Prepared in cooperation with the City of Palo Alto, California

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: 2008

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Daniel J. Cain, Janet K. Thompson, Jessica L. Dyke, Francis Parchaso,
Samuel N. Luoma, and Michelle I. Hornberger

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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 (°C) may be converted to degrees Fahrenheit (°F) as follows:
$°F=(1.8\times°C)+32$
Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:
$°C=(°F-32)/1.8$
Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).
NOTE TO USGS USERS: Use of liter (L) as a special name for cubic decimeter (dm^3) is restricted to the measurement of liquids and gases. No prefix other than milli should be used with liter.

Abbreviations and Acronyms

Abbreviations and Acronyms	Meaning
mL	milliliter
μΩ	microohm
μg/g	Microgram per gram
μM	micrometer
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

Results reported herein include trace element concentrations in sediment and in the clam *Macoma petalum* (formerly reported as *Macoma balthica* (Cohen and Carlton, 1995)), clam reproductive activity, and benthic macroinvertebrate community structure for a mudflat one kilometer south of the discharge of the Palo Alto Regional Water Quality Control Plant (PARWQCP) in South San Francisco Bay. This report includes data collected for the period January 2008 to December 2008 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.

In 2008, metal concentrations in both sediments and clam tissue were among the lowest concentrations on record and consistent with results observed since 1991. Following significant reductions in the late 1980's, silver (Ag) and copper (Cu) concentrations appeared to have stabilized. Annual mean concentrations have fluctuated modestly (2-4 fold) in a nondirectional manner. Data for other metals, including chromium, mercury, nickel, selenium, vanadium, and zinc, have been collected since 1994. Over this period, concentrations of these elements, which more likely reflect regional inputs and systemwide processes, have remained relatively constant, aside from typical seasonal variation that is common to all elements. Within years, concentrations generally reach maximum in winter months (January-March) and decline to annual minima in spring through fall. Mercury (Hg) in sediments spiked to the highest observed level in January 2008. However, sedimentary concentrations for the rest of the year and concentrations of Hg in *M. petalum* for the entire year were consistent with data from previous years. Average selenium (Se) concentrations in sediment were the highest on record, but there is no evidence, yet, to suggest a temporal trend of increasing sedimentary Se. Selenium in *M. petalum* was not elevated relative to past years. Overall, Cu and Ag concentrations in sediments and soft tissues of the clam, *M. petalum*, remained representative of the concentrations observed since 1991 following significant reductions in the discharge of these elements from PARWQCP, suggesting that, similar

to other elements of regulatory interest, regional scale factors now largely influence sedimentary and bioavailable concentrations of Cu and Ag.

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 biosentinel clam, *M. 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 and is now showing signs of population stability. An unidentified disturbance occurred on the mudflat in early 2008 that resulted in the loss of the benthic animals, except for those deep dwelling animals like *Macoma petalum*. Animals immediately returned to the mudflat, which is indicative that the disturbance was not due to a persistent toxin or due to anoxia. This event allows us to examine the response of the mudflat benthic community to a natural disturbance (possible causes include sediment accretion or freshwater inundation) and compare this recovery to the longer term recovery we observed in the 1970s.

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, U.S Geological Survey, 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, which can result in changes in predator/prey interactions and 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 (Alpine and Cloern, 1992, provides 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 (Wang and Fisher, 1999, provides 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 that link changes in exposure at multiple time scales (in this case seasonal to decadal) to changes at individual, population, and community levels.

RWQCB and NPDES

The California Regional Water Quality Control Board (RWQCB) has prescribed a Self Monitoring Program with its reissuance 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 *M. 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 more than 30 years of previous data collections and investigations by the USGS at this inshore location.

Objectives

The data presented by this study include trace-metal concentrations in sediments and clams, clam reproductive activity, and benthic-community structure. These data and those reported earlier (Hornberger and others, 2000a; Luoma and others 1991; 1992; 1993; 1995a; 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; Cain and others, 2006; Lorenzi and others, 2007) 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 clam species, *Macoma petalum*. Analysis of trace element concentrations in the sediments provides a record of metal contamination of 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, 1995b). 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 interannual variation in metal concentrations. The tissue of *M. 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 *M. 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. Interannual 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, 1995b) and that some crustacean and polychaete species are particularly sensitive to elevated sedimentary copper (Morrisey and others, 1996; Rygg, 1985). In addition, the benthic community was examined for changes in structure: that is, shifts in the species composition of the macroinvertebrate community resulting in a change in the function of the community. We hypothesized that a shift in community composition and potentially in function of the benthic community in the ecosystem would result from changes in the concentrations of specific metals or from a composite of all contaminants for several reasons. First, prior studies have shown that South Bay benthic communities were dominated by opportunistic species in the 1980s (Nichols and Thompson, 1985a). These opportunistic species might become less dominant as environmental stressors decrease. Second, environmental pollutants may differentially affect benthic species that use different feeding and reproductive modes. An intertidal mudflat community, such as this study site, should include a combination of species that feed on particles in the water column, on settled and buried food particles in the mud, and on other organisms. Any absence of one of these feeding groups may show limitations on species due to environmental stressors that target specific feeding groups. For example, pollutants attached to sediment particles are more likely to affect species that consume the sediment as part of their feeding mode or those species that lay their eggs in the sediment.

Previous analysis of this community has shown no correlation between changes in the community and measured environmental parameters (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 adjacent to Sand Point on a mudflat on the western shore of San Francisco Bay (not a slough) (*fig. 1*). The site is one kilometer southeast of the intertidal discharge point of the PARWQCP. The sample 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; 1995a; 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; Cain and others, 2006; Lorenzi and others, 2007). 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 controls were employed (Hornberger and others, 2000b). Frequent sampling each year was necessary to characterize those trends because there was significant seasonal variability (Cain and Luoma, 1990; Luoma and others, 1985). This report characterizes data for the year 2008, 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 San Francisco Bay 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 and Duration

In dynamic ecosystems such as San Francisco Bay, the environmental effects of anthropogenic stressors are difficult to distinguish from natural seasonal changes. Sustained sampling at frequent intervals can characterize seasonal patterns, capture episodic events, and identify longer term trends, thereby increasing the probability that anthropogenic effects can be identified. Analyses of early community data (1974 through 1983; Nichols and Thompson, 1985a, 1985b) showed that benthic samples need to be collected at monthly to bimonthly intervals to distinguish between natural and anthropogenic effects. Therefore, data reported herein are based on samples collected, with a few exceptions, on a monthly basis from the exposed mudflat at low tide between January and December 2008. 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. Data for sediments, *M.*

petalum, and surface water have been collected continuously since 1977, while community data were collected during 1974-1990 and 1998 to the present.

Measurements of Metal Exposure

Sediment

Sediment samples were scraped from the visibly oxidized (brownish) surface layer (top 1-2 cm) of mud. This surface layer represents recently deposited sediments and detritus, or sediments affected by recent chemical reactions 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 mesh polyethylene screen 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, 1995a; 1996; 1997; 1998; Wellise and others, 1999; David and others, 2002; Moon and others, 2003; 2004; Cain and others, 2006; 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 (SFEI, 1997), the fraction of sediment that did not pass through the sieve (≥100 µm) was determined. This fraction is termed the sand fraction. Bulk sediment samples were sieved to determine the percent sand and percent silt/clay (<100 µm) (appendix A-1). The percentage of the bulk sediment sample composed of sand-size 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 60ºC, weighed, and then subsampled to provide replicates weighing 0.4 to 0.6 g. These were redried (60ºC), reweighed, 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-percent 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 percent 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 B). 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 laboratory, where it was measured for salinity with a handheld refractometer.

Clam Tissue

Specimens of *M. 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 part per thousand (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, California) was diluted with deionized water to the measured salinity of the site water. Clams were immersed in this water and moved to a constant temperature room (12ºC) 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 (for example, 10.00-10.99 mm, 11.00-11.99 mm). The soft tissues from all of the individuals within a given size class were dissected from the shell and collected in preweighed 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 6 to 10 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 subboiling 16 N nitric acid. 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 g wet weight. To meet this requirement, especially for the smaller clams, the 1-mm size classes were usually combined to form broader size classes (within 3-4 mm of each other, as appropriate). Once the composites were formed, the clams were dissected as described above, and the soft tissue was placed into preweighed 30-mL screw-top polycarbonate vials. These vials were closed and transferred to a freezer (-20ºC). Once frozen, the samples were freeze-dried. After drying, the samples were shipped to the USGS analytical laboratory in Atlanta, Georgia, where they were prepared and analyzed for Se and Hg 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 Spectrophotometry (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 C—E.

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 deionized water, followed with a 10 percent hydrochloric-acid wash and thorough rinse in double-deionized water (approximately 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 (that is, all elements except Se and Hg) 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 H—I). Method detection limits (MDL) and reporting levels (MRL) were determined using the procedures outlined by Glaser and others (1981), Childress and others (1999), and U.S. Environmental Protection Agency (2004) (appendix J). 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 Se and Hg. Observed concentrations fell within the range of certified values for these materials (appendix F).

Other Data Sources

Precipitation data for San Francisco Bay is reported from a station at San Francisco International Airport (station identification SFF) and was obtained from the California Data Exchange Center (http://cdec.water.ca.gov/).

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-percent formalin at the time of collection. The visceral mass of each clam was removed in the laboratory, stored in 70-percent ethyl alcohol, and then prepared using standard histological techniques. Tissues were dehydrated in a graded series of alcohol, cleared in toluene (twice for 1 hour each), and infiltrated in a saturated solution of toluene and Paraplast® for 1 hour, and two changes of melted Tissuemat® for 1 hour each. Samples were embedded in Paraplast® in a vacuum chamber and then thin sectioned (10 µm) using a microtome (Weesner, 1960). 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 K).

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 taken arbitrarily, within a square-meter area, during each sampling date.

Benthic community samples were washed on a 500-µm screen, fixed in 10-percent formalin and then later preserved in 70-percent 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, California) (appendix L). 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 that has been defined as months with rainfall amounts greater than 0.25 inches (November through April) and a summer dry season (May through October) (*fig. 2*). The average cumulative annual rainfall during the record (1994-2008) is 23.3 inches. Rainfall during 2008 was 16.7 inches, marking the second consecutive year of below average rainfall. The maximum average monthly rainfall in 2008 occurred in January. Rainfall during that month alone accounted for 52 percent of the yearly total.

Surface-water salinity typically exhibits a seasonal pattern that is generally the inverse of regional rainfall (*fig. 3*, *table 1*). This general pattern was again observed in 2008. However, because of the small amount of local rainfall in 2008, the winter-spring decline in salinity was minimal. Salinity remained above 20 ppt for the entire year and has not been lower than 20 ppt since September 2006.

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 interannual 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 resuspension in the summer and fall. Because metal concentrations vary as a function of the surface area to volume of a particle, metal concentrations of fine-grained particles are typically higher on a weight basis than larger particles. Thomson-Becker and Luoma (1985) showed that the composition of surface sediments was dominated by fine-grained particles, 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 typical seasonal pattern of variation in sediment properties was repeated in 2008 (fig. 4, appendix A-1 and A-2).

The percentage of silt/clay in the sediment ascended from 52 percent in the fall of 2007 to values of greater than 70 percent following the onset of winter rains. Values were at their maximum in March (87 percent) and thereafter declined to a seasonal minimum (41 percent) in September. The concentrations of Al and Fe changed directly in response to the proportion of silt/clay size (maximum concentrations occurred during January through March) (*fig. 4*, *table 1*), as described above, reflecting the contribution of clays composed of Al and Fe.

Surface sediments comprise roughly 1 percent (by weight) organic carbon (*table1*). Carbon content varied slightly during the year, tracking the seasonal changes in sediment composition described above. Specifically, total organic carbon varied between 1.21 and 1.55 percent during January to April, declined to a minimum of 0.68 percent in September, and increased to 0.98 percent in December.

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 (*fig. 5, table 2*). The minimum Ni concentration occurred in the fall of 2008 (72 µg/g in September) and the maximum in winter (105 µg/g in March). The concentration range and timing of variation is typical of the record. Concentrations of Cr and V also declined from their maximum concentrations in March to their minima in summer/fall. Average concentrations of Cr and V tended to increase during the last three years and in 2008 were at concentrations roughly comparable to 2003.

Copper concentrations in sediments are shown with sediment guidelines set by the National Oceanic and Atmospheric Administration (Long and others, 1995) (*fig. 6*, *table 2*). Long and others (1995) defined values between ERL (Effects Range-Low) and ERM (Effects Range-Median) as concentrations that are occasionally associated with adverse effects (21–47 percent of the time for different metals). Values greater than the ERM were frequently associated with adverse effects (42–93 percent 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 site-specific sediment toxicity. In 2006-2007, Cu concentrations increased to concentrations similar to those observed before 2000, apparently reversing a trend of declining concentrations during the intervening years. In 2008, Cu concentrations remained above the ERL (34 µg/g) for much of the year. The typical seasonal pattern was evident, as Cu concentrations peaked in March (48 µg/g), fell below the ERL in June (31 µg/g), and reached their minimum concentration (29 µg/g) in September (*fig. 6*, *table 2*). The partial-extractable concentrations have generally remained relatively constant outside of the typical seasonal variation and in particular, did not increase during 2006-2008.

Near-total and partially extractable Zn concentrations were at or near the Zn ERL (150 µg/g) in February–March, 2008, but thereafter remained below the ERL 2008 (*fig. 7*, *table 2*).

Silver extracted from sediments averaged 0.20 µg/g for the year (*table 2*), the lowest concentration recorded (*table 4*). Intraannual variation was also modest compared to the past (*fig. 8*; *table 2*). As with other elements, concentrations were relatively high during the late winter-early spring (January –April), declined to their minima in late spring-early summer (May-June), and increased in fall-winter.

Mercury concentrations during 2008 were mostly within the range usually observed within San Francisco Bay (0.2–0.4 µg/g) throughout the entire year. Concentrations in sediment briefly increased to 0.62 µg/g in January 2008. By February, concentrations were at 0.26 µg/g and thereafter gradually declined to their minimal value of 0.21 µg/g in December (*fig. 9*, *table 2*).

Selenium concentrations in 2008 increased sharply in January, like many elements. However, Se concentrations remained relatively high through the year. Mean concentrations were 0.8 µg/g, the highest annual concentration on record (*fig. 9*, *table 2*).

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 because of the high tissue concentrations observed at this site in the past (*fig. 10* and *fig. 11*, *table 3* and *table 4,* respectively). During the period 1977–1987, the ranges 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. Concentrations were particularly low and stable from 1997 through 2005. Annual mean concentrations of Cu and Ag for 2008 were, respectively, 28±3 and 1.8±0.3 µg/g. They, along with the concentrations observed in 1991 and 2005, are the lowest concentrations observed at the site.

Intraannual variations in Ag and Cu concentrations in clam soft tissues display a consistent seasonal signal characterized by fall/winter maxima and spring/summer minima. The amplitude of this seasonal cycle varies from year to year. For example, the winter maxima and the magnitude of seasonal Cu and Ag concentrations during 1994–1997 and in 2007 were relatively large and bracketed years of less variability (*figs. 12, 13).* 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). In January 2008, Cu and Ag concentrations were, respectively, 44 and 2.8 µg/g but thereafter declined through the spring and reached their annual minima of 18 and 0.8 µg/g. Concentrations increased through the fall and early winter and in December were 29 and 1.8 µg/g.

As with Cu and Ag, tissue concentrations of Cr (*fig. 14*, *table 3*), Ni (*fig. 15*, *table 5*) and Zn (*fig. 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 (1994–2008). Maximum concentrations occurred in the winter of 1996-1997, while 2000–2002 was a period of relatively low winter-maximum concentrations. However, neither element exhibited a clear temporal trend (either decreasing or increasing) in concentration. Cr and Ni concentrations for 2008 were similar in magnitude and timing to the previous year. In addition to the typical seasonal pattern, Zn concentrations exhibited a slight long-term decline through 2005. During 1994-1997, Zn concentrations were notably higher throughout the year when compared to subsequent years. However, in 2006, the seasonal cycle was weakly expressed and concentrations increased notably to values comparable to those observed in the mid to late 1990s. Seasonal patterns were again evident in 2007-2008. In 2008, maximum Zn concentrations occurred in January–February (average of 366 µg/g) and decreased to their lowest concentration in May (186 µg/g). Wellise and others (1999) observed that seasonal and interannual 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.

The average Hg concentration for 2008 was 0.37 µg/g, essentially the same as for 2007. Average concentrations in general, and seasonal minima concentrations in particular, have trended upward since 2005. However, a longer term trend in Hg concentrations is not evident (*fig. 17*).

Selenium concentrations in *M. petalum* varied seasonally like those of other elements (*fig. 18*, *table 5*). Long-term trends in the data were not evident. In 2008, the annual minimum concentrations (during summer/fall) were slightly greater than in 2007.

The condition index (CI) for *M. petalum* at Palo Alto extends back to 1988 (*fig. 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. In 2006, the maximum CI was one of the lowest observed (81 mg), but in 2008 the maximum CI (222 mg) was consistent with values found since 2000.

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 coincided with highly elevated concentrations of silver (and perhaps Cu) in the soft tissues. During this period, *Macoma* exhibited extended periods (up to 2 months) of reproductive inactivity. Following the decline in tissue concentrations of Ag and Cu in the 1980s, reproductive activity of *M. petalum* improved (*fig. 20*). Furthermore, the low reproductive activity observed during the late 1970s has not been observed during the entire period of reduced metal exposures. The temporal coincidence of these events suggests that reproductive activity was related to the concentration of metals in the animal. This finding has implications for the reproductive success of the population.

Data for 2008 show that *M. petalum* continues to be highly reproductive relative to the 1970s, with a high percentage of the animals being reproductively active at any time during the normal seasonal cycle of reproduction. That cycle begins in fall, with spawning occurring the following spring (see *appendix* K for detailed reproduction data for 2008 and *figure 21* for short-term history of reproduction).

Benthic Community

Estimates of species diversity and total animal abundance are simple metrics that are used in assessing environmental stress on biological communities. Species diversity, as estimated by a time series of number of species, has steadily increased (with one exception) since the last very wet year in 1998 (*fig. 22*). Total animal abundance also varies significantly during the sampling period (*fig. 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 or that high abundance is based on one species. Depending on the characteristics of a species new to the community or newly dominant in the community, the community structure and function may change as a result of this change in species composition or dominance. 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. In general, the species composition has changed little since 1998, although there have been seasonal eruptions of several species in some years.

Three common bivalves (*Macoma petalum*, *Mya arenaria*, and *Gemma gemma*) have not shown any consistent trend over the 30-year period (*figs. 24*, *25*, and *26*). There was significant seasonal and interannual variability in species abundances for all species, and that is well illustrated in these three bivalves; *Gemma gemma* has been particularly volatile since 2005. *Gemma gemma* abundance dropped to near zero in late fall 2007 and has not regained its previous high density. There were six species that did show trends in their abundance since the 1970s, and these trends continued through 2008. The first species, *Ampelisca abdita*, is a small crustacean that lives above the surface of the mudflat in a tube built from selected sediment particles. *A. abdita* showed a general decline in both the annual average abundances and annual maximum abundances (seasonal peaks in abundance; *fig. 27*) between 1990 and 1998. That pattern mostly continues through today; there was a small increase in population size in 2008. The second species to show 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* annual maximum abundances declined, as well as annual average abundances *(fig. 28)*, but they showed a small increase in 2008. The maximum seasonal abundance of the small burrowing crustacean *Grandiderella japonica*, a deposit feeder, declined through the 1980s, but it has since become more abundant *(fig. 29)* and has shown a consistent peak in abundance in fall since 1999. *Neanthes succinea*, a burrowing polychaete that feeds on surface deposits and scavenges for detrital food, similarly showed large seasonal fluctuations in abundance through the 1980s. *N. succinea* abundance had increased by the late 1990s, and the annual average abundances and annual maximum abundances *(fig. 30)* remained relatively stable until 2005, when the abundance decreased. *N. succinea* also showed a small resurgence in 2008. Two species showed an increase in abundance within the time series. The first was the polychaete worm *Heteromastus filiformis (fig. 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 1980s. Abundances remained higher than in the late 1970s until 2008, when we saw a large drop in the population abundance. The second species showing an increase was *Nippoleucon hinumensis*, a small burrowing crustacean, which appeared in the dataset in 1988 *(fig. 32)* following its introduction into the bay in 1986 (Cohen and Carlton, 1995). Another nonindigenous species, *Corbula amurensis*, a filter-feeding bivalve that first appeared in the benthic community in significant numbers in April 2005 and persisted into 2006 with peaks in abundance occurring in spring and fall, has shown another small peak in fall 2008 (appendix L).

We observed a sudden drop in animal abundance in February 2008. Very few animals were found at the site, and the mudflat community was evidently stressed by some event between the January and February sampling. Possible causes of the stress include a sedimentation or freshwater inundation event. There was a large storm on January 25, with rainfall rates exceeding 0.5 cm/hr for over half the day, including during the low-tide period. We did not observe any obvious changes in the sediment surface, but sediment changes can occur and be incorporated quickly in this tidal environment. Other possible causes of benthic community death or exodus include a toxic event or anoxia. We do not believe these occurred because we were able to collect *Macoma* from the deep sediment in February and we saw animals quickly return to the site by March; this would not happen with toxicity or anoxia. We know the timeline for recovery from anoxia based on an anoxic event at this site in 1975, when macroalgae was deposited on the mudflat surface and decayed there. It took many months for the community to recover. Animals that returned in 2008 after the disturbance included those species with pelagic larvae and mobile adults, as would be expected. This was a change in our community structure, but we do not expect it to be maintained.

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. Comparison of metal concentration and benthic species abundance 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 until 2008 *(fig. 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 *(figs. 34* and *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, we do not believe this species is likely to move into an area quickly after an environmental stressor. We observed a large spike in *H. filiformis* abundance in January 2008 due to the settling of larvae. These larvae did not survive the event that occurred before the February sampling, and thus we now have the opportunity to observe the dynamics of recovery for this species.

We have hypothesized that silver, but probably not copper, adversely affected reproduction in *H. filiformis* (Ahn and others, 1995) and that the gradual increase in *H. filiformis* abundance through 1984 was a response to the gradual reduction of metals in the environment. We will now have an environment with much lower metal concentrations in which we can examine our hypothesis. We will also look for the "boom and bust" population behavior that we observed before, 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).

The two species that have declined in abundance coincident with the decline in metals, the crustacean *A. abdita (figs. 36*, *37*, and *38)* and the worm *S. benedicti (figs. 39, 40*, and 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 not surprising that both species immediately responded to the near-empty community in February, 2008. It was unclear why these species became less competitive in the present-day environment, but the data from 2008 and beyond may help us understand how this community cycles with a natural stressor. The abundance of *G. gemma* has also declined dramatically since the 1970s and 1980s *(figs. 42, 43*, *and 44)*. This small clam reproduces by brooding their young and lives on the sediment surface, which makes them fairly resistant to sediment borne stresses. *G. gemma* abundance has been variable throughout the study. As with *H. filiformis*, we expect the nonpelagic larvae of *G. gemma* will limit the speed of its reintroduction in the benthic community at Palo Alto.

The change in function of the benthic community over time can be examined by ranking the top 10 species by abundance and plotting the ln (abundance +1) against the rank of each species (*fig. 45*). The plot for 2008 is indicative of a healthy benthic community, with species dominance, as revealed by abundance, being equally represented by the top 10 species. If we examine similar plots for August of 4 years during our study (1977, 1989, 2002, and 2008), we can see that the shape of the curve has changed greatly and that the curve is remarkably flat in 2008 (*fig. 46*). The series of lines shows a community that was heavily dominated by three species in 1977 and 1989 when compared to the community in 2002, when there was one dominant species. The 1977 community plot is the most extreme and reflects a bimodal species distribution, with three species dominating the community and the remainder having similar but relatively low abundances. In contrast, the 2008 community plot is dissimilar to that seen at any other time, probably as a result of the community reestablishing itself in March. A level plot, which is indicative of a more evenly diverse community, has been a consistent pattern since the 1980s.

It is informative to examine the rank-abundance plots within the context of the life history characteristics of each species to determine if shifts in plot shape coincide with a shift in community structure and function that might be indicative of a healthier environment. We have shown two critical life history characteristics here: feeding mode (*fig. 46*) and reproductive mode (*fig. 47*). The 1977 community was dominated by filter-feeding species (species that consume particles in the water column), species that have the option of either filter-feeding or feeding on the sediment surface (mixed feeders), and one species that feeds on food particles on the sediment surface. In 1989 the species composition had shifted such that filter-feeding species and subsurface deposit feeding species (those that ingest sediment and strip the food off of the sediment in their gut) dominated the community. In 2002 we again saw a shift towards species that could either filter feed or deposit feed (mixed feeders) and those species that feed on subsurface sediment. The most recent data shows that this homogenous community (the abundances are most similar between species) is mostly composed of a mix of surface and subsurface deposit feeding species and mixed feeding species. Thus, over the period of this study we have seen a shift from a community dominated by species that fed either in the water column or on recently settled food particles on the sediment surface to a mixed community of species that feed directly on the subsurface sediment, those capable of feeding in the water column, and those feeding on the sediment surface.

