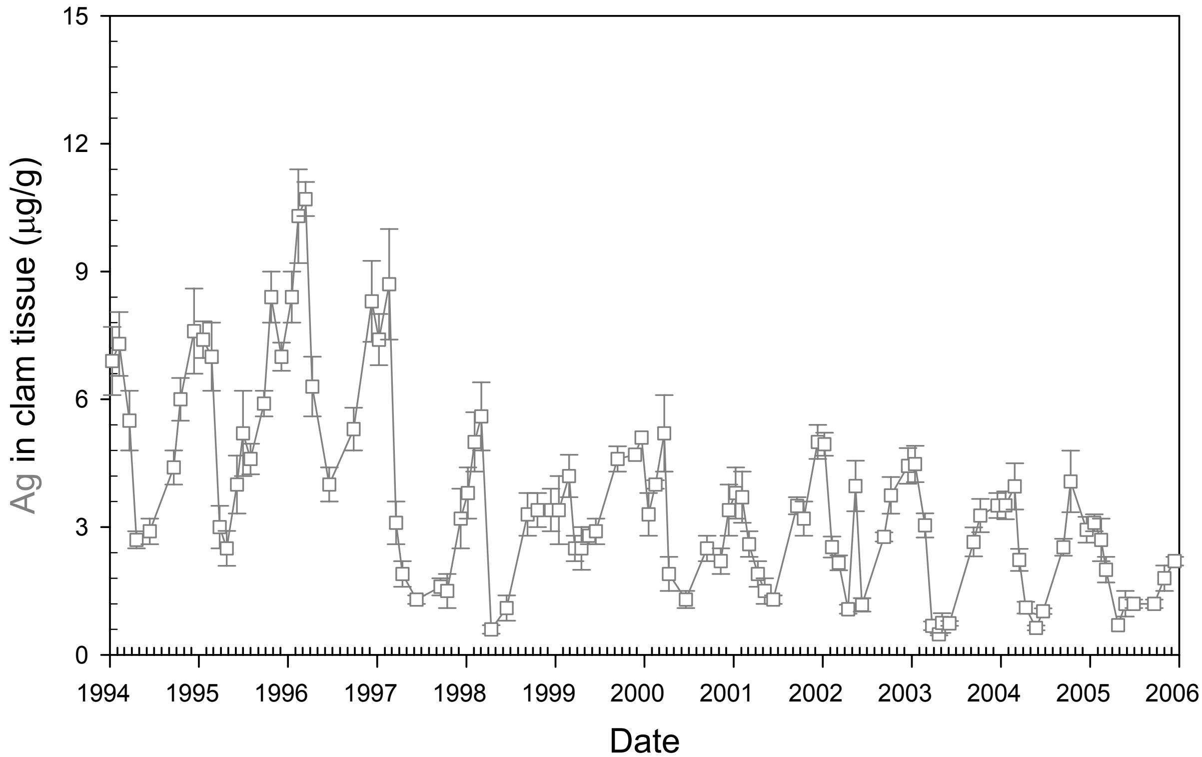


Figure 13. Silver in *Macoma petalum*

Each value is the mean concentration for the sample collected on a given date. The error bar is the standard error of the mean (SEM).

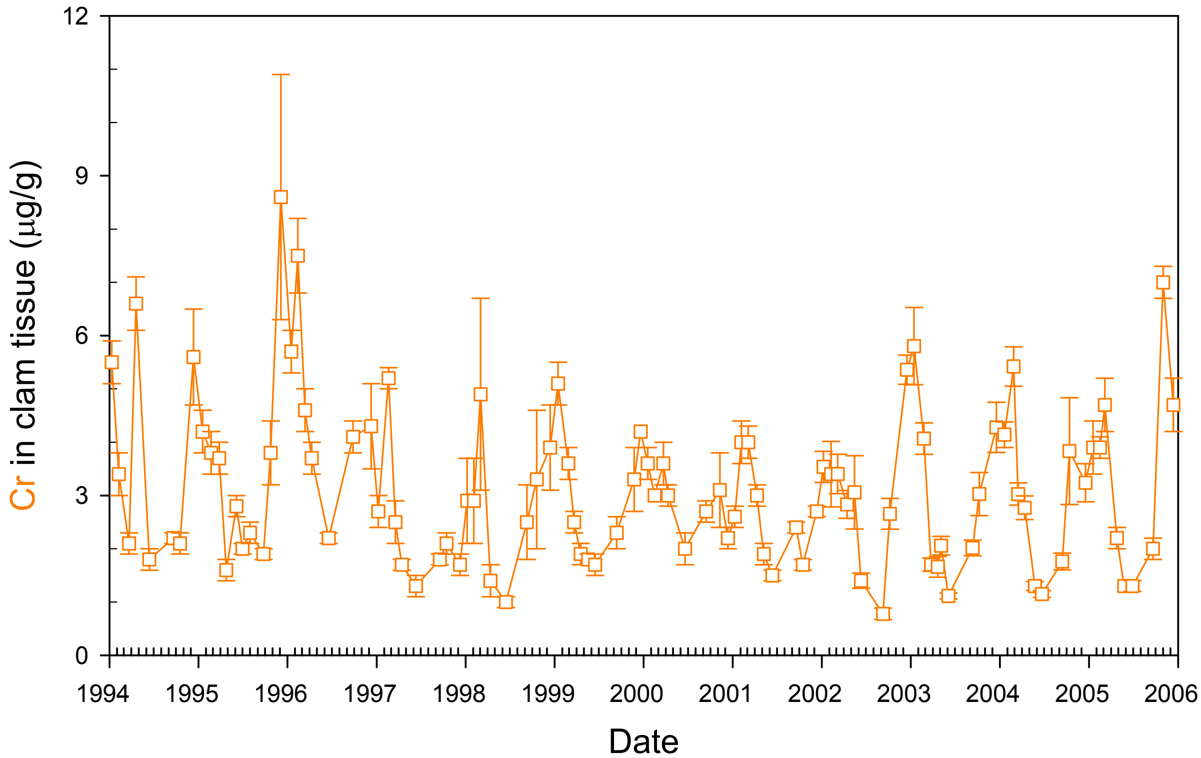


Figure 14. Chromium in *Macoma petalum*

Each value is the mean concentration for the sample collected on a given date. The error bar is the standard error of the mean (SEM).

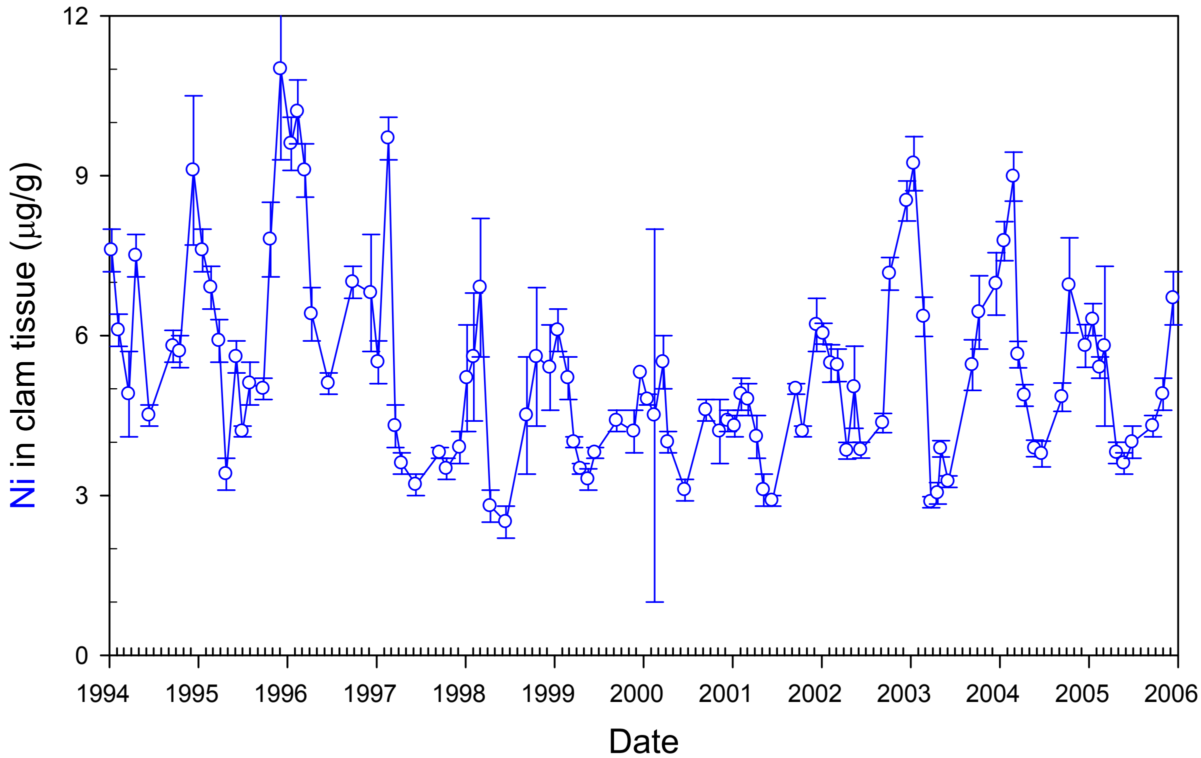


Figure 15. Nickel in *Macoma petalum*

Each value is the mean concentration for the sample collected on a given date. The error bar is the standard error of the mean (SEM).

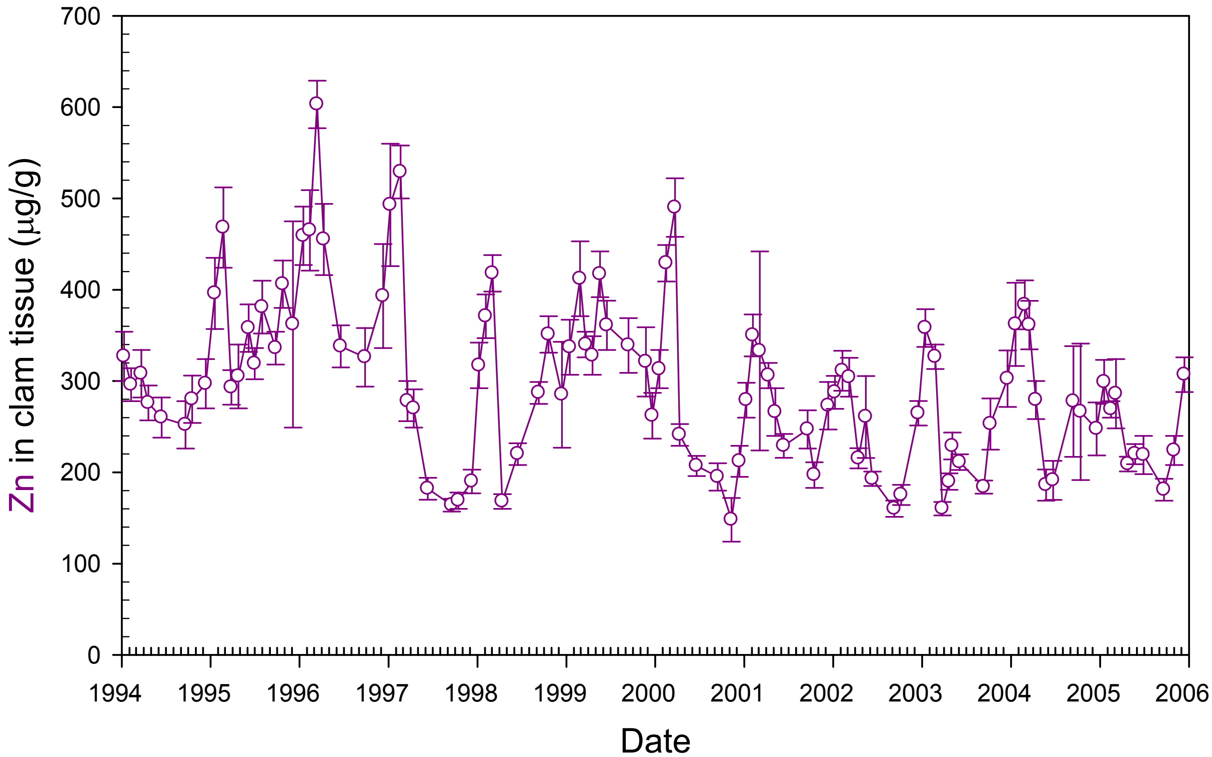


Figure 16. Zinc in *Macoma petalum*

Each value is the mean concentration for the sample collected on a given date. The error bar is the standard error of the mean (SEM).

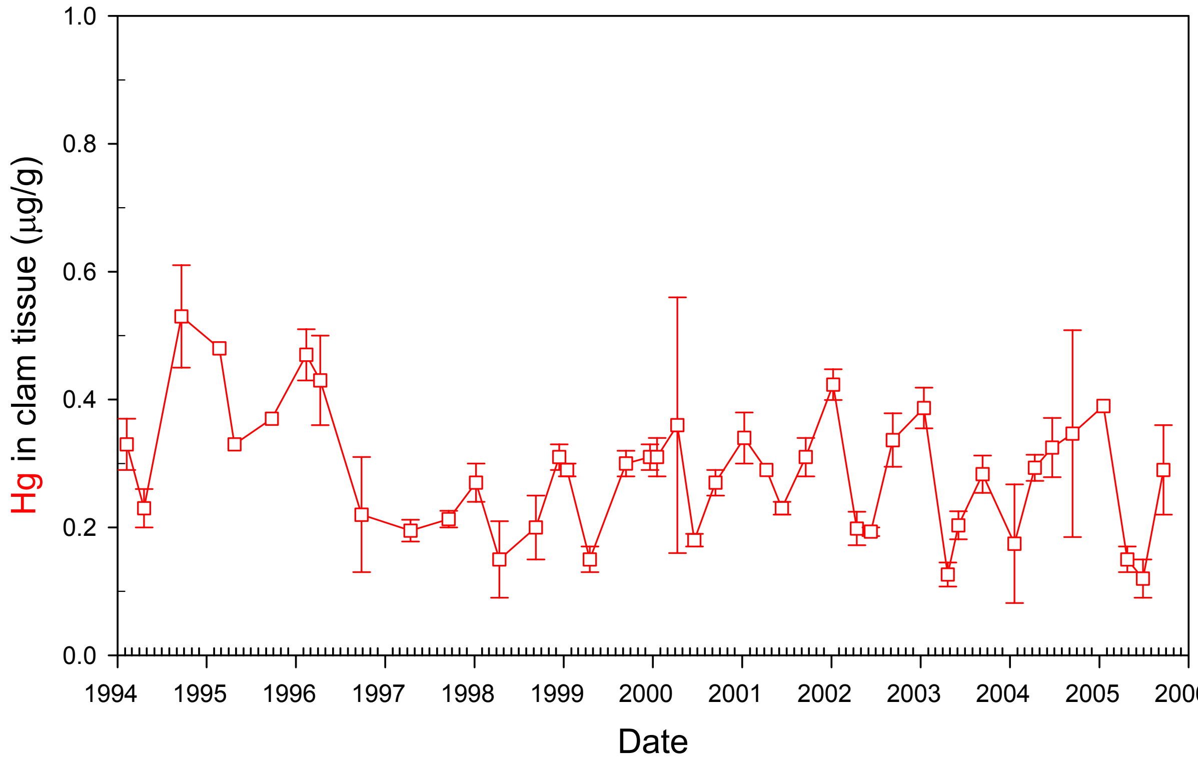


Figure 17. Mercury in *Macoma petalum*

Each value is the mean concentration for the sample collected on a given date. The error bar is the standard error of the mean (SEM).

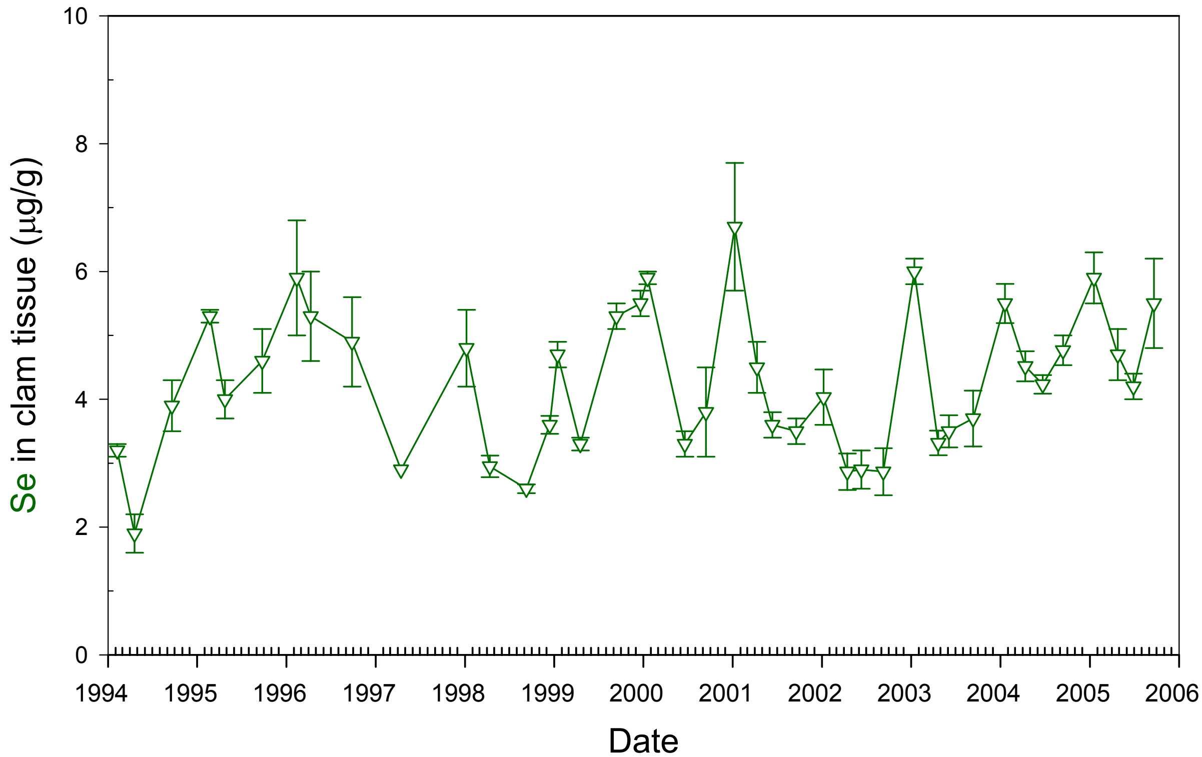


Figure 18. Selenium in *Macoma petalum*

Each value is the mean concentration for the sample collected on a given date. The error bar is the standard error of the mean (SEM).

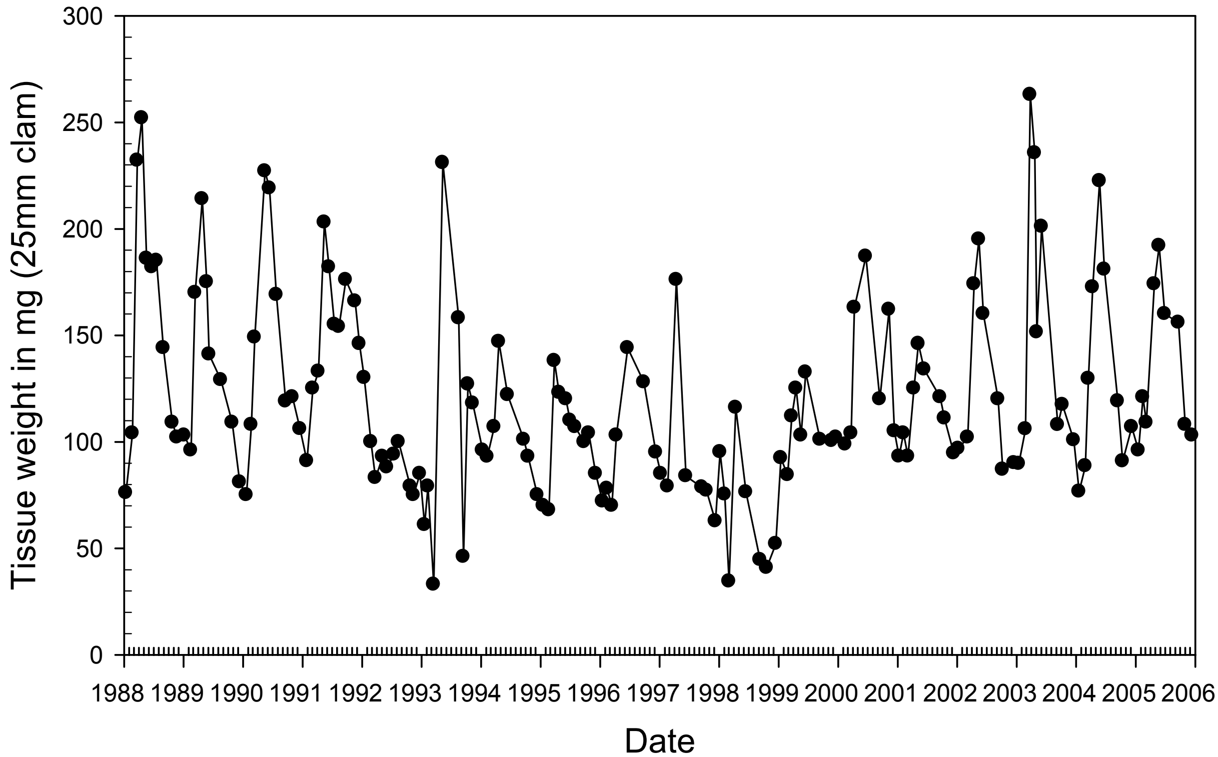


Figure 19. Condition index of *Macoma petalum*

The condition index (CI) is defined as the weight of the soft tissues for an individual clam having a shell length of 25 mm.

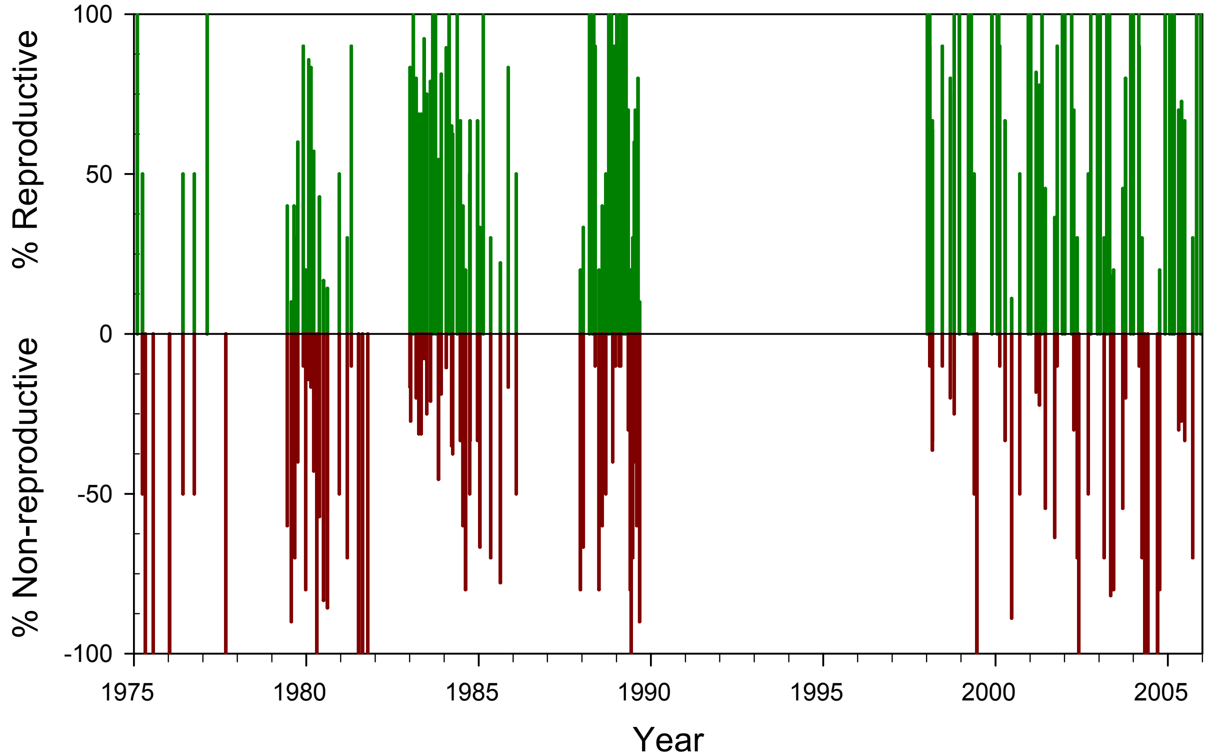


Figure 20. Reproductive activity of *Macoma petalum*

Data are for the period from 1974 through 2005.