An examination of these rank-abundance plots using reproductive mode as the descriptor for each point is equally informative (*fig. 47*). The dominant species in 1977 were species that brood their young and release fully functional juveniles into the environment. In 1989 there were still several brooders, but there were also two species that lay their eggs in the sediment. Although brooding species remain in the 10 most abundant species in the 2002 plots, the reproductive mode of the dominant species shifted to include those that spawn their gametes into the water column and those that lay eggs in the sediment (oviparous). It is possible that some of the metal contaminants found in the sediment in the 1970s at this location limited the success of species that consumed the sediment for food, laid eggs in the sediment, or depended on water borne larvae to repopulate the community. As stated earlier, the reproductive mode of the species present in 2008 is reflective of the species that were available either as pelagic larvae or as mobile adults during the early spring. Although egg layers were not present in this group, we hypothesize that these species will return slowly as more species move back into the area.

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, 1995a, 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; Cain and others, 2006, Lorenzi and others, 2007) with additional data from January 2008 through December 2008, to create a record spanning 34 years. This long-term dataset includes sediment chemistry, tissue concentrations of metals, condition index, and reproductive activity in *M. 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* (1970s) 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 1970s showed that sediments and *M. 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 Palo Alto Regional Water Quality Control Plant (PARWQCP) to South Bay. In the early 1980s, the point-source metal loading from the nearby PARWQCP 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 (2000b). Interannual trends in clams and sediments are highly correlated with copper loadings from PARWQCP. 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 (Hornberger and others, 2000b).

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 (that is, 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 intraannual 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 nonindigenous, opportunistic species that dominated because of 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, because the decline in metal concentrations in *M. petalum* and sediment had just begun.

However, data collected throughout the period of declining metal exposure have revealed biological responses to this metal decline. 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 interannual variation.

The ecology of the mudflats in Palo Alto are part of the larger South Bay, which has been undergoing some changes in recent years. In 1999-2005 USGS scientists noticed an increase in phytoplankton biomass in the southern bay. Sampling in the deeper water of the southern bay showed that the bivalves were mostly absent from the system during this increase in primary production. Cloern and others (2007) showed that the cause of the decline in bivalves was an increase in fish predators resulting from increased offshore upwelling activity. The higher reproductive success of demersal fish, crabs, and shrimp during this period resulted in a higher number of juveniles moving into the South Bay to grow. Since 2005 we have seen the large bivalve populations fluctuate more than in previous years, and these fluctuations have been reflected in changes in phytoplankton biomass in the system (primarily through an increase in phytoplankton biomass in late summer and fall). The value of these findings in greater South Bay to our study is two fold. First, it reinforces the importance of the benthic community in structuring the ecosystem function. Second, it shows that the high intertidal community at the Palo Alto site has not been demonstrably affected by these greater South Bay influences during these years. This finding solidifies our confidence that the changes that we have observed on the benthic community are in large part due to local factors.

2008

Copper and silver concentrations in sediments and soft tissues of the clam, *M. petalum*, throughout 2008 remain representative of the concentrations observed since 1991, following the significant reductions in concentrations during the 1980s that coincided with reductions in the discharge of these elements from PARWQCP. Since 1991, annual mean copper and silver concentrations have fluctuated modestly and without any extended trends. This is also true for other elements. For example, Se concentrations of sediments in 2008 were the highest on record, but there is no evidence, yet, to suggest a temporal trend of increasing sedimentary Se. Interannual variation in bioavailable Cu and Ag between 1991 and 2006 did not correlate with discharge of Cu and Ag from PARWQCP (Lorenzi and others, 2007), suggesting that, similar to other elements of regulatory interest, including Cr, V, Ni, and Zn, regional scale factors now largely influence sedimentary and bioavailable concentrations (see, for example, Luoma and others, 1998). Factors that influence the seasonal and year-to-year patterns in sedimentary and tissue concentrations may include precipitation, nonpoint-source runoff, cycling of legacy contamination, and accelerated erosion of salt marsh banks in recent years. The influence of these variables 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 *M. petalum* that has been sustained though 2008. The benthic community declined, with few animals present in February 2008. We believe this decline was due to a natural stressor, such as a sedimentation or freshwater event. Mobile animals such as *Macoma* that were capable of burrowing down out of the influence of the stressor probably did so, but many other species either relocated or were killed. This natural disturbance gives us a great opportunity to observe the mudflat community recover from a natural stressor and to compare this recovery to that observed over the long-term decline in metals. We have interpreted shifts in species abundance at Palo Alto to be a response to decreasing sediment contaminants. These community changes have included a shift from species that live on the surface, filter food out of the water column or consume particles on the sediment surface, and brood their young to a community dominated by species that live on and below the surface, consume the sediment directly to harvest food particles, and spawn and lay eggs in the sediment. Future data will refine our understanding of the response of the benthic community to natural and anthropogenic stressors.

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 interannual 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 interannual 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. Nanotechnologies, 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 human activities in the watershed continue to change.

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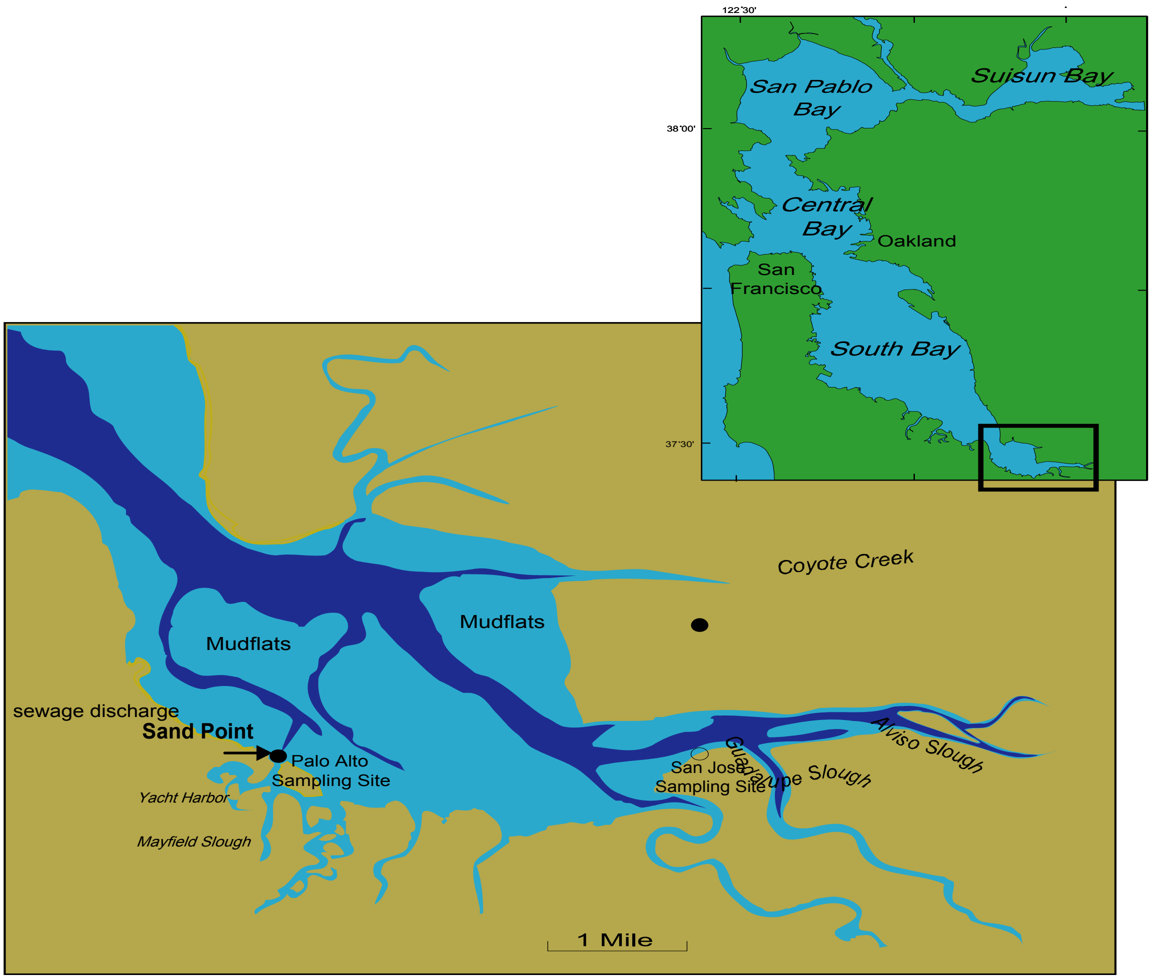


EXPLANATION

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

Figure 1. Map showing the location of the Palo Alto sampling site in South San Francisco Bay.

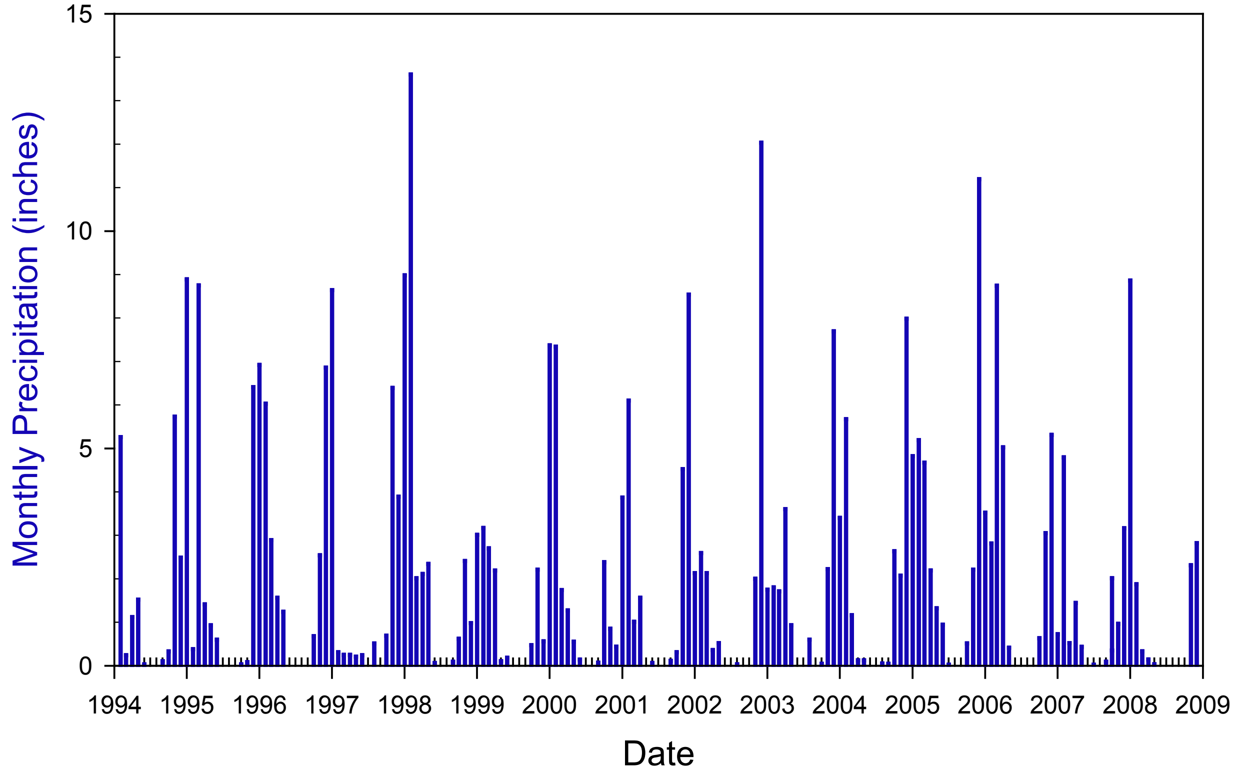


Figure 2. Total monthly rainfall (inches) recorded at San Francisco WB AP in San Mateo County, 1994–2008. The station (identification SFF) is operated by the National Weather Service.

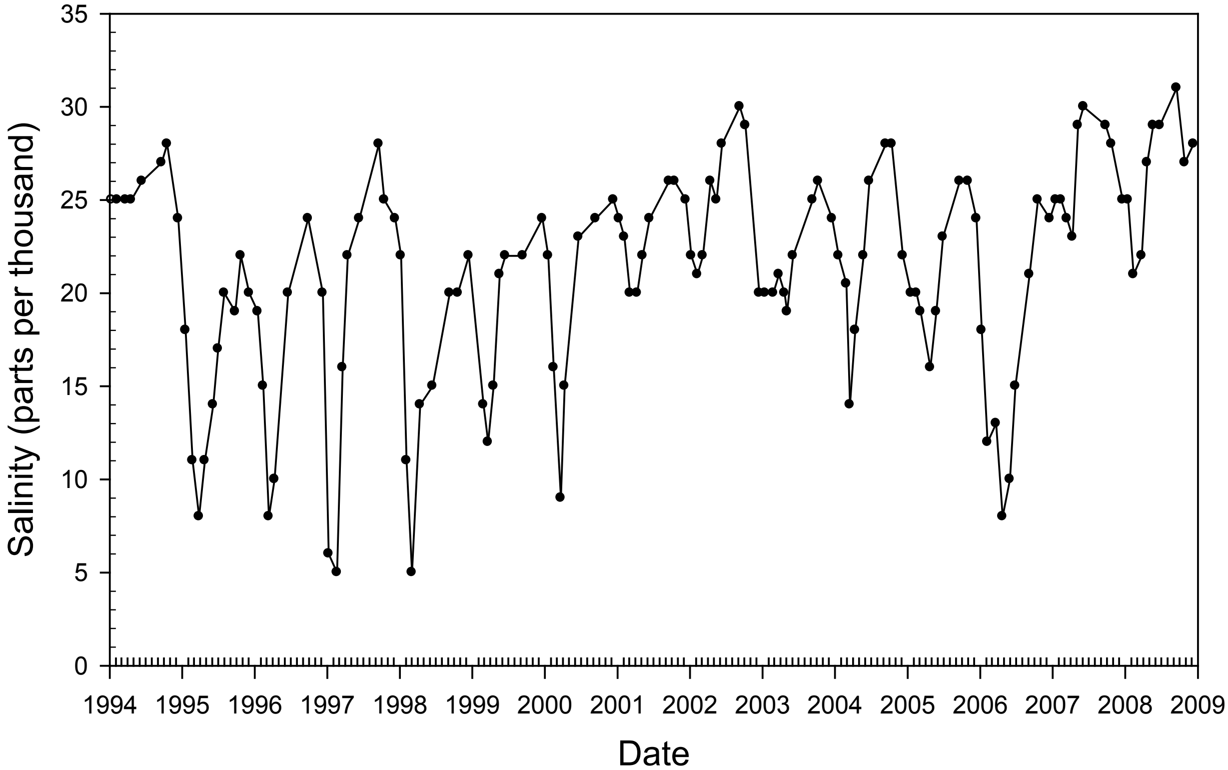
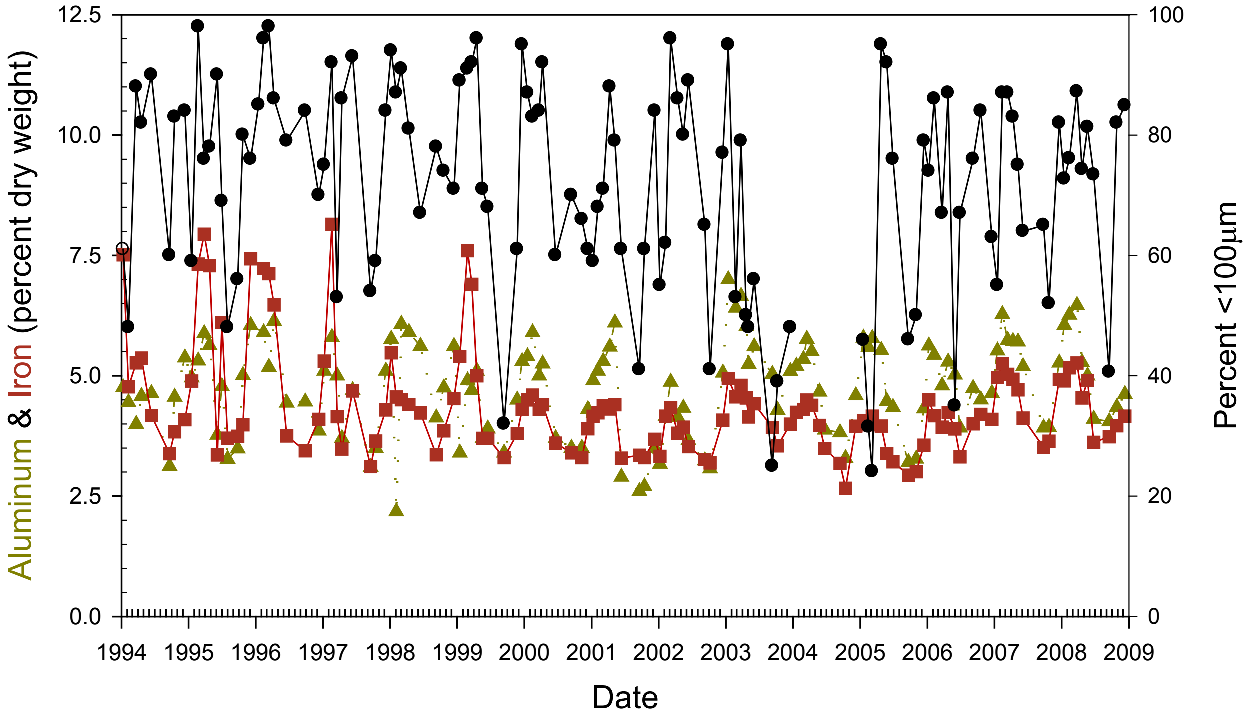


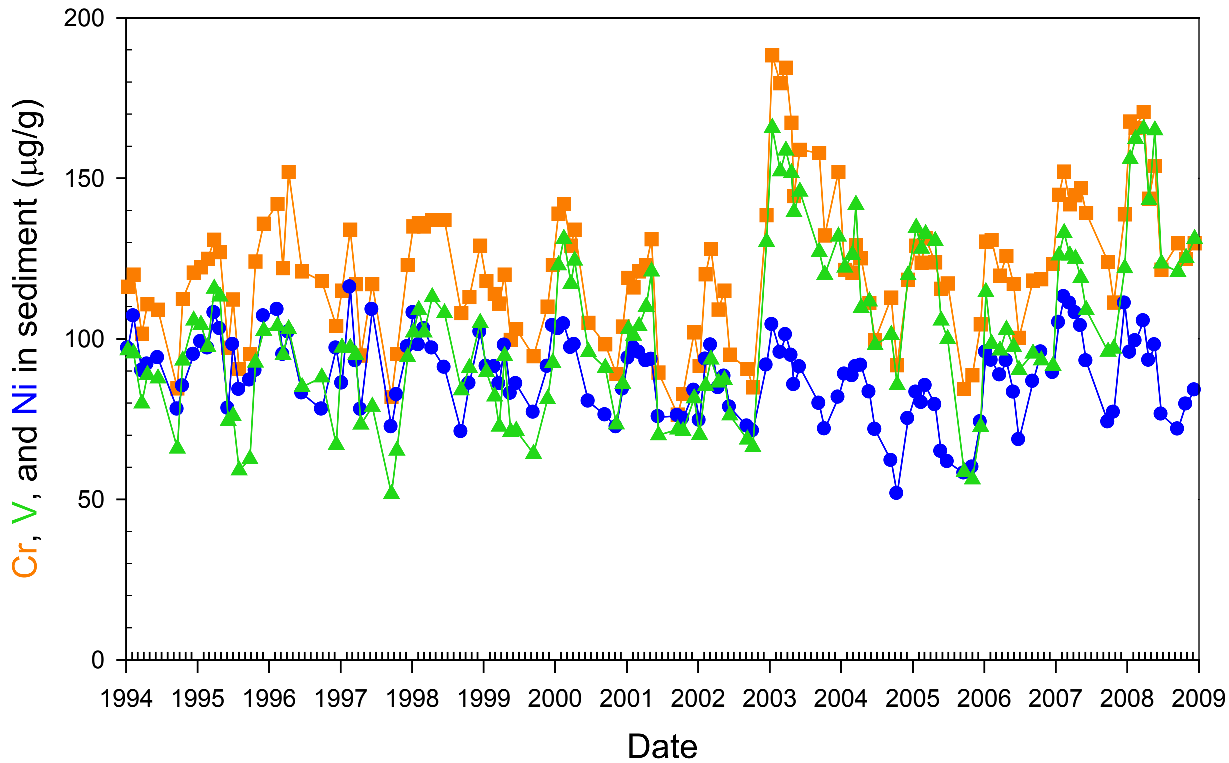
Figure 3. Surface-water salinity at the Palo Alto site,1994–2008.



EXPLANATION

Percent aluminum (▲) iron (■) (extracted by near-total digest) and silt/clay (<100 µm) (●). 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 appendix A-1 for qualitative purposes only.

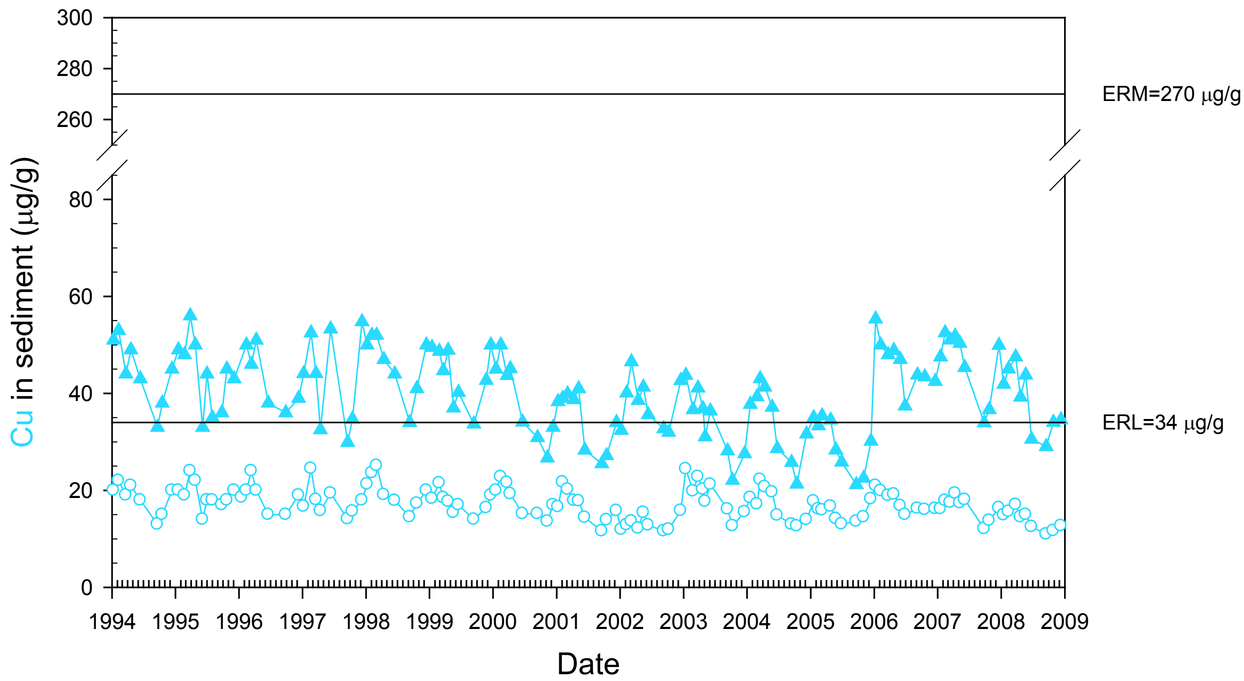
Figure 4. Aluminum, iron and silt/clay in sediments, 1994–2008.



EXPLANATION

Concentrations of chromium (Cr) (■), nickel (Ni) (●) and vanadium (V) (▲) extracted by near-total digest.

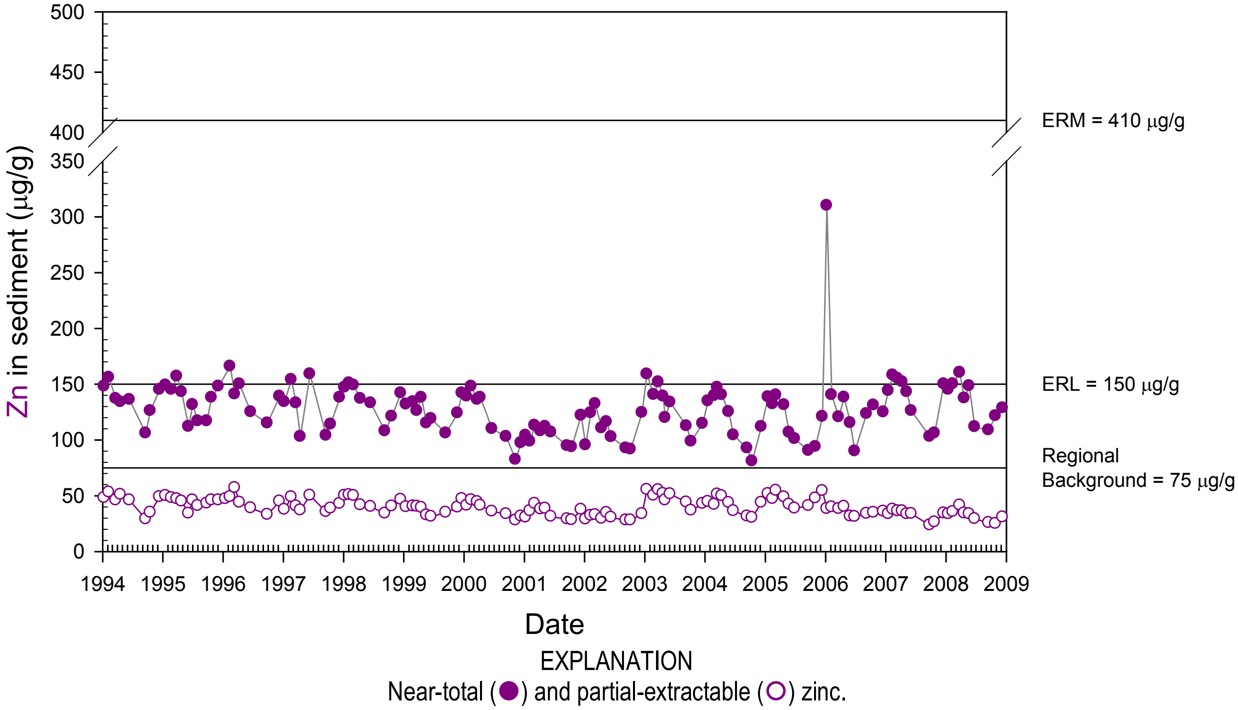
Figure 5. Chromium, nickel and vanadium in sediments,1994–2008.