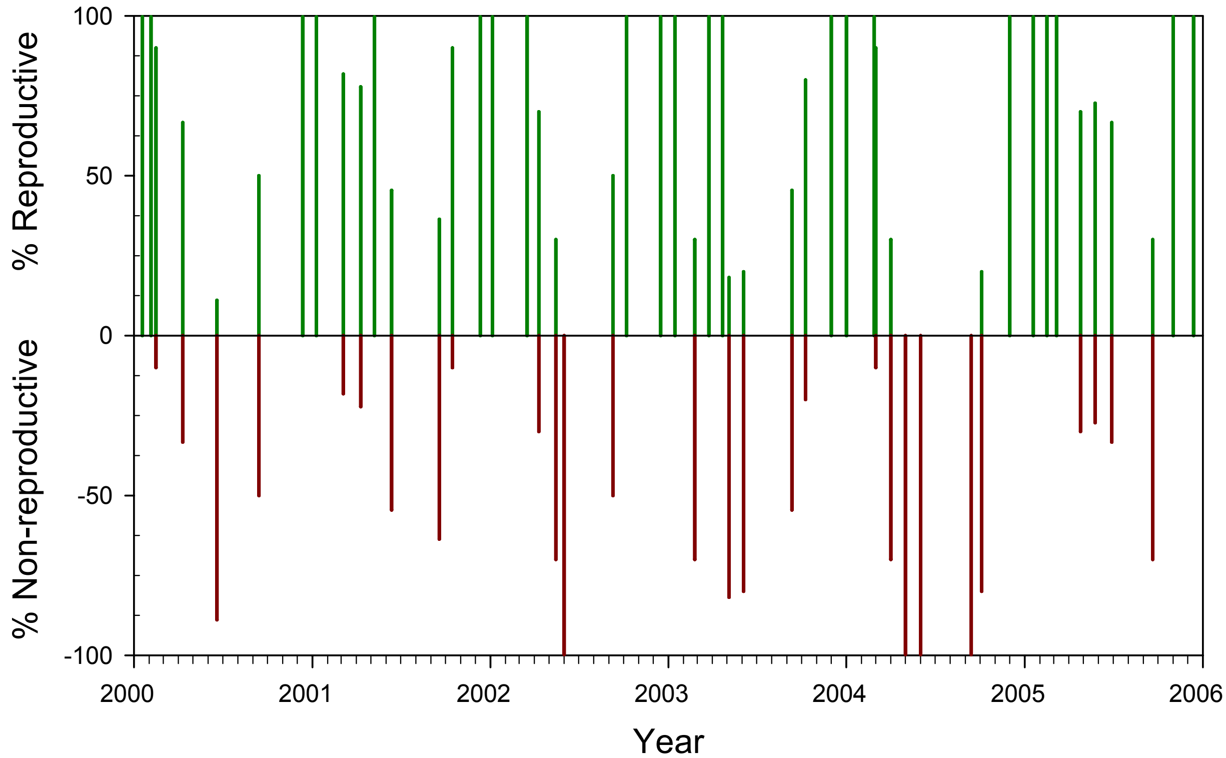


Figure 21. Reproductive activity of *Macoma petalum* 2000 thru 2005

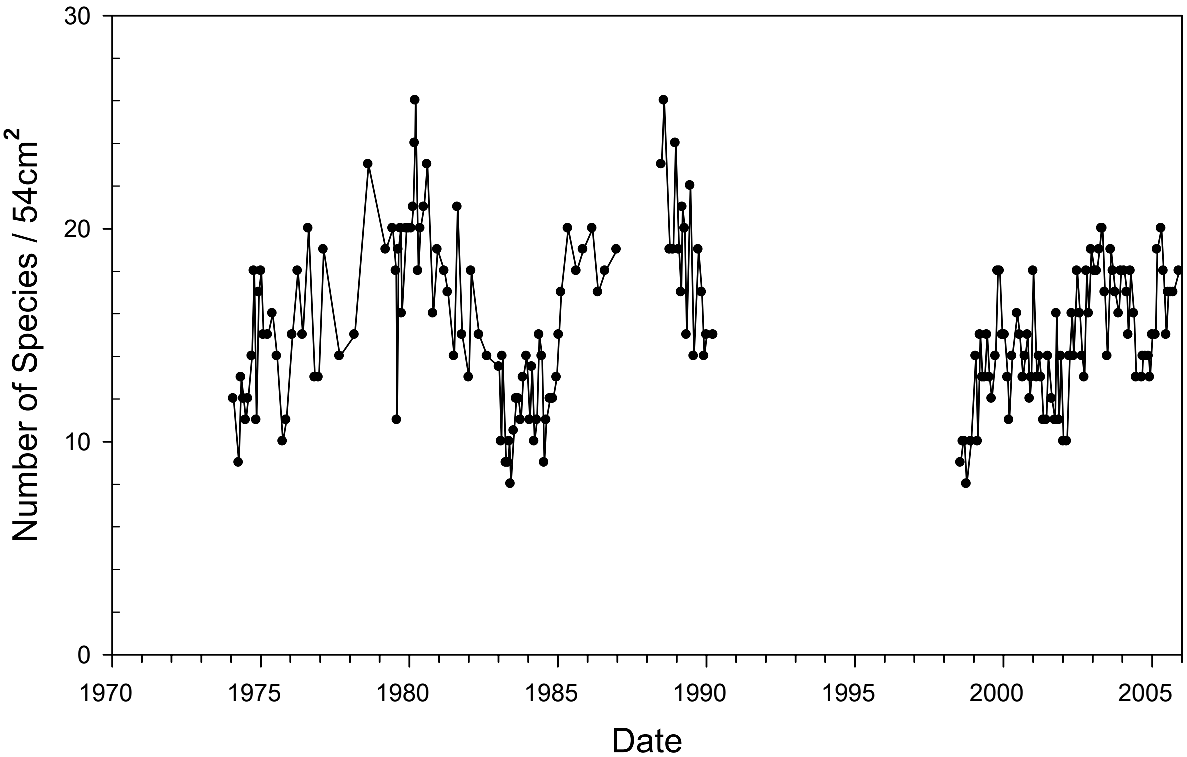


Figure 22. Total number of species present

Data are for the period from 1974 through 2005.

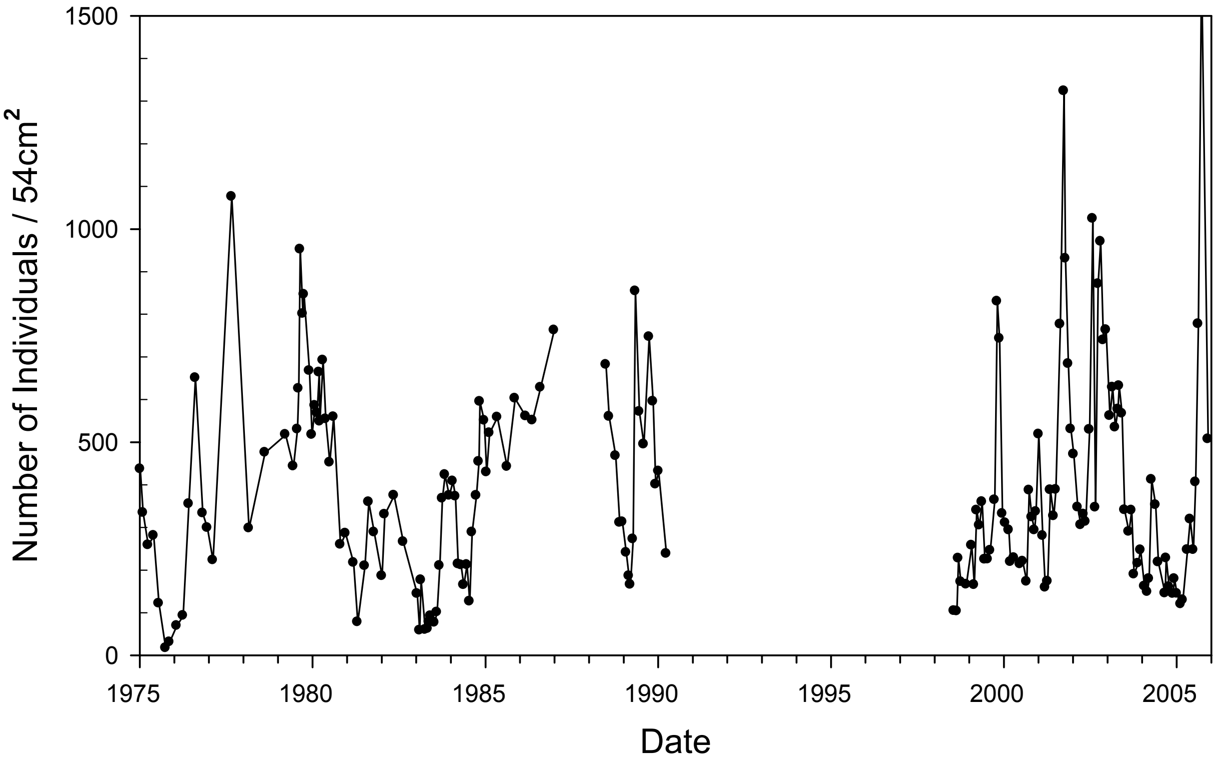


Figure 23. Total average number of individuals present

Data are for the period from 1974 through 2005.

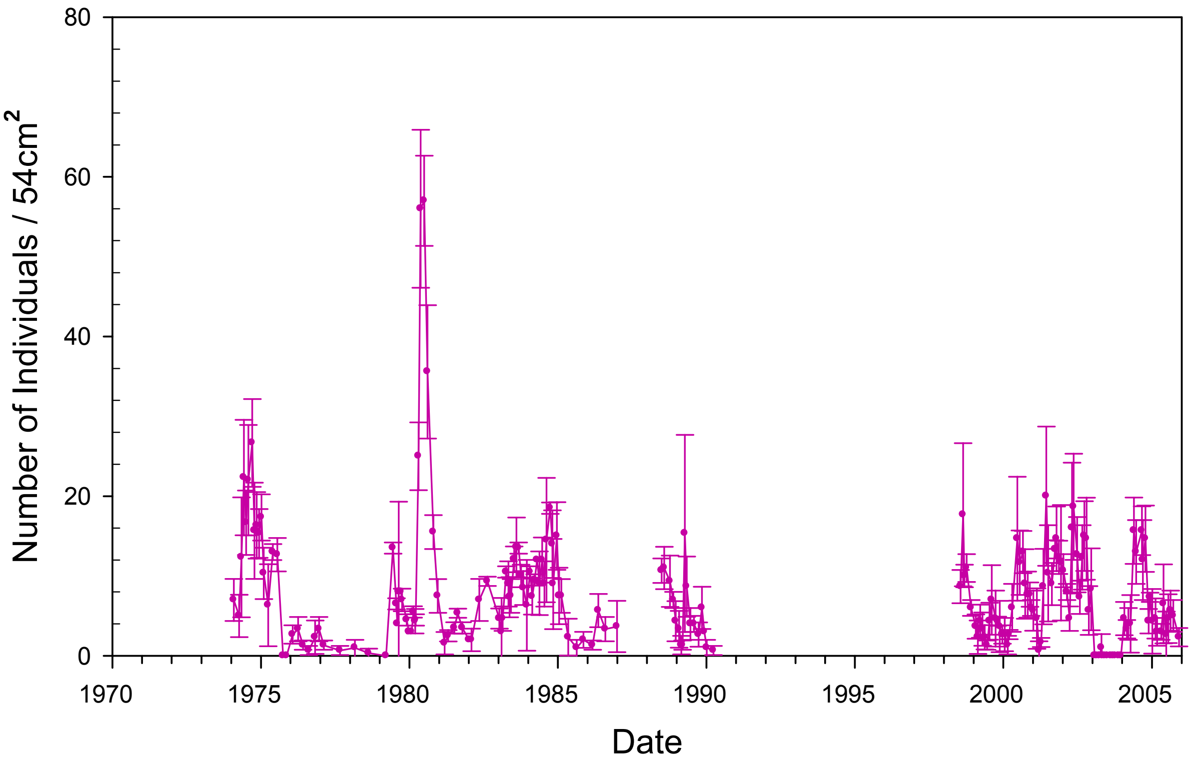


Figure 24. Average abundance of *Macoma petalum*

Data are for the period from 1974 through 2005. Error bars represent standard deviation from 3 replicate samplings.

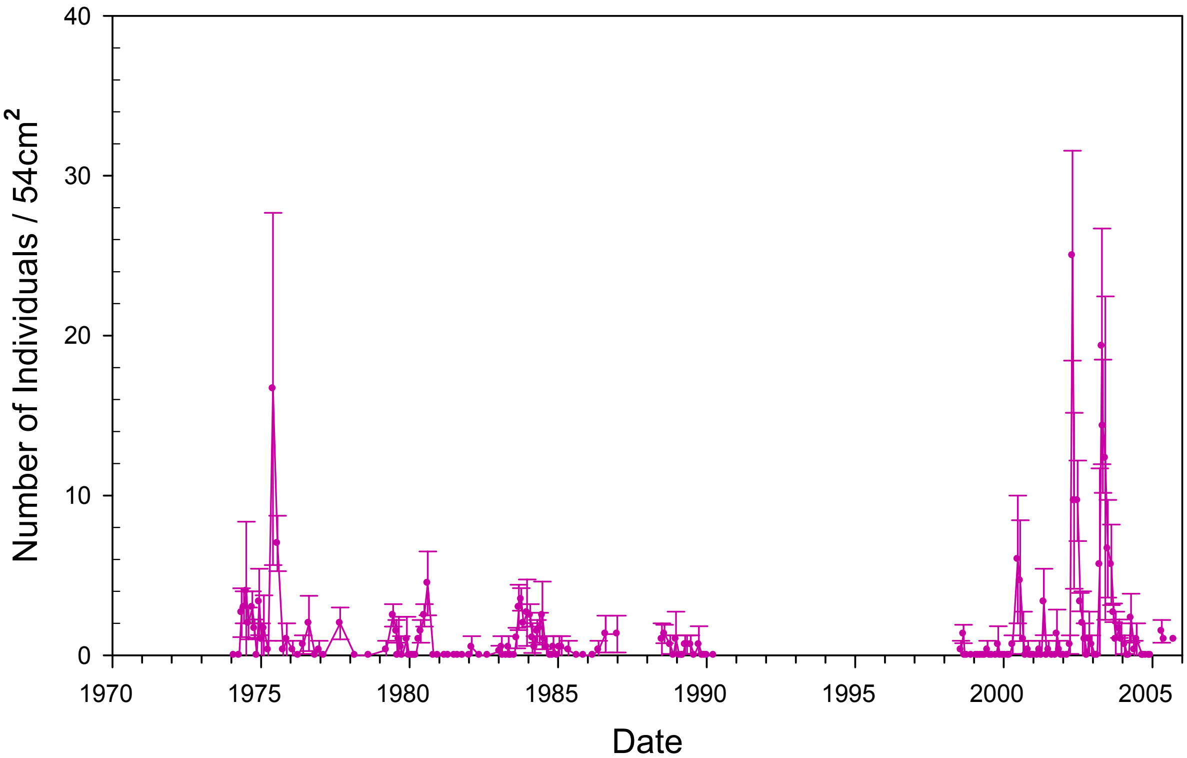


Figure 25. Average abundance of *Mya arenaria*

Data are for the period from 1974 through 2005. Error bars represent standard deviation from 3 replicate samplings.

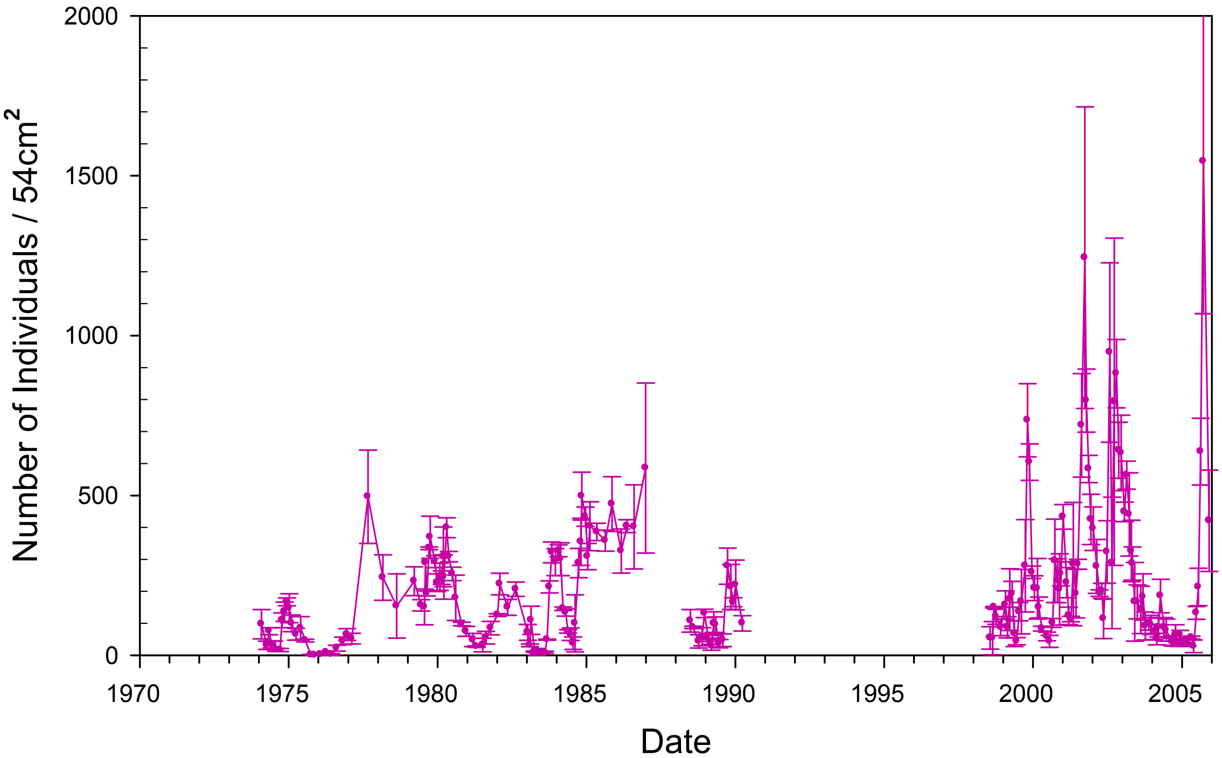


Figure 26. Average abundance of *Gemma gemma*

Data are for the period from 1974 through 2005. Error bars represent standard deviation from 3 replicate samplings.

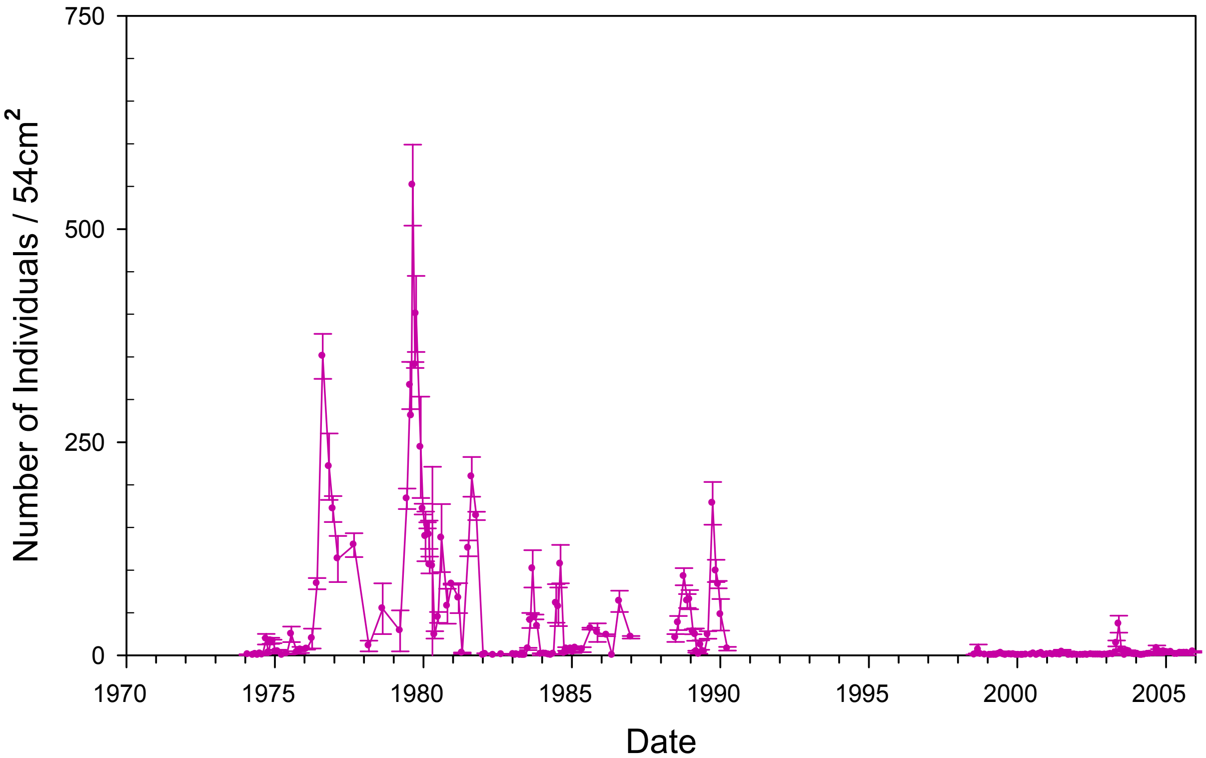


Figure 27. Average abundance of *Ampelisca abdita*

Data are for the period from 1974 through 2005. Error bars represent standard deviation from 3 replicate samplings.

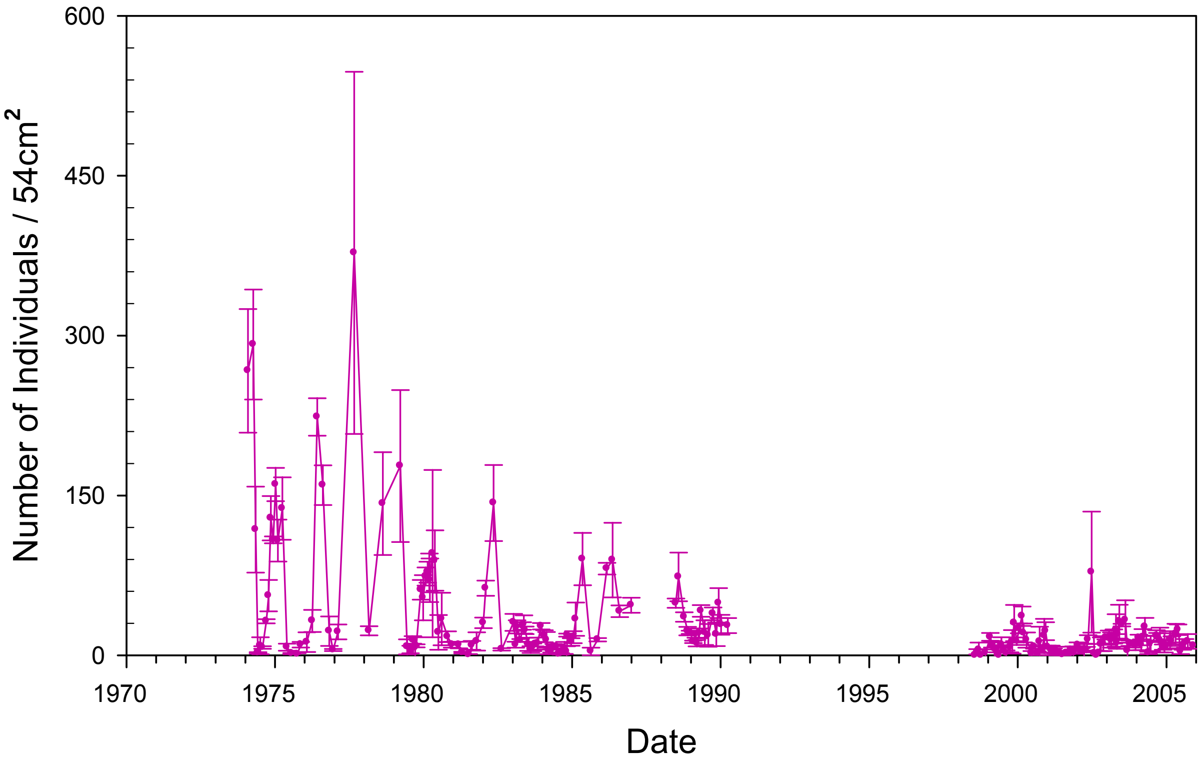


Figure 28. Average abundance of *Streblospio benedicti*

Data are for the period from 1974 through 2005. Error bars represent standard deviation from 3 replicate samplings.

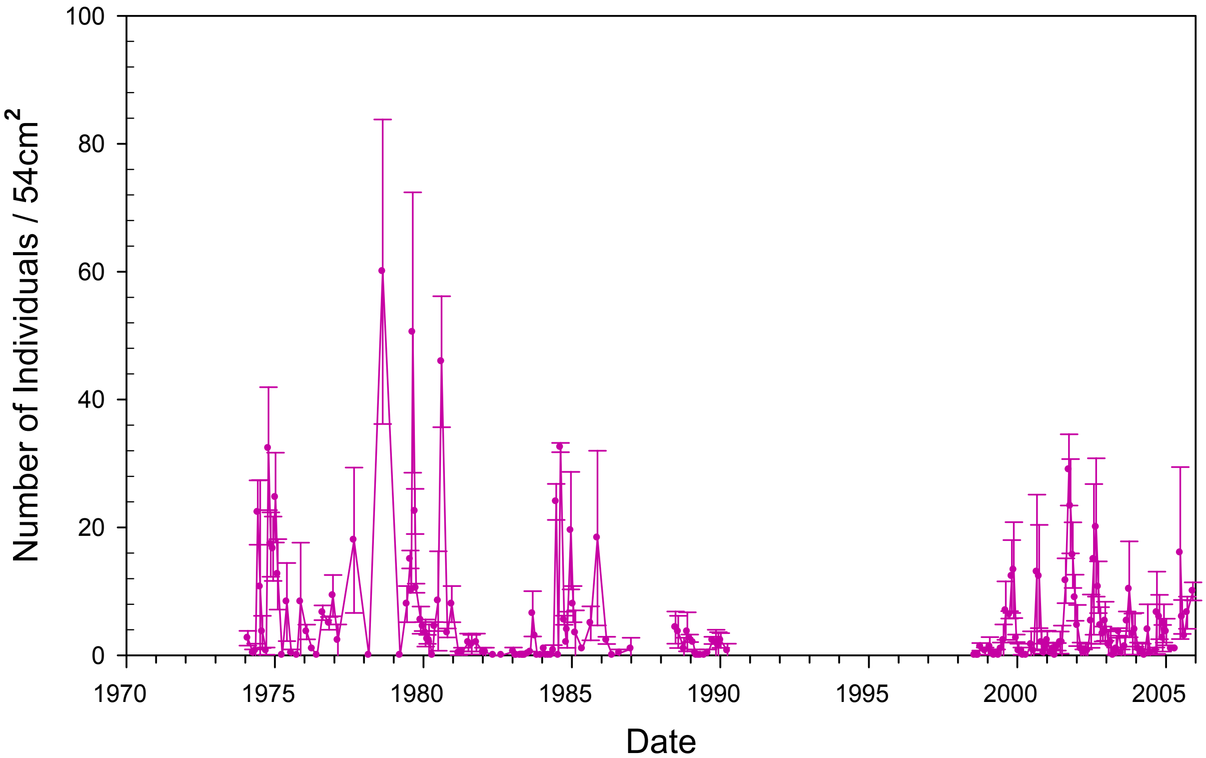


Figure 29. Average abundance of *Grandiderella japonica*

Data are for the period from 1974 through 2005. Error bars represent standard deviation from 3 replicate samplings.