EXPLANATION
Near-total (▲) and partial-extractable (○) copper.

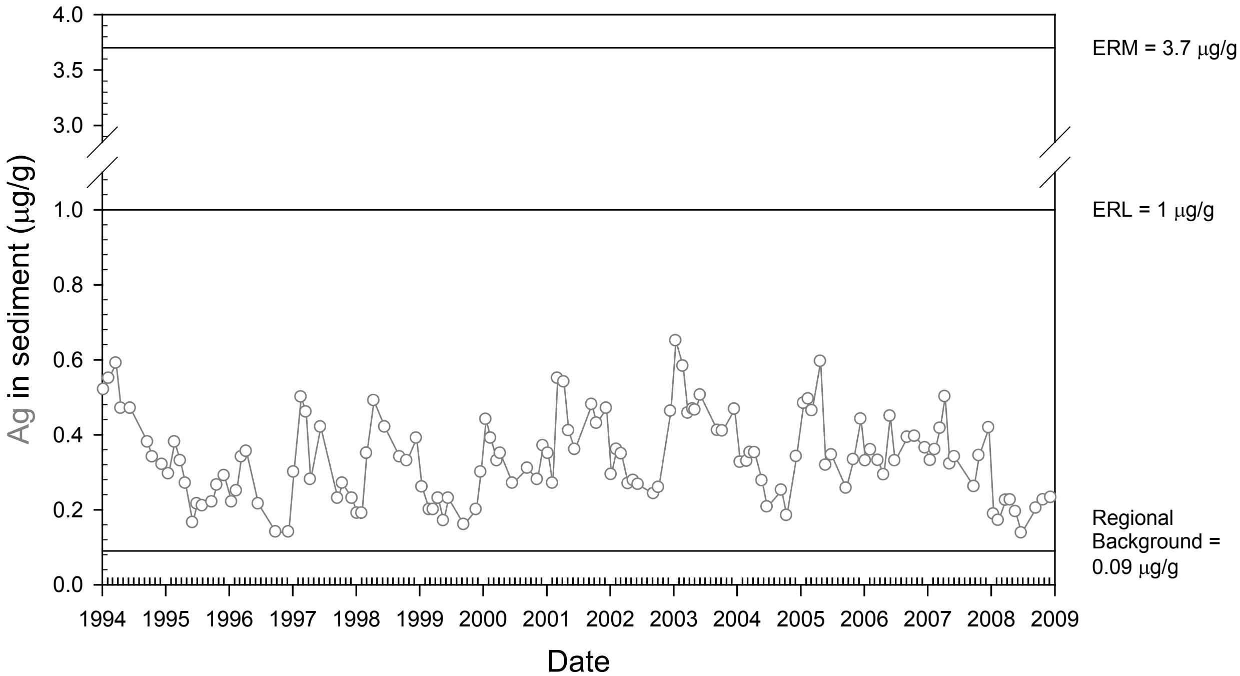
The ERL is the concentration below which the expected incidence of adverse effects is low (9 percent).
The ERM is the concentration above which the expected incidence of adverse effects is high (84 percent).

Figure 6. Copper in sediments, 1994–2008.



The ERL is the concentration below which the expected incidence of adverse effects is low (6 percent).
The ERM is the concentration above which the expected incidence of adverse effects is high (70 percent).

Figure 7. Zinc in sediments, 1994–2008.



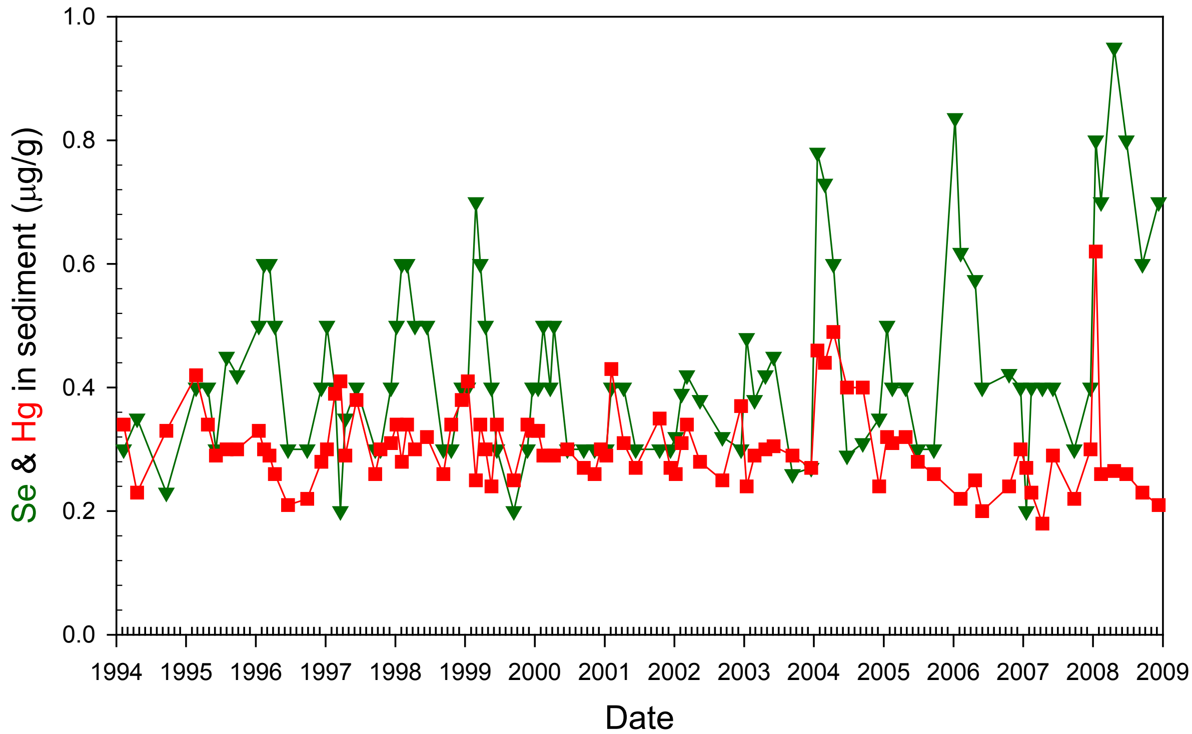
EXPLANATION

Data represent partial-extractable silver (treatment with 0.6 N hydrochloric acid).

The ERL is the concentration below which the expected incidence of adverse effects is low (3 percent).

The ERM is the concentration above which the expected incidence of adverse effects is high (93 percent).

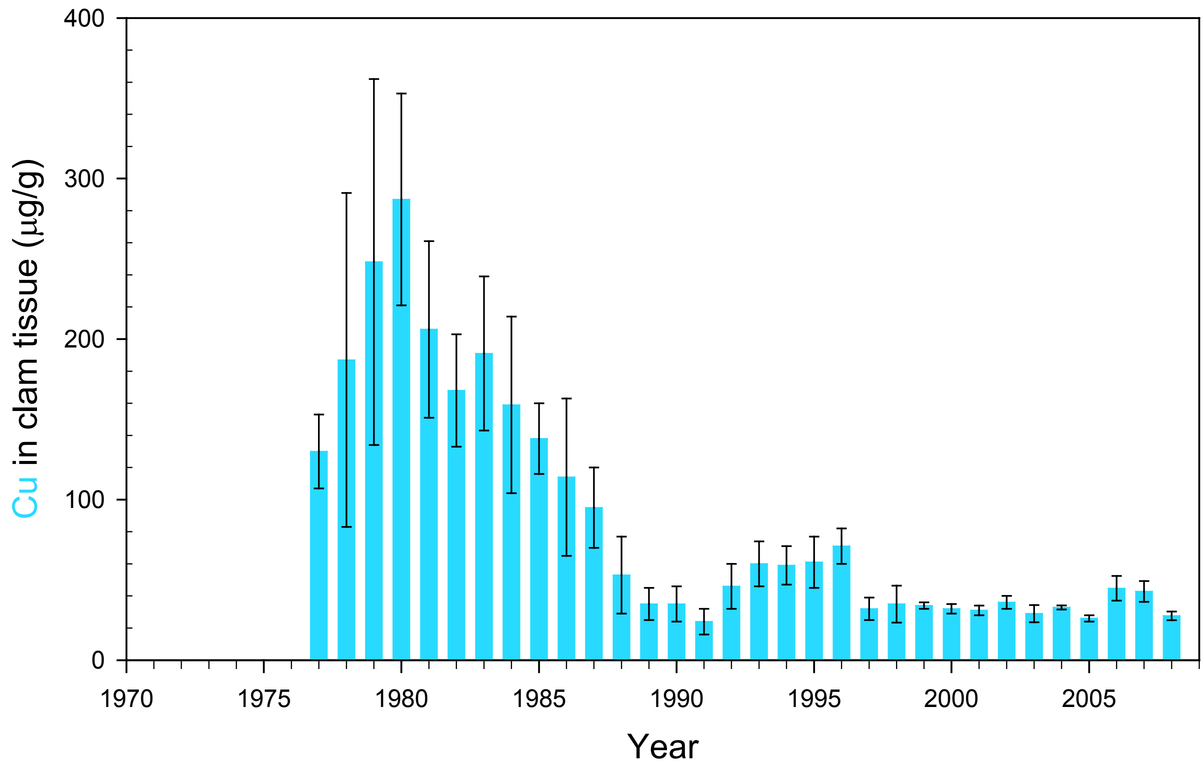
Figure 8. Silver in sediments, 1994–2008.



EXPLANATION

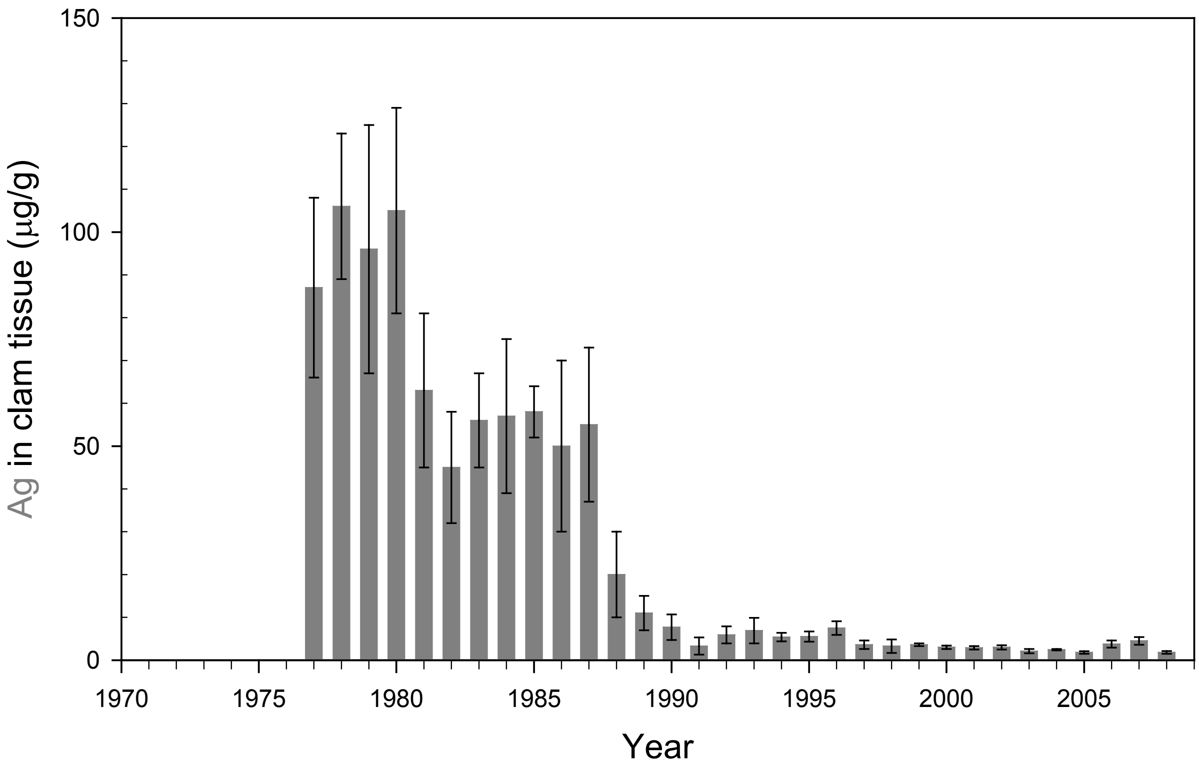
Selenium (▼); mercury (■).

Figure 9. Selenium and mercury in sediments, 1994–2008.



EXPLANATION
The error bars are the standard error of the mean (SEM) for samples collected within the year.

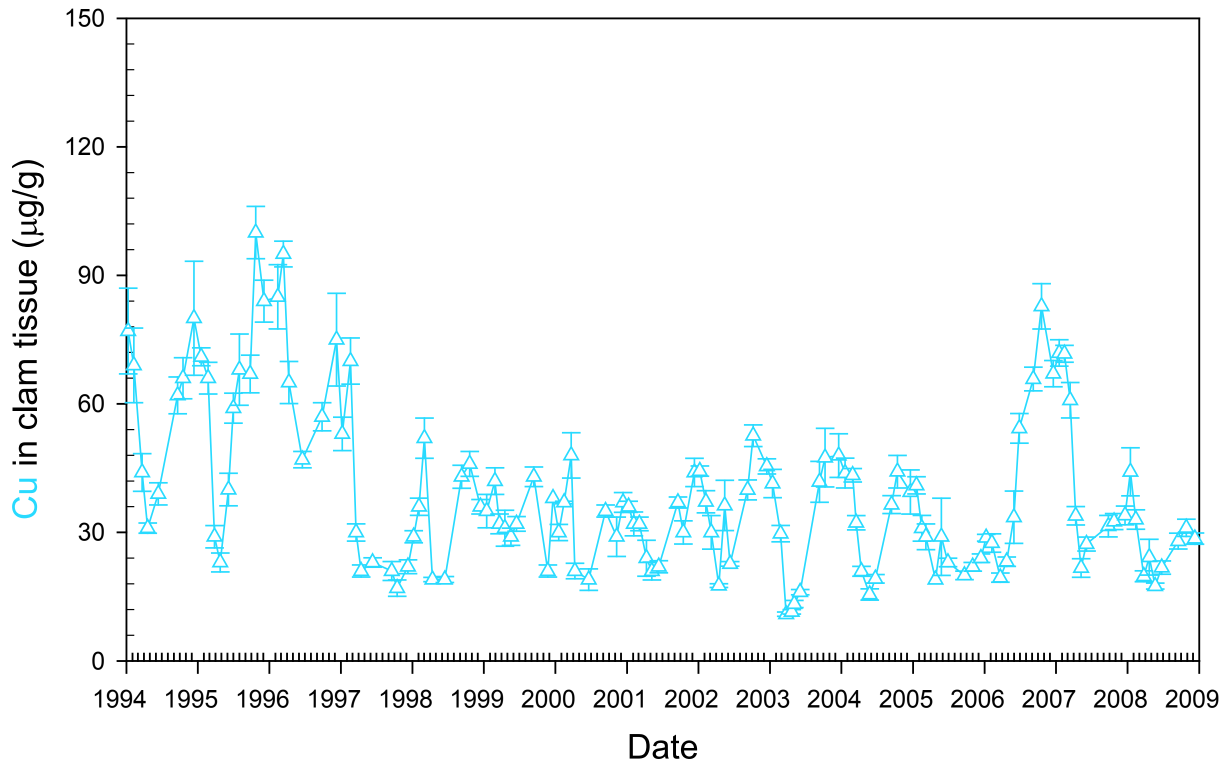
Figure 10. Annual mean copper in the clam *Macoma petalum*, 1977–2008.



EXPLANATION

The error bars are the standard error of the mean (SEM).

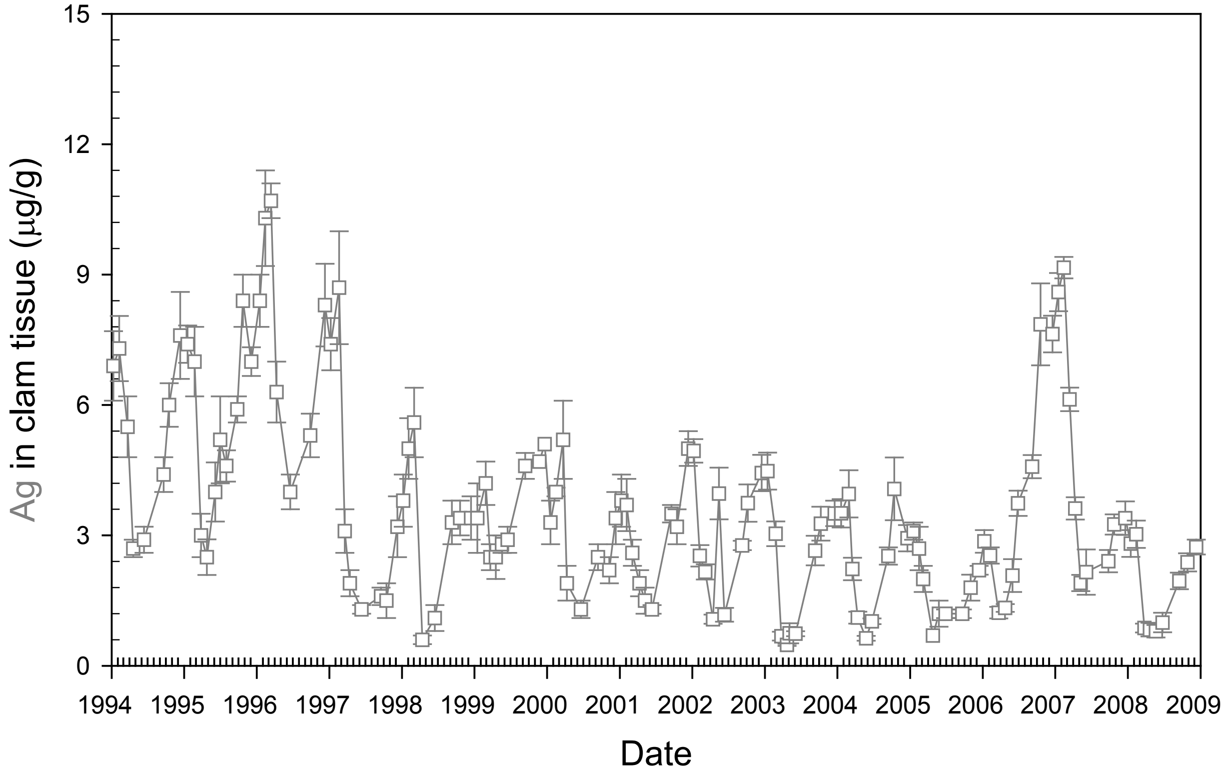
Figure 11. Annual mean silver in the clam *Macoma petalum*, 1977–2008.



EXPLANATION

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).

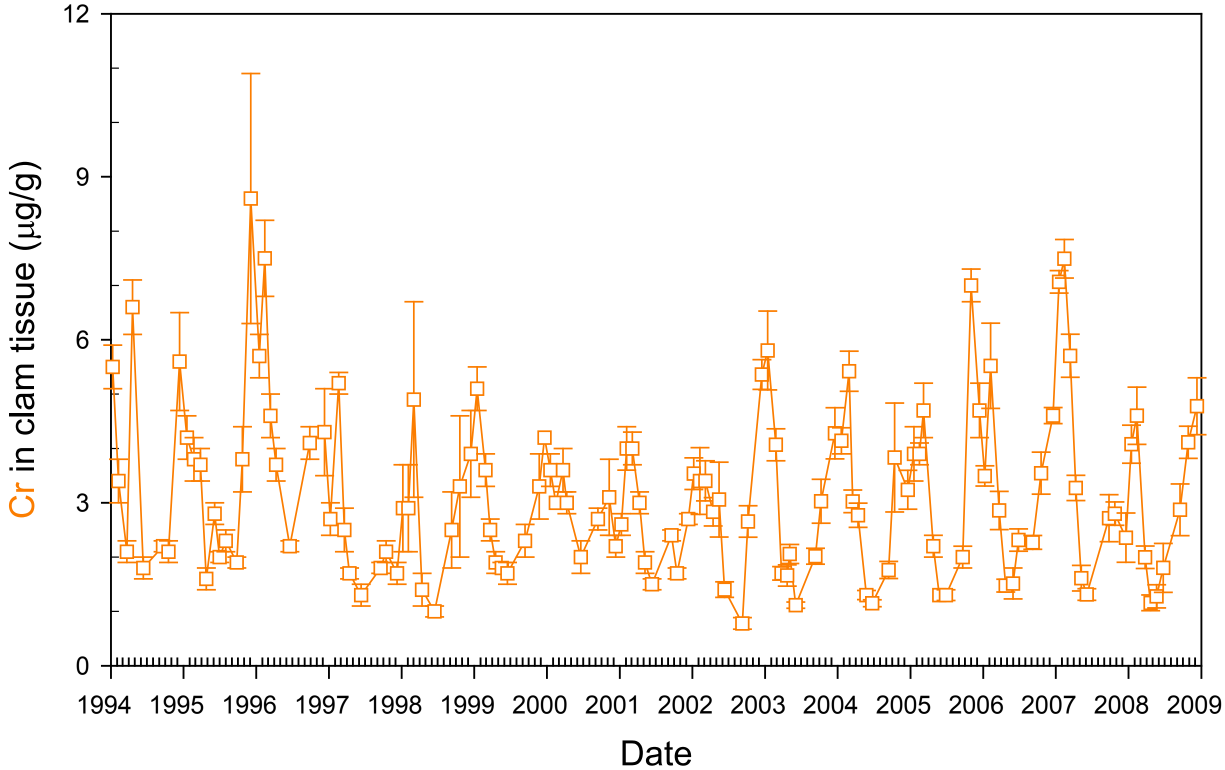
Figure 12. Copper in the clam *Macoma petalum*, 1994–2008.



EXPLANATION

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).

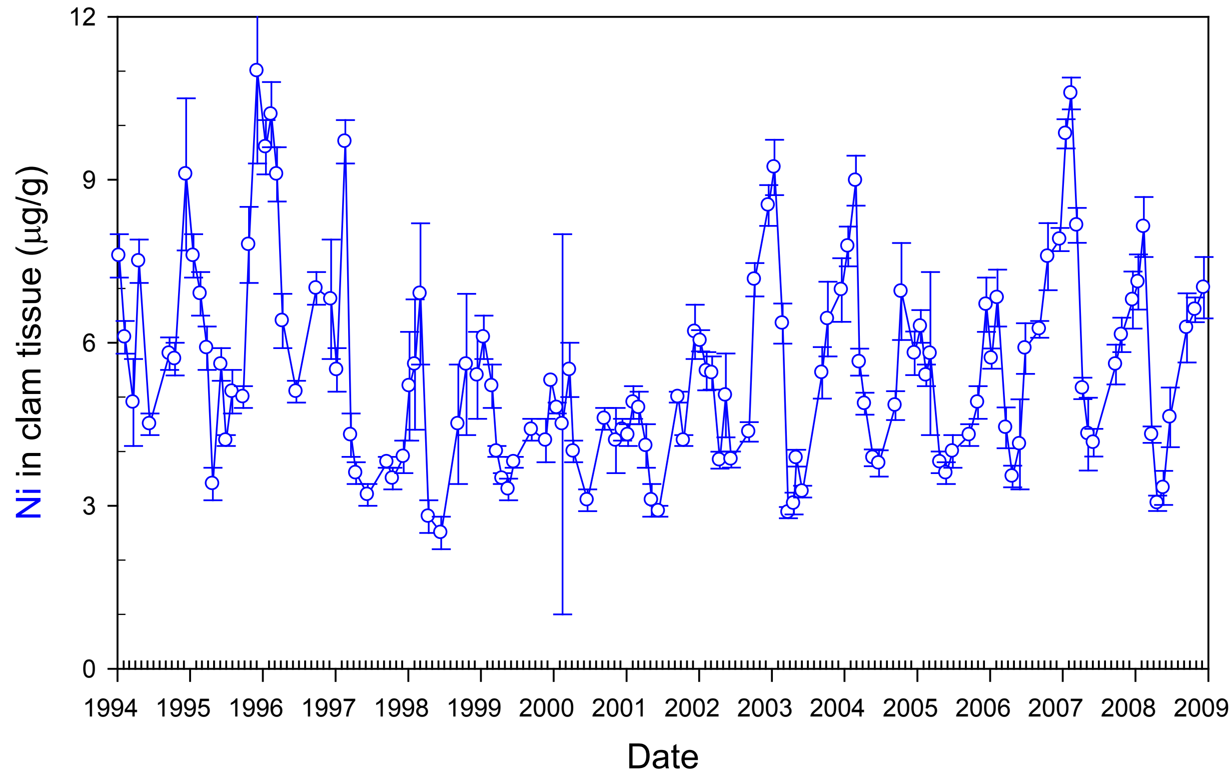
Figure 13. Silver in the clam *Macoma petalum*, 1994–2008.



EXPLANATION

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).

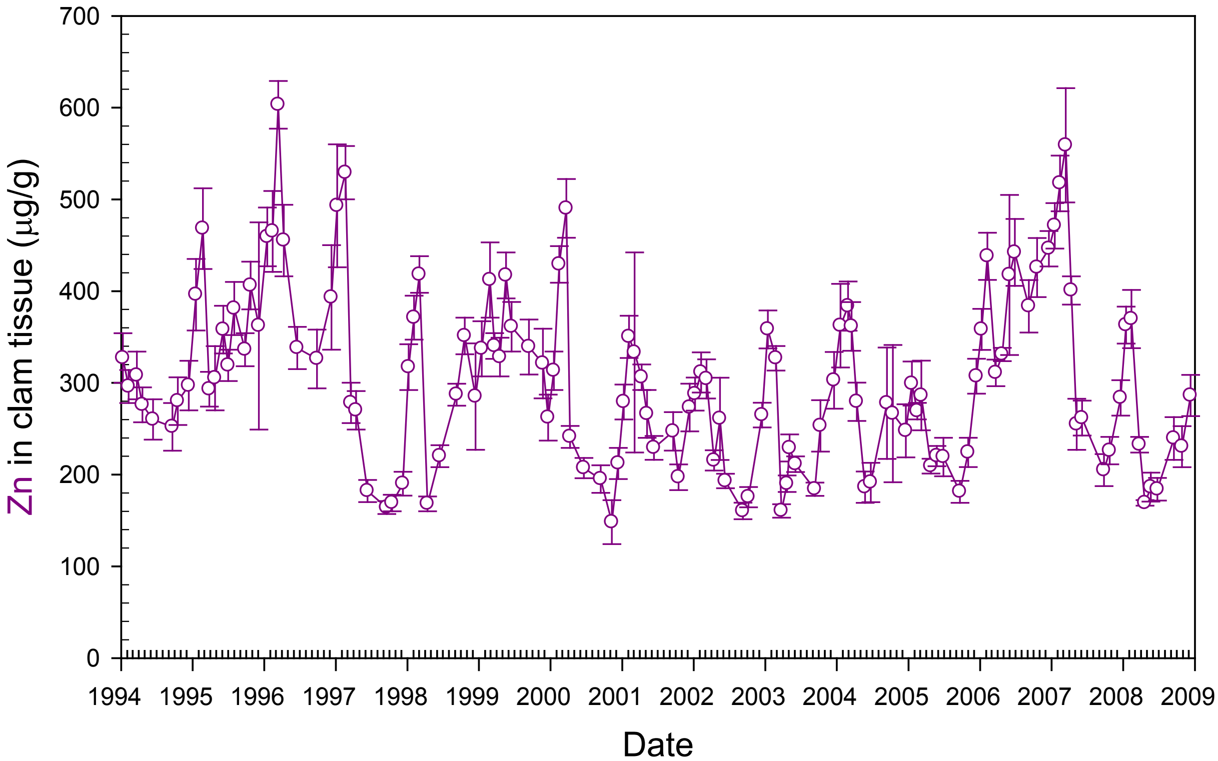
Figure 14. Chromium in the clam *Macoma petalum*, 1994–2008.



EXPLANATION

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).

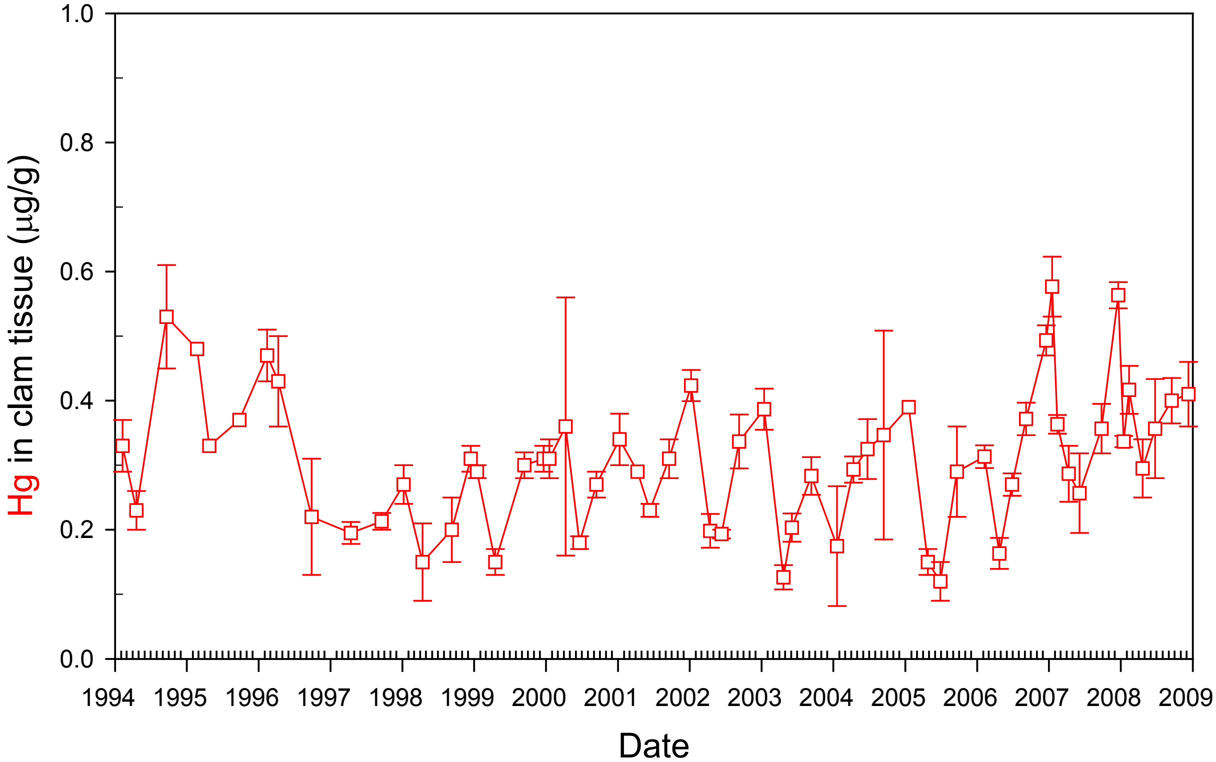
Figure 15. Nickel in the clam *Macoma petalum*, 1994–2008.



EXPLANATION

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).

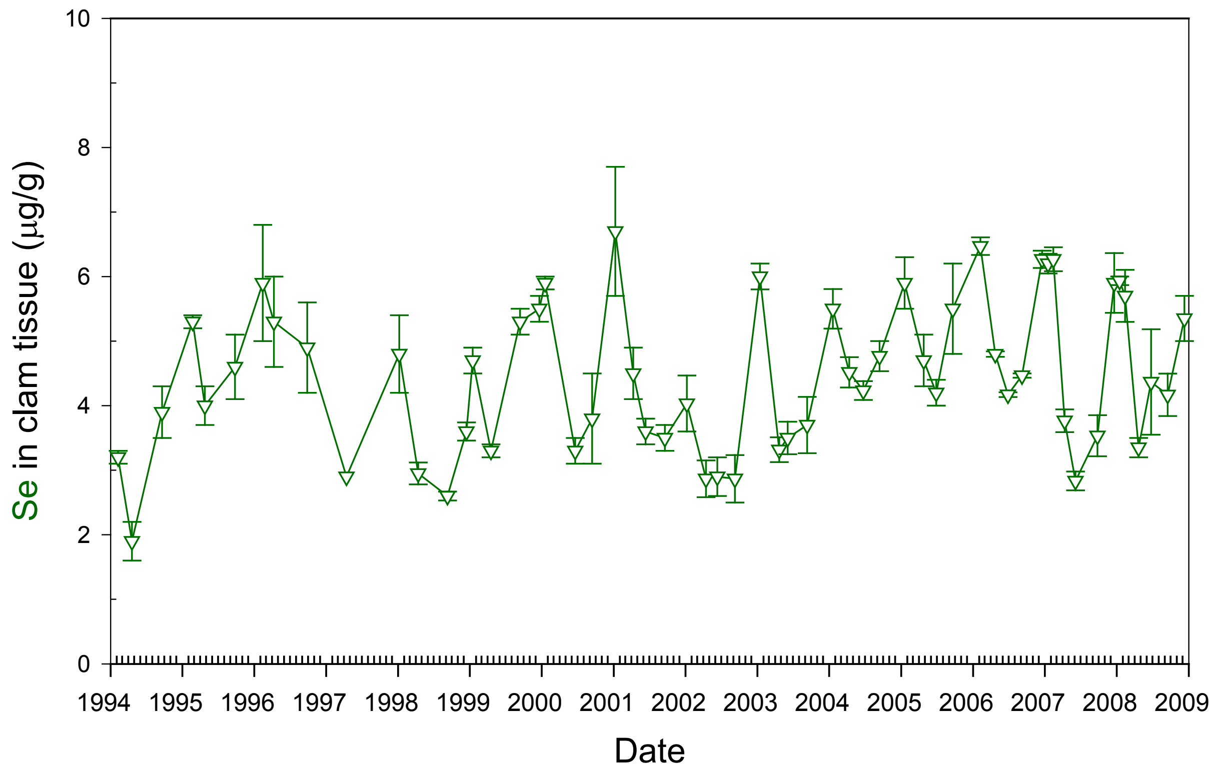
Figure 16. Zinc in the clam *Macoma petalum,* 1994–2008.



EXPLANATION

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).

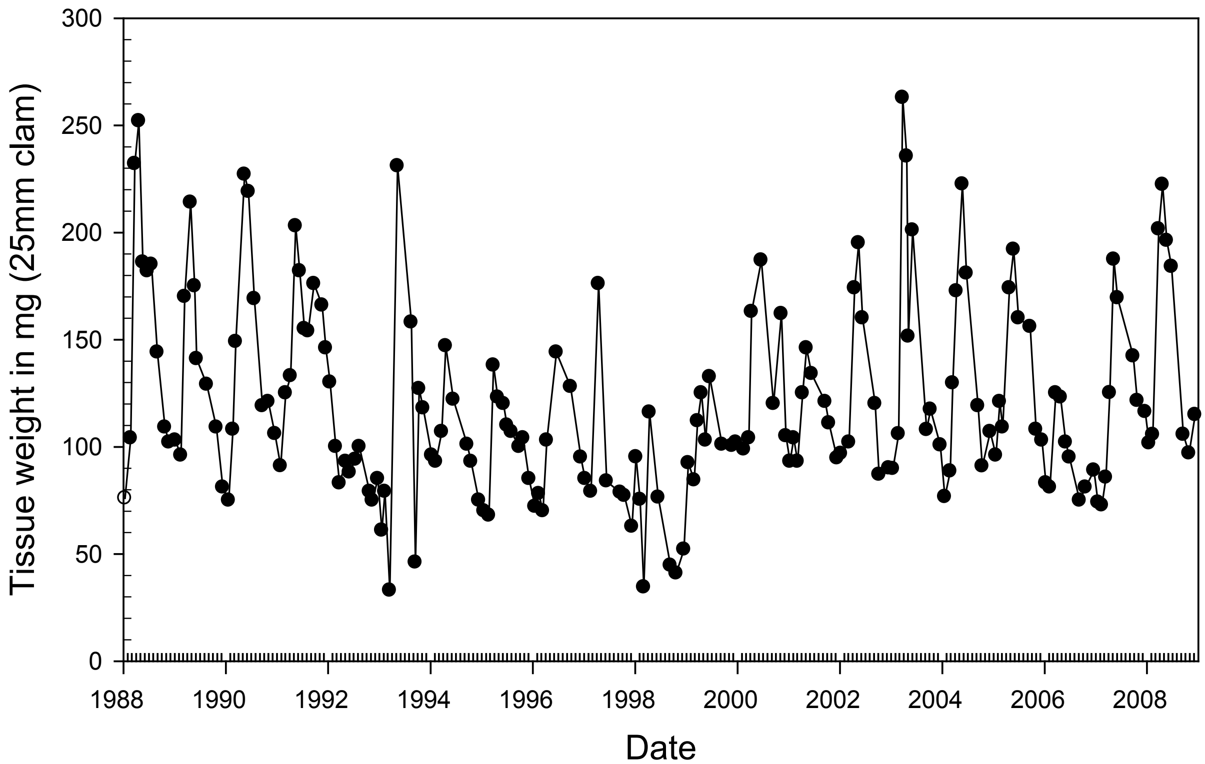
Figure 17. Mercury in the clam *Macoma petalum,* 1994–2008.



EXPLANATION

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).

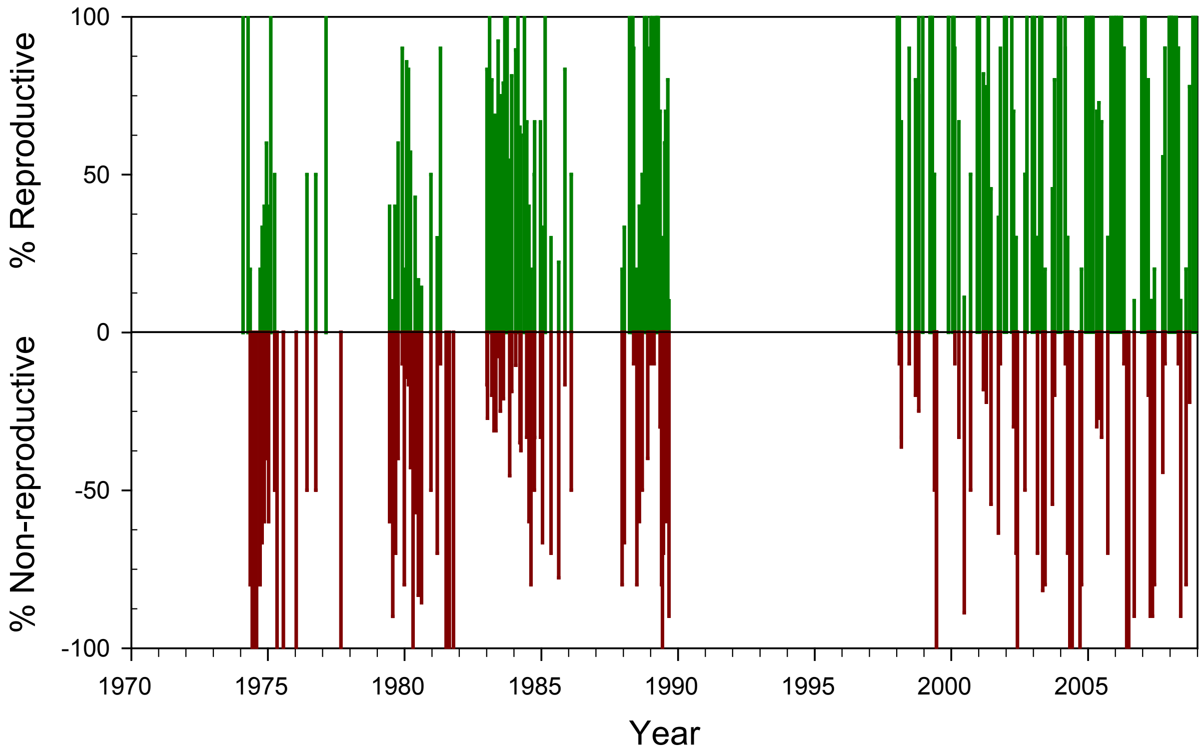
Figure 18. Selenium in the clam *Macoma petalum*, 1994–2008.



EXPLANATION

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

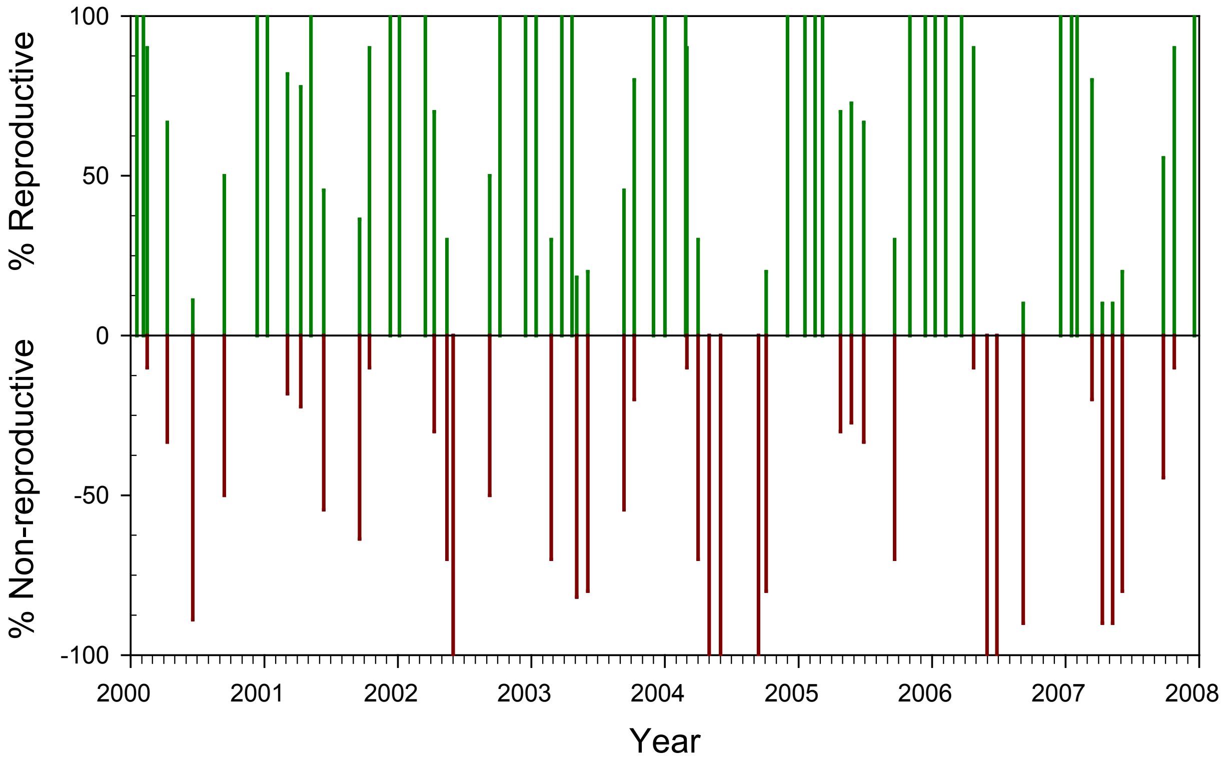
Figure 19. Condition index of the clam *Macoma petalum*, 1988–2008.



EXPLANATION

Values are the percent of individuals that were either reproductively inactive (non-reproductive) or in various stages of reproduction (reproductive). The percent of non-reproductive individuals is reported as a negative value.

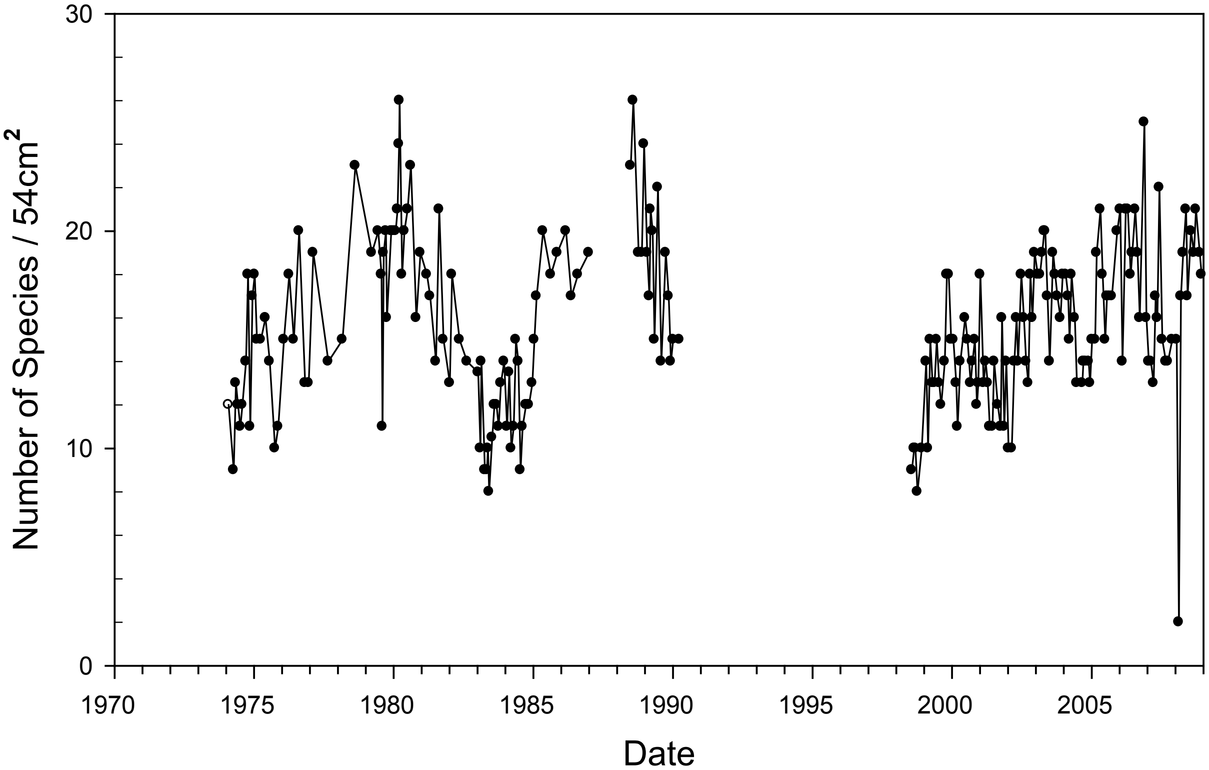
Figure 20. Reproductive activity of the clam *Macoma petalum*, 1974–2008.



EXPLANATION

Values are the percent of individuals that were either reproductively inactive (non-reproductive) or in various stages of reproduction (reproductive). The percent of non-reproductive individuals is reported as a negative value.

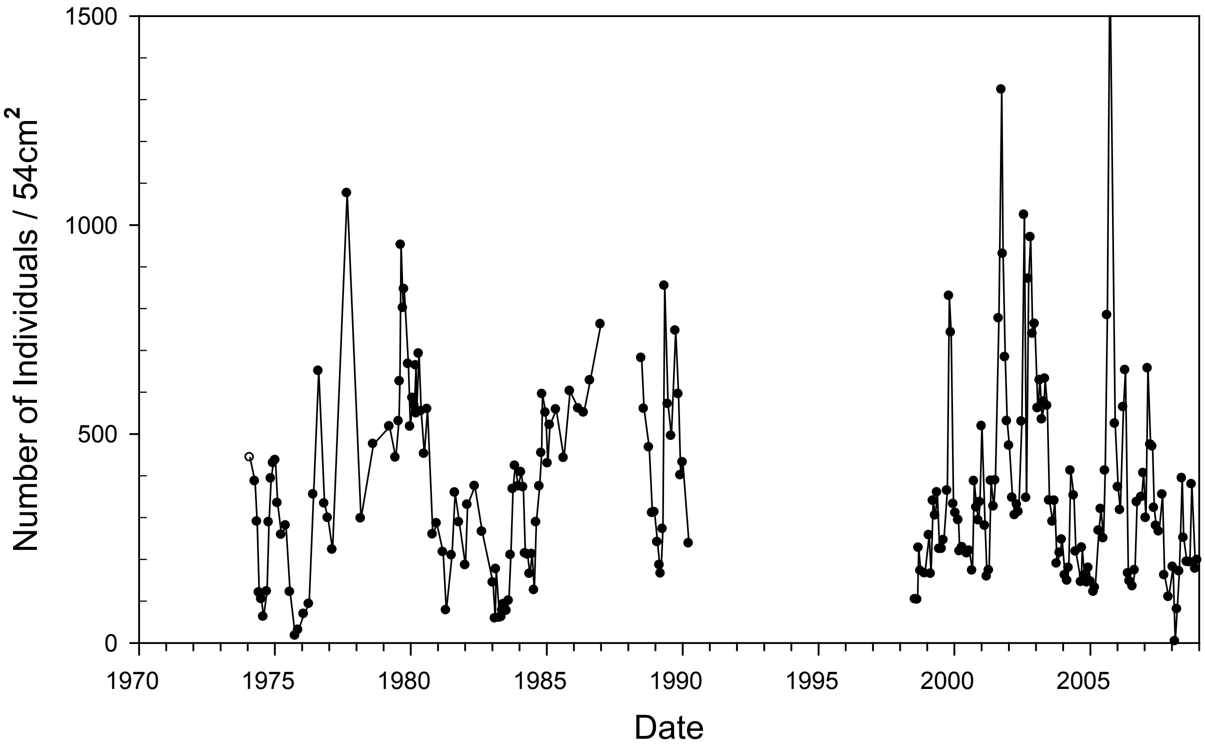
Figure 21. Reproductive activity of the clam *Macoma petalum*, 2000–2008.