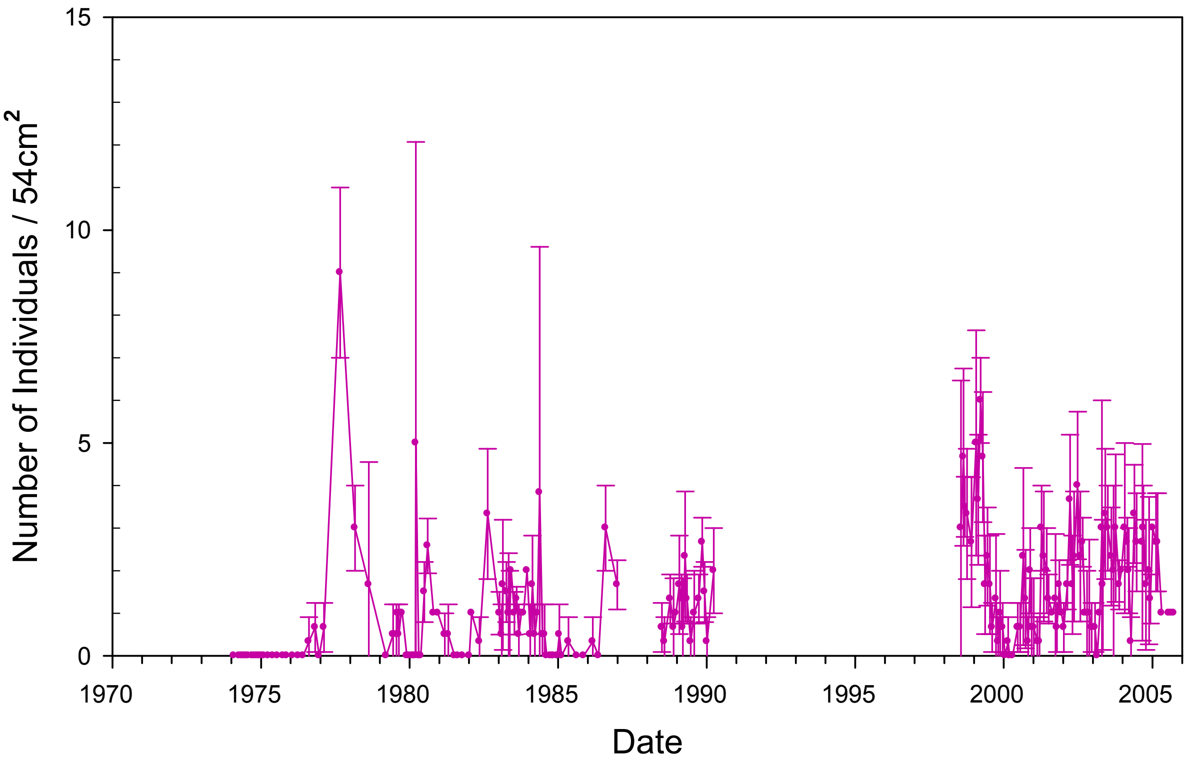


Figure 30. Average abundance of *Neanthes succinea*

Data are for the period from 1974 through 2005. Error bars represent standard deviation from 3 replicate samplings.

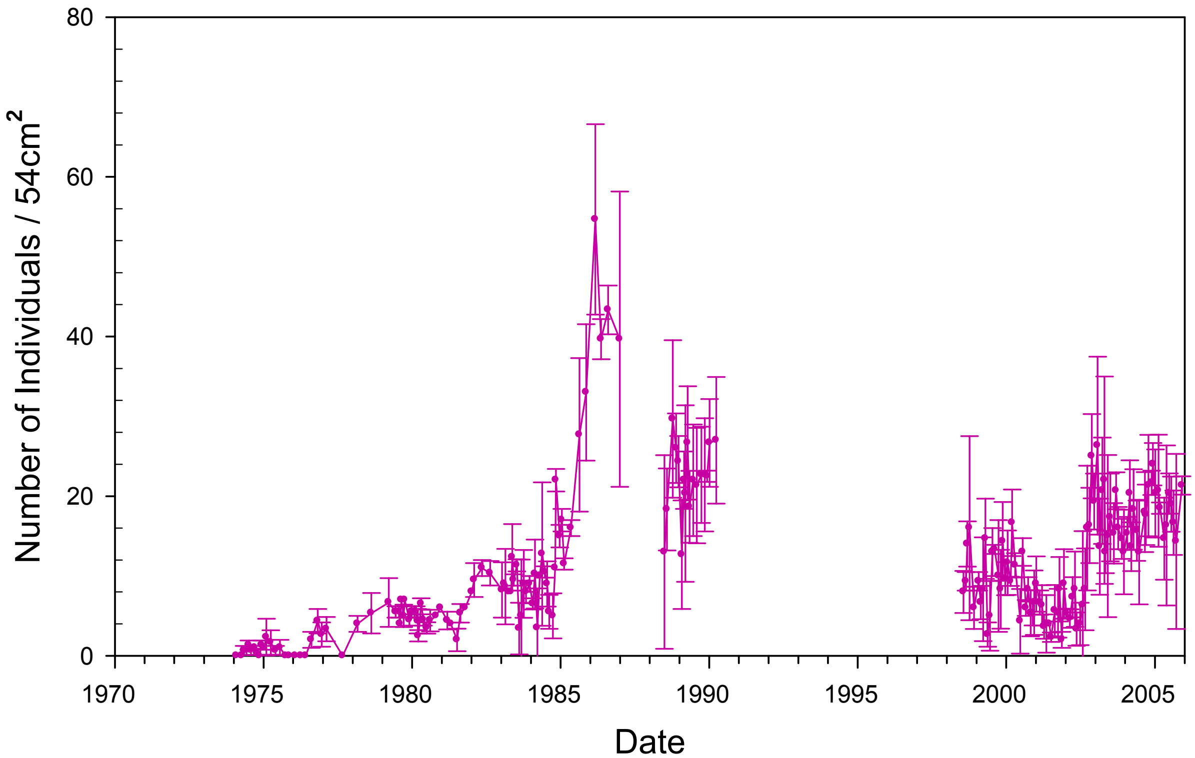


Figure 31. Average abundance of *Heteromastus filiformis*

Data are for the period from 1974 through 2005. Error bars represent standard deviation from 3 replicate samplings.

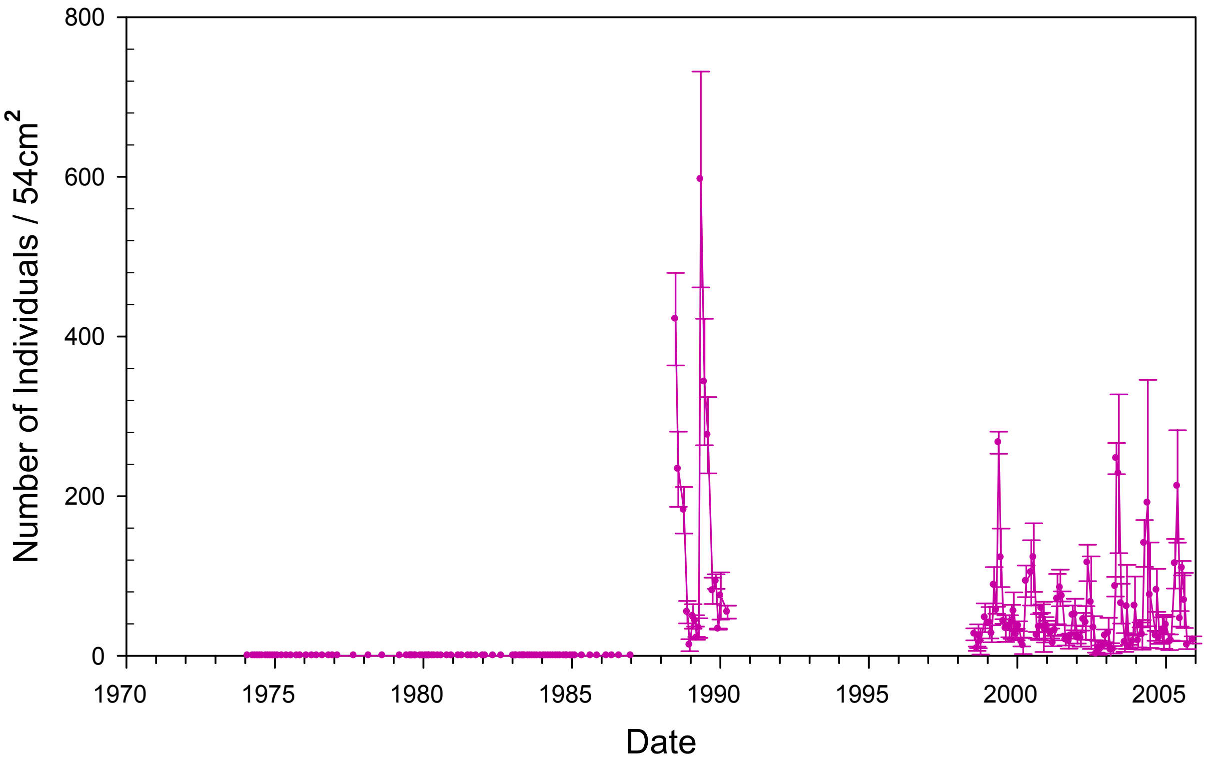


Figure 32. Average abundance of *Nippoleucon hinumensis*

Data are for the period from 1974 through 2005. Error bars represent standard deviation from 3 replicate samplings.

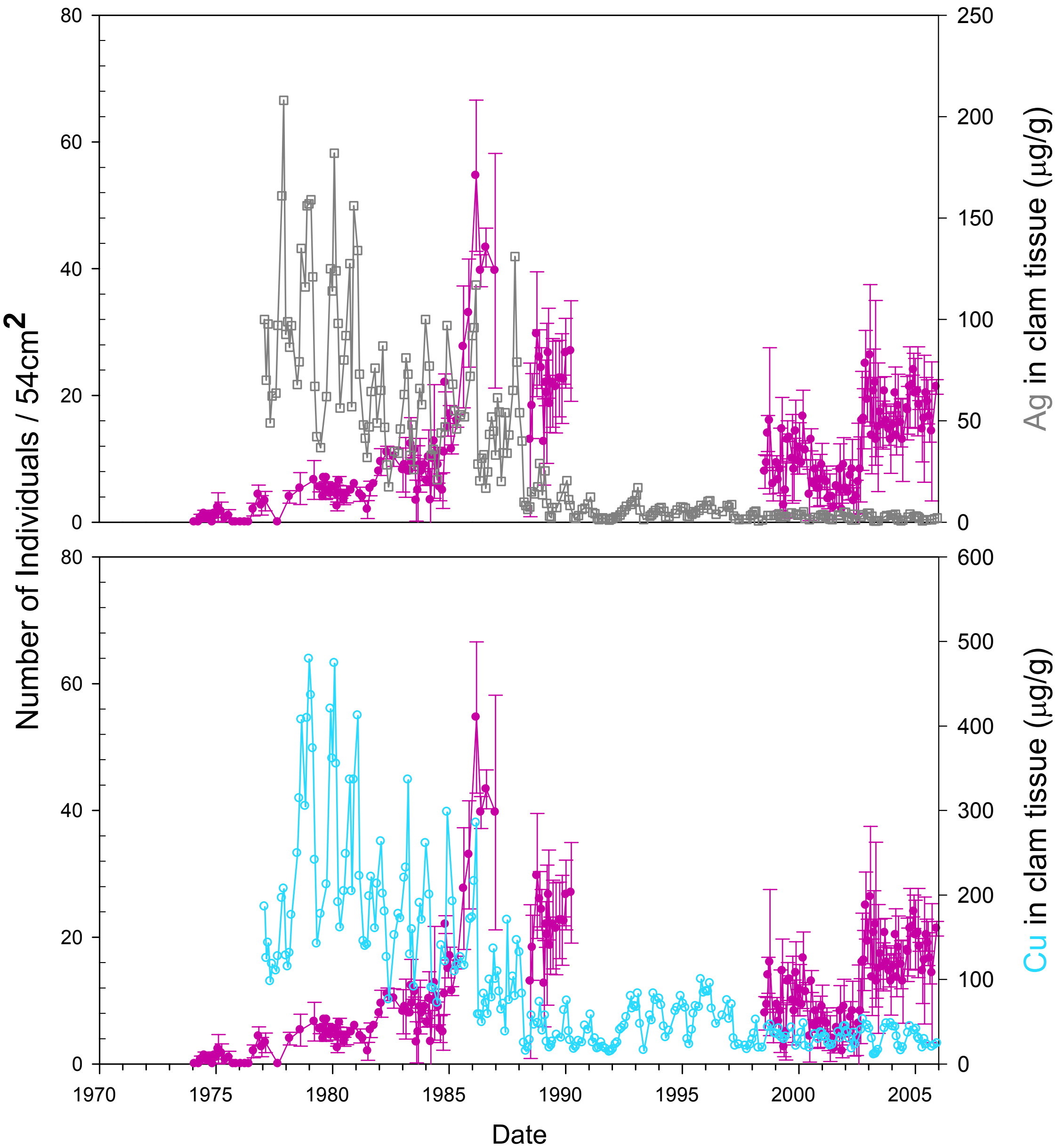


Figure 33. *Heteromastus filiformis* abundance with silver and copper in *Macoma petalum.*

Data are for the period from 1974 through 2005. Error bars represent standard deviation from 3 replicate samplings. The number of individuals (●); tissue concentration of silver (□) and copper (○) in *M. petalum.*

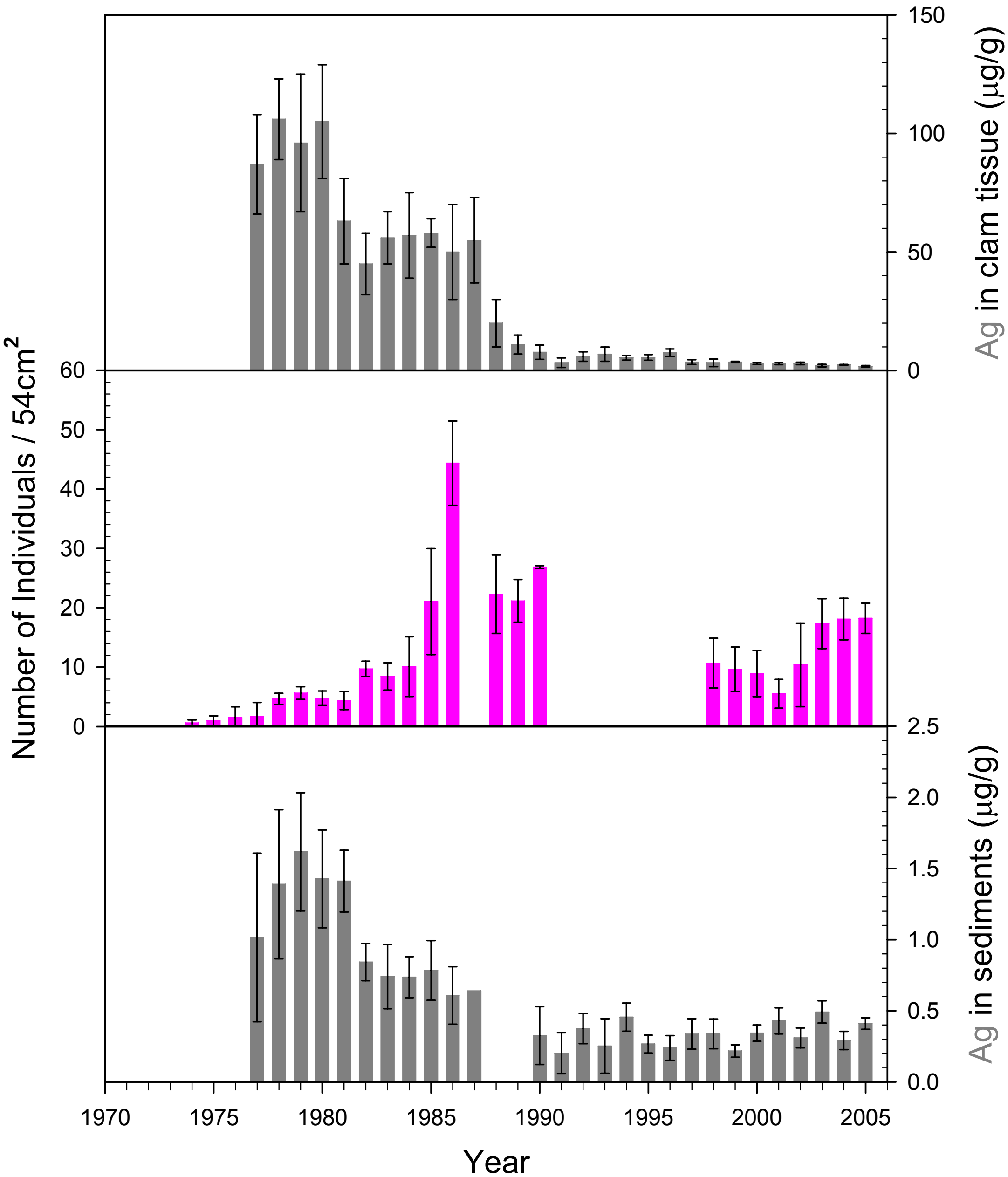


Figure 34. *Heteromastus filiformis* annual abundance with silver in *M. petalum* and sediment

Data are for the period from 1974 through 2005. Error bars for abundance and metals in sediments are the standard deviation of the means. Error bars for metals in clams are the standard error of the mean (SEM).

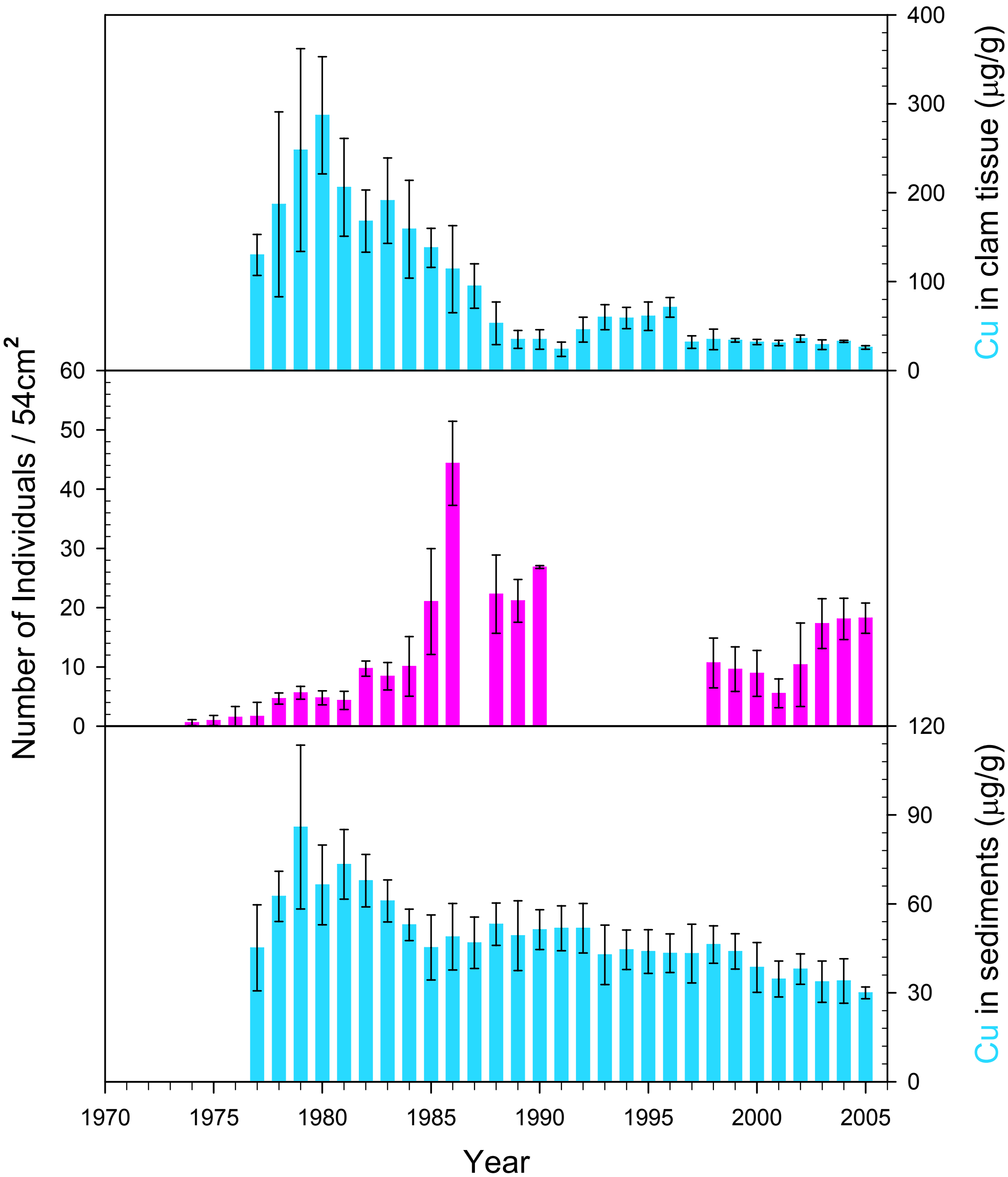


Figure 35. *Heteromastus filiformis* annual abundance with copper in *M. petalum* and sediment

Data are for the period from 1974 through 2004. Error bars for abundance and metals in sediments are the standard deviation of the means. Error bars for metals in clams are the standard error of the mean (SEM).

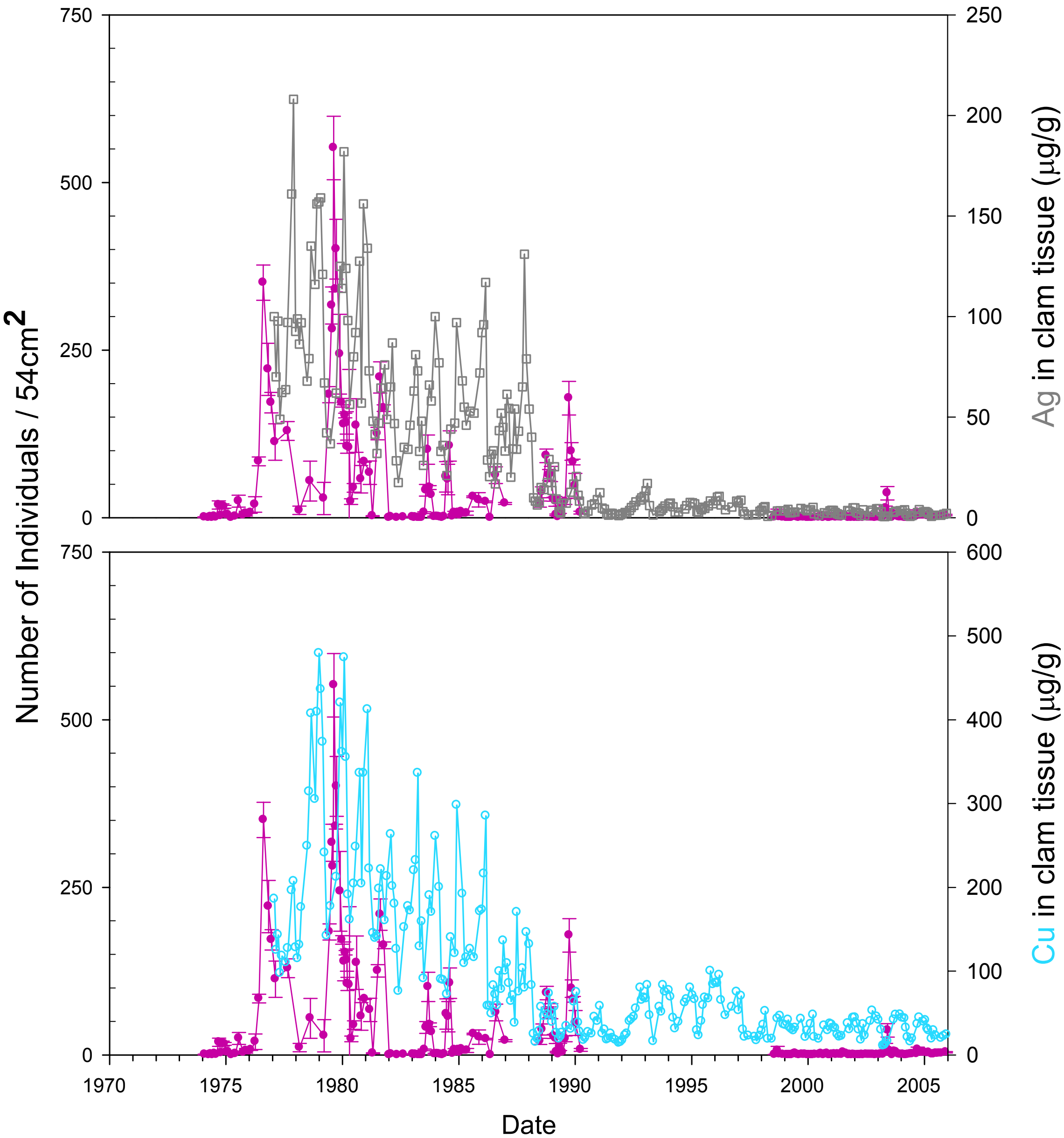


Figure 36. *Ampelisca abdita* abundance with silver and copper in *M. petalum*

Data are for the period from 1974 through 2005. Error bars represent standard deviation from 3 replicate samplings. Number of individuals (●) with silver (□) and copper (○) tissue concentrations in *Macoma petalum.*

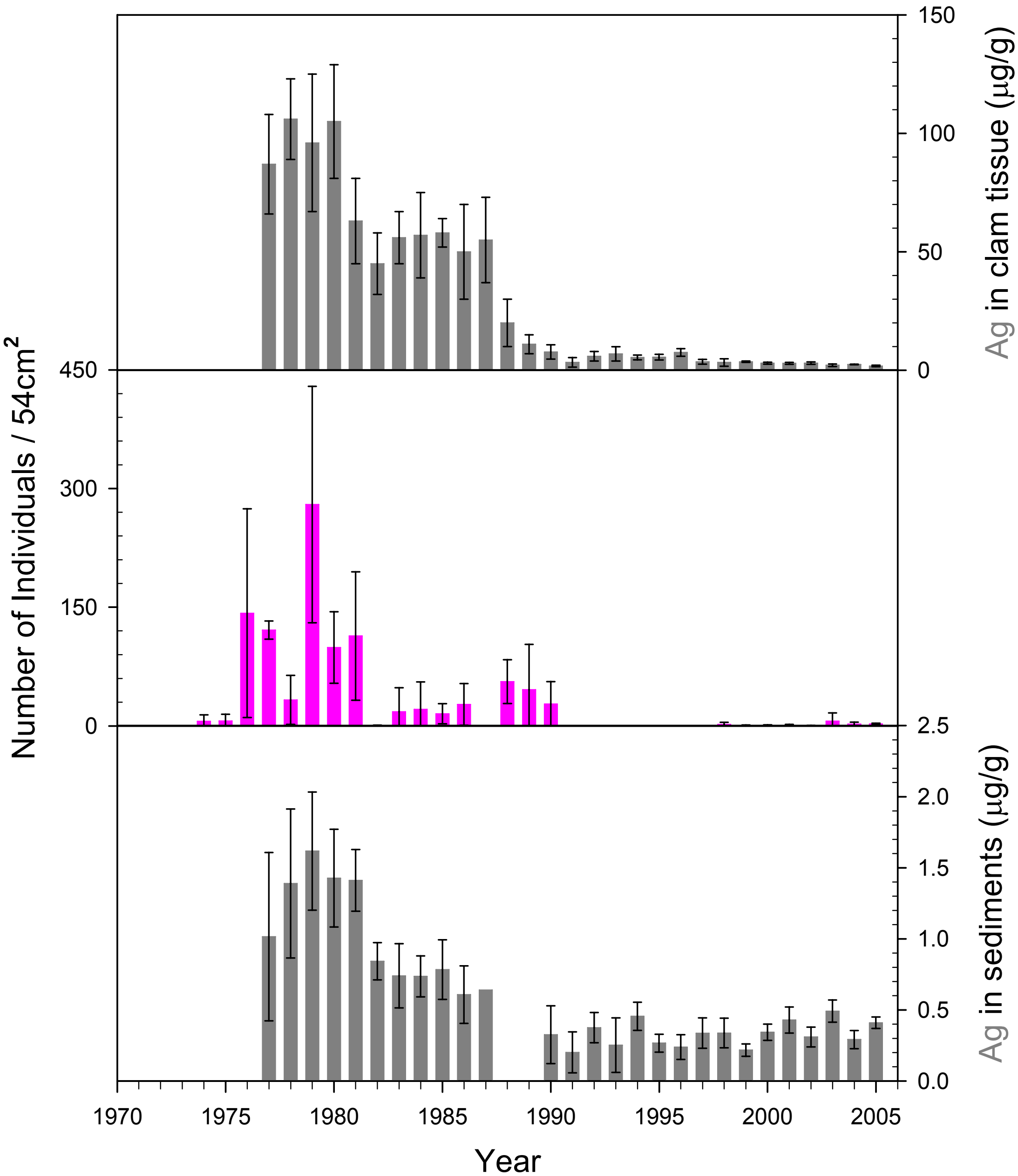


Figure 37. *Ampelisca abdita* annual abundance with silver in *M. petalum* and sediment

Data are for the period from 1974 through 2005. Error bars for abundance and metals in sediments are the standard deviation of the means. Error bars for metals in clams are the standard error of the mean (SEM).