EXPLANATION

Collections were not made between 1991 and 1998.

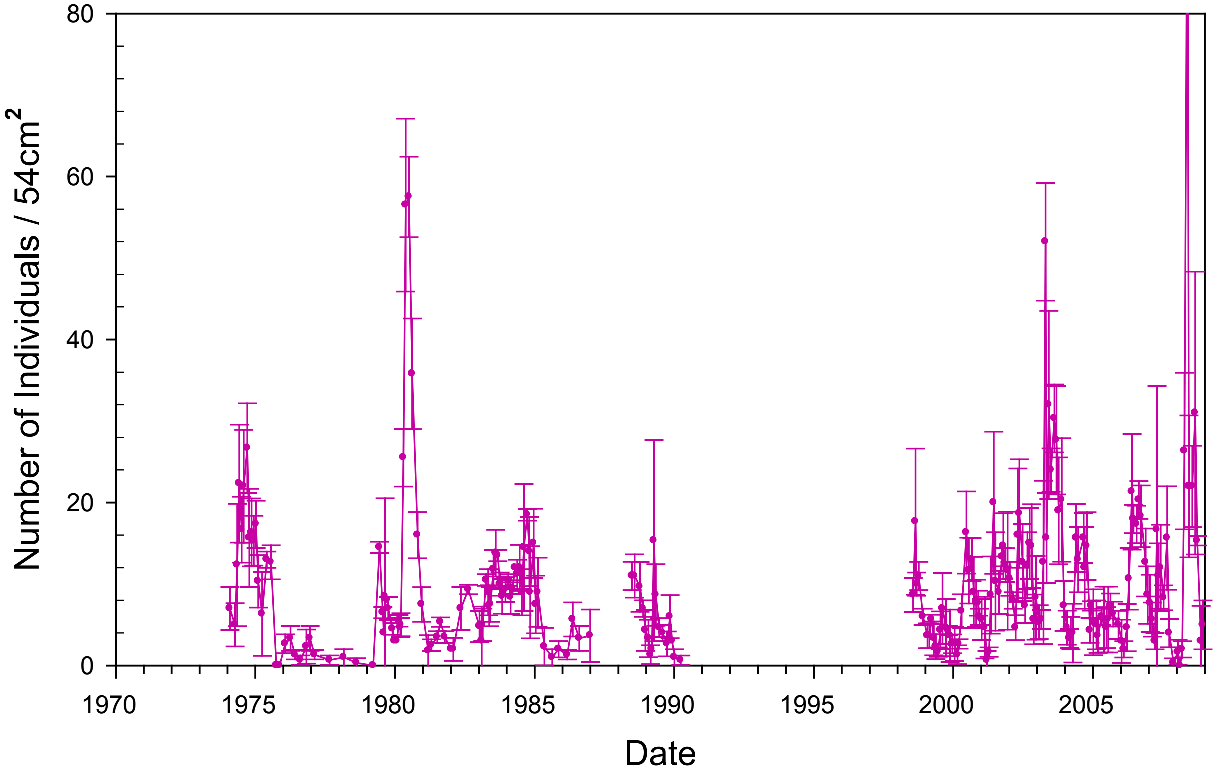
Figure 22. Total number of species present, 1974–2008.



EXPLANATION

Collections were not made between 1991 and 1998.

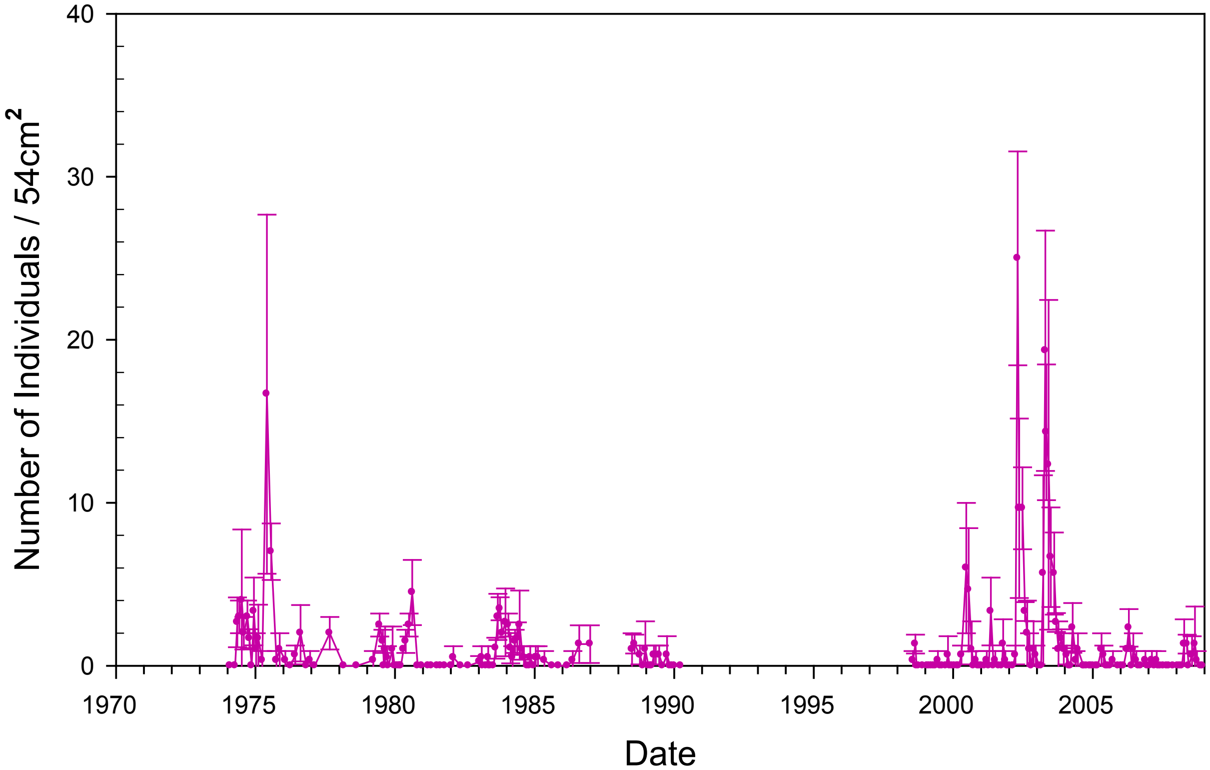
Figure 23. Total average number of individuals present, 1974–2008.



EXPLANATION

Error bars represent standard deviation from 3 replicate samplings. Collections were not made between 1991 and 1998.

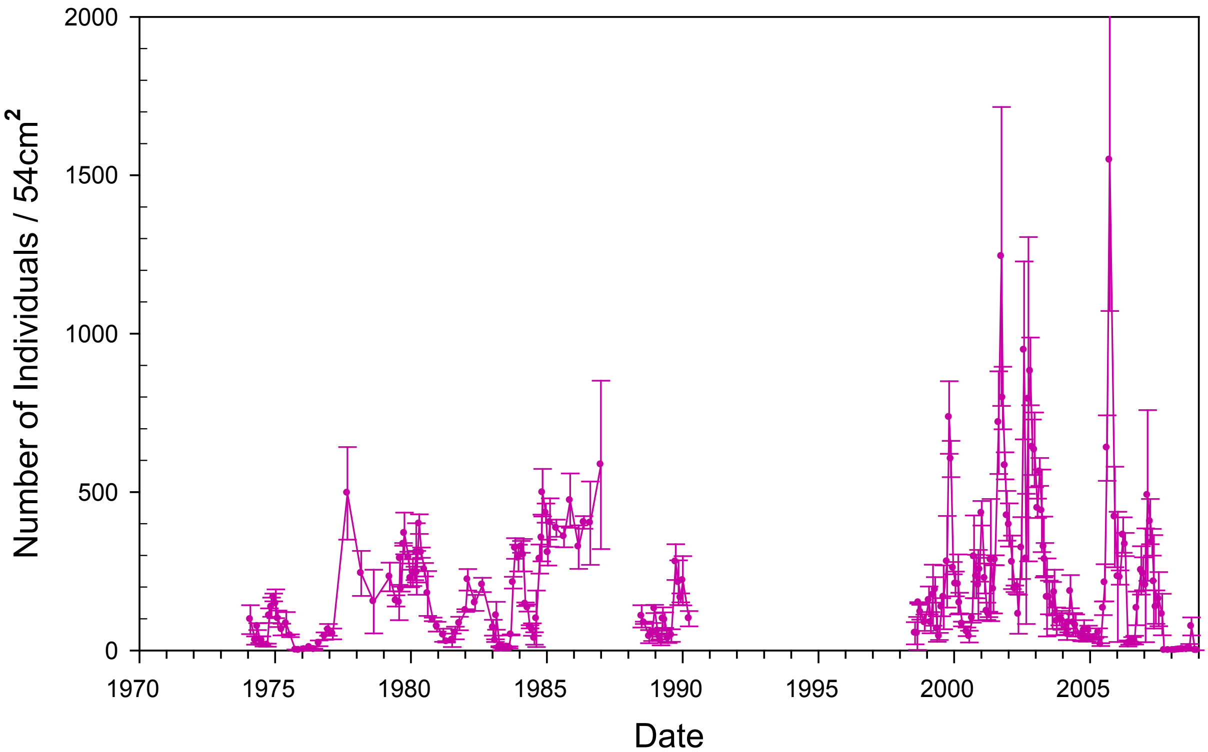
Figure 24. Monthly average abundance of *Macoma petalum*, 1974–2008.



EXPLANATION

Error bars represent standard deviation from 3 replicate samplings. Collections were not made between 1991 and 1998.

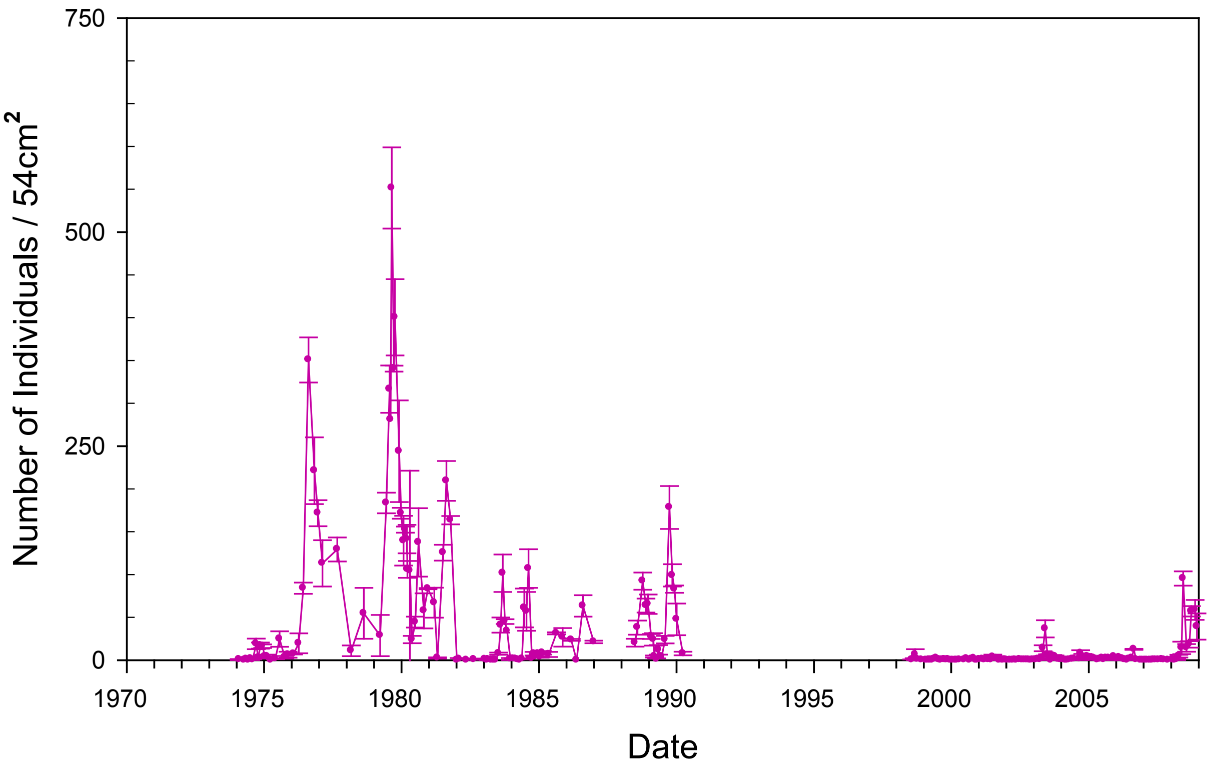
Figure 25. Monthly average abundance of *Mya arenaria*, 1974–2008.



EXPLANATION

Error bars represent standard deviation from 3 three replicate samplings. Collections were not made between 1991 and 1998.

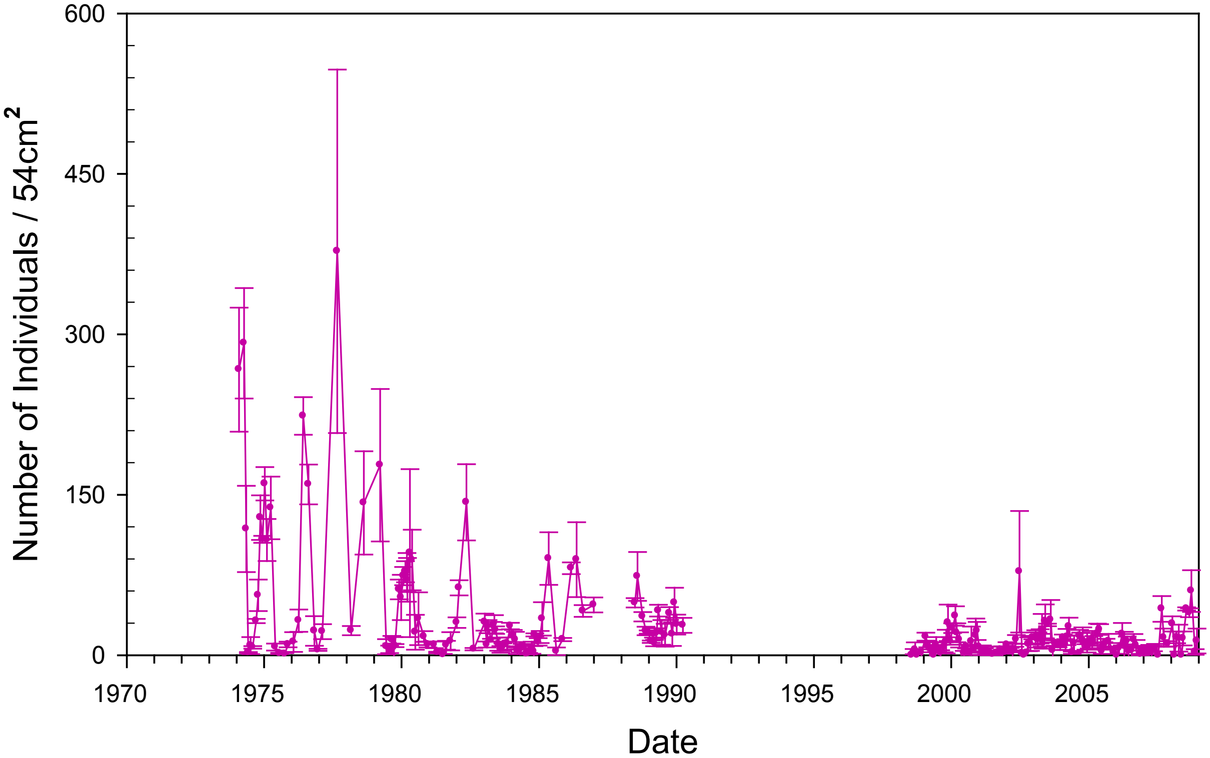
Figure 26. Monthly average abundance of *Gemma gemma*, 1974–2008.



EXPLANATION

Error bars represent standard deviation from three replicate samplings. Collections were not made between 1991 and 1998.

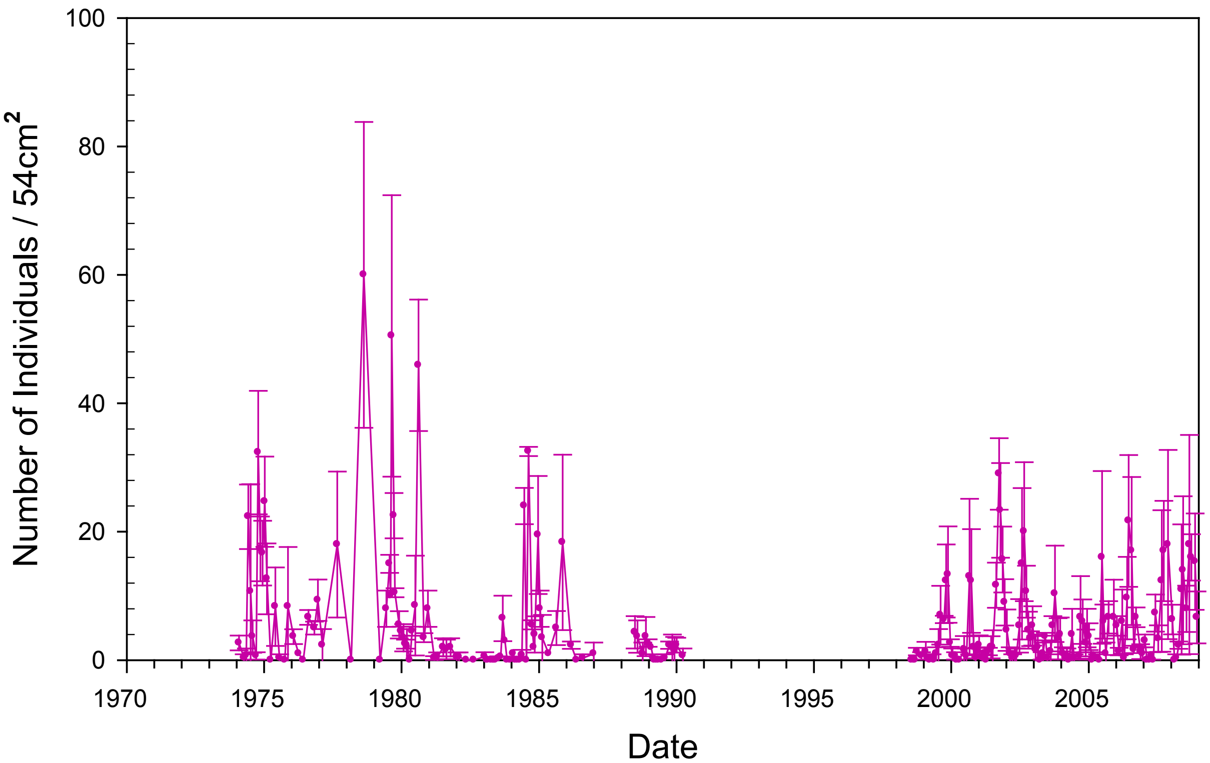
Figure 27. Monthly average abundance of *Ampelisca abdita*, 1974–2008.



EXPLANATION

Error bars represent standard deviation from three replicate samplings. Collections were not made between 1991 and 1998.

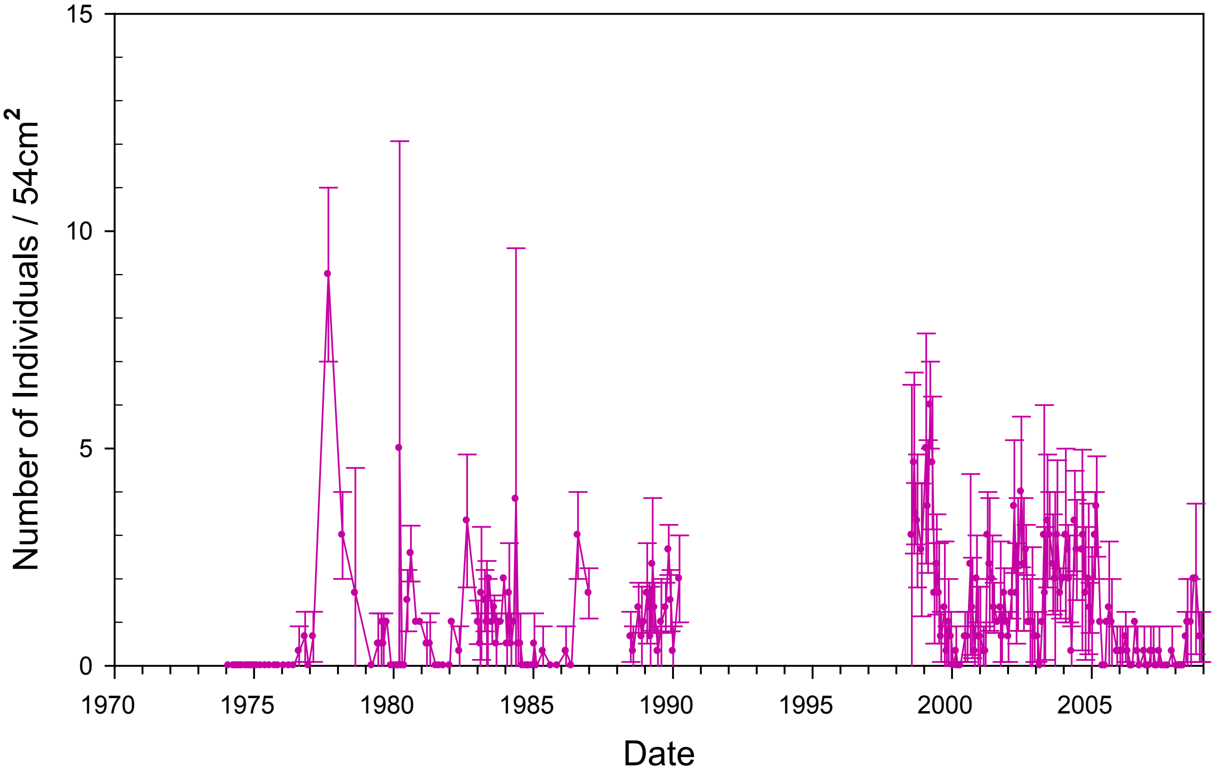
Figure 28. Monthly average abundance of *Streblospio benedicti*, 1974–2008.



EXPLANATION

Error bars represent standard deviation from three replicate samplings. Collections were not made between 1991 and 1998.

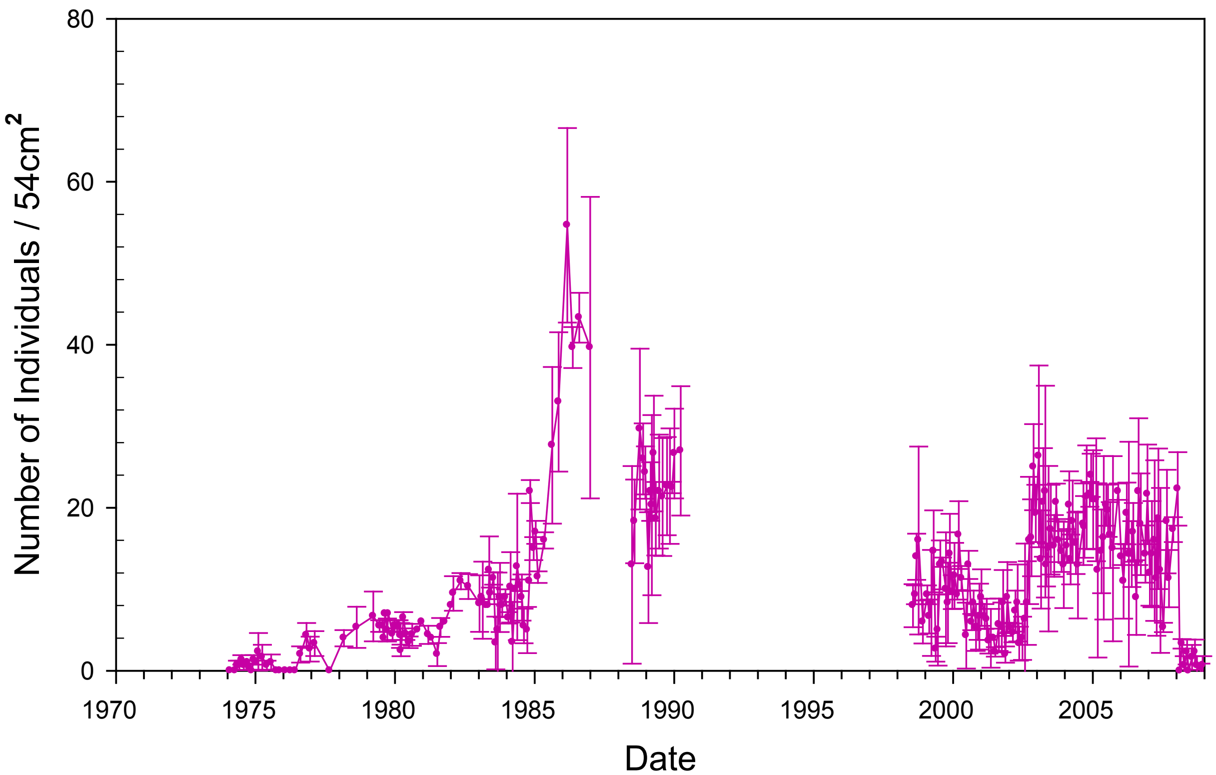
Figure 29. Monthly average abundance of *Grandiderella japonica*, 1974–2008.