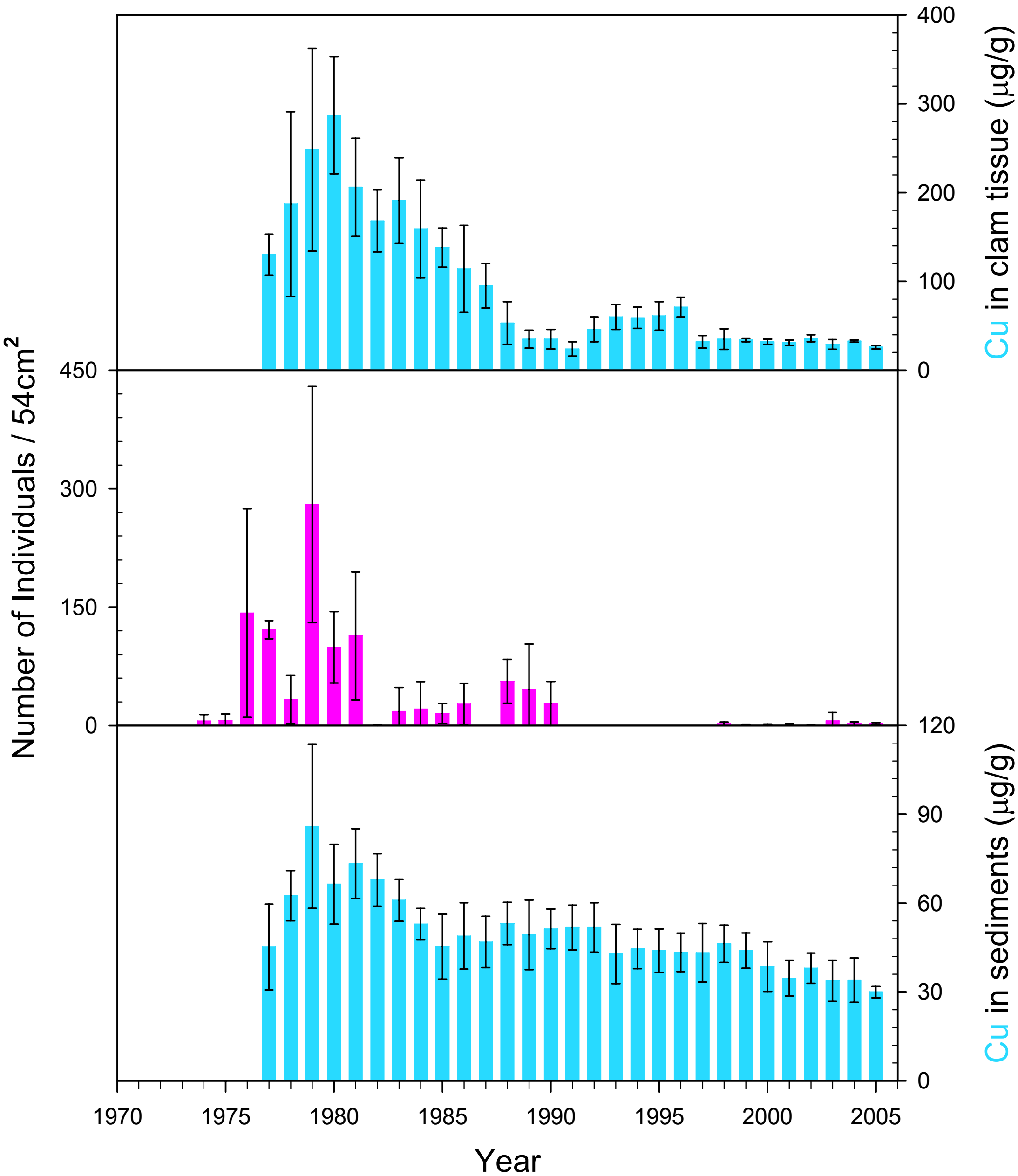


Figure 38. *Ampelisca abdita* annual abundance with copper in *M. petalum* and sediment

Data are for the period from 1974 through 2005. Error bars for abundance and metals in sediments are the standard deviation of the means. Error bars for metals in clams are the standard error of the mean (SEM).

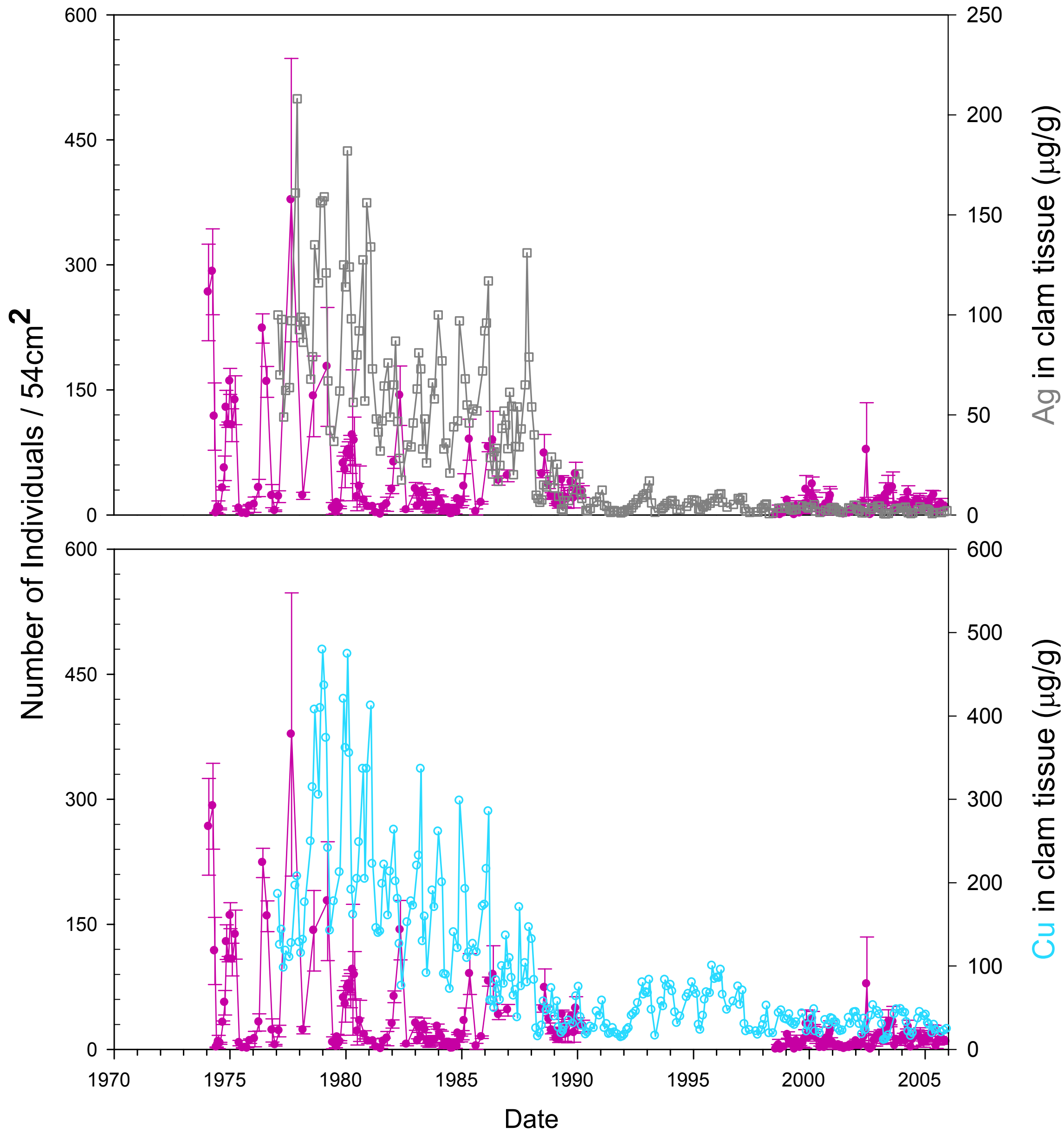


Figure 39. *Streblospio benedicti* abundance with silver and copper in *M. petalum*

Data are for the period from 1974 through 2005. Error bars represent standard deviation from 3 replicate samplings. Number of individuals (●) with silver (□) and copper (○) tissue concentrations in *Macoma petalum.*

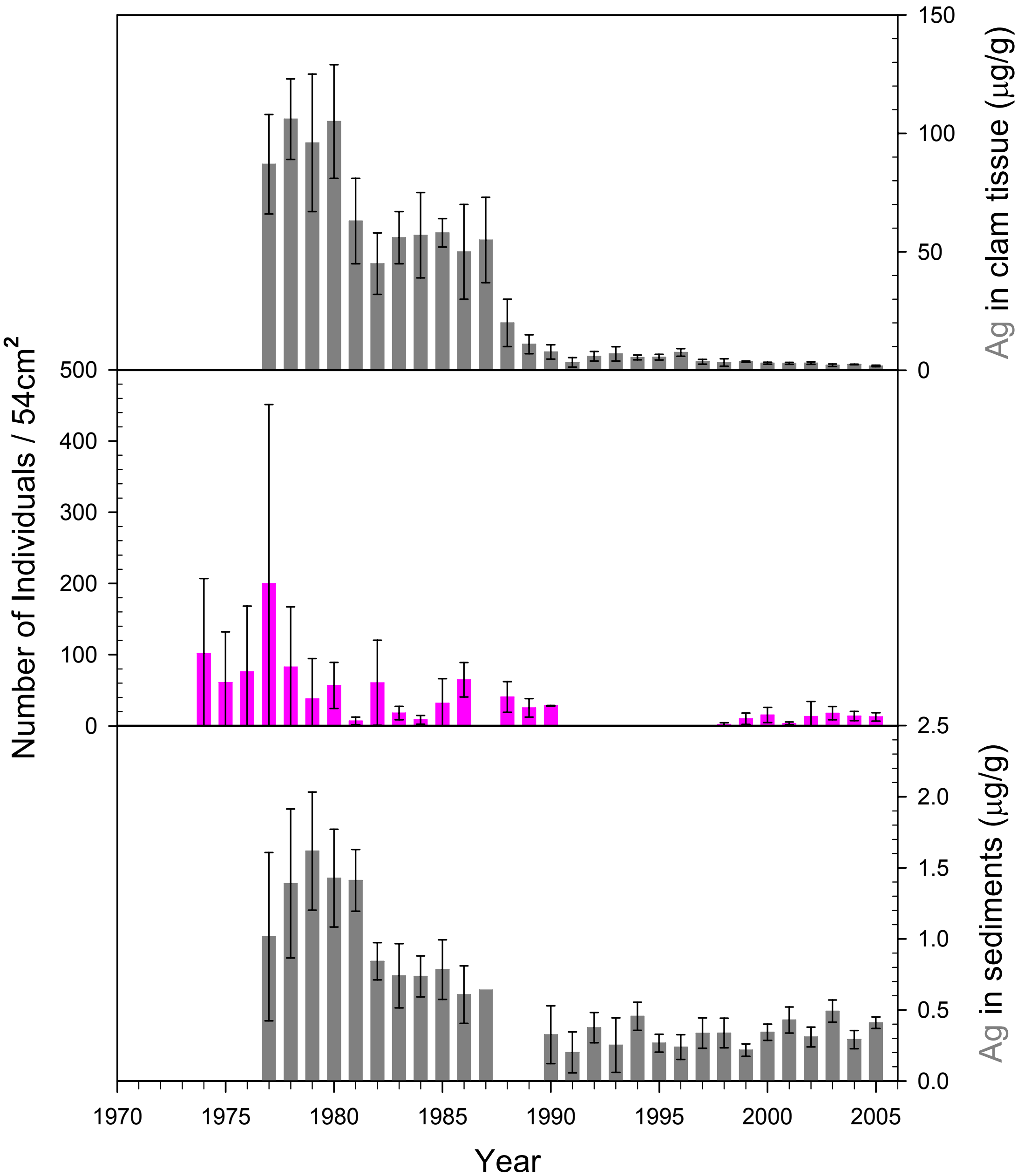


Figure 40. *Streblospio benedicti* annual abundance with silver in *M. petalum* and sediment.

Data are for the period from 1974 through 2005. Error bars for abundance and metals in sediments are the standard deviation of the means. Error bars for metals in clams are the standard error of the mean (SEM).

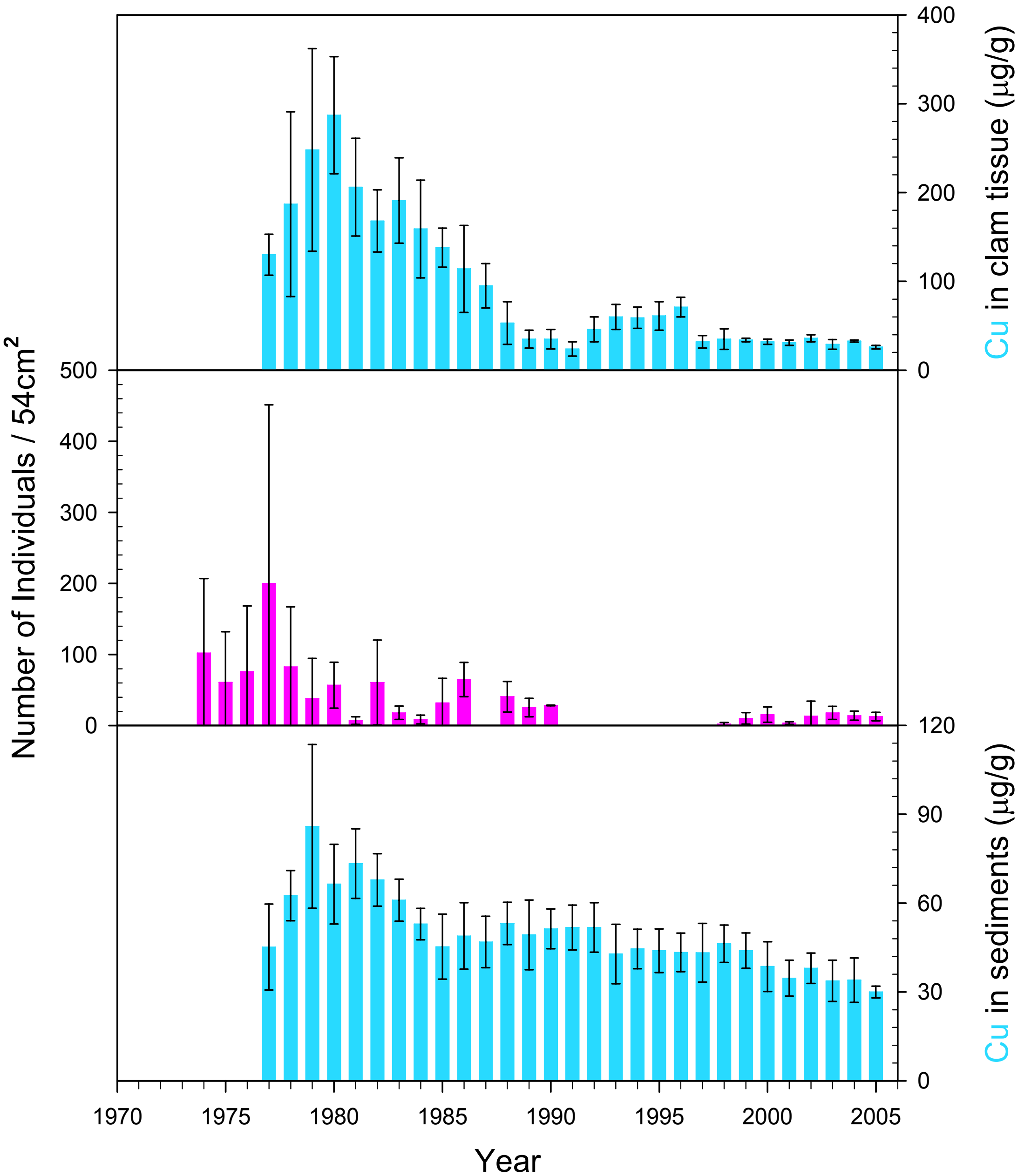


Figure 41. *Streblospio benedicti* annual abundance with copper in *M. petalum* and sediment

Data are for the period from 1974 through 2005. Error bars for abundance and metals in sediments are the standard deviation of the means. Error bars for metals in clams are the standard error of the mean (SEM).

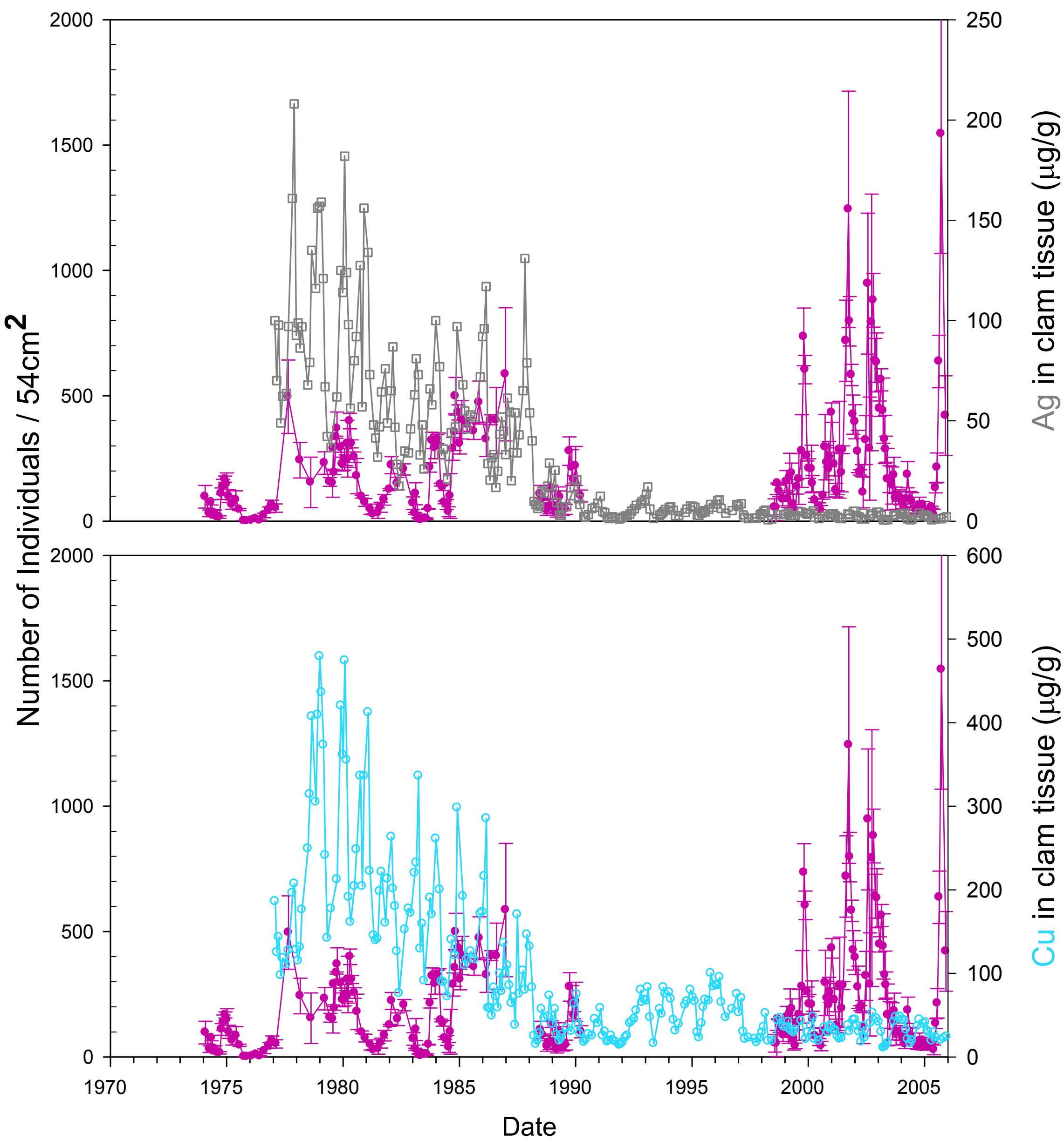


Figure 42. *Gemma gemma* abundance with silver and copper in *M. petalum*

Data are for the period from 1974 through 2005. Error bars represent standard deviation from 3 replicate samplings. Number of individuals (●) with silver (□) and copper (○) tissue concentrations in *Macoma petalum.*

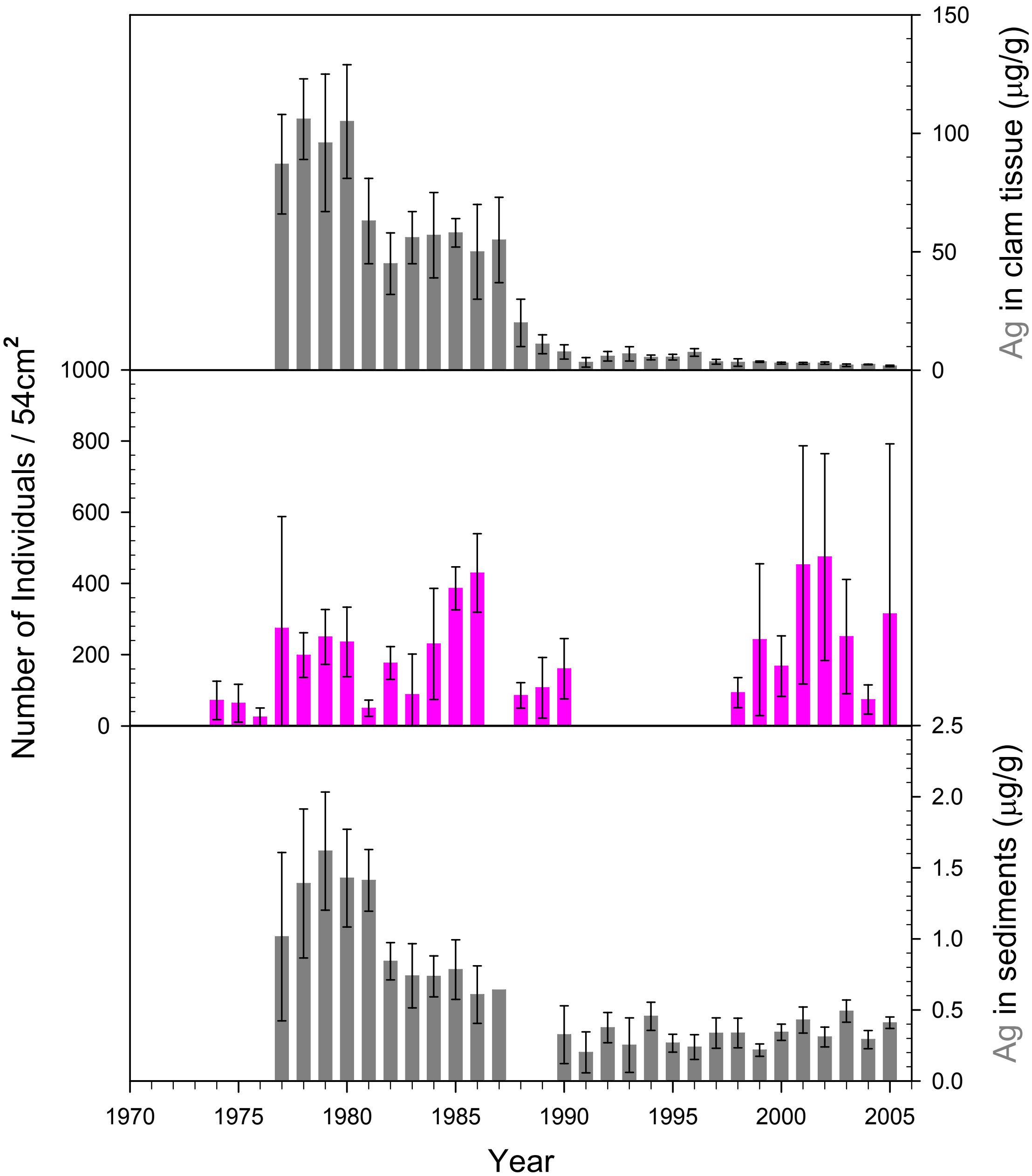


Figure 43. *Gemma gemma* annual abundance with silver in *M. petalum* and sediment.