EXPLANATION

Error bars represent standard deviation from three replicate samplings. Collections were not made between 1991 and 1998.

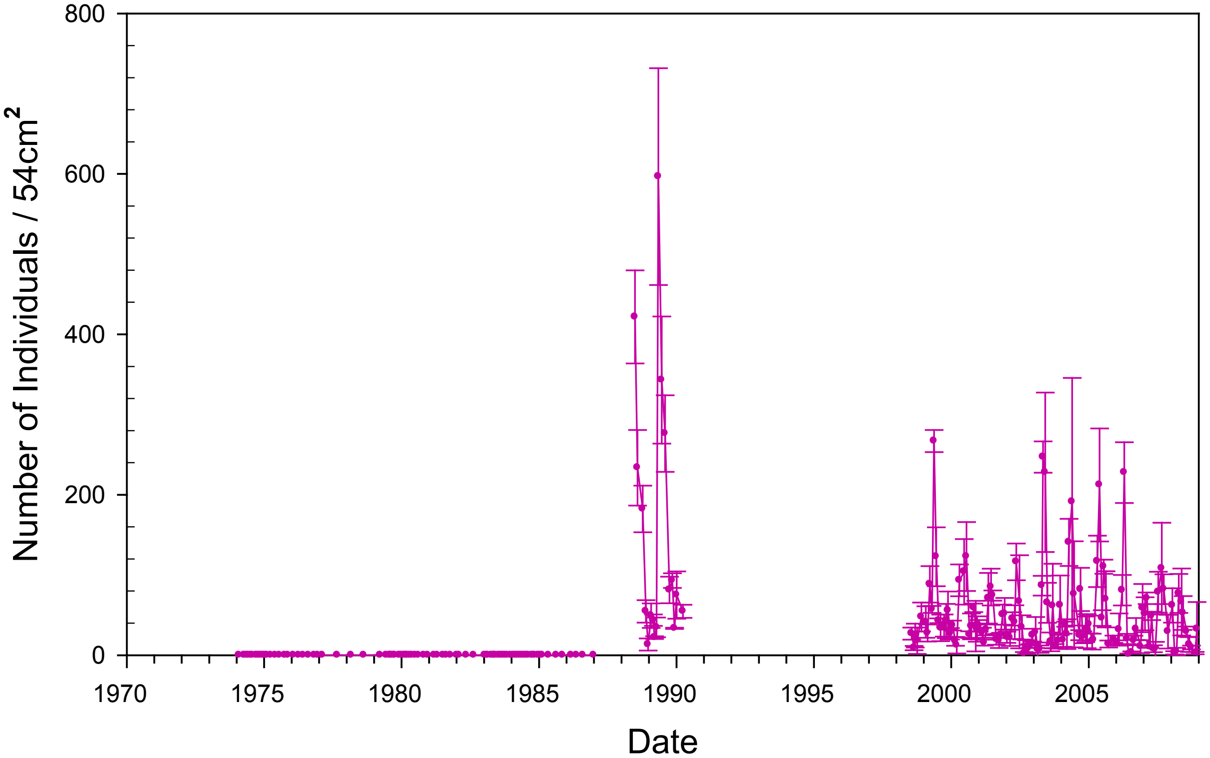
Figure 30. Monthly average abundance of *Neanthes succinea*, 1974–2008.



EXPLANATION

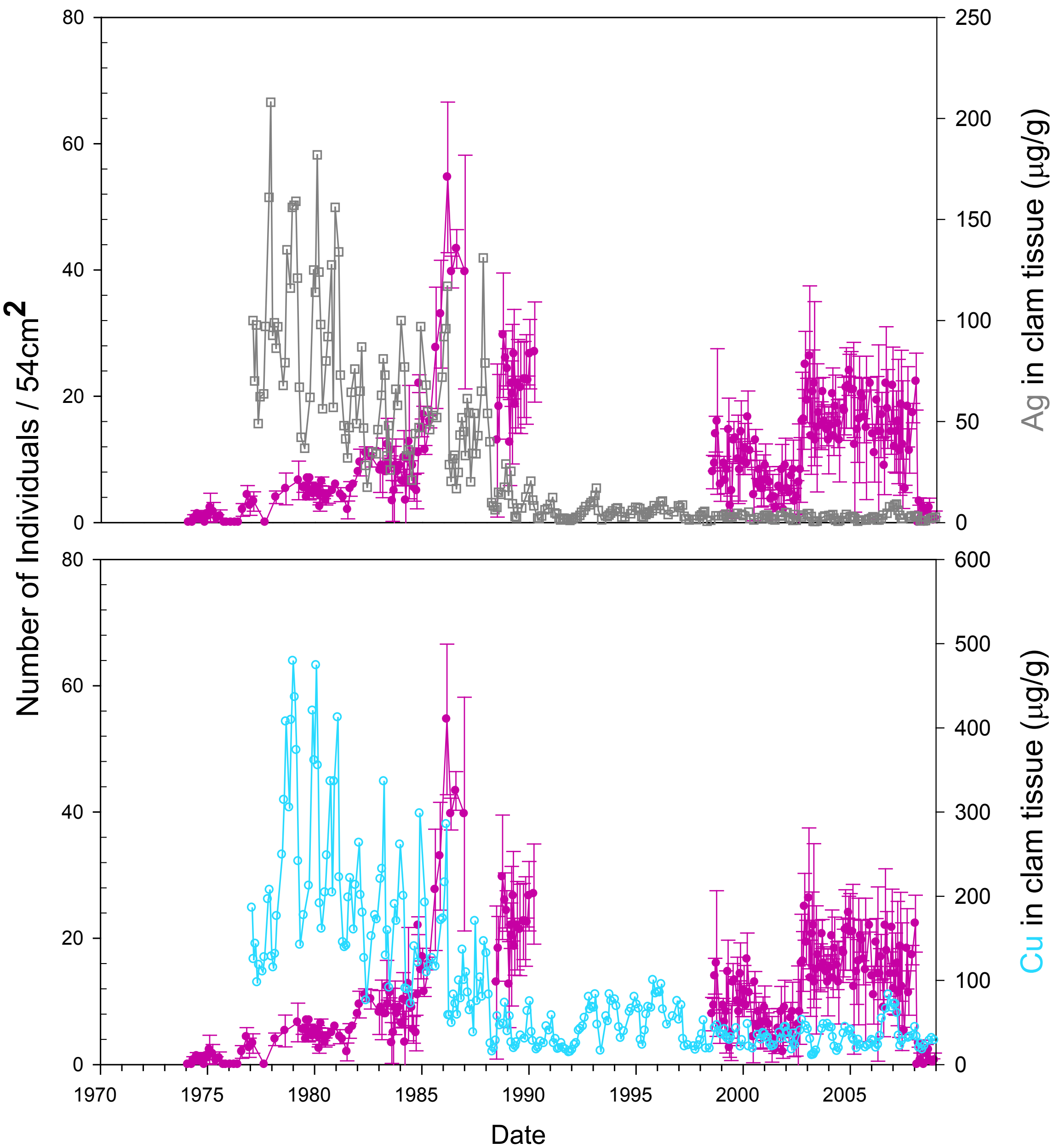
Error bars represent standard deviation from three replicate samplings. Collections were not made between 1991 and 1998.

Figure 31. Monthly average abundance of *Heteromastus filiformis*, 1974–2008.



EXPLANATION
Error bars represent standard deviation from three replicate samplings. Collections were not made between 1991 and 1998.

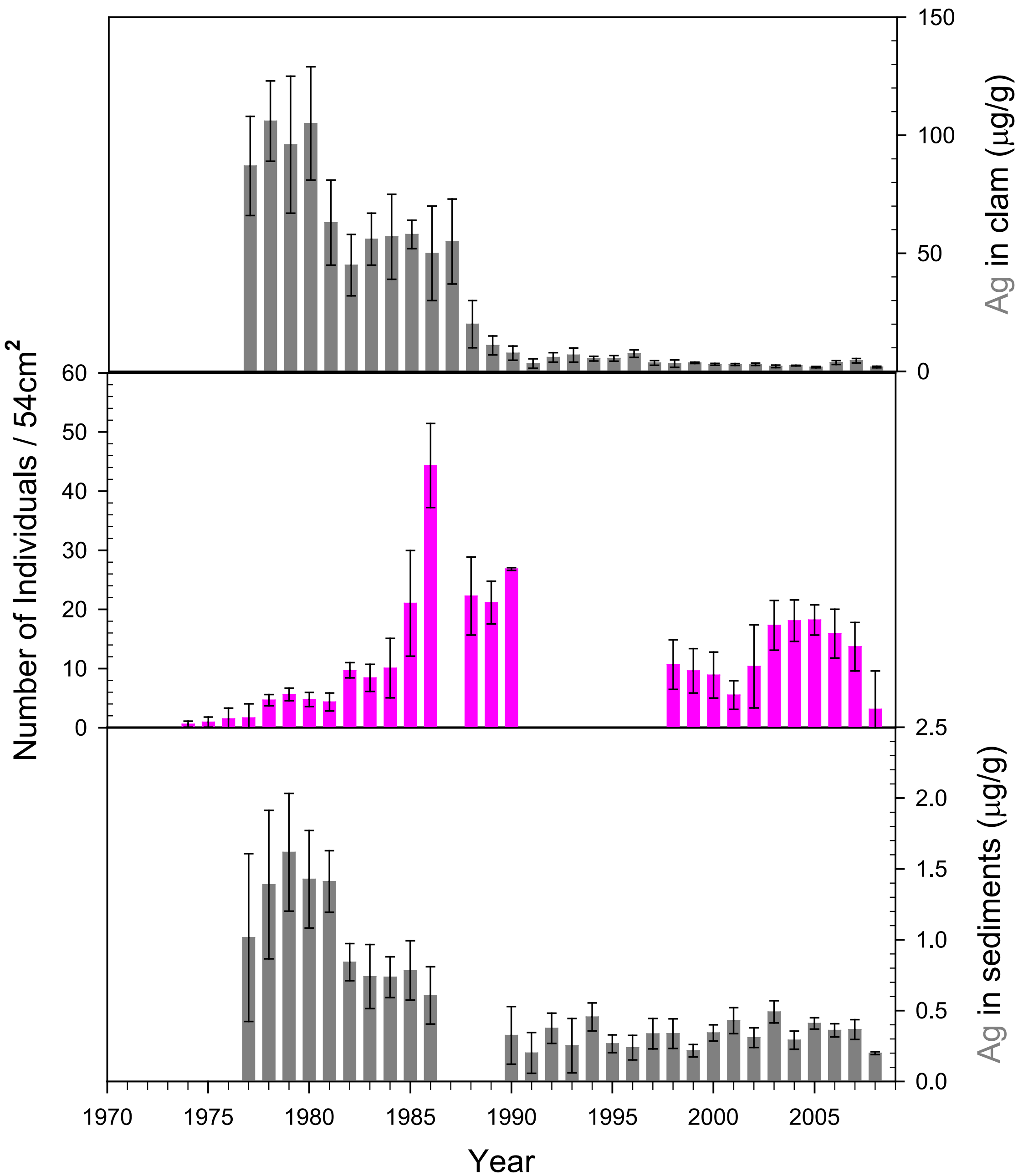
Figure 32. Monthly average abundance of *Nippoleucon hinumensis*, 1974–2008.



EXPLANATION

Error bars represent standard deviation from three replicate samplings. The number of individuals (●); tissue concentration of silver (□) and copper (○) in *M. petalum.*

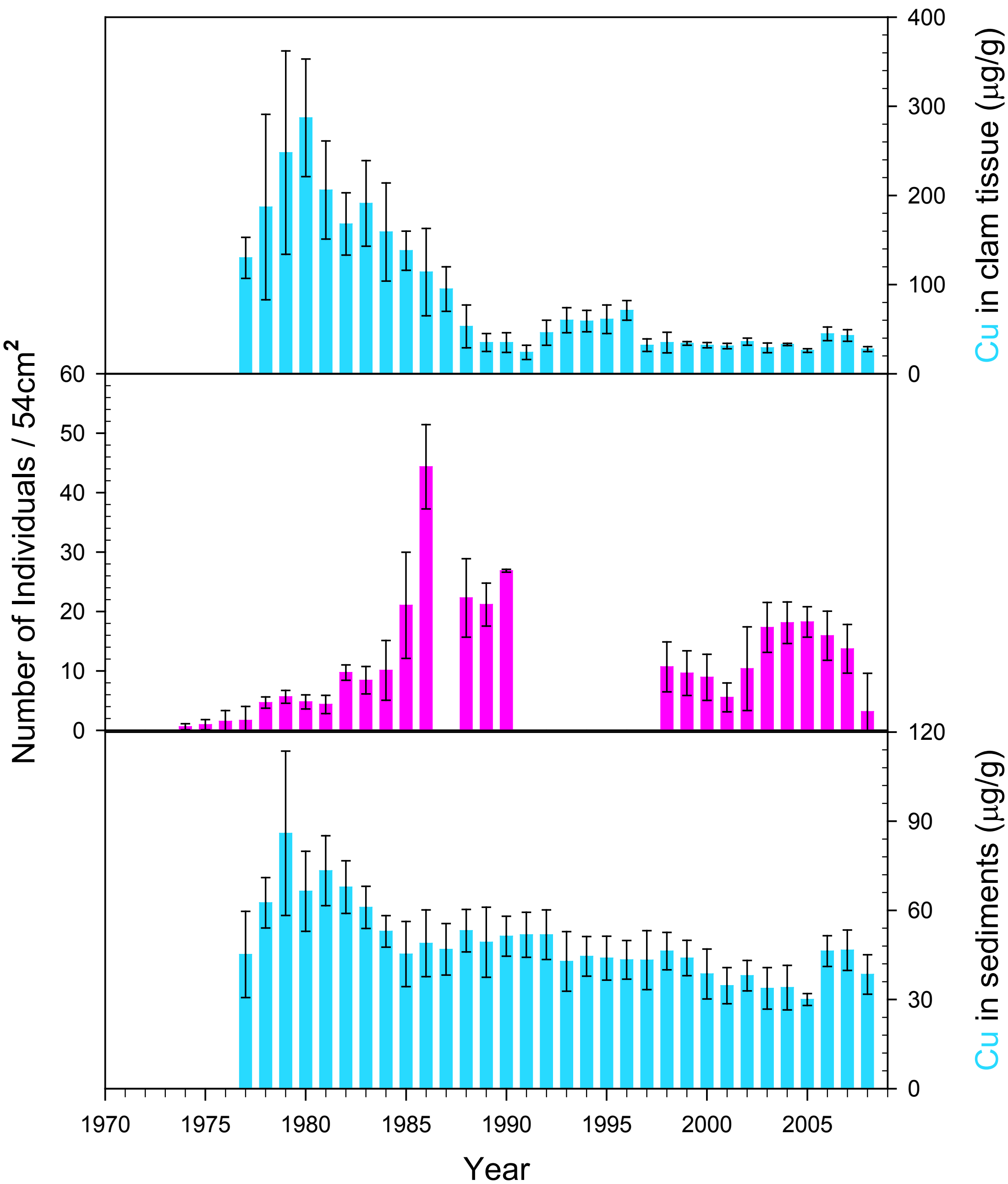
Figure 33. *Heteromastus filiformis* abundance with silver and copper in the clam *Macoma petalum*, 1974–2008.



EXPLANATION

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).

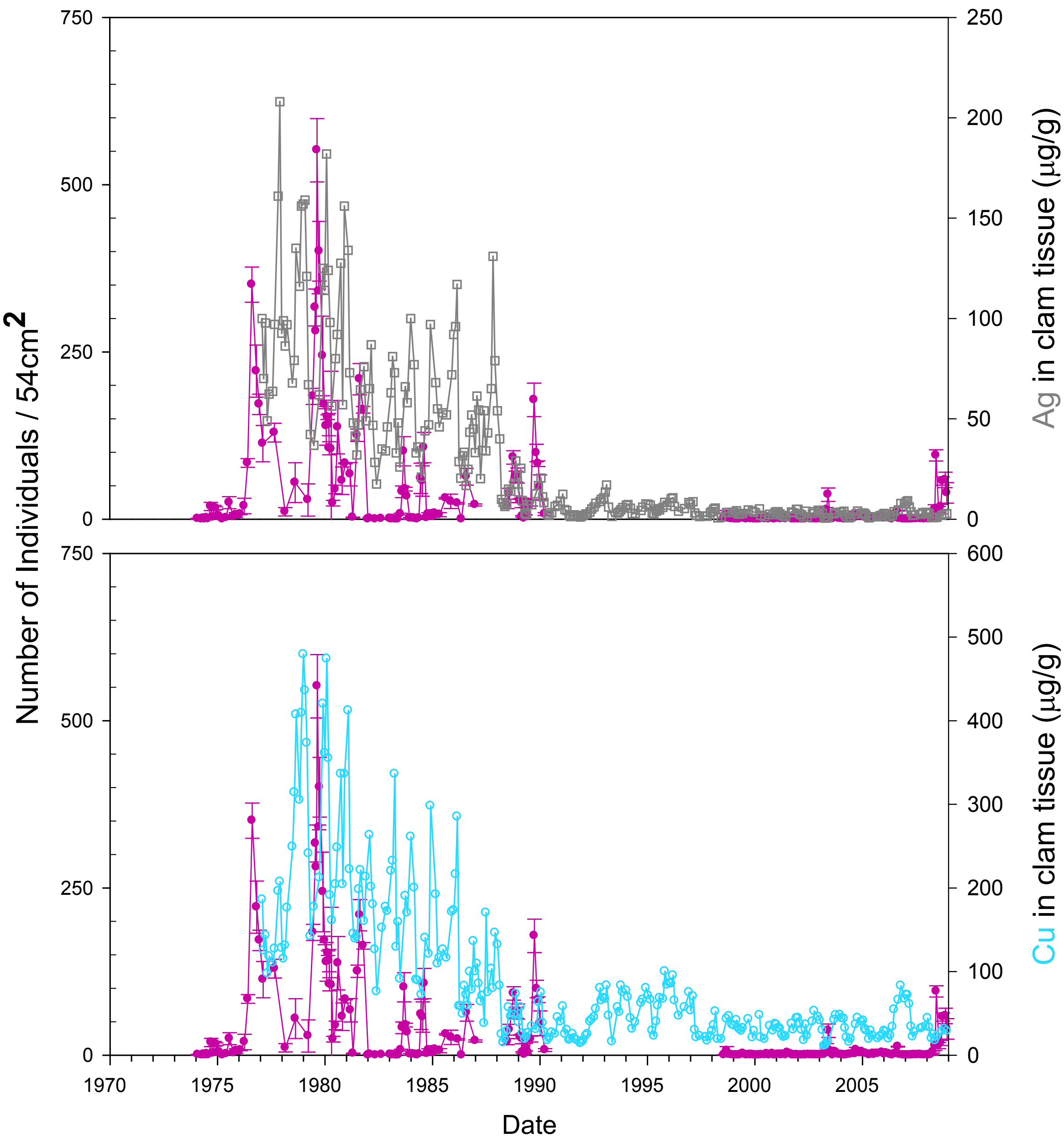
Figure 34. *Heteromastus filiformis* annual abundance with silver in the clam *Macoma petalum* and in sediment, 1974–2008.



EXPLANATION

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).

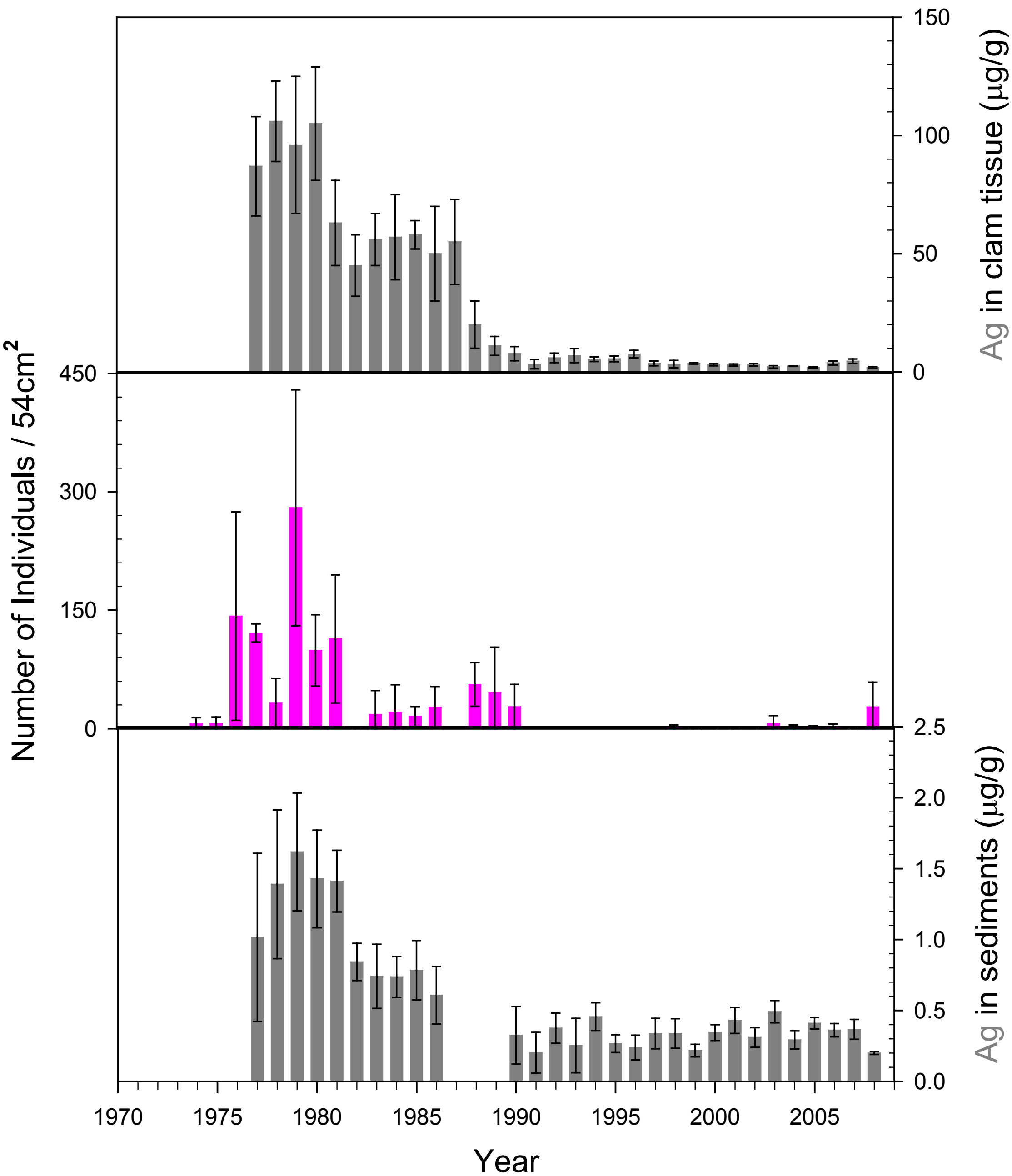
Figure 35. *Heteromastus filiformis* annual abundance with copper in the clam *Macoma petalum* and in sediment, 1974–2008.