Data are for the period from 1974 through 2005. Error bars for abundance and metals in sediments are the standard deviation of the means. Error bars for metals in clams are the standard error of the mean (SEM).

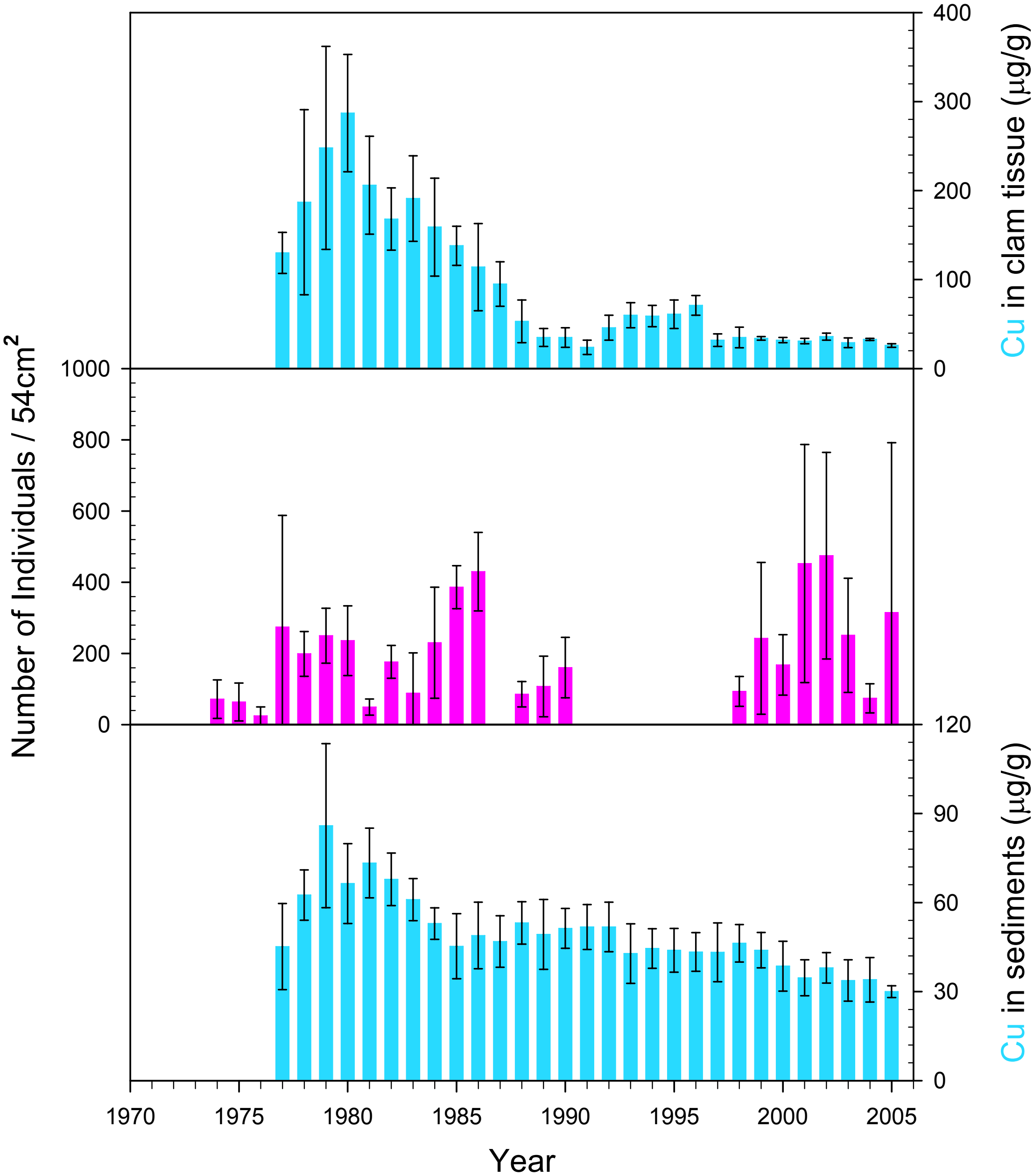


Figure 44. *Gemma gemma* annual abundance with copper in *M. petalum* and sediment

Data are for the period from 1974 through 2005. Error bars for abundance and metals in sediments are the standard deviation of the means. Error bars for metals in clams are the standard error of the mean (SEM).

Tables

Table 1. Sediment characteristics and salinity in 2005

Composition of sediment and salinity of water pooled on the sediment surface. Units for Al, Fe, total organic carbon (TOC) and sand are percent of dry weight. Sand is operationally determined as ≥ 100 μm grain size. Salinity is reported in units of parts per thousand (ppt). Data for Al and Fe are reported as the mean ± 1 standard deviation (std) for replicate subsamples (n=2); results for other constituents are for a single (n=1) measurement. Means for monthly samples were summarized and reported as the annual mean ± the standard error (SEM) (n=9).

Date of sample	**Al** (percent)		**Fe** (percent)		**TOC** (percent)	**Sand** (percent)	**Salinity** (ppt)
	mean	std	mean	std			
January 18, 2005	5.8	0.04	4.1	0.09	1.48	54	20
February 15, 2005	5.6	0.09	4.0	0.04	1.44	69	20
March 7, 2005	5.8	0.16	4.2	0.00	1.46	76	19
April 25, 2005	5.5	0.06	4.0	0.04	1.46	5	16
May 25, 2005	4.5	0.02	3.4	0.03	1.07	8	19
June 28, 2005	4.3	0.00	3.2	0.02	0.96	24	23
September 20, 2005	3.2	0.28	2.9	0.15	0.88	54	26
November 1, 2005	3.3	0.00	3.0	0.06	0.89	50	26
December 13, 2005	4.3	0.12	3.6	0.02	1.23	21	24
Annual Mean:	**4.7**		**3.6**		**1.21**	**40**	**21**
SEM:	*0.3*		*0.2*		*0.09*	*9*	*1*

Table 2. Concentrations of trace elements in sediments in 2005

Elemental concentrations for the monthly samples are reported as the mean ± 1 standard deviation (std) for replicate subsamples (n=2). Units are micrograms per gram dry weight. Means are summarized as the annual mean (the average of monthly means) and the standard error of the monthly means (SEM) (n=9). All concentrations are based on near-total extracts, except for silver (Ag) which is based on partial extraction (See Methods).

Date of sample	Ag		Cr		Cu		Hg	Ni		Se	V		Zn	
	mean	*STD*	*mean*	*STD*	*mean*	*STD*	*mean*	*mean*	*STD*	*mean*	*mean*	*STD*	*mean*	*STD*
January 18, 2005	0.48	0.006	129	3.4	35	1.1	0.32	83	1.7	0.5	135	3.2	138	1.3
February 15, 2005	0.49	0.003	124	2.5	33	0.4	0.31	80	1.0	0.4	128	1.0	132	2.1
March 7, 2005	0.46	0.002	131	5.6	35	0.1	-	85	0.6	-	133	2.1	140	0.6
April 25, 2005	0.59	0.007	124	1.4	35	0.3	0.32	79	0.5	0.4	130	1.4	131	0.2
May 25, 2005	0.32	0.007	116	1.0	28	0.1	-	65	0.6	-	106	0.6	107	0.7
June 28, 2005	0.35	0.001	117	1.7	26	0.3	0.28	62	0.1	0.3	100	3.4	101	1.3
September 20, 2005	0.26	0.083	84	7.6	21	0.1	0.26	58	2.6	0.3	59	8.5	90	3.4
November 1, 2005	0.33	0.001	89	0.1	23	0.2	-	60	1.4	-	56	4.9	94	0.6
December 13, 2005	0.44	0.015	104	3.4	30	0.9	-	74	0.4	-	73	2.0	121	1.6
Annual Mean:	**0.41**		**113**		**30**		**0.30**	**72**		**0.38**	**102**		**117**	
SEM:	***0.04***		***6***		***2***		***0.01***	***4***		***0.04***	***11***		***7***	

Table 3. Annual mean copper in *Macoma petalum* and sediments 1977 through 2005

Values are the annual (grand) means for 7 to 12 separate samples per year and standard errors of those means. Samples were collected between January and December of each year. Units are microgram per gram dry weight of soft tissue for the clam (*Macoma petalum*) and microgram per gram dry weight for sediment.

Year	*Sediment*		*Clam Tissue*
	Partial	*Total*	
1977	28 ± 6	45 ± 13	130 ± 23
1978	42 ± 11	57 ± 13	187 ± 104
1979	55 ± 13	86 ± 18	248 ± 114
1980	47 ± 5	66 ± 9	287 ± 66
1981	48 ± 7	57 ± 22	206 ± 55
1982	35 ± 4	34 ± 24	168 ± 35
1983	22 ± 9	38 ± 21	191 ± 48
1984	26 ± 10	40 ± 16	159 ± 55
1985	27 ± 3	45 ± 7	138 ± 22
1986	24 ± 3	49 ± 9	114 ± 49
1987	21 ± 3	47 ± 6	95 ±25
1988	27 ± 3	53 ± 5	53 ±24
1989	23 ± 6	44 ± 13	35 ± 10
1990	23 ± 2	51 ± 4	35 ± 11
1991	25 ± 2	52 ± 5	24 ± 8
1992	27 ± 6	52 ± 5	46 ± 14
1993	21 ± 3	43 ± 7	60 ± 14
1994	19 ± 2	45 ± 4	59 ± 12
1995	19 ± 2	44 ± 5	61 ± 16
1996	19 ± 2	43 ± 4	71 ± 11
1997	18 ± 1	43 ± 3	32 ± 7
1998	20 ± 1	46 ± 2	35 ± 4
1999	18 ± 1	44 ± 2	34 ± 2
2000	18 ± 1	39 ± 3	32 ± 3
2001	17 ± 1	35 ± 2	31 ± 3
2002	13 ± 1	38 ± 2	36 ± 4
2003	19 ± 4	34 ± 8	29 ± 16
2004	17 ± 4	34 ± 8	33 ± 11
2005	16 ± 2	30 ± 2	26 ± 2

Table 4. Annual mean silver in *Macoma petalum* and sediments 1977 through 2005

Values are annual (grand) means for 7 to 12 separate samples per year and standard errors of those means. Samples were collected between January and December of each year. Units are microgram per gram dry weight of soft tissue for the clam (*Macoma petalum*) and microgram per gram dry weight for sediment. Sediment was extracted with 0.6 N hydrochloric acid.

Year	*Sediment Partial*	*Clam Tissue*
1977	0.65 ± 0.59	87 ± 21
1978	1.39 ± 0.35	106 ± 17
1979	1.62 ± 0.28	96 ± 29
1980	1.28 ± 0.38	105 ± 24
1981	1.41 ± 0.15	63 ± 18
1982	0.74 ± 0.21	45 ± 13
1983	0.56 ± 0.26	56 ± 11
1984	0.64 ± 0.20	57 ± 18
1985	0.78 ± 0.14	58 ± 6
1986	0.61 ± 0.14	50 ± 20
1987	ND	55 ± 18
1988	ND	20 ± 10
1989	ND	11 ± 4
1990	0.39 ± 0.09	7.7 ± 3.4
1991	0.25 ± 0.07	3.3± 2.0
1992	0.35 ± 0.11	5.9 ± 1.9
1993	0.36± 0.09	6.9 ± 3.2
1994	0.46 ± 0.07	5.4 ± 1.1
1995	0.27 ± 0.05	5.5 ± 1.2
1996	0.24 ± 0.06	7.5 ± 1.6
1997	0.34 ± 0.04	3.6 ± 1.0
1998	0.34 ± 0.04	3.3 ± 0.6
1999	0.22 ± 0.01	3.6 ± 0.3
2000	0.34 ± 0.02	3.0 ± 0.4
2001	0.43 ± 0.03	3.0 ± 0.4
2002	0.31 ± 0.02	3.0 ± 0.5
2003	0.49 ± 0.08	2.1 ± 1.5
2004	0.29 ± 0.06	2.4 ± 1.3
2005	0.41 ± 0.04	1.8 ± 0.3

Table 5. Concentrations of trace elements in *Macoma petalum* in 2005.

Monthly data are the mean and standard error (*SEM) for replicate composites (n= 6-14). The monthly means are summarized as the grand annual mean (the average of monthly means) and the standard error (SEM) (n=9). Elemental concentrations are microgram per gram soft tissue dry weight. The condition index is the soft tissue weight in milligrams of a 25 mm shell length clam.

Date of sample		*Ag*	*Cr*	*Cu*	*Hg*	*Ni*	*Se*	*Zn*	*Condition Index*
January 18, 2005	mean	3.1	3.9	41	0.39	6.3	5.9	299	96
	*SEM	0.2	0.5	2	0.00	0.3	0.8	24	
February 15. 2005	mean	2.7	3.9	31		5.4		269	121
	*SEM	0.5	0.2	3		0.2		9	
March 7, 2005	mean	2.0	4.7	29		5.8		286	109
	*SEM	0.3	0.5	3		1.5		38	
April 25, 2005	mean	0.7	2.2	19	0.15	3.8	4.7	209	174
	*SEM	0.0	0.2	0	0.05	0.2	0.8	8	
May 25, 2005	mean	1.2	1.3	29		3.6		220	192
	*SEM	0.3	0.0	9		0.2		11	
June 28, 2005	mean	1.2	1.3	23	0.12	4.0	4.2	219	160
	*SEM	0.1	0.1	1	0.05	0.3	0.4	21	
September 20, 2005	mean	1.2	2.0	20	0.29	4.3	5.5	181	156
	*SEM	0.1	0.2	1	0.14	0.2	1.3	12	
November 1, 2005	mean	1.8	7.0	22		4.9		224	108
	*SEM	0.1	0.3	1		0.3		16	
December 13, 2005	mean	2.2	4.7	24		6.7		307	103
	*SEM	0.1	0.5	1		0.5		19	
Annual Mean:		1.8	3.4	26	0.2	5.0	5.1	246	135
SEM:		0.3	0.6	2	0.1	0.4	0.4	15	12

Appendix A

Sediment characteristics for samples collected between 1994 and 2005. Results are for percent fine-grained particles (silt and clay < 100 μM) (A-1, A-2), and percent organic carbon (A-3). Data for percent fines for 2004 contain unquantifiable biases due to errors in sample processing. These data are shown for qualitative purposes only.

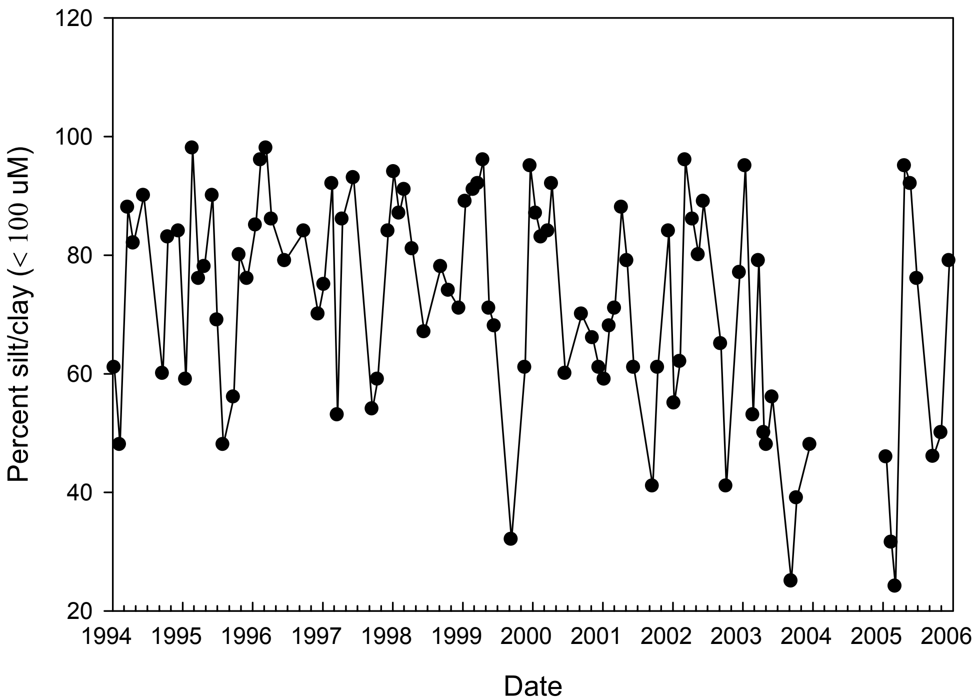
A-1. PALTO ALTO GRAIN SIZE DATA: <100 µM

Year	Date	%<100um
1994	01/10/94	61
	02/08/94	48
	03/22/94	88
	04/20/94	82
	06/13/94	90
	09/20/94	60
	10/17/94	83
	12/12/94	84
1995	01/18/95	59
	02/22/95	98
	03/27/95	76
	04/25/95	78
	06/06/95	90
	07/01/95	69
	08/01/95	48
	09/25/95	56
	10/24/95	80
	12/05/95	76
1996	01/17/96	85
	02/13/96	96
	03/13/96	98
	04/10/96	86
	06/18/96	79
	09/26/96	84
	12/09/96	70
1997	01/08/97	75
	02/19/97	92
	03/19/97	53
	04/14/97	86
	06/11/97	93
	09/17/97	54
	10/15/97	59
	12/09/97	84
1998	01/07/98	94
	02/04/98	87
	03/03/98	91
	04/13/98	81
	06/15/98	67
	09/09/98	78
	10/20/98	74
	12/14/98	71

Year	Date	%<100um
1999	01/15/99	89
	02/26/99	91
	03/22/99	92
	04/18/99	96
	05/19/99	71
	06/16/99	68
	09/13/99	32
	11/23/99	61
	12/20/99	95
2000	01/18/00	87
	02/15/00	83
	03/22/00	84
	04/10/00	92
	06/19/00	60
	09/13/00	70
	11/09/00	66
	12/12/00	61
2001	01/09/01	59
	02/05/01	68
	03/05/01	71
	04/10/01	88
	05/08/01	79
	06/12/01	61
	09/18/01	41
	10/15/01	61
	12/11/01	84
2002	01/08/02	55
	02/08/02	62
	03/07/02	96
	04/15/02	86
	05/15/02	80
	06/11/02	89
	09/09/02	65
	10/07/02	41
	12/16/02	77
2003	01/14/03	95
	02/24/03	53
	03/25/03	79
	04/22/03	50
	05/05/03	48
	06/04/03	56
	09/11/03	25
	10/09/03	39
	12/18/03	48

Year	Date	%<100um
2004	01/20/04	45
	02/27/04	42
	03/16/04	49
	04/12/04	49
	05/24/04	64
	06/22/04	71
	09/13/04	24
	10/13/04	28
	12/08/04	15
2005	01/18/05	46
	02/15/05	32
	03/07/05	24
	04/25/05	95
	05/25/05	92
	06/28/05	76
	09/20/05	46
	11/01/05	50
	12/13/05	79

A-2. Percent of sediment composed of silt/clay-sized particles (< 100 uM)



A-3. Total organic carbon (TOC) content (expressed as percent) of sediment collected in 2005.

Date of collection	*TOC (%)*
January 18, 2005	1.48
February 15, 2005	1.44
March 7, 2005	1.46
April 25, 2005	1.46
May25, 2005	1.07
June 28, 2005	0.96
September 20, 2005	0.88
November 1, 2006	0.89
December 13, 2005	1.23

Appendix B

Metal concentrations in sediments collected at the Palo Alto mudflat during 2005 and determined by ICP-OES. Replicate subsamples were analyzed for each collection. The dry weight, reconstitution volume and dilution factor (if applicable) are shown for each replicate. Concentrations are reported for sample solutions (in micrograms per milliliter, µg/ml) and the calculated weight standardized concentration (reported as microgram per gram dry sediment, µg/g). The sample mean and standard deviation for the weight standardized concentration are reported, also.

Palo Alto Total Extracts: 2005

1/18/2005: 46% <100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
				Concentration, µg/mL								
Tot1	0.5643	10	5	649.7	1.429	0.404	452.5	12.14	0.9259	0.3598	1.545	1.552
Tot2	0.4975	10	5	578.7	1.307	0.3402	411.5	10.9	0.8403	0.3228	1.317	1.387

Concentration, µg/g

		AL	CR	CU	FE	MN	NI	PB	V	ZN
		57566.9	126.617	35.79656	40093.92	1075.669	82.0397	31.88021	136.8953	137.5155
		58160.8	131.3568	34.19095	41356.78	1095.477	84.45226	32.44221	132.3618	139.397
Tot1	***Average***	**57863.85**	**128.9869**	**34.99376**	**40725.35**	**1085.573**	**83.24598**	**32.16121**	**134.6285**	**138.4562**
Tot2	***Std***	**419.9557**	**3.3515**	**1.135336**	**892.9785**	**14.00667**	**1.705942**	**0.397398**	**3.20564**	**1.330407**

2/15/2005: 32% < 100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
				Concentration, µg/mL								
Tot1	0.5275	10	5	583.6	1.286	0.3487	417.4	12.14	0.8365	0.3307	1.359	1.379
Tot2	0.5069	10	5	573.1	1.272	0.3409	406.3	11.89	0.8188	0.3162	1.292	1.355

Concentration, µg/g

		AL	CR	CU	FE	MN	NI	PB	V	ZN
		55317.54	121.8957	33.05213	39563.98	1150.711	79.2891	31.34597	128.8152	130.7109
		56529.89	125.4685	33.62596	40076.94	1172.815	80.76544	31.18958	127.4413	133.6556
Tot1	***Average***	**55923.71**	**123.6821**	**33.33905**	**39820.46**	**1161.763**	**80.02727**	**31.26778**	**128.1282**	**132.1832**
Tot2	***Std***	**857.2623**	**2.526351**	**0.405758**	**362.7155**	**15.63007**	**1.043928**	**0.110583**	**0.971463**	**2.082184**

Concentration, µg/mL

3/07/2005: 24% <100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
Tot1	0.5072	10	5	597.3	1.372	0.3584	422.3	11.44	0.8613	0.3368	1.361	1.417
Tot2	0.5041	10	5	571.4	1.284	0.357	419.7	11.46	0.8643	0.3362	1.323	1.417

Concentration, µg/g

		AL	CR	CU	FE	MN	NI	PB	V	ZN
		58882.1	135.2524	35.33123	41630.52	1127.76	84.90733	33.20189	134.168	139.6885
		56675.26	127.3557	35.40964	41628.65	1136.679	85.72704	33.34656	131.224	140.5475
Tot1	***Average***	**57778.68**	**131.304**	**35.37044**	**41629.58**	**1132.22**	**85.31719**	**33.27423**	**132.696**	**140.118**
Tot2	***Std***	**1560.468**	**5.583798**	**0.055445**	**1.326104**	**6.30667**	**0.579618**	**0.102294**	**2.081735**	**0.607422**

Concentration, µg/mL

4/25/2005: 8895% <100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
Tot1	0.2514	5	5	551.7	1.235	0.349	395.3	12.54	0.7948	0.3062	1.302	1.322
Tot2	0.234	5	5	521.8	1.168	0.3214	372.9	11.75	0.7464	0.2875	1.231	1.228

Concentration, µg/g

		AL	CR	CU	FE	MN	NI	PB	V	ZN
		54862.77	122.8123	34.70565	39309.86	1247.017	79.03739	30.44948	129.4749	131.4638
		55747.86	124.7863	34.33761	39839.74	1255.342	79.74359	30.71581	131.5171	131.1966
Tot1	***Average***	**55305.32**	**123.7993**	**34.52163**	**39574.8**	**1251.179**	**79.39049**	**30.58265**	**130.496**	**131.3302**
Tot2	***Std***	**625.8565**	**1.395881**	**0.260245**	**374.6809**	**5.886787**	**0.499358**	**0.188323**	**1.444021**	**0.188954**

Concentration, µg/mL

5/025/2005: 92% < 100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
Tot1	0.5134	10	5	461.2	1.194	0.2916	350	5.257	0.6704	0.2429	1.09	1.1
Tot2	0.549	10	5	489.3	1.262	0.3105	369	5.568	0.7071	0.2618	1.156	1.166

Concentration, µg/g

		AL	CR	CU	FE	MN	NI	PB	V	ZN
		44916.24	116.2836	28.39891	34086.48	511.979	65.29022	23.65602	106.155	107.1289
		44562.84	114.9362	28.27869	33606.56	507.1038	64.39891	23.84335	105.2823	106.1931
Tot1	***Average***	**44739.54**	**115.6099**	**28.3388**	**33846.52**	**509.5414**	**64.84456**	**23.74969**	**105.7187**	**106.661**
Tot2	***Std***	**249.8937**	**0.952722**	**0.085009**	**339.3581**	**3.447244**	**0.630255**	**0.132464**	**0.617101**	**0.661757**