EXPLANATION

Error bars represent standard deviation from 3 replicate samplings. Number of individuals (●) with silver (□) and copper (○) tissue concentrations in *Macoma petalum.*

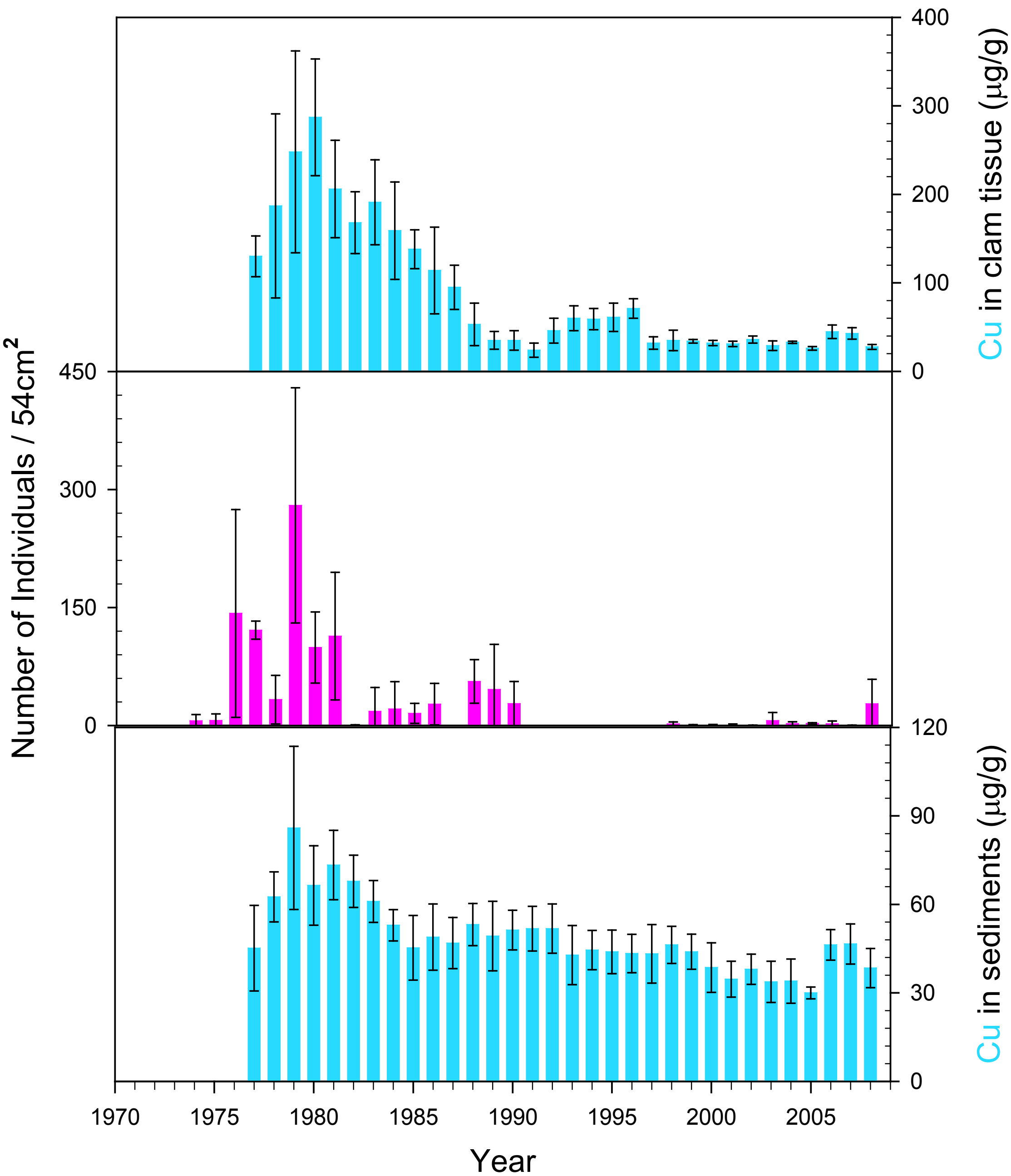
Figure 36. *Ampelisca abdita* abundance with silver and copper in the clam *Macoma petalum*, 1974–2008.



EXPLANATION

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).

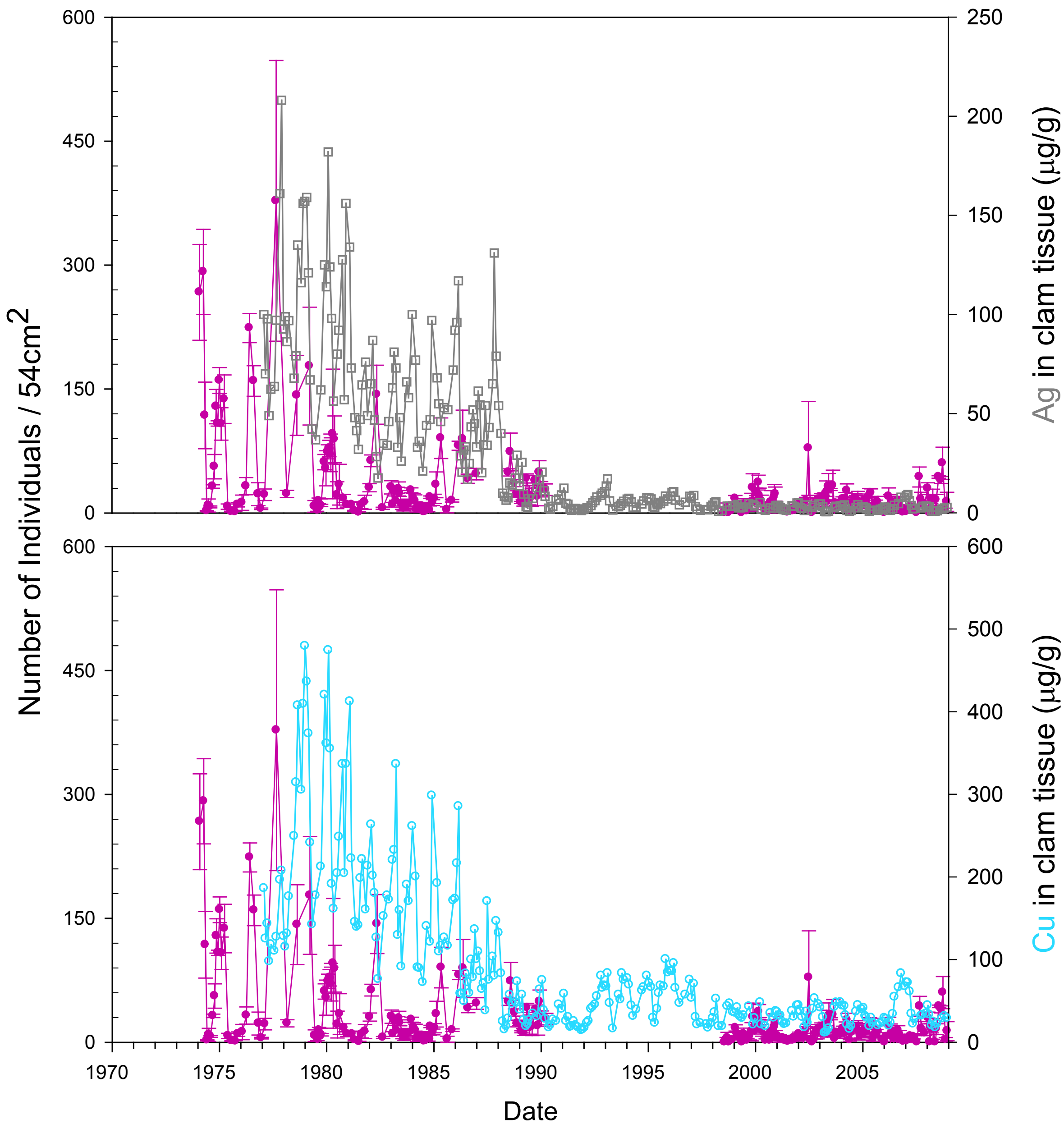
Figure 37. *Ampelisca abdita* annual abundance with silver in the clam *Macoma petalum* and in sediment, 1974–2008.



EXPLANATION

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).

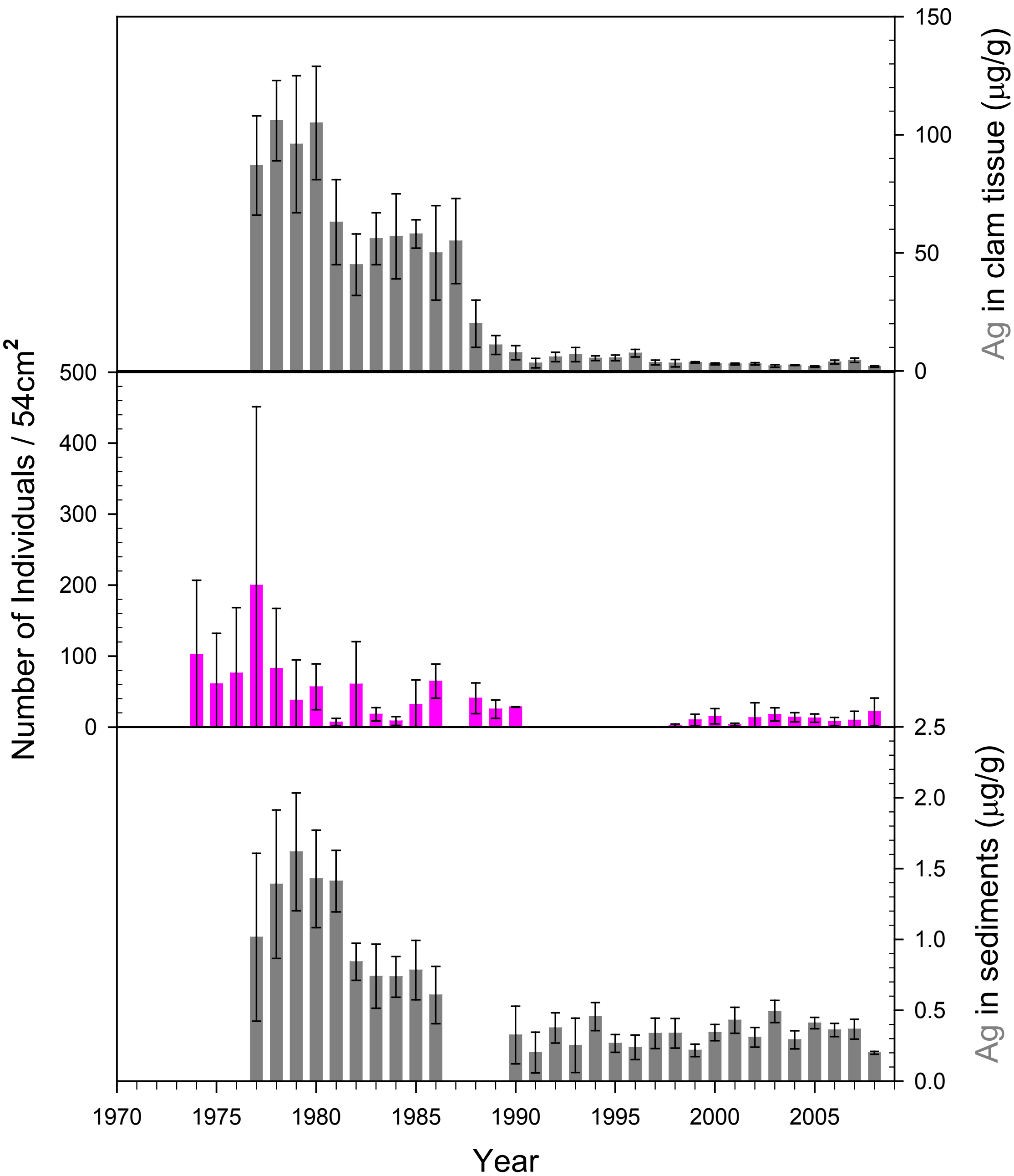
Figure 38. *Ampelisca abdita* annual abundance with copper in the clam *Macoma petalum* and sediment, 1974–2008.



EXPLANATION

Error bars represent standard deviation from 3 replicate samplings. Number of individuals (●) with silver (□) and copper (○) tissue concentrations in Macoma petalum.

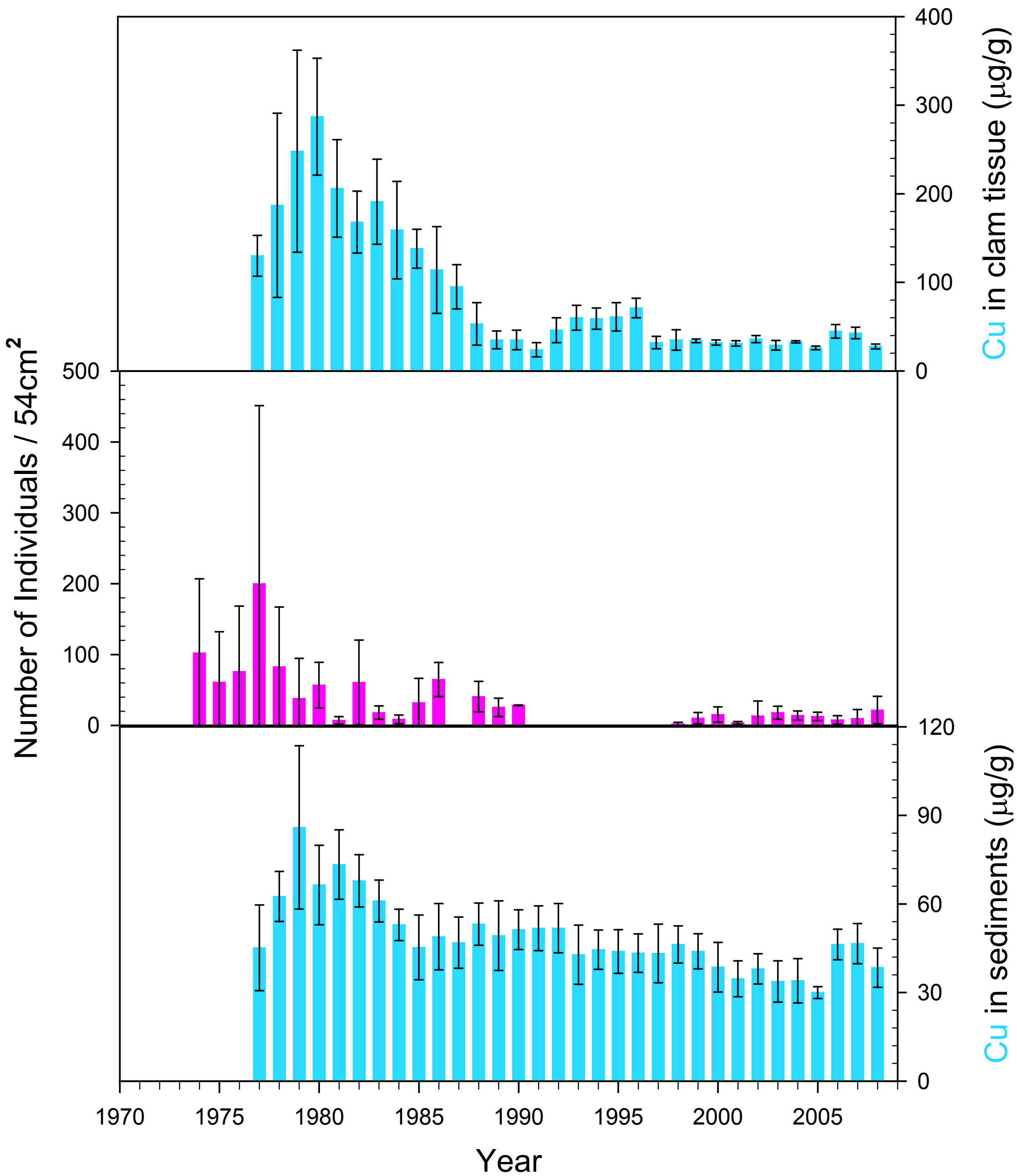
Figure 39. *Streblospio benedicti* abundance with silver and copper in the clam *Macoma petalum*, 1974–2008.



EXPLANATION

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).

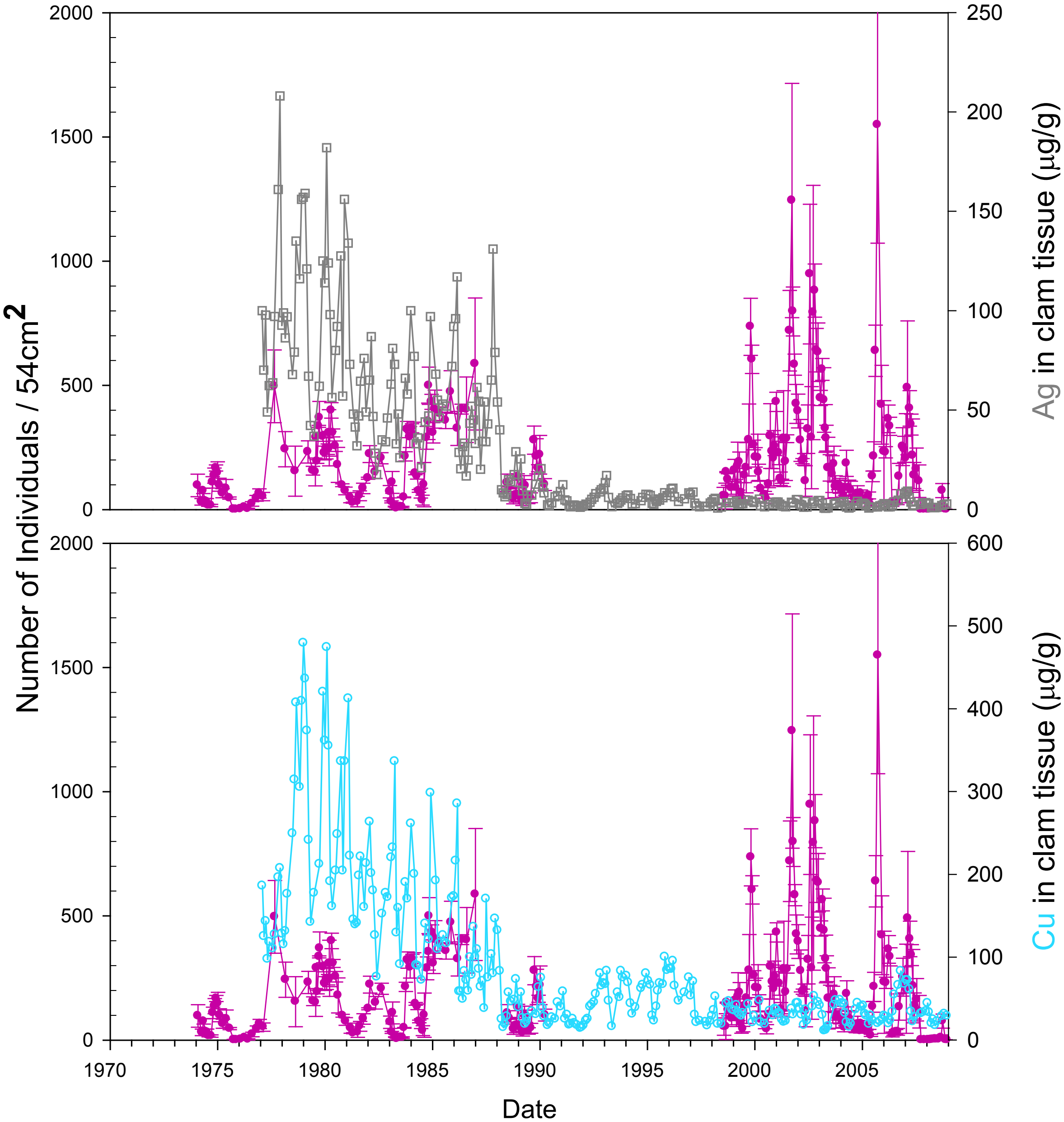
Figure 40. *Streblospio benedicti* annual abundance with silver in the clam *Macoma petalum* and in sediment, 1974–2008.



EXPLANATION

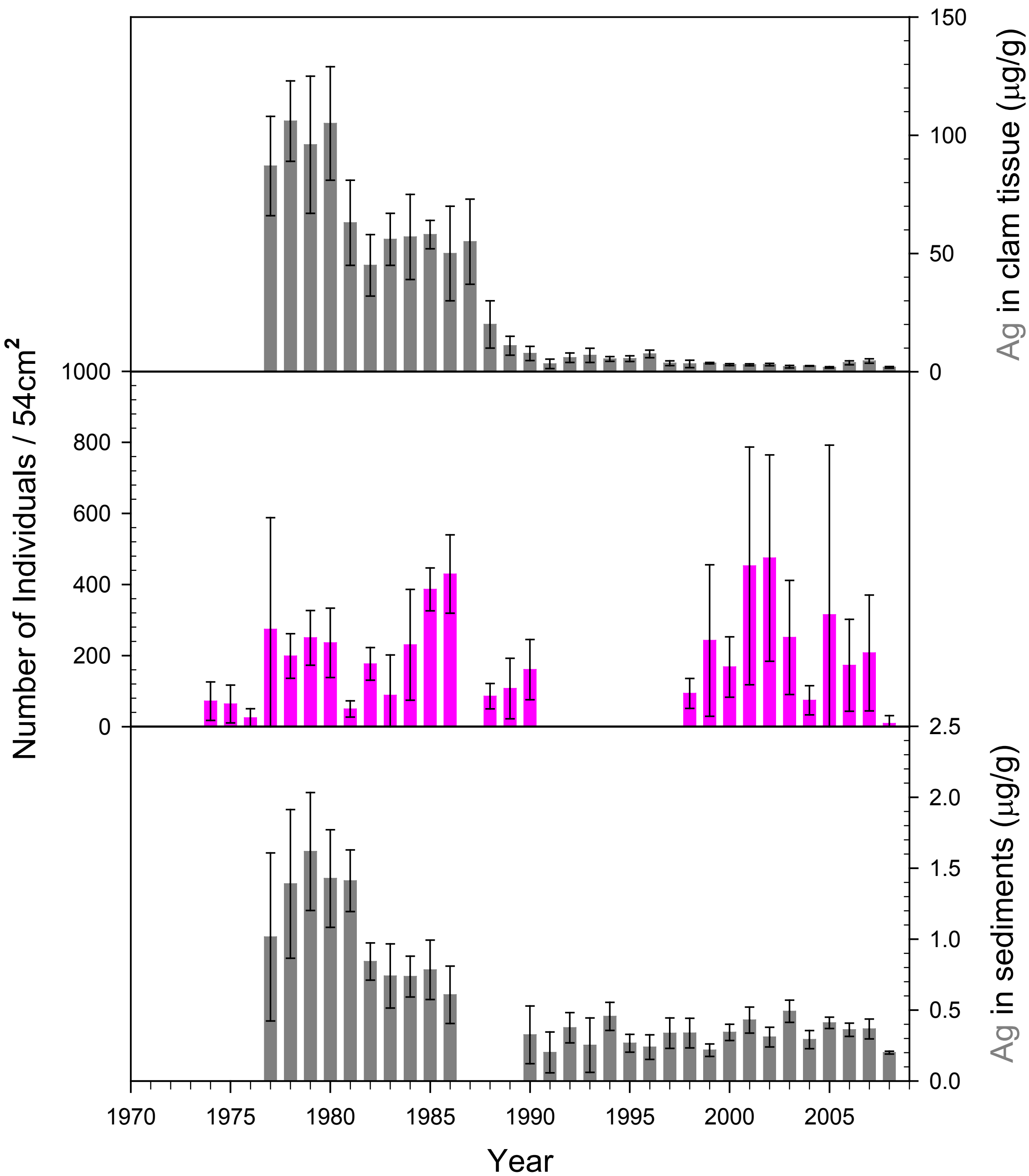
Error bars for abundance and metals in sediments are the standard deviation of the means. Error bars for metals in clams are the standard error of the mean (SEM).

Figure 41. *Streblospio benedicti* annual abundance with copper in the clam *Macoma petalum* and in sediment, 1974–2008.



EXPLANATION
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).

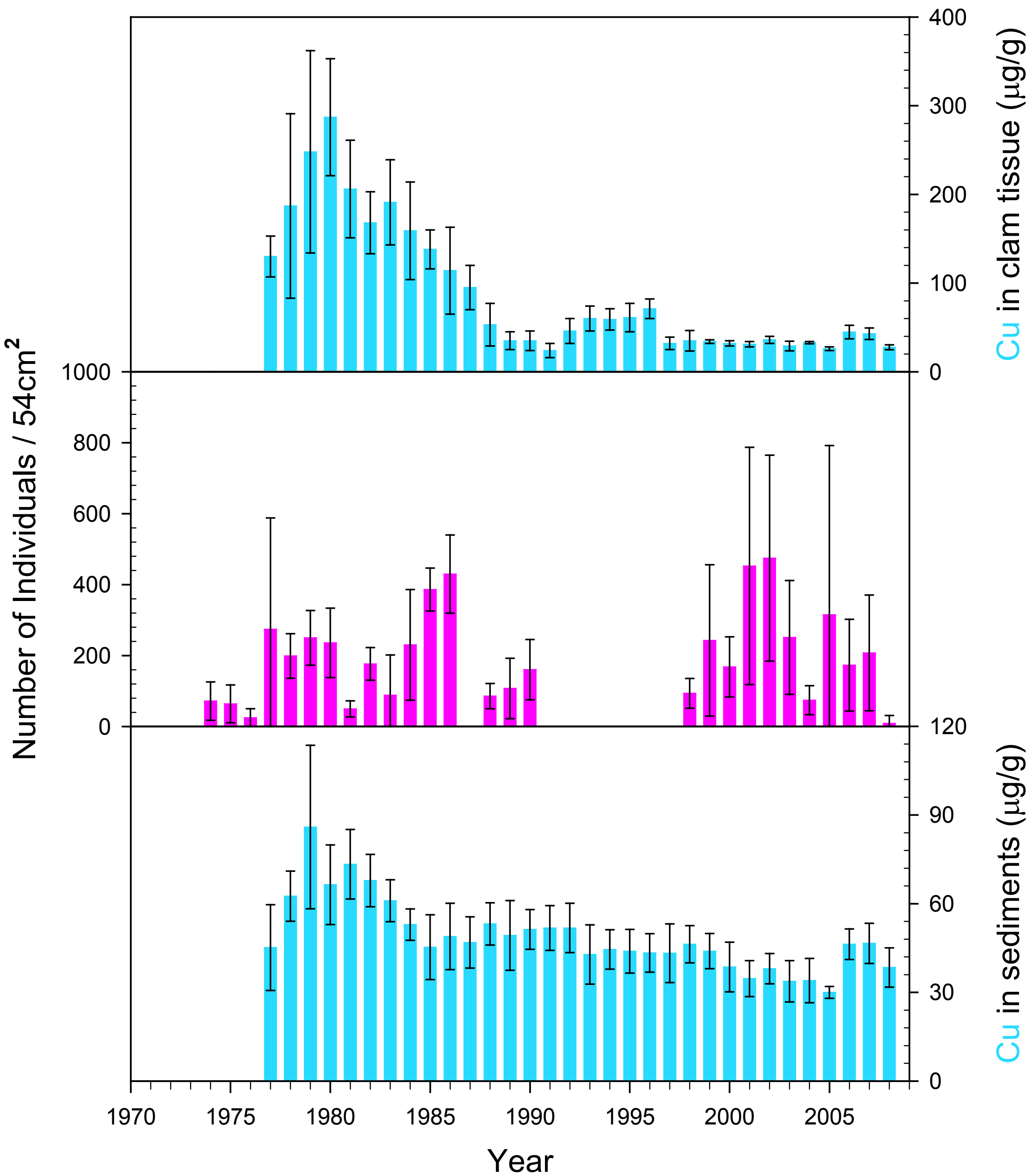
Figure 42. *Gemma gemma* abundance with silver and copper in the clam *Macoma petalum*, 1974–2008.