Concentration, µg/mL

6/28/2005: 76% <100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
Tot1	0.5602	10	5	487.3	1.327	0.2922	358.2	7.461	0.6903	0.2587	1.093	1.142
Tot2	0.5203	10	5	452.4	1.207	0.2667	336.3	7.009	0.6422	0.2479	1.065	1.041

Concentration, µg/g

		AL	CR	CU	FE	MN	NI	PB	V	ZN
		43493.4	118.4398	26.07997	31970.72	665.9229	61.61192	23.08997	97.55444	101.9279
		43474.92	115.9908	25.62944	32317.89	673.5537	61.7144	23.82279	102.3448	100.0384
Tot1	***Average***	**43484.16**	**117.2153**	**25.85471**	**32144.31**	**669.7383**	**61.66316**	**23.45638**	**99.94962**	**100.9832**
Tot2	***Std***	**13.06514**	**1.731753**	**0.318571**	**245.4854**	**5.395815**	**0.072458**	**0.518187**	**3.387293**	**1.336038**

9/20/2005: 46% <100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
				Concentration, µg/mL								
Tot1	0.4924	10	5	334.9	0.8838	0.2083	299.3	5.336	0.5895	0.2239	0.6359	0.9137
Tot2	0.5942	10	5	357.5	0.9389	0.2523	336.1	6.081	0.6679	0.2534	0.6245	1.045

Concentration, µg/g

	34006.9	89.74411	21.1515	30391.96	541.8359	59.85987	22.73558	64.57149	92.78026
	30082.46	79.00539	21.23023	28281.72	511.6964	56.20162	21.32279	52.54965	87.93336
Tot1 ***Average***	**32044.68**	**84.37475**	**21.19086**	**29336.84**	**526.7662**	**58.03074**	**22.02918**	**58.56057**	**90.35681**
Tot2 ***Std***	**2774.999**	**7.593425**	**0.055665**	**1492.161**	**21.31185**	**2.586776**	**0.998996**	**8.500725**	**3.427279**

11/01/2005: 50% <100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
				Concentration, µg/mL								
Tot1	0.51	10	5	333.9	0.9049	0.2309	311.4	6.074	0.6211	0.2426	0.5379	0.9612
Tot2	0.5646	10	5	369.4	1	0.253	334.8	6.484	0.6653	0.2585	0.6744	1.055

Concentration, µg/g

	32735.29	88.71569	22.63725	30529.41	595.4902	60.89216	23.78431	52.73529	94.23529
	32713.43	88.55827	22.40524	29649.31	574.2118	58.91782	22.89231	59.7237	93.42898
Tot1 ***Average***	**32724.36**	**88.63698**	**22.52125**	**30089.36**	**584.851**	**59.90499**	**23.33831**	**56.2295**	**93.83214**
Tot2 ***Std***	**15.46349**	**0.111309**	**0.164057**	**622.3265**	**15.04608**	**1.396068**	**0.63074**	**4.941548**	**0.570153**

Concentration, µg/mL

12/13/052001: 79% <100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	AL	CR	CU	FE	MN	NI	PB	V	ZN
Tot1	0.55	10	5	465.5	1.123	0.3247	389.6	9.034	0.8111	0.304	0.783	1.318
Tot2	0.5483	10	5	482.6	1.172	0.3376	392	9.026	0.8148	0.3056	0.8122	1.338

Concentration, µg/g

		AL	CR	CU	FE	MN	NI	PB	V	ZN
		42318.18	102.0909	29.51818	35418.18	821.2727	73.73636	27.63636	71.18182	119.8182
		44008.75	106.8758	30.78607	35746.85	823.0895	74.30239	27.86796	74.06529	122.0135
Tot1	***Average***	**43163.47**	**104.4834**	**30.15212**	**35582.52**	**822.1811**	**74.01938**	**27.75216**	**72.62356**	**120.9158**
Tot2	***Std***	**1195.415**	**3.383427**	**0.89653**	**232.4063**	**1.284687**	**0.400241**	**0.16376**	**2.038924**	**1.552322**

Palo Alto HCl Extracts: 2005

1/18/05: 46% < 100µm

Concentration, µg/mL

Sample	Weight (g)	Recon. (ml)	AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.5123	12	0.0209	112.7	0.2179	0.7696	229.6	38.4	0.3262	0.995	0.4542	2.254
HCL2	0.5054	12	0.0201	107.5	0.2109	0.7381	220.3	37.58	0.3152	0.9657	0.4613	2.121

Concentration, µg/g

		AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
		0.4895569	2639.859	5.104041	18.026937	5378.099	899.473	7.640835	23.30666	10.63908	52.79719
		0.47724575	2552.434	5.007519	17.525129	5230.708	892.2833	7.483973	22.92917	10.95291	50.36011
HCl1	Average	**0.48340132**	**2596.147**	**5.05578**	**17.776033**	**5304.404**	**895.8782**	**7.562404**	**23.11791**	**10.79599**	**51.57865**
HCl2	Std	**0.00615558**	**43.71287**	**0.048261**	**0.2509044**	**73.69521**	**3.594813**	**0.078431**	**0.188746**	**0.156915**	**1.218539**

2/15/05: 32% < 100µm

Concentration, µg/mL

Sample	Weight (g)	Recon. (ml)	AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.5057	12	0.0207	104.9	0.1974	0.6747	213.8	40.41	0.3	0.9487	0.4336	1.978
HCL2	0.4962	12	0.0206	103.6	0.196	0.6733	210.3	39.97	0.2947	0.9328	0.4867	1.972

Concentration, µg/g

		AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
		0.49120032	2489.223	4.6842	16.010283	5073.364	958.9084	7.118845	22.51216	10.2891	46.93692
		0.49818622	2505.441	4.740024	16.28295	5085.852	966.6264	7.126965	22.55865	11.77025	47.69045
HCl1	Average	**0.49469327**	**2497.332**	**4.712112**	**16.146617**	**5079.608**	**962.7674**	**7.122905**	**22.5354**	**11.02968**	**47.31368**
HCl2	Std	**0.00349295**	**8.109247**	**0.027912**	**0.1363338**	**6.244412**	**3.858958**	**0.00406**	**0.023242**	**0.740575**	**0.376764**

Concentration, µg/mL

3/07/05: 24% < 100µm

Sample	Weight (g)	Recon. (ml)	AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.4988	12	0.0192	111.3	0.2226	0.6596	253.4	38.94	0.341	1.027	0.5215	2.232
HCL2	0.5056	12	0.0196	117.1	0.2441	0.6747	267.1	39.49	0.3637	1.04	0.5266	2.335

Concentration, µg/g

		AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
		0.46190858	2677.626	5.355253	15.868484	6096.231	936.8083	8.203689	24.7073	12.54611	53.69687
		0.46518987	2779.272	5.793513	16.013449	6339.399	937.2627	8.63212	24.68354	12.49842	55.4193
HCl1	Average	**0.46354923**	**2728.449**	**5.574383**	**15.940967**	**6217.815**	**937.0355**	**8.417905**	**24.69542**	**12.52226**	**54.55809**
HCl2	Std	**0.00164065**	**50.82292**	**0.21913**	**0.0724825**	**121.5839**	**0.227159**	**0.214216**	**0.011877**	**0.023846**	**0.861216**

Concentration, µg/mL

4/25/05: 95% < 100µm

Sample	Weight (g)	Recon. (ml)	AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.417	12	0.0209	86.21	0.1678	0.5763	173.9	36.88	0.2658	0.7847	0.377	1.67
HCL2	0.4406	12	0.0216	93.26	0.1864	0.6196	190	39.07	0.2901	0.8252	0.405	1.808

Concentration, µg/g

		AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
		0.60143885	2480.863	4.828777	16.584173	5004.317	1061.295	7.648921	22.58129	10.84892	48.05755
		0.5882887	2539.991	5.076714	16.87517	5174.762	1064.094	7.901044	22.47481	11.03041	49.24194
HCl1	Average	**0.59486377**	**2510.427**	**4.952745**	**16.729671**	**5089.539**	**1062.695**	**7.774982**	**22.52805**	**10.93967**	**48.64975**
HCl2	Std	**0.00657508**	**29.56381**	**0.123968**	**0.1454988**	**85.22257**	**1.399726**	**0.126062**	**0.053244**	**0.090746**	**0.592194**

5/25/05: 92% < 100μm

Concentration, μg/mL

Sample	Weight (g)	Recon. (ml)	AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.5128	12	0.0139	84.93	0.1713	0.6076	200.3	12.06	0.2864	0.7659	0.3481	1.826
HCL2	0.5364	12	0.0139	86.01	0.1739	0.6297	205.2	12.59	0.292	0.7854	0.3194	1.858

Concentration, μg/g

		AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
		0.32527301	1987.441	4.00858	14.218409	4687.207	282.2153	6.702028	17.92278	8.145866	42.73011
		0.31096197	1924.161	3.89038	14.087248	4590.604	281.6555	6.532438	17.57047	7.145414	41.566
HCl1	Average	**0.31811749**	**1955.801**	**3.94948**	**14.152829**	**4638.906**	**281.9354**	**6.617233**	**17.74662**	**7.64564**	**42.14805**
HCl2	Std	**0.00715552**	**31.64021**	**0.0591**	**0.0655802**	**48.30173**	**0.279904**	**0.084795**	**0.176154**	**0.500226**	**0.582057**

6/28/05: 76% < 100μm

Concentration, μg/mL

Sample	Weight (g)	Recon. (ml)	AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.534	12	0.0154	83.57	0.1724	0.5798	200.6	20.98	0.2658	0.7276	0.3068	1.717
HCl2	0.5192	12	0.0149	82.14	0.1695	0.5669	197.9	20.58	0.2644	0.7085	0.2918	1.681

Concentration, μg/g

		AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
		0.34606742	1877.978	3.874157	13.029213	4507.865	471.4607	5.973034	16.35056	6.894382	38.58427
		0.34437596	1898.459	3.917565	13.102465	4573.96	475.6549	6.11094	16.37519	6.744222	38.85208
HCl1	Average	**0.34522169**	**1888.218**	**3.895861**	**13.065839**	**4540.913**	**473.5578**	**6.041987**	**16.36288**	**6.819302**	**38.71817**
HCl2	Std	**0.00084573**	**10.24082**	**0.021704**	**0.0366259**	**33.04738**	**2.09709**	**0.068953**	**0.012315**	**0.07508**	**0.133905**

Concentration, µg/mL

9/20/05: 46% < 100µm

Sample	Weight (g)	Recon. (ml)	AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.4969	12	0.0072	40.81	0.1781	0.5565	213.5	15.17	0.295	0.7138	-0.1214	1.686
HCl2	0.5158	12	0.0146	84.97	0.1857	0.5904	220.3	15.7	0.3095	0.7406	0.3163	1.762

Concentration, µg/g

		AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
		0.17387804	985.5504	4.301067	13.439324	5155.967	366.3514	7.12417	17.23808	-2.931777	40.71644
		0.33966654	1976.813	4.320279	13.735556	5125.242	365.2579	7.200465	17.22993	7.358666	40.99263
HCl1	Average	**0.25677229**	**1481.182**	**4.310673**	**13.58744**	**5140.605**	**365.8046**	**7.162318**	**17.23401**	**2.213445**	**40.85454**
HCl2	Std	**0.08289425**	**495.6312**	**0.009606**	**0.1481163**	**15.36233**	**0.546763**	**0.038148**	**0.004071**	**5.145222**	**0.138095**

Concentration, µg/mL

11/01/05: 50% < 100µm

Sample	Weight (g)	Recon. (ml)	AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.4956	12	0.0138	84.38	0.1789	0.5915	217.4	17.69	0.3169	0.7639	0.3113	1.751
HCl2	0.5289	12	0.0146	90.51	0.1915	0.646	231	18.75	0.3403	0.8278	0.336	2.328

Concentration, µg/g

		AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
		0.33414044	2043.099	4.331719	14.322034	5263.923	428.3293	7.673123	18.49637	7.53753	42.39709
		0.33125355	2053.545	4.344867	14.656835	5241.066	425.4112	7.72093	18.78162	7.623369	52.81906
HCl1	Average	**0.33269699**	**2048.322**	**4.338293**	**14.489434**	**5252.494**	**426.8703**	**7.697027**	**18.639**	**7.58045**	**47.60808**
HCl2	Std	**0.00144345**	**5.22291**	**0.006574**	**0.1674005**	**11.42808**	**1.459033**	**0.023903**	**0.142627**	**0.042919**	**5.210982**

Concentration, µg/mL

12/13/05: 79% < 100µm

Sample	Weight (g)	Recon. (ml)	AG	AL	CR	CU	FE	MN	NI	PB	V	ZN
HCl1	0.5432	12	0.0193	111.4	0.2397	0.8219	278	29.49	0.3856	0.9755	0.4465	2.484
HCl2	0.5212	12	0.0198	107.9	0.2293	0.7949	269.2	29.12	0.3693	0.9494	0.4125	2.337

Concentration, µg/g

		0.4263623	2460.972	5.295287	18.156848	6141.384	651.4728	8.518409	21.55007	9.86377	54.87482
		0.45587107	2484.267	5.279355	18.301612	6198.005	670.4528	8.502686	21.85879	9.497314	53.8066
HCl1	Average	**0.44111668**	**2472.62**	**5.287321**	**18.22923**	**6169.694**	**660.9628**	**8.510548**	**21.70443**	**9.680542**	**54.34071**
HCl2	Std	**0.01475438**	**11.64753**	**0.007966**	**0.0723817**	**28.31011**	**9.490024**	**0.007862**	**0.154357**	**0.183228**	**0.534108**

Appendix C

Metal concentrations in the clam *Macoma petalum* collected at the Palo Alto Mudflat. Each monthly collection is reported on two pages. The first page contains summary statistics:

Mean concentrations in microgram per gram dry tissue weight (µg/g).

- STD is the standard deviation of the mean.
- SEM is the standard error of the mean.
- CV percent is the coefficient of variation.
- r wt x [] is the correlation coefficient for the concentration versus weight correlation for each element.
- X 100mg is the concentration interpolated from the above regression for a 100 mg animal.
- r l x [] is the correlation coefficient for the concentration versus shell length regression.
- X 20 mm and X 25 mm are concentrations interpolated from the regression for 20mm and 25 mm animals.

Condition index (CI) is an estimate of the tissue dry weight (g or mg) standardized to a constant shell length (shell length of 25 mm is used for interpretive purposes). This index, along with weights for animals of 15 mm and 20 mm shell length, was estimated from a linear regression analysis of log tissue dry weight vs. log average shell length for each monthly collection.

Content (a measure of metal bioaccumulation that is standardized to tissue mass) is show from 15 mm, 20 mm and 25 mm animals.

The second page shows the analysis of each composite within the sample, the number of animals in each composite, concentration as calculated from sample dry weight and the dilution factor and the metal content for each composite.

Station: Palo Alto

Statistical Summary

Date: 1/18/05

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	3.0962	0.2065	3.8795	41.2623	6.3217	1.7580	4.4338	299.0293
STD	0.6493	0.0760	1.4413	5.5812	0.8578	0.6015	1.5460	66.9230
SEM	0.230	0.027	0.510	1.973	0.303	0.213	0.547	23.661
CV%	20.972	36.800	37.151	13.526	13.569	34.212	34.868	22.380
n	8	8	8	8	8	8	8	8
r wt x [ ]	0.217	0.677	0.965	0.675	0.665	0.950	0.950	0.251
X 100mg	3.142	0.190	3.431	40.047	6.138	1.574	3.960	304.451
r l x [ ]	0.087	0.666	0.967	0.651	0.658	0.963	0.958	0.232
X 20mm	3.072	0.228	4.478	42.822	6.564	2.007	5.070	292.373
X 25mm	3.119	0.186	3.323	39.812	6.096	1.527	3.842	305.217

Estimated content (ug) for 15mm and 20mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
20mm	0.1615	0.0112	0.2157	2.2348	0.3429	0.0980	0.2468	15.4136
25mm	0.2904	0.0163	0.2915	3.7565	0.5740	0.1368	0.3415	28.2917

Estimated weight for 15mm clam

0.025 gm
24.970 mg

Estimated weight for 20mm clam

0.053 gm
53.189 mg

Estimated weight for 25mm clam

0.096 gm
95.618 mg

Station: Palo Alto

Date: 1/18/05

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
					Concentration (ug/ml) - Blank Corrected from ICP-AES							
Mb1	13.89	0.1664	0.0185	10	0.0609	0.0044	0.0966	0.7041	0.1178	0.0435	0.1113	5.264
Mb2	15.32	0.2615	0.0327	10	0.0814	0.008	0.1483	1.289	0.1927	0.065	0.1643	6.88
Mb3	19.49	0.221	0.0442	10	0.0541	0.0047	0.1012	1.038	0.142	0.0474	0.1102	5.786
Mb4	21.07	0.2299	0.0575	10	0.0536	0.0039	0.0922	0.8977	0.1374	0.0392	0.1036	6.254
Mb5	26.17	0.3491	0.1164	10	0.1305	0.0059	0.0988	1.247	0.1849	0.0408	0.1122	11.58
Mb6	26.48	0.3143	0.1048	10	0.0961	0.0093	0.1184	1.393	0.2244	0.0522	0.1392	11.06
Mb7	28.77	0.2824	0.1412	10	0.0689	0.0029	0.0721	0.9249	0.1762	0.0333	0.0864	5.327
Mb8	29.53	0.3039	0.1520	10	0.121	0.004	0.0553	1.206	0.1534	0.0336	0.07	12.36
				MDL	0.0011	0.0002	0.0073	0.0021	0.0016	0.0036	0.0018	0.0054
				MRL	0.0021	0.0003	0.0146	0.0043	0.0032	0.0072	0.0036	0.0108

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	Mb1	3.6599	0.2644	5.8053	42.3137	7.0793	2.6142	6.6887	316.346
	Mb2	3.1128	0.3059	5.6711	49.2925	7.3690	2.4857	6.2830	263.098
	Mb3	2.4480	0.2127	4.5792	46.9683	6.4253	2.1448	4.9864	261.810
	Mb4	2.3314	0.1696	4.0104	39.0474	5.9765	1.7051	4.5063	272.031
	Mb5	3.7382	0.1690	2.8301	35.7204	5.2965	1.1687	3.2140	331.710
	Mb6	3.0576	0.2959	3.7671	44.3207	7.1397	1.6608	4.4289	351.893
	Mb7	2.4398	0.1027	2.5531	32.7514	6.2394	1.1792	3.0595	188.633
	Mb8	3.9816	0.1316	1.8197	39.6841	5.0477	1.1056	2.3034	406.713

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	Mb1	0.0677	0.0049	0.1073	0.7823	0.1309	0.0483	0.1237	5.8489
	Mb2	0.1018	0.0100	0.1854	1.6113	0.2409	0.0813	0.2054	8.6000
	Mb3	0.1082	0.0094	0.2024	2.0760	0.2840	0.0948	0.2204	11.5720
	Mb4	0.1340	0.0098	0.2305	2.2443	0.3435	0.0980	0.2590	15.6350
	Mb5	0.4350	0.0197	0.3293	4.1567	0.6163	0.1360	0.3740	38.6000
	Mb6	0.3203	0.0310	0.3947	4.6433	0.7480	0.1740	0.4640	36.8667
	Mb7	0.3445	0.0145	0.3605	4.6245	0.8810	0.1665	0.4320	26.6350
	Mb8	0.6050	0.0200	0.2765	6.0300	0.7670	0.1680	0.3500	61.8000

Station:Palo Alto

Date: 2/15/05

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	2.7347	0.1386	3.8578	30.7929	5.3820	1.4474	4.3918	268.7910
STD	1.3224	0.0508	0.6857	9.1042	0.6971	0.3056	0.7353	26.8471
SEM	0.468	0.018	0.242	3.219	0.246	0.108	0.260	9.492
CV%	48.358	36.672	17.773	29.566	12.952	21.114	16.743	9.988
n	8	8	8	8	8	8	8	8
r wt x [ ]	0.684	0.617	0.005	0.875	0.876	0.553	0.234	0.842
X 100mg	3.773	0.175	3.862	39.937	6.083	1.641	4.589	294.717
r l x [ ]	0.680	0.588	0.036	0.893	0.887	0.582	0.265	0.815
X 20mm	3.268	0.156	3.872	35.612	5.749	1.553	4.507	281.763
X 25mm	3.973	0.180	3.892	41.987	6.233	1.692	4.660	298.922

Estimated content (ug) for 15mm and 20mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
20mm	0.2001	0.0100	0.2509	2.3241	0.3806	0.1020	0.2945	18.5968
25mm	0.4263	0.0207	0.4636	4.9210	0.7482	0.2018	0.5568	35.8472

Estimated weight for 15mm clam	Estimated weight for 20mm clam
0.030 gm	0.066 gm
29.867 mg	65.793 mg

Estimated weight for 25mm clam

0.121 gm
121.401 mg

Station:Palo Alto Macoma petula

Date: 2/15/05

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
					Concentration (ug/ml) - Blank Corrected from ICP-AES							
Mb1	9.23	0.2287	0.0079	10	0.0554	0.0034	0.0878	0.5450	0.1117	0.0308	0.0952	6.2600
Mb2	10.17	0.1928	0.0101	10	0.0363	0.0019	0.0700	0.4522	0.0924	0.0215	0.0790	4.3660
Mb3	10.82	0.176	0.0117	10	0.0381	0.0013	0.0596	0.4638	0.0851	0.0214	0.0660	4.4890
Mb4	12.21	0.217	0.0181	10	0.0379	0.0023	0.0880	0.4604	0.0991	0.0283	0.0956	5.1850
Mb5	17.62	0.2217	0.0443	10	0.0483	0.0034	0.0958	0.7050	0.1269	0.0369	0.1090	5.9970
Mb6	21.70	0.2647	0.0882	10	0.0737	0.0058	0.1358	0.9524	0.1711	0.0546	0.1551	7.7600
Mb7	23.65	0.3268	0.1089	10	0.0926	0.0065	0.1209	1.1440	0.1966	0.0511	0.1453	9.8350
Mb8	24.37	0.2082	0.1041	10	0.1221	0.0023	0.0583	1.0140	0.1202	0.0272	0.0728	6.0700
				MDL	0.0011	0.0002	0.0073	0.0021	0.0016	0.0036	0.0018	0.0054
				MRL	0.0021	0.0003	0.0146	0.0043	0.0032	0.0072	0.0036	0.0108

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	Mb1	2.4224	0.1487	3.8391	23.8303	4.8841	1.3467	4.1627	273.721
	Mb2	1.8828	0.0985	3.6307	23.4544	4.7925	1.1151	4.0975	226.452
	Mb3	2.1648	0.0739	3.3864	26.3523	4.8352	1.2159	3.7500	255.057
	Mb4	1.7465	0.1060	4.0553	21.2166	4.5668	1.3041	4.4055	238.940
	Mb5	2.1786	0.1534	4.3212	31.7997	5.7240	1.6644	4.9166	270.501
	Mb6	2.7843	0.2191	5.1303	35.9804	6.4639	2.0627	5.8595	293.162
	Mb7	2.8335	0.1989	3.6995	35.0061	6.0159	1.5636	4.4461	300.949
	Mb8	5.8646	0.1105	2.8002	48.7032	5.7733	1.3064	3.4966	291.547

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	Mb1	0.0191	0.0012	0.0303	0.1879	0.0385	0.0106	0.0328	2.1586
	Mb2	0.0191	0.0010	0.0368	0.2380	0.0486	0.0113	0.0416	2.2979
	Mb3	0.0254	0.0009	0.0397	0.3092	0.0567	0.0143	0.0440	2.9927
	Mb4	0.0316	0.0019	0.0733	0.3837	0.0826	0.0236	0.0797	4.3208
	Mb5	0.0966	0.0068	0.1916	1.4100	0.2538	0.0738	0.2180	11.9940
	Mb6	0.2457	0.0193	0.4527	3.1747	0.5703	0.1820	0.5170	25.8667
	Mb7	0.3087	0.0217	0.4030	3.8133	0.6553	0.1703	0.4843	32.7833
	Mb8	0.6105	0.0115	0.2915	5.0700	0.6010	0.1360	0.3640	30.3500

Station: Palo Alto

Date: 03/08/2005

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V
Mean(ug/g)	1.9814	0.1941	4.7303	28.5787	5.8330	1.8242	5.2627
STD	0.7891	0.0676	1.3332	9.1795	1.5393	0.6386	1.6210
SEM	0.298	0.026	0.504	3.470	0.582	0.241	0.613
CV%	39.827	34.806	28.185	32.120	26.390	35.008	30.802
n	7	7	7	7	7	7	7
r wt x [ ]	0.872	0.522	0.461	0.873	0.588	0.539	0.513
X 100mg	2.674	0.230	5.349	36.637	6.744	2.171	6.100
r l x [ ]	0.897	0.583	0.587	0.928	0.704	0.669	0.639
X 20mm	2.283	0.211	5.064	32.210	6.295	2.006	5.704
X 25mm	2.852	0.243	5.692	39.056	7.166	2.349	6.536

Estimated content (ug) for 15mm and 20mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V
20mm	0.1406	0.0129	0.3170	2.0326	0.3969	0.1251	0.3568
25mm	0.2994	0.0252	0.6071	4.2158	0.7685	0.2506	0.6971

Estimated weight for 15mm clam	Estimated weight for 20mm clam
0.031 gm	0.063 gm
31.354 mg	63.159 mg

Estimated weight for 25mm clam

0.109 gm
108.732 mg

Station: Palo Alto

Date: 03/08/2005

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
					Concentration (ug/ml) - Blank Corrected from ICP-AES							
Mb1	11.41	0.3139	0.0149	10	0.0501	0.0058	0.135	0.7364	0.162	0.0485	0.1442	7.489
Mb2	12.27	0.3278	0.0193	10	0.054	0.0052	0.1226	0.6959	0.1538	0.0421	0.1318	7.838
Mb3	12.98	0.3211	0.0229	10	0.048	0.0068	0.1518	0.7239	0.1742	0.0539	0.164	7.222
Mb4	14.15	0.2632	0.0292	10	0.0256	0.0023	0.0775	0.4895	0.1055	0.0289	0.0849	5.27
Mb5	19.72	0.1806	0.0602	10	0.0379	0.0034	0.1055	0.6276	0.1233	0.0438	0.1192	5.784
Mb6	23.89	0.1797	0.0899	10	0.0556	0.0056	0.1254	0.7335	0.1554	0.0522	0.1448	8.963
Mb7	27.01	0.2771	0.1386	10	0.0822	0.006	0.1269	1.071	0.1682	0.0508	0.145	7.767
				MDL	0.0011	0.0002	0.0073	0.0021	0.0016	0.0036	0.0018	0.0054
				MRL	0.0021	0.0003	0.0146	0.0043	0.0032	0.0072	0.0036	0.0108

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	Mb1	1.5960	0.1848	4.3007	23.4597	5.1609	1.5451	4.5938	238.579
	Mb2	1.6473	0.1586	3.7401	21.2294	4.6919	1.2843	4.0207	239.109
	Mb3	1.4949	0.2118	4.7275	22.5444	5.4251	1.6786	5.1074	224.914
	Mb4	0.9726	0.0874	2.9445	18.5980	4.0084	1.0980	3.2257	200.228
	Mb5	2.0986	0.1883	5.8416	34.7508	6.8272	2.4252	6.6002	320.266
	Mb6	3.0940	0.3116	6.9783	40.8180	8.6477	2.9048	8.0579	498.776
	Mb7	2.9664	0.2165	4.5796	38.6503	6.0700	1.8333	5.2328	280.296

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	Mb1	0.0239	0.0028	0.0643	0.3507	0.0771	0.0231	0.0687	3.5662
	Mb2	0.0318	0.0031	0.0721	0.4094	0.0905	0.0248	0.0775	4.6106
	Mb3	0.0343	0.0049	0.1084	0.5171	0.1244	0.0385	0.1171	5.1586
	Mb4	0.0284	0.0026	0.0861	0.5439	0.1172	0.0321	0.0943	5.8556
	Mb5	0.1263	0.0113	0.3517	2.0920	0.4110	0.1460	0.3973	19.2800
	Mb6	0.2780	0.0280	0.6270	3.6675	0.7770	0.2610	0.7240	44.8150
	Mb7	0.4110	0.0300	0.6345	5.3550	0.8410	0.2540	0.7250	38.8350

Station:Palo Alto

Date: 4/25/05

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	0.7277	0.0677	2.1632	18.8436	3.8003	0.9253	2.3310	208.5782
STD	0.0914	0.0303	0.5777	1.2084	0.5238	0.2176	0.6893	25.0942
SEM	0.030	0.011	0.193	0.403	0.175	0.073	0.230	8.365
CV%	12.556	44.764	26.706	6.413	13.782	23.517	29.569	12.031
n	9	8	9	9	9	9	9	9
r wt x [ ]	0.424	0.098	0.259	0.322	0.361	0.323	0.152	0.918
X 100mg	0.709	0.064	2.091	18.656	3.892	0.891	2.281	219.701
r l x [ ]	0.497	0.296	0.215	0.375	0.350	0.309	0.118	0.885
X 20mm	0.702	0.056	2.093	18.588	3.904	0.887	2.285	221.090
X 25mm	0.646	0.038	1.938	18.025	4.132	0.804	2.184	248.704

Estimated content (ug) for 15mm and 20mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
20mm	0.0629	0.0041	0.1833	1.6848	0.3552	0.0781	0.2000	20.1487
25mm	0.1118	0.0059	0.3278	3.1310	0.7153	0.1375	0.3684	42.6031

Estimated weight for 15mm clam

0.040 gm
39.578 mg

Estimated weight for 20mm clam

0.091 gm
91.131 mg

Estimated weight for 25mm clam

0.174 gm
174.028 mg

Station:Palo Alto

Date: 4/25/05

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Concentration (ug/ml) - Blank Corrected from ICP-OES Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mb1	13.47	0.6459	0.0323	20	0.028	0.0027	0.057	0.6332	0.1041	0.0272	0.0577	6.473
Mb2	14.31	0.6514	0.0326	20	0.0248	0.0026	0.0621	0.6189	0.1145	0.0294	0.0656	6.423
Mb3	15.39	0.5437	0.0418	20	0.021	0.0027	0.0797	0.5142	0.117	0.0327	0.0883	5.072
Mb4	15.88	0.5021	0.0456	20	0.0177	0.0023	0.0713	0.4963	0.1058	0.031	0.078	4.774
Mb5	16.77	0.5796	0.0580	20	0.0187	0.0016	0.051	0.5857	0.1077	0.0202	0.0556	5.719
Mb6	17.35	0.3203	0.0534	15	0.0147	0.0003	0.0384	0.3552	0.0721	0.0172	0.0374	4.617
Mb7	18.56	0.3554	0.0711	15	0.016	0.0008	0.0528	0.4673	0.0761	0.0202	0.0551	4.546
Mb8	21.54	0.4996	0.1249	20	0.0211	0.0021	0.0714	0.4307	0.1173	0.0286	0.0815	5.889
Mb9	26.35	0.2	0.2000	10	0.0118	0	0.0276	0.3698	0.0789	0.0129	0.0313	5.233
				MDL	0.0011	0.0002	0.0073	0.0021	0.0016	0.0036	0.0018	0.0054
				MRL	0.0021	0.0003	0.0146	0.0043	0.0032	0.0072	0.0036	0.0108

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	Mb1	0.8670	0.0836	1.7650	19.6068	3.2234	0.8422	1.7867	200.434
	Mb2	0.7614	0.0798	1.9067	19.0021	3.5155	0.9027	2.0141	197.206
	Mb3	0.7725	0.0993	2.9318	18.9148	4.3038	1.2029	3.2481	186.573
	Mb4	0.7050	0.0916	2.8401	19.7690	4.2143	1.2348	3.1070	190.161
	Mb5	0.6453	0.0552	1.7598	20.2105	3.7164	0.6970	1.9186	197.343
	Mb6	0.6884	0.0140	1.7983	16.6344	3.3765	0.8055	1.7515	216.219
	Mb7	0.6753	0.0338	2.2285	19.7228	3.2119	0.8526	2.3255	191.868
	Mb8	0.8447	0.0841	2.8583	17.2418	4.6958	1.1449	3.2626	235.749
	Mb9	0.5900		1.3800	18.4900	3.9450	0.6450	1.5650	261.650

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	Mb1	0.0280	0.0027	0.0570	0.6332	0.1041	0.0272	0.0577	6.4730
	Mb2	0.0248	0.0026	0.0621	0.6189	0.1145	0.0294	0.0656	6.4230
	Mb3	0.0323	0.0042	0.1226	0.7911	0.1800	0.0503	0.1358	7.8031
	Mb4	0.0322	0.0042	0.1296	0.9024	0.1924	0.0564	0.1418	8.6800
	Mb5	0.0374	0.0032	0.1020	1.1714	0.2154	0.0404	0.1112	11.4380
	Mb6	0.0368	0.0008	0.0960	0.8880	0.1803	0.0430	0.0935	11.5425
	Mb7	0.0480	0.0024	0.1584	1.4019	0.2283	0.0606	0.1653	13.6380
	Mb8	0.1055	0.0105	0.3570	2.1535	0.5865	0.1430	0.4075	29.4450
	Mb9	0.1180		0.2760	3.6980	0.7890	0.1290	0.3130	52.3300

Station:Palo Alto

Date:5/25/05

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	1.1725	0.1464	1.2800	29.3699	3.6114	1.1597	1.5150	219.6712
STD	0.8368	0.0258	0.1442	25.9842	0.6253	0.1856	0.1953	33.4198
SEM	0.279	0.009	0.048	8.661	0.208	0.062	0.065	11.140
CV%	71.366	17.637	11.267	88.472	17.316	16.003	12.888	15.214
n	9	9	9	9	9	9	9	9
r wt x [ ]	0.167	0.317	0.263	0.338	0.703	0.709	0.460	0.313
X 100mg	1.206	0.148	1.289	31.481	3.717	1.128	1.537	222.184
r l x [ ]	0.242	0.365	0.214	0.429	0.591	0.673	0.430	0.335
X 20mm	1.239	0.149	1.290	33.025	3.733	1.119	1.543	223.339
X 25mm	1.492	0.161	1.329	46.965	4.195	0.963	1.648	237.329

Estimated content (ug) for 15mm and 20mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
20mm	0.0872	0.0131	0.1135	2.3010	0.3275	0.0962	0.1358	19.5746
25mm	0.1826	0.0299	0.2517	5.9251	0.7816	0.1827	0.3108	44.4160

Estimated weight for 15mm clam	Estimated weight for 20mm clam
0.033 gm	0.089 gm
32.566 mg	88.507 mg

Estimated weight for 25mm clam

0.192 gm
192.208 mg

Station:Palo Alto

Date:5/25/05

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Concentration (ug/ml) - Blank Corrected from ICP-OES Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mb1	14.67	0.2799	0.0280	15	0.0268	0.0028	0.0257	0.4277	0.0658	0.0233	0.0305	3.84
Mb2	15.37	0.3675	0.0408	15	0.0309	0.0034	0.0298	0.635	0.0794	0.0341	0.0326	5.766
Mb3	15.83	0.375	0.0417	20	0.018	0.0027	0.0215	0.4087	0.0684	0.0231	0.0274	3.82
Mb4	16.35	0.3096	0.0387	15	0.0159	0.0031	0.0286	0.4026	0.0763	0.027	0.0321	4.983
Mb5	16.98	0.3577	0.0511	15	0.0199	0.0032	0.0336	0.5413	0.0697	0.0254	0.0372	4.826
Mb6	18.84	0.3972	0.0662	20	0.0142	0.0025	0.0212	0.3063	0.0602	0.0211	0.0232	4.237
Mb7	20.08	0.2908	0.0969	15	0.0171	0.0024	0.0215	0.4501	0.0781	0.0218	0.0279	3.173
Mb8	24.20	0.3206	0.1603	15	0.0697	0.0045	0.0307	2.094	0.0727	0.0266	0.0394	6.088
Mb9	25.89	0.2289	0.2289	10	0.0099	0.0032	0.0314	0.3405	0.1146	0.0174	0.0376	5.185
				MDL	0.0011	0.0002	0.0073	0.0021	0.0016	0.0036	0.0018	0.0054
				MRL	0.0021	0.0003	0.0146	0.0043	0.0032	0.0072	0.0036	0.0108

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	Mb1	1.4362	0.1501	1.3773	22.9207	3.5263	1.2487	1.6345	205.788
	Mb2	1.2612	0.1388	1.2163	25.9184	3.2408	1.3918	1.3306	235.347
	Mb3	0.9600	0.1440	1.1467	21.7973	3.6480	1.2320	1.4613	203.733
	Mb4	0.7703	0.1502	1.3857	19.5058	3.6967	1.3081	1.5552	241.424
	Mb5	0.8345	0.1342	1.4090	22.6992	2.9228	1.0651	1.5600	202.376
	Mb6	0.7150	0.1259	1.0675	15.4230	3.0312	1.0624	1.1682	213.343
	Mb7	0.8820	0.1238	1.1090	23.2170	4.0285	1.1245	1.4391	163.669
	Mb8	3.2611	0.2105	1.4364	97.9726	3.4014	1.2445	1.8434	284.841
	Mb9	0.4325	0.1398	1.3718	14.8755	5.0066	0.7602	1.6426	226.518

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	Mb1	0.0402	0.0042	0.0386	0.6416	0.0987	0.0350	0.0458	5.7600
	Mb2	0.0515	0.0057	0.0497	1.0583	0.1323	0.0568	0.0543	9.6100
	Mb3	0.0400	0.0060	0.0478	0.9082	0.1520	0.0513	0.0609	8.4889
	Mb4	0.0298	0.0058	0.0536	0.7549	0.1431	0.0506	0.0602	9.3431
	Mb5	0.0426	0.0069	0.0720	1.1599	0.1494	0.0544	0.0797	10.3414
	Mb6	0.0473	0.0083	0.0707	1.0210	0.2007	0.0703	0.0773	14.1233
	Mb7	0.0855	0.0120	0.1075	2.2505	0.3905	0.1090	0.1395	15.8650
	Mb8	0.5228	0.0338	0.2303	15.7050	0.5453	0.1995	0.2955	45.6600
	Mb9	0.0990	0.0320	0.3140	3.4050	1.1460	0.1740	0.3760	51.8500

Station:Palo Alto

Statistical Summary

Date:6/28/05

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	1.2074	0.1553	1.2463	23.1143	3.9771	0.9418	1.4605	219.1300
STD	0.1650	0.0288	0.2872	3.2238	0.8804	0.2405	0.3106	65.8869
SEM	0.052	0.009	0.091	1.019	0.278	0.076	0.098	20.835
CV%	13.664	18.572	23.047	13.947	22.136	25.533	21.270	30.067
n	10	10	10	10	10	10	10	10
r wt x [ ]	0.197	0.499	0.618	0.546	0.150	0.554	0.449	0.292
X 100mg	1.225	0.147	1.151	22.165	4.049	0.870	1.385	229.499
r l x [ ]	0.104	0.466	0.505	0.439	0.221	0.477	0.332	0.216
X 20mm	1.211	0.152	1.212	22.784	4.023	0.915	1.436	222.445
X 25mm	1.236	0.132	1.000	20.708	4.308	0.747	1.285	243.281

Estimated content (ug) for 15mm and 20mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
20mm	0.0903	0.0112	0.0878	1.6887	0.2987	0.0657	0.1052	16.1324
25mm	0.1953	0.0209	0.1577	3.3066	0.6827	0.1157	0.2037	36.2024

Estimated weight for 15mm clam	Estimated weight for 20mm clam
0.028 gm	0.075 gm
28.433 mg	75.186 mg

Estimated weight for 25mm clam

0.160 gm
159.848 mg

Station:Palo Alto

Date:6/28/05

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
					Concentration (ug/ml) - Blank Corrected from ICP-OES							
Mb1	15.06	0.2925	0.0293	15	0.0252	0.0032	0.0264	0.4749	0.0764	0.0191	0.0294	4.206
Mb2	15.80	0.3236	0.0360	15	0.0273	0.0033	0.023	0.4884	0.0742	0.019	0.0239	4.394
Mb3	16.89	0.3306	0.0413	15	0.0249	0.0033	0.0275	0.5479	0.0683	0.0203	0.0313	4.035
Mb4	17.38	0.3215	0.0459	15	0.0185	0.0036	0.0291	0.4333	0.0736	0.0223	0.0334	4.188
Mb5	18.15	0.292	0.0487	15	0.0261	0.0031	0.0272	0.4471	0.0756	0.0185	0.0324	3.738
Mb6	18.82	0.3022	0.0604	15	0.0268	0.003	0.0272	0.4888	0.0707	0.0208	0.0318	3.787
Mb7	19.80	0.2662	0.0666	15	0.0217	0.0039	0.0324	0.5206	0.1102	0.0261	0.037	6.199
Mb8	20.51	0.2888	0.0963	15	0.0205	0.0028	0.0222	0.4777	0.0875	0.017	0.0289	3.3
Mb9	24.11	0.3403	0.1702	15	0.0325	0.0032	0.0203	0.4113	0.0916	0.0165	0.0264	7.524
Mb10	25.51	0.2902	0.1451	15	0.0219	0.002	0.0158	0.3786	0.0715	0.0103	0.0197	3.117
				MDL	0.0011	0.0002	0.0073	0.0021	0.0016	0.0036	0.0018	0.0054
				MRL	0.0021	0.0003	0.0146	0.0043	0.0032	0.0072	0.0036	0.0108

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	Mb1	1.2923	0.1641	1.3538	24.3538	3.9179	0.9795	1.5077	215.692
	Mb2	1.2655	0.1530	1.0661	22.6391	3.4394	0.8807	1.1078	203.677
	Mb3	1.1298	0.1497	1.2477	24.8593	3.0989	0.9211	1.4201	183.076
	Mb4	0.8631	0.1680	1.3577	20.2162	3.4339	1.0404	1.5583	195.397
	Mb5	1.3408	0.1592	1.3973	22.9675	3.8836	0.9503	1.6644	192.021
	Mb6	1.3302	0.1489	1.3501	24.2621	3.5093	1.0324	1.5784	187.972
	Mb7	1.2228	0.2198	1.8257	29.3351	6.2096	1.4707	2.0849	349.305
	Mb8	1.0648	0.1454	1.1530	24.8113	4.5447	0.8830	1.5010	171.399
	Mb9	1.4326	0.1411	0.8948	18.1296	4.0376	0.7273	1.1637	331.649
	Mb10	1.1320	0.1034	0.8167	19.5693	3.6957	0.5324	1.0183	161.113

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	Mb1	0.0378	0.0048	0.0396	0.7124	0.1146	0.0287	0.0441	6.3090
	Mb2	0.0455	0.0055	0.0383	0.8140	0.1237	0.0317	0.0398	7.3233
	Mb3	0.0467	0.0062	0.0516	1.0273	0.1281	0.0381	0.0587	7.5656
	Mb4	0.0396	0.0077	0.0624	0.9285	0.1577	0.0478	0.0716	8.9743
	Mb5	0.0653	0.0078	0.0680	1.1178	0.1890	0.0463	0.0810	9.3450
	Mb6	0.0804	0.0090	0.0816	1.4664	0.2121	0.0624	0.0954	11.3610
	Mb7	0.0814	0.0146	0.1215	1.9523	0.4133	0.0979	0.1388	23.2463
	Mb8	0.1025	0.0140	0.1110	2.3885	0.4375	0.0850	0.1445	16.5000
	Mb9	0.2438	0.0240	0.1523	3.0848	0.6870	0.1238	0.1980	56.4300
	Mb10	0.1643	0.0150	0.1185	2.8395	0.5363	0.0773	0.1478	23.3775

Station:Palo Alto Statistical Summary

Date: 9/20/2005

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	1.1749	0.0830	1.9802	20.0444	4.2462	1.2504	2.1876	181.4699
STD	0.2309	0.0641	0.5426	1.8523	0.6627	0.2934	0.6419	35.1094
SEM	0.082	0.024	0.192	0.655	0.234	0.104	0.227	12.413
CV%	19.650	77.241	27.401	9.241	15.606	23.463	29.343	19.347
n	8	7	8	8	8	8	8	8
r wt x [ ]	0.515	0.502	0.634	0.258	0.928	0.648	0.764	0.661
X 100mg	1.005	0.003	1.489	19.362	3.369	0.979	1.488	148.377
r l x [ ]	0.634	0.583	0.639	0.322	0.933	0.634	0.784	0.735
X 20mm	1.071	0.039	1.735	19.623	3.809	1.119	1.832	163.204
X 25mm	0.851	-0.031	1.213	18.724	2.876	0.838	1.073	124.283

Estimated content (ug) for 15mm and 20mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
20mm	0.0752	0.0034	0.1185	1.3964	0.2690	0.0772	0.1237	11.5122
25mm	0.1409	0.0046	0.2054	2.9261	0.4906	0.1387	0.1989	21.1850

Estimated weight for 15mm clam	Estimated weight for 20mm clam
0.026 gm	0.072 gm
26.265 mg	71.665 mg

Estimated weight for 25mm clam

0.156 gm
156.112 mg

Station:Palo Alto

Macoma petalum

Date: 9/20/2005

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Concentration (ug/ml) - Blank Corrected from ICP-OES Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mb1	13.44	0.1483	0.0185	10	0.0211	0.0033	0.0317	0.3360	0.0716	0.0187	0.0389	3.1710
Mb2	14.04	0.1646	0.0206	10	0.0242	0.0010	0.0394	0.3551	0.0829	0.0244	0.0456	3.7850
Mb3	15.33	0.1826	0.0261	10	0.0237	0.0008	0.0371	0.3400	0.0821	0.0235	0.0408	4.0880
Mb4	17.29	0.2509	0.0418	10	0.0220	0.0022	0.0706	0.5180	0.1186	0.0402	0.0724	3.6480
Mb5	18.21	0.3515	0.0586	15	0.0250	0.0018	0.0502	0.3880	0.0967	0.0345	0.0578	3.7400
Mb6	19.63	0.358	0.0716	15	0.0312	0.0013	0.0431	0.4692	0.0982	0.0301	0.0480	3.5150
Mb7	20.13	0.3423	0.0685	15	0.0204	0.0008	0.0245	0.4628	0.0801	0.0181	0.0266	3.7740
Mb8	23.15	0.2322	0.1161	10	0.0247	0.0001	0.0335	0.4728	0.0727	0.0196	0.0312	3.8650
				MDL	0.0011	0.0002	0.0073	0.0021	0.0016	0.0036	0.0018	0.0054
				MRL	0.0021	0.0003	0.0146	0.0043	0.0032	0.0072	0.0036	0.0108

Concentration (ug/g) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mb1	1.4228	0.2225	2.1376	22.6568	4.8281	1.2610	2.6231	213.823
Mb2	1.4702	0.0608	2.3937	21.5735	5.0365	1.4824	2.7704	229.951
Mb3	1.2979	0.0438	2.0318	18.6199	4.4962	1.2870	2.2344	223.877
Mb4	0.8768	0.0877	2.8139	20.6457	4.7270	1.6022	2.8856	145.397
Mb5	1.0669	0.0768	2.1422	16.5576	4.1266	1.4723	2.4666	159.602
Mb6	1.3073	0.0545	1.8059	19.6592	4.1145	1.2612	2.0112	147.277
Mb7	0.8940	0.0351	1.0736	20.2805	3.5101	0.7932	1.1656	165.381
Mb8	1.0637		1.4427	20.3618	3.1309	0.8441	1.3437	166.451

Content (ug) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mb1	0.0264	0.0041	0.0396	0.4200	0.0895	0.0234	0.0486	3.9638
Mb2	0.0303	0.0013	0.0493	0.4439	0.1036	0.0305	0.0570	4.7313
Mb3	0.0339	0.0011	0.0530	0.4857	0.1173	0.0336	0.0583	5.8400
Mb4	0.0367	0.0037	0.1177	0.8633	0.1977	0.0670	0.1207	6.0800
Mb5	0.0625	0.0045	0.1255	0.9700	0.2418	0.0863	0.1445	9.3500
Mb6	0.0936	0.0039	0.1293	1.4076	0.2946	0.0903	0.1440	10.5450
Mb7	0.0612	0.0024	0.0735	1.3884	0.2403	0.0543	0.0798	11.3220
Mb8	0.1235		0.1675	2.3640	0.3635	0.0980	0.1560	19.3250

Station:Palo Alto

Date:11/01/05

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	1.7569	0.0774	3.5709	22.1437	4.9075	1.6865	3.5419	224.2923
STD	0.3617	0.0382	1.1811	3.8988	1.0686	0.4127	1.1688	55.4973
SEM	0.104	0.011	0.341	1.125	0.308	0.119	0.337	16.021
CV%	20.587	49.395	33.076	17.607	21.776	24.469	32.998	24.743
n	12	9	12	12	12	12	12	12
r wt x [ ]	0.083	0.209	0.688	0.559	0.788	0.761	0.792	0.550
X 100mg	1.675	0.054	1.348	28.110	2.601	0.826	1.008	140.761
r l x [ ]	0.188	0.261	0.648	0.506	0.774	0.704	0.781	0.600
X 20mm	1.696	0.068	2.885	23.909	4.167	1.426	2.724	194.466
X 25mm	1.612	0.054	1.932	26.360	3.139	1.065	1.588	153.041

Estimated content (ug) for 15mm and 20mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
20mm	0.0931	0.0032	0.1520	1.3076	0.2278	0.0782	0.1448	10.6068
25mm	0.1747	0.0054	0.2398	2.7128	0.3781	0.1302	0.2197	17.9956

Estimated weight for 15mm clam	Estimated weight for 20mm clam
0.024 gm	0.056 gm
23.771 mg	55.723 mg

Estimated weight for 25mm clam

0.108 gm

107.902 mg

Station:Palo Alto
Date:11/01/05

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Concentration (ug/ml) - Blank Corrected from ICP-OES Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mb1	10.17	0.0583	0.0083	10	0.0149	-0.0017	0.0232	0.1194	0.0341	0.0094	0.0266	2.016
Mb2	11.59	0.141	0.0108	10	0.0223	0.0016	0.059	0.2801	0.0825	0.0295	0.07	3.315
Mb3	12.46	0.1353	0.0123	10	0.0262	0.0012	0.0534	0.2983	0.0767	0.0284	0.0547	3.647
Mb4	13.58	0.1436	0.0180	10	0.018	0.0013	0.0824	0.2676	0.0865	0.0324	0.0628	3.008
Mb5	14.59	0.1093	0.0219	10	0.0171	-0.0004	0.0443	0.2195	0.0573	0.0215	0.0457	2.524
Mb6	15.46	0.1175	0.0235	10	0.0168	0.0004	0.0514	0.2261	0.0656	0.0237	0.0562	3.058
Mb7	17.15	0.2462	0.0352	10	0.0478	0.0023	0.0862	0.5368	0.1135	0.0373	0.0714	4.142
Mb8	18.39	0.2448	0.0490	10	0.0433	0.0005	0.0371	0.5416	0.0726	0.0251	0.0386	2.994
Mb9	19.54	0.3323	0.0554	15	0.0488	0.0031	0.0941	0.7065	0.1231	0.0398	0.0885	4.696
Mb10	20.25	0.2274	0.0569	10	0.0327	0.0012	0.0547	0.4368	0.097	0.0318	0.0529	5.423
Mb11	21.27	0.205	0.0683	10	0.0352	0.0013	0.0609	0.5666	0.0845	0.0281	0.0594	3.848
Mb12	22.35	0.1453	0.0727	10	0.0246	-0.0009	0.0281	0.3299	0.0458	0.0158	0.0276	3.076
				MDL	0.0011	0.0002	0.0073	0.0021	0.0016	0.0036	0.0018	0.0054
				MRL	0.0021	0.0003	0.0146	0.0043	0.0032	0.0072	0.0036	0.0108

Concentration (ug/g) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mb1	2.5557	<MDL	3.9794	20.4803	5.8491	1.6123	4.5626	345.798
Mb2	1.5816	0.1135	4.1844	19.8652	5.8511	2.0922	4.9645	235.106
Mb3	1.9364	0.0887	3.9468	22.0473	5.6689	2.0990	4.0429	269.549
Mb4	1.2535	0.0905	5.7382	18.6351	6.0237	2.2563	4.3733	209.471
Mb5	1.5645	<MDL	4.0531	20.0823	5.2425	1.9671	4.1812	230.924
Mb6	1.4298	0.0340	4.3745	19.2426	5.5830	2.0170	4.7830	260.255
Mb7	1.9415	0.0934	3.5012	21.8034	4.6101	1.5150	2.9001	168.237
Mb8	1.7688	0.0204	1.5155	22.1242	2.9657	1.0253	1.5768	122.304
Mb9	2.2028	0.1399	4.2477	31.8914	5.5567	1.7966	3.9949	211.977
Mb10	1.4380	0.0528	2.4055	19.2084	4.2656	1.3984	2.3263	238.478
Mb11	1.7171	0.0634	2.9707	27.6390	4.1220	1.3707	2.8976	187.707
Mb12	1.6930	<MDL	1.9339	22.7047	3.1521	1.0874	1.8995	211.700

Content (ug) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mb1	0.0213	<MDL	0.0331	0.1706	0.0487	0.0134	0.0380	2.8800
Mb2	0.0172	0.0012	0.0454	0.2155	0.0635	0.0227	0.0538	2.5500
Mb3	0.0238	0.0011	0.0485	0.2712	0.0697	0.0258	0.0497	3.3155
Mb4	0.0225	0.0016	0.1030	0.3345	0.1081	0.0405	0.0785	3.7600
Mb5	0.0342	<MDL	0.0886	0.4390	0.1146	0.0430	0.0914	5.0480
Mb6	0.0336	0.0008	0.1028	0.4522	0.1312	0.0474	0.1124	6.1160
Mb7	0.0683	0.0033	0.1231	0.7669	0.1621	0.0533	0.1020	5.9171
Mb8	0.0866	0.0010	0.0742	1.0832	0.1452	0.0502	0.0772	5.9880
Mb9	0.1220	0.0078	0.2353	1.7663	0.3078	0.0995	0.2213	11.7400
Mb10	0.0818	0.0030	0.1368	1.0920	0.2425	0.0795	0.1323	13.5575
Mb11	0.1173	0.0043	0.2030	1.8887	0.2817	0.0937	0.1980	12.8267
Mb12	0.1230	<MDL	0.1405	1.6495	0.2290	0.0790	0.1380	15.3800

Station:Palo Alto

Date:12/13/05

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	2.1763	0.1472	4.6964	23.9117	6.6689	1.9373	5.4205	306.7428
STD	0.4357	0.0559	1.7196	3.0080	1.7119	0.5177	2.1549	66.0008
SEM	0.131	0.017	0.518	0.907	0.516	0.156	0.650	19.900
CV%	20.021	37.966	36.616	12.579	25.669	26.725	39.754	21.517
n	11	6	11	11	11	11	11	11
r wt x [ ]	0.079	0.012	0.741	0.539	0.795	0.696	0.726	0.608
X 100mg	2.283	0.145	0.752	18.891	2.457	0.822	0.580	182.531
r l x [ ]	0.074	0.149	0.782	0.451	0.786	0.639	0.764	0.561
X 20mm	2.213	0.139	3.176	22.376	5.147	1.563	3.557	264.876
X 25mm	2.251	0.125	1.578	20.763	3.549	1.170	1.599	220.889

Estimated content (ug) for 15mm and 20mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
20mm	0.1139	0.0077	0.1635	1.1907	0.2721	0.0817	0.1816	14.0053
25mm	0.2200	0.0168	0.2454	2.2057	0.4445	0.1368	0.2674	24.6473

Estimated weight for 15mm clam	Estimated weight for 20mm clam
0.023 gm	0.053 gm
22.752 mg	53.190 mg

Estimated weight for 25mm clam

0.103 gm

102.776 mg

Station:Palo Alto

Date:12/13/05

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Concentration (ug/ml) - Blank Corrected from ICP-OES Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mb1	9.19	0.0363	0.0061	10	0.0078	-0.0017	0.0246	0.0796	0.0303	0.0081	0.0298	0.9678
Mb2	10.56	0.0476	0.0095	10	0.0092	-0.001	0.0359	0.1223	0.0422	0.0117	0.0412	1.486
Mb3	11.52	0.0862	0.0096	10	0.0195	-0.0002	0.034	0.2084	0.0549	0.0149	0.0409	3.52
Mb4	12.48	0.1276	0.0116	10	0.026	0.0023	0.0641	0.3566	0.0995	0.0298	0.0772	4.953
Mb5	13.48	0.0968	0.0161	10	0.0248	0	0.0462	0.2537	0.0621	0.0175	0.0491	3.147
Mb6	14.64	0.1715	0.0172	10	0.0368	0.0034	0.0911	0.4344	0.1239	0.0378	0.0954	5.644
Mb7	16.05	0.0722	0.0241	10	0.015	0.0003	0.0439	0.1814	0.0637	0.0204	0.0567	2.45
Mb8	18.38	0.2795	0.0466	10	0.057	0.0043	0.0873	0.6268	0.1446	0.0412	0.089	6.842
Mb9	19.63	0.2442	0.0611	10	0.0395	0.0042	0.0977	0.4657	0.1361	0.0413	0.11	7.764
Mb10	20.39	0.2476	0.0619	10	0.0811	0.0034	0.0873	0.6529	0.1294	0.0371	0.1003	6.654
Mb11	21.34	0.1174	0.0587	10	0.0216	-0.0015	0.0183	0.2202	0.0416	0.0124	0.0204	2.041
				MDL	0.0011	0.0002	0.0073	0.0021	0.0016	0.0036	0.0018	0.0054
				MRL	0.0021	0.0003	0.0146	0.0043	0.0032	0.0072	0.0036	0.0108

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	Mb1	2.1488	<MDL	6.7769	21.9284	8.3471	2.2314	8.2094	266.612
	Mb2	1.9328	<MDL	7.5420	25.6933	8.8655	2.4580	8.6555	312.185
	Mb3	2.2622	<MDL	3.9443	24.1763	6.3689	1.7285	4.7448	408.353
	Mb4	2.0376	0.1803	5.0235	27.9467	7.7978	2.3354	6.0502	388.166
	Mb5	2.5620	<MDL	4.7727	26.2087	6.4153	1.8079	5.0723	325.103
	Mb6	2.1458	0.1983	5.3120	25.3294	7.2245	2.2041	5.5627	329.096
	Mb7	2.0776	0.0416	6.0803	25.1247	8.8227	2.8255	7.8532	339.335
	Mb8	2.0394	0.1538	3.1234	22.4258	5.1735	1.4741	3.1843	244.794
	Mb9	1.6175	0.1720	4.0008	19.0704	5.5733	1.6912	4.5045	317.936
	Mb10	3.2754	0.1373	3.5258	26.3691	5.2262	1.4984	4.0509	268.740
	Mb11	1.8399	<MDL	1.5588	18.7564	3.5434	1.0562	1.7376	173.850

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	Mb1	0.0130	<MDL	0.0410	0.1327	0.0505	0.0135	0.0497	1.6130
	Mb2	0.0184	<MDL	0.0718	0.2446	0.0844	0.0234	0.0824	2.9720
	Mb3	0.0217	<MDL	0.0378	0.2316	0.0610	0.0166	0.0454	3.9111
	Mb4	0.0236	0.0021	0.0583	0.3242	0.0905	0.0271	0.0702	4.5027
	Mb5	0.0413	<MDL	0.0770	0.4228	0.1035	0.0292	0.0818	5.2450
	Mb6	0.0368	0.0034	0.0911	0.4344	0.1239	0.0378	0.0954	5.6440
	Mb7	0.0500	0.0010	0.1463	0.6047	0.2123	0.0680	0.1890	8.1667
	Mb8	0.0950	0.0072	0.1455	1.0447	0.2410	0.0687	0.1483	11.4033
	Mb9	0.0988	0.0105	0.2443	1.1643	0.3403	0.1033	0.2750	19.4100
	Mb10	0.2028	0.0085	0.2183	1.6323	0.3235	0.0928	0.2508	16.6350
	Mb11	0.1080	<MDL	0.0915	1.1010	0.2080	0.0620	0.1020	10.2050

Appendix D

Concentrations of Hg and Se in surface sediments and the clam *Macoma petalum* from Palo Alto (D-1a, D-1b) and in standard reference materials (D-2).

D-1a. Mercury and selenium concentrations (µg/g dry weight) determined in surface sediments and *M. petalum* in 2005. One analysis was conducted on homogenized sediment. Values for *M. petalum* are the mean and 95% confidence interval (n=3). Not analyzed (NA).

Date	*Sediment*		*M. petalum*	
	mercury	selenium	mercury	selenium
January 18, 2005	0.32	0.5	0.39±8E-17	5.9±0.77
February 15, 2005	0.31	0.4	NA	NA
April 25, 2005	0.32	0.4	0.15±0.05	4.7±0.79
June 28, 2005	0.28	0.3	0.12±0.05	4.2±0.43
September 20, 2005	0.26	0.3	0.29±0.14	5.5±1.3

D-1b. Mercury and selenium concentrations (µg/g dry weight) determined in sample splits of surface sediments and *M. petalum* collected in April 2005.

Date	*Sediment*		*M. petalum*	
	mercury	selenium	Mercury	selenium
April 25, 2005	0.32/0.33	0.4/0.5	0.17/0.19	5.4/5.6

D-2. Observed and certified concentrations of mercury and selenium in standard reference materials analyzed in 2005. Certified concentrations as reported by National Research Council Canada are the mean and 95% confidence interval. The three materials are marine sediments (MESS-3), dogfish liver (DOLT-2), and dogfish muscle (DORM-2).

SRM	*Mercury*		*Selenium*	
	Observed	Certified	Observed	Certified
MESS-3	0.08	0.09±0.01	0.8	0.7±0.1
DOLT-2	2.1	2.14±0.28	6.6	6.1±0.5
DORM-2	4.5	4.64±0.26	1.5	1.4±0.1

Appendix E

Results of the analyses of National Institute of Science and Technology (NIST) standard reference materials for elements, excluding selenium and mercury. Recoveries are reported as the observed concentrations and the percent recoveries relative to the certified values for the standard. Results for SRM 2709 (San Joaquin Soil) are shown in E-1, for SRM 2976 (mussel tissue) in E-2, and E-3, respectively.

E-1. Observed and certified concentrations in SRM 2709. Units in upper table are µg/mL. The lower table reports the percent recovery.

Month	Rep	AL	CR	CU	FE	MN	NI	PB	V	ZN
January	1	57566.897	126.62	35.80	40093.92	1075.67	82.04	31.88	136.90	137.52
	2	58160.804	131.36	34.19	41356.78	1095.48	84.45	32.44	132.36	139.40
February	1	55318	121.90	33.05	39563.98	1150.71	79.29	31.35	128.82	130.71
	2	56530	125.47	33.63	40076.94	1172.82	80.77	31.19	127.44	133.66
March	1	58882.098	135.25	35.33	41630.52	1127.76	84.91	33.20	134.17	139.69
	2	56675.263	127.36	35.41	41628.65	1136.68	85.73	33.35	131.22	140.55
April	1	54862.768	122.81	34.71	39309.86	1247.02	79.04	30.45	129.47	131.46
	2	55747.863	124.79	34.34	39839.74	1255.34	79.74	30.72	131.52	131.20
May	1	44916.245	116.28	28.40	34086.48	511.98	65.29	23.66	106.16	107.13
	2	44562.842	114.94	28.28	33606.56	507.10	64.40	23.84	105.28	106.19
June	1	43493.395	118.44	26.08	31970.72	665.92	61.61	23.09	97.55	101.93
	2	43474.918	115.99	25.63	32317.89	673.55	61.71	23.82	102.34	100.04
September	1	34007	89.74	21.15	30391.96	541.84	59.86	22.74	64.57	92.78
	2	30082	79.01	21.23	28281.72	511.70	56.20	21.32	52.55	87.93
October	1	32735	88.72	22.64	30529.41	595.49	60.89	23.78	52.74	94.24
	2	32713	88.56	22.41	29649.31	574.21	58.92	22.89	59.72	93.43
December	1	42318.18	102.09	29.52	35418.18	821.27	73.74	27.64	71.18	119.82
	2	44008.75	106.88	30.79	35746.85	823.09	74.30	27.87	74.07	122.01
	Cert. Value	75000	130.00	34.60	35000	538	88.0	18.9	112.0	106.0
	Std	0	4.00	0.70	0	17	5.0	0.5	5.0	3.0

Month	Rep	AL	CR	CU	FE	MN	NI	PB	V	ZN
January	1	77	97.40	103.46	115	200	93.23	168.68	122.23	129.73
	2	78	101.04	98.82	118	204	95.97	171.65	118.18	131.51
February	1	74	93.77	95.53	113	214	90.10	165.85	115.01	123.31
	2	75	96.51	97.18	115	218	91.78	165.02	113.79	126.09
March	1	79	104.04	102.11	119	210	96.49	175.67	119.79	131.78
	2	76	97.97	102.34	119	211	97.42	176.44	117.16	132.59
April	1	73	94.47	100.31	112	232	89.82	161.11	115.60	124.02
	2	74	95.99	99.24	114	233	90.62	162.52	117.43	123.77
May	1	60	89.45	82.08	97	95	74.19	125.16	94.78	101.07
	2	59	88.41	81.73	96	94	73.18	126.16	94.00	100.18
June	1	58	91.11	75.38	91	124	70.01	122.17	87.10	96.16
	2	58	89.22	74.07	92	125	70.13	126.05	91.38	94.38
September	1	45	69.03	61.13	87	101	68.02	120.29	57.65	87.53
	2	40	60.77	61.36	81	95	63.87	112.82	46.92	82.96
October	1	44	68.24	65.43	87	111	69.20	125.84	47.09	88.90
	2	44	68.12	64.76	85	107	66.95	121.12	53.32	88.14
December	1	56	78.53	85.31	101	153	83.79	390.14	24.68	67.15
	2	59	82.21	88.98	102	153	84.43	147.45	66.13	115.11
	AVG	**63**	**87.02**	**85.51**	**102**	**160**	**81.62**	**159.12**	**89.01**	**108.02**
	STDEV	**13**	**12.91**	**15.31**	**13**	**54**	**11.91**	**61.99**	**31.64**	**20.61**

E-2. Observed and certified values for inorganic elements in NIST Standard Reference Material 2976 (mussel tissue) prepared in 2005. Values for different dates are the observed mean concentrations and 1 standard deviation for either replicate or triplicates of the standard (n=2-3). The mean values are summarized as the median. The certified values for the standard reference material are shown below the observed values (vanadium is not certified for this material). All values are reported as µg/g dry weight. Standards for September could not be analyzed because of a processing error.

Date prepared	*Cadmium*	*Chromium*	*Copper*	*Lead*	*Nickel*	*Silver*	*Vanadium*	*Zinc*
01/18/2005	0.65±0.01	0.51±0.01	4.18±0.02	0.58±0.02	0.97±0.01	<MDL	0.64±0.2	133±1
02/15/2005	0.66±0.01	0.61±0.05	4.29±0.09	0.59±0.01	0.98±0.02	0.015	0.67±0.01	157±37
03/07/2005	0.66±0.02	0.58±0.02	4.40±0.1	0.59±0.06	1.00±0.02	<MDL	0.68±0	137±4
04/25/2005	0.61±0.01	0.62±0.08	4.40±0.02	0.58±0.08	0.97±0.02	<MDL	0.69±0.01	134±1
05/25/2005	0.62±0.01	0.54±0.15	4.39±0.17	0.56±0.04	1.00±0.01	<MDL	0.69±0.03	136±2
06/28/2005	0.60±0.01	0.53±0.08	4.31±0.1	0.57±0.01	0.95±0.03	<MDL	0.70±0.01	133±2
11/01/2005	0.63±0.01	0.43±0.01	4.02±0.01	0.62±0.01	0.85±0.01	<MDL	0.69±0.01	132±1
12/13/2005	0.68±0.05	0.34±0.03	4.20±0.35	0.61±0.08	1.01±0.08	<MDL	0.65±0.05	140±11
Median	0.64	0.54	4.30	0.59	0.98	0.015	0.69	135
Certified Value Mean	0.82	0.50	4.02	0.93	1.19	0.011	Not certified	137
95% CI	0.16	0.02	0.33	0.12	0.18	0.005		13

E-3. Percent recovery of inorganic elements in NIST Standard Reference Material 2976 (mussel tissue) prepared in 2005. Values are reported as the percent of the certified mean concentration, and are the means of duplicate or triplicates (n=2-3) of the material on each date.

Date prepared	*Cadmium*	*Chromium*	*Copper*	*Lead*	*Nickel*	*Silver*	*Vanadium*	*Zinc*
01/18/2005	79	102	104	81	63	NA	NA	97
02/15/2005	80	121	107	82	63	140	NA	115
03/07/2005	80	115	109	84	63	NA	NA	100
04/25/2005	75	123	109	82	62	NA	NA	98
05/25/2005	75	107	109	84	60	NA	NA	98
06/28/2005	74	105	107	79	61	NA	NA	97
11/01/2005	76	86	100	72	66	NA	NA	96
12/13/2005	82	70	104	85	66	NA	NA	101
Mean	78	104	106	81	63			100
Median	78	106	107	82	63			98

Appendix F

Method detection limits (MDL) and reporting levels (MRL) for the analysis of sediment and tissue samples by ICP-OES (F-1). Values are in units of µg/mL.

F-1. Method detection limits and reporting levels for ICP-OES methods. Concentration markers are method detection limit (MDL) and method reporting level (MRL). All units are µg/mL. Elements for which MDL and MDL were not determined in a particular method are designated ND.

Method	*marker*	*Ag*	*Al*	*Cd*	*Cr*	*Cu*	*Fe*	*Mn*	*Ni*	*Pb*	*V*	*Zn*
Sediment: near-total digestion	MDL	ND	0.007	ND	0.001	0.003	0.008	0.001	0.001	0.003	0.001	0.004
	MRL	ND	0.020	ND	0.004	0.01	0.020	0.002	0.003	0.009	0.004	0.010
Sediment: partial extraction	MDL	0.001	0.020	ND	0.002	0.003	0.005	0.001	0.0004	0.001	0.001	0.001
	MRL	0.002	0.060	ND	0.007	0.01	0.020	0.002	0.001	0.004	0.003	0.004
Tissue	MDL	0.001	ND	0.0002	0.004	0.001	ND	ND	0.001	0.002	0.0006	0.0019
	MRL	0.002	ND	0.0003	0.007	0.002	ND	ND	0.002	0.004	0.0012	0.0038

Appendix G

Reproduction data for the year 2005 (G-1).

G-1. Reproductive stage of *M. petalum* sampled from Palo Alto during 2005.

Date of sample	*Inactive*	*Active*	*Ripe*	*Spawning*	*Spent*	*n*	*Reproductive*	*Non-reproductive*
January 18	0.0	0.0	100.0	0.0	0.0	10	100	0
February 15	0.0	0.0	100.0	0.0	0.0	10	100	0
March 7	0.0	0.0	20.0	80.0	0.0	10	100	0
April 25	0.0	0.0	10.0	60.0	30.0	10	70.0	-30
May 25	0.0	0.0	45.5	27.3	27.3	11	72.7	-27
June 28	0.0	41.7	25.0	0.0	33.3	12	66.7	-33
September 20	0.0	0.0	0.0	30.0	70.0	10	30.0	-70
November 1	0.0	81.8	18.2	0.0	0.0	11	100	0
December 13	0.0	0.0	100.0	0.0	0.0	10	100	0

Appendix H

Complete list of benthic species found at Palo Alto in the year 2005.

Species	1/5/2005		2/15/2005		3/7/2005		4/25/2005		5/25/2005		6/27/2005		7/20/2005		8/18/2005		9/21/2005		11/30/2005	
	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
Acari	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ampelisca abdita	3.3	0.6	2.7	1.5	2.3	2.1	0.3	0.6	1.0	0.0	2.3	1.5	0.7	1.2	2.3	1.2	2.3	2.3	4.0	1.0
Ampithoe spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthozoa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Balanus ?aquila	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Balanus improvisus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Balanus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boonea bisuturalis	0	0	0.3	0.6	0.3	0.6	0.7	0.6	0.3	0.6	0.3	0.6	2.0	2.0	0.3	0.6	1.7	1.2	0.7	0.6
Calinoida	0	0	0	0	0.3	0.6	0.7	1.2	0	0	0	0	0	0	0	0	0	0	0	0
Callianassidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capitella "capitata"	0	0	0	0	0	0	0	0	0.3	0.6	0	0	0	0	0	0	0	0	0	0
Caprella californica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cirratulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cirripedia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corophium ?insidiosum	0.7	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.6
Corophium acherusicum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corophium insidiosum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corophium spinicorne	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corophium spp.	0	0	0.3	0.6	0.3	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.6
Corophium spp. (female & juvenile)	2.3	1.5	0	0	0.3	0.6	0	0	0	0	0.7	1.2	0.3	0.6	0	0	0.3	0.6	2.7	3.1
Corophium spp. (male)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cumella vulgaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprideis spp.	0	0	0	0	0	0	0.3	0.6	0.3	0.6	0	0	0	0	0	0	0	0	0	0
Dynamenella spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eogammarus confervicolus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eteone ?californica	0	0	0	0	0	0	0.3	0.6	5.3	9.2	0	0	0	0	0	0	0	0	0	0
Eteone lighti	3.3	1.5	1.7	1.5	1.3	1.5	4.7	3.1	4.7	5.7	4.7	3.1	1.3	1.5	4.0	2.6	4.7	2.9	3.7	4.0
Eteone spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3	4.0

Species	1/5/2005		2/15/2005		3/7/2005		4/25/2005		5/25/2005		6/27/2005		7/20/2005		8/18/2005		9/21/2005		11/30/2005	
	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
Euchone limnicola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euchone spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eusarsiella zostericola	5.0	2.6	2.3	1.5	4.0	3.5	7.7	2.5	3.0	1.7	0.3	0.6	0	0	1.3	0.6	2.3	3.2	8.3	2.5
Gemma gemma	37.7	2.9	36.7	2.1	41.3	13.6	56.3	4.5	18.7	21.4	133.0	20.0	213.7	58.8	638.7	103.5	1548.0	476.5	421.3	158.5
Glycera spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycinde armigera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycinde polygnatha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycinde spp.	0	0	0	0	0	0	2.7	0.6	0	0	0	0	0	0	0	0	0	0	0	0
Gnorisphaeroma oregonensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grandidierella japonica	3.7	2.1	0	0	0.7	0.6	0.3	0.6	0	0	16	13.5	6.0	2.6	1.0	1.7	6.7	2.5	6.7	5.9
Harmothoe imbricata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harpacticoida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemigrapsus oregonensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	21.0	6.1	21.0	7.5	12.3	10.7	14.7	5.1	16.3	10.0	20.3	2.5	19.7	3.2	16.7	4.0	15.0	11.4	22.0	1.0
Ilyanassa obsoleta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macoma petalum	5.3	4.0	5.0	3.0	3.7	2.1	6.0	1.0	5.7	4.0	4.7	2.5	5.7	4.0	7.3	1.5	6.3	1.5	5.0	1.7
Macoma spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marphysa sanguinea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melita nitida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Musculista senhousia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mya arenaria	0	0	0	0	0	0	1.0	1.0	0.7	0.6	0	0	0	0	0	0	0.3	0.6	0	0
Mysidacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naididae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neanthes succinea	1.0	1.7	3.0	1.0	3.7	1.2	1.0	0	0	0	0	0	1	0	1.3	1.5	1.0	1.0	0.3	0.6
Nematoda	0	0	0	0	1.3	1.5	1.3	0.6	2.0	2.6	0	0	3.7	4.0	3.0	3.6	1.0	1.7	0.7	1.2
Nippoleucon hinumensis	38.3	11.0	17.0	9.8	19.0	0	117.0	32.0	212.3	70.4	46.3	9.7	110.3	8.7	69.7	35.0	14.0	4.4	20.0	4.6
Odostomia fetella	2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Odostomia spp.	0	0	0.3	0.6	2.7	1.2	3.7	1.5	3.3	1.2	1.3	1.5	1.3	1.5	1.0	1.0	2.3	0.6	2.3	2.3
Oligochaeta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	1/5/2005		2/15/2005		3/7/2005		4/25/2005		5/25/2005		6/27/2005		7/20/2005		8/18/2005		9/21/2005		11/30/2005	
	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
Planariidae A	0.3	0.6	3.3	4.2	0	0	0.3	0.6	0	0	0	0	0	0	0	0	0	0	0	0
Polydora cornuta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.6	0	0	0	0
Polydora spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Potamocorbula amurensis	0	0	0	0	0	0	1.7	0.6	6.0	6.0	4.3	2.5	4.7	1.5	2.3	1.2	1.3	1.5	0.7	1.2
Pseudopolydora kempi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rochefortia grippi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rochefortia spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sabaco elongatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaeromatidae (juv.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerosyllis californiensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerosyllis erinaceus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Streblospio benedicti	9.0	2.6	14.7	8.0	13.3	4.5	20.0	9.5	24.0	5.0	3.7	2.5	8.7	3.5	11.3	4.0	13.0	6.9	3.0	5.2
Synidotea laevidorsalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tellinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tharyx spp. ?	0	0	0.7	0.6	1.0	1.7	0	0	0.3	0.6	0.7	0.6	1.0	1.0	0	0	0	0	0.7	0.6
Tubificidae	13.3	5.5	12.3	11.1	22.7	23.8	27.3	15.2	15.3	11.4	11.0	10.1	31.0	19.0	22.3	31.8	12.0	9.0	19.0	27.0
Turbellaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unid. Actiniaria	0	0	0	0	0.7	1.2	0	0	0	0	0	0	0.3	0.6	0.3	0.6	0	0	0	0
Unid. Amphipod	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unid. Balanomorpha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unid. Bivalvia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unid. Cumacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unid. Gastropoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unid. Isopoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unid. Nudibranchia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unid. Ostracoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unid. Polychaeta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unid. Spionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unid. Syllidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unid. Tanaidacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urosalpinx cinerea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0