EXPLANATION

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 43. *Gemma gemma* annual abundance with silver in the clam *Macoma petalum* and in sediment, 1974–2008.



EXPLANATION

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 the clam *Macoma petalum* and in sediment, 1974–2008.

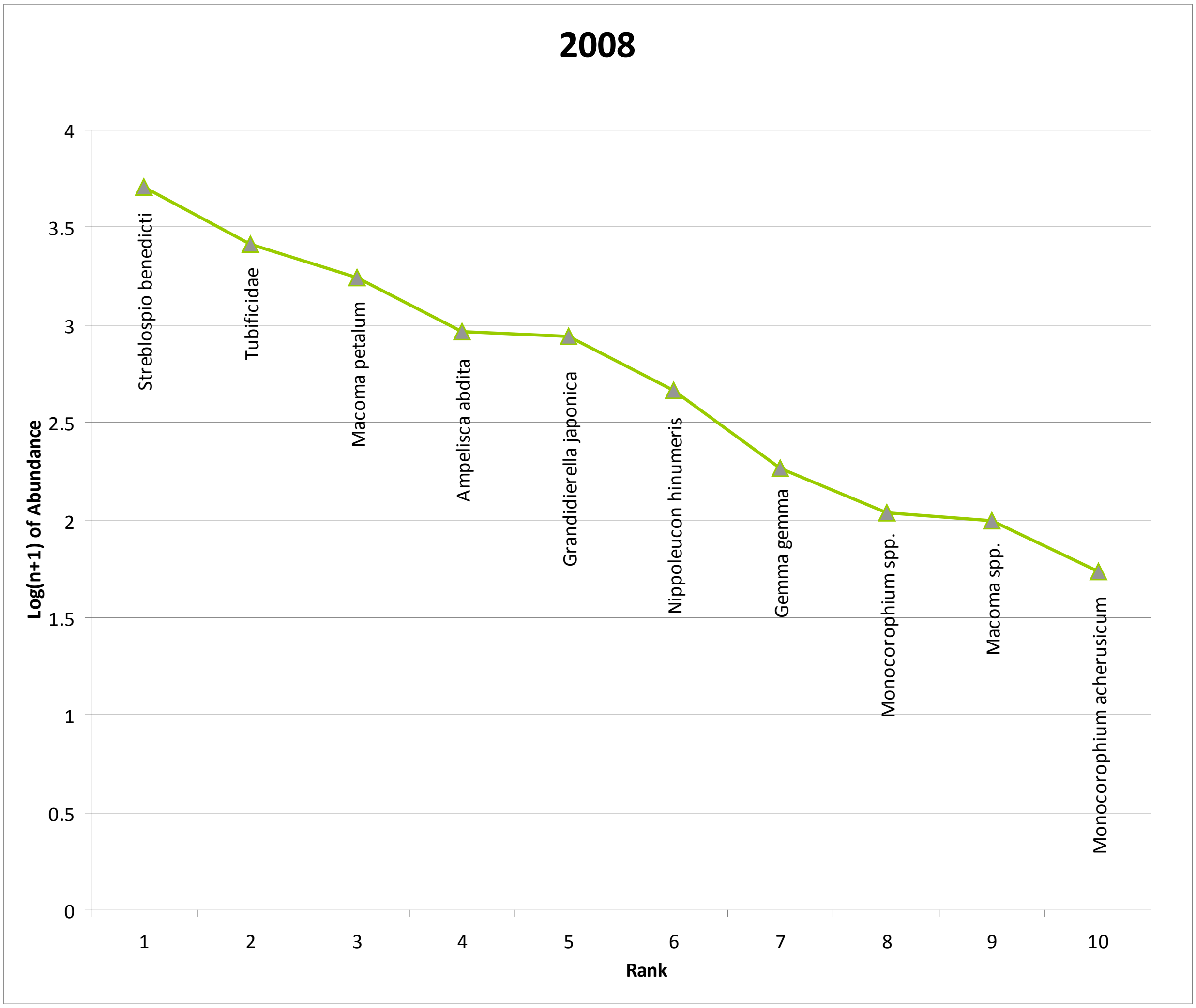
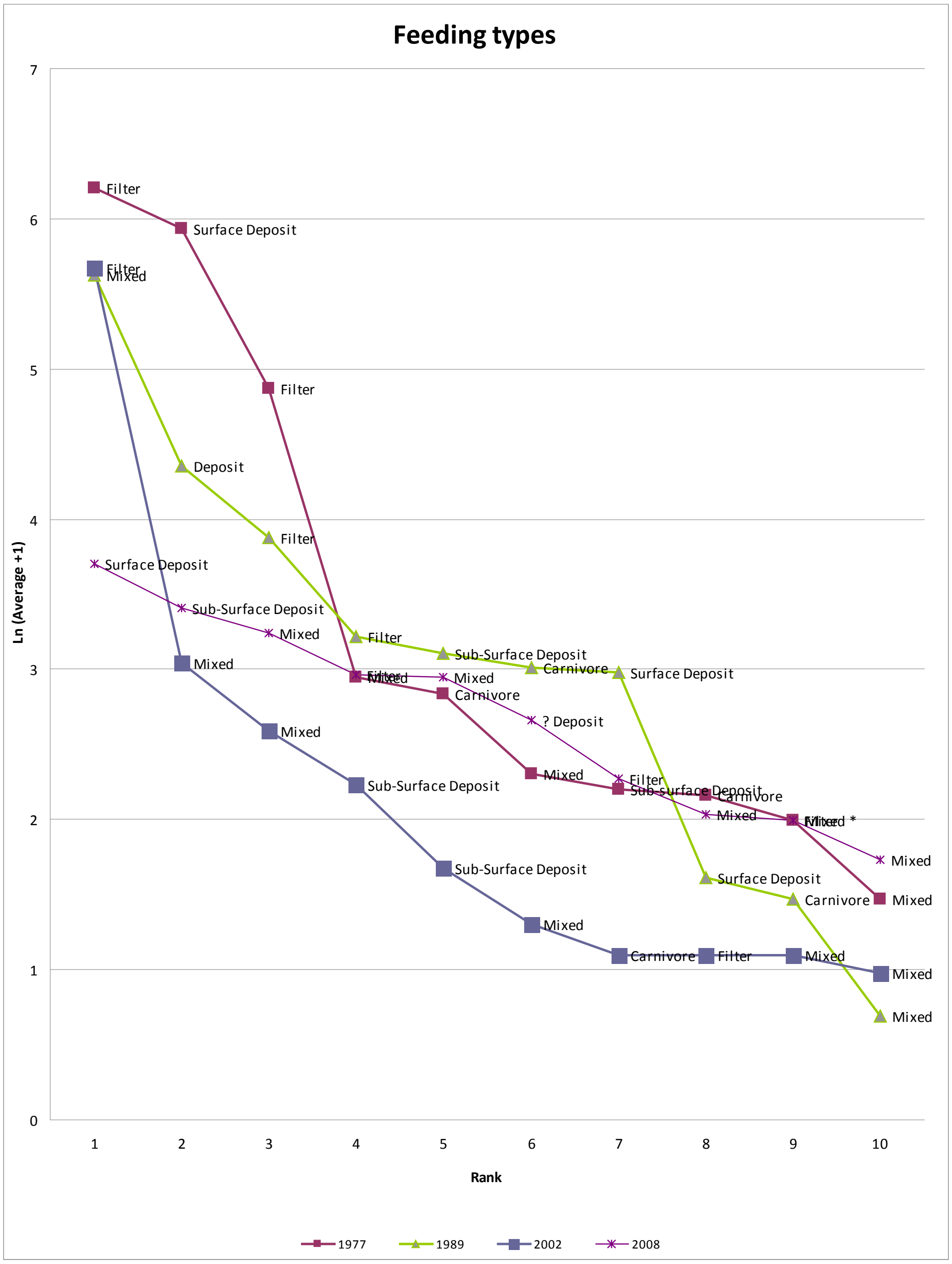


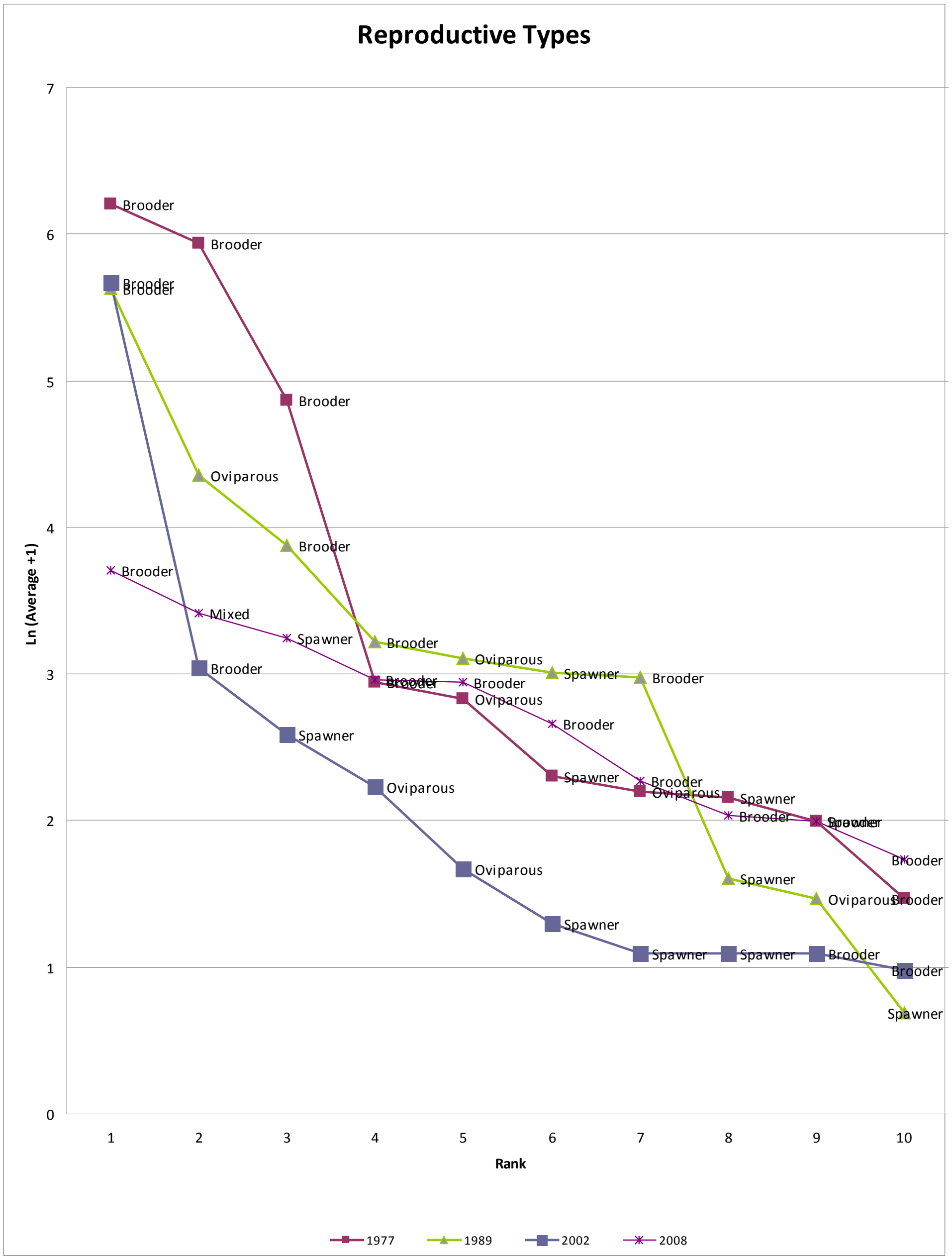
Figure 45. Species rank-abundance for the benthic community, 2008.



EXPLANATION

The feeding mode for each species at each rank is shown: Filter: filters food particles from water column; Deposit: ingests subsurface sediment and removes food from sediment in gut; Surface Deposit: ingests food particles on surface sediment; Mixed: capable of filter feeding and surface deposit feeding: Carnivore: predator on other fauna.

Figure 46. Species rank-abundance identified by feeding mode for 1977, 1989, 2002, and 2008.



EXPLANATION

Reproductive mode for each species at each rank is shown: Brooder: broods young and release juveniles as fully functional "miniature adults"; Oviparous: lays eggs in or on sediment; Spawner: releases gametes into water column and juveniles settle out of plankton onto sediment surface after growth in the plankton.

Figure 47. Species rank-abundance data identified by reproductive mode for 1977, 1989, 2002, and 2008.

Table 1. Sediment characteristics and salinity, 2008.

[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) for water pooled at the sediment surface during low tide. 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	Al (percent)		Fe (percent)		TOC (percent)	Sand (percent)	Salinity (ppt)
	mean	std	mean	std			
01/17/2007	6.1	0.0	4.9	0.1	1.21	27	25
02/13/ 2007	6.3	0.1	5.2	0.1	1.34	24	21
03/14/2007	6.5	0.2	5.3	0.0	1.55	13	22
04/11/2007	5.3	0.4	4.5	0.5	1.30	26	27
05/9/2007	5.0	1.3	4.3	1.0	1.14	19	29
06/05/2007	4.1	0.0	3.6	0.1	0.96	27	29
09/25/ 2007	4.0		3.7		0.68	59	31
10/24/2007	4.3	0.4	4.0	0.3	0.96	18	27
12/19/2007	4.6	0.2	4.2	0.1	0.98	15	28
Annual Mean:	5.1		4.4		1.12	25	27
sem:	0.3		0.2		0.09	5	1

Table 2. Concentrations of trace elements in sediments, 2008.

[Elemental concentrations for the monthly samples are reported as the mean ±1 standard deviation (std) for replicate subsamples (n=2). The standard deviation is not reported for a single measurement (n=1). 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 text section on Methods).]

Date	Ag		Cr		Cu		Hg	Ni		Se	V		Zn	
	mean	std	mean	std	mean	std	mean	mean	std	mean	mean	std	mean	std
January 16, 2008	0.19	0.002	156	0.3	42	0.5	0.62	96	0.5	0.8	156	3	145	1
February 12, 2008	0.17	0.001	152	2.4	45	2.5	0.26	99	0.5	0.7	162	3	150	1
March 25, 2008	0.22	0.002	159	3.3	48	0.4		105	0.8		165	1	160	1
April 21, 2008	0.23	0.010	133	12.3	39	3.6	0.265	93	5.8	0.95	143	12	137	8
May 21, 2008	0.19	0.002	143	10.7	44	0.6		98	3.5		165	1	148	6
June 24, 2008	0.14	0.007	112	3.6	31	0.4	0.26	76	0.9	0.8	123	0	112	1
September 16, 2008	0.20	0.001	120		29		0.23	72		0.6	121		109	
October 27, 2008	0.23	0.007	116	9.9	34	3.1		80	3.7		125	12	121	5
December 10, 2008	0.23	0.007	120	3.7	35	0.4	0.21	84	0.5	0.7	131	4	129	1
Annual Mean:	0.20		135		38		0.3	89		0.8	144		133	
SEM:	0.01		6		2		0.1	4		0.0	6		7	

Table 3. Annual mean copper concentration in sediments and the clam *Macoma petalum*, 1977—2008.

[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. HCl refers to hydrochloric acid extractable copper.]

	Copper in sediment		Copper in clams
Year	HCl	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
2006	18±2	46±2	45±8
2007	17±1	47±2	43±7
2008	13±1	38±2	28±3

Table 4. Annual mean silver in sediments and the clam *Macoma petalum*, 1977—2008.

[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. ND means No Data.]

Year	Silver in sediment	Silver in clams
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 ± 0.03	2.1 ± 0.5
2004	0.29 ± 0.06	2.4 ± 1.3
2005	0.41 ± 0.04	1.8 ± 0.3
2006	0.36 ± 0.05	3.8 ± 0.8
2007	0.37 ± 0.02	4.5 ± 0.9
2008	0.20 ± 0.01	1.8 ± 0.3

Table 5. Concentrations of trace elements in the clam *Macoma petalum*, 2008.

[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 (CI) is the soft tissue weight in milligrams of a clam of 25-mm shell length.]

Date		Ag	Cr	Cu	Hg	Ni	Se	Zn	Condition Index
1/16/2008	*mean*	2.8	4.1	44	0.34	7.1	5.9	363	102
	**sem*	0.3	0.3	6	0.01	0.5	0.1	20	
2/12/2008	*mean*	3.0	4.6	33	0.42	8.1	5.7	369	106
	**sem*	0.3	0.5	2	0.04	0.6	0.4	32	
3/25/2008	*mean*	0.9	2.0	20		4.3		232	202
	**sem*	0.1	0.2	1		0.2		9	
4/21/2008	*mean*	0.8	1.2	24	0.30	3.0	3.4	169	222
	**sem*	0.2	0.1	4	0.05	0.1	0.2	3	
5/21/2008	*mean*	0.8	1.3	18		3.3		186	196
	**sem*	0.1	0.2	1		0.3		16	
6/24/2008	*mean*	1.0	1.8	22	0.36	4.6	4.4	184	184
	**sem*	0.2	0.5	2	0.08	0.5	0.8	12	
9/16/2008	*mean*	2.0	2.9	28	0.40	6.3	4.2	239	106
	**sem*	0.2	0.5	2	0.04	0.6	0.3	23	
10/27/2008	*mean*	2.4	4.1	31		6.6		230	97
	**sem*	0.2	0.3	2		0.2		22	
12/10/2008	*mean*	2.7	4.8	29	0.41	7.0	5.4	286	115
	**sem*	0.2	0.5	1	0.05	0.6	0.4	22	
Annual Mean:		1.8	3.0	28	0.37	5.6	4.8	251	148
SEM:		0.3	0.5	3	0.02	0.6	0.4	25	17

Appendixes

Appendix A-1. Percent of sediment composed of clay- and silt-sized particles, 1994 -2008.

[Results are for percent fine-grained particles (silt and clay, <100 µm). Data for percent fines for 2004 (shaded) contain unquantifiable biases due to errors in sample processing. These data are shown for qualitative purposes only.]

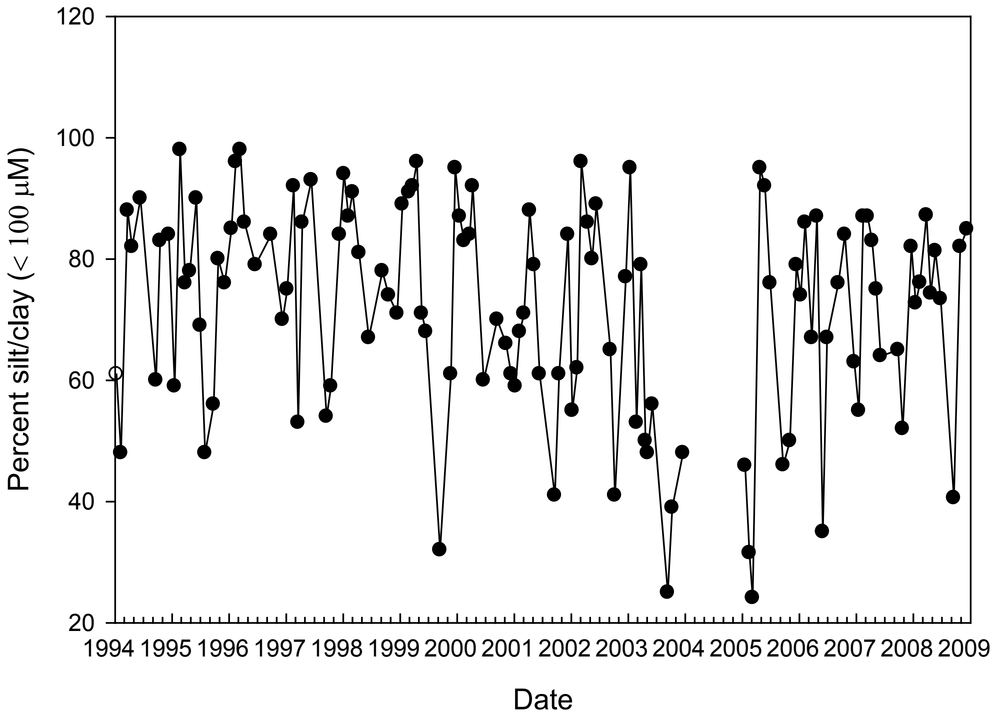
Year	Date	%<100µm
1994	01/10/94	61
	02/08/94	48
	03/22/94	88
	04/20/94	82
	06/13/94	90
	09/20/94	60
	10/17/94	83
	12/12/94	84
1995	01/18/95	59
	02/22/95	98
	03/27/95	76
	04/25/95	78
	06/06/95	90
	07/01/95	69
	08/01/95	48
	09/25/95	56
	10/24/95	80
	12/05/95	76
1996	01/17/96	85
	02/13/96	96
	03/13/96	98
	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	%<100µm
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	%<100µm
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
	10/01/05	50
	12/13/05	79
2006	01/09/06	74
	02/07/06	86
	03/22/06	67
	04/24/06	87
	05/31/06	35
	06/27/06	67
	09/07/06	76
	10/19/06	84
	12/18/06	63
2007	01/17/07	55
	02/13/07	87
	03/14/07	87
	04/11/07	83
	05/09/07	75
	06/05/07	64
	09/25/07	65
	10/24/07	52
	12/19/07	82
2008	01/16/08	73
	02/12/08	76
	03/25/08	87
	04/21/08	74
	05/21/08	81
	06/24/08	73
	09/16/08	41
	10/27/08	82
	12/10/08	85

Appendix A-2. Percent of sediment composed of clay- and silt-sized particles, 1994-2008.

[Results are for percent fine-grained particles (silt and clay, <100 µm). Data for2004 were not plotted (see Appendix A-1).



Appendix B. Total organic carbon (TOC) content (expressed as percent of dry weight) of sediment collected in 2008.

Date of collection	TOC (%)
1/16/2008	1.21
2/12/2008	1.34
3/25/2008	1.55
4/21/2008	1.30
5/21/2008	1.14
6/24/2008	0.96
9/16/2008	0.68
10/27/2008	0.96
12/10/2008	0.98

Appendix C. Metal concentrations in sediment samples collected at the Palo Alto mudflat during 2008.

[For each collection, replicate subsamples were digested in nitric acid (near-total metal extraction) and in dilute hydrochloric acid (partial metal extraction). The dry weight, reconstitution volume, and dilution factor (if applicable) are shown for each replicate and extraction method. 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 also reported.]

Near-total metal extractions

1/16/2008: 72.7% <100 µm					Concentration, µg/mL								
Sample	Weight (g)	Recon. (ml)	Dil. Factor		Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	0.4939	10	10		298	0.770	0.205	239	6.11	0.475	0.113	0.762	0.721
Tot2	0.4622	10	10		280	0.718	0.195	229	5.89	0.441	0.108	0.733	0.668
					Concentration, µg/g								
Tot1					60356	156	41.5	48350	1237	96.1	22.9	154	146
Tot2					60645	155	42.2	49546	1274	95.4	23.4	159	144
				Average	60501	156	41.9	48948	1256	95.7	23.2	156	145
				Std	204	0.3	0.5	846	26	0.5	0.3	3	1

2/12/2008: 76.1% < 100 µm					Concentration, µg/mL								
Sample	Weight (g)	Recon. (ml)	Dil. Factor		Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	0.5358	10	10		331	0.806	0.251	282	6.83	0.534	0.128	0.860	0.807
Tot2	0.4960	10	10		315	0.763	0.215	251	6.05	0.490	0.114	0.814	0.743
					Concentration, µg/g								
Tot1					61851	150	46.8	52688	1275	99.6	23.8	160	151
Tot2					63448	154	43.3	50645	1219	98.9	23.0	164	150
				Average	62650	152	45.0	51666	1247	99.2	23.4	162	150
				Std	1129	2	2.5	1444	40	0.5	0.6	3	1

3/25/2008: 87.2% <100 µm					Concentration, µg/mL								
Sample	Weight (g)	Recon. (ml)	Dil. Factor		Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	0.483	10	10		317	0.778	0.228	255	6.03	0.507	0.120	0.803	0.772
Tot2	0.4582	10	10		291	0.717	0.219	241	5.71	0.486	0.118	0.754	0.738
					Concentration, µg/g								
Tot1					65714	161	47.3	52816	1248	105	24.8	166	160
Tot2					63575	156	47.8	52510	1246	106	25.8	165	161
				Average	64645	159	47.5	52663	1247	105	25.3	165	160
				Std	1513	3	0.4	216	2	1	0.7	1	1

Near-total metal extractions, continued

4/21/2008: 74.3% <100 µm					Concentration, µg/mL								
Sample	Weight (g)	Recon. (ml)	Dil. Factor		Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	0.5035	10	10		251	0.624	0.185	212	5.23	0.448	0.108	0.678	0.661
Tot2	0.4943	10	10		275	0.698	0.207	240	5.88	0.481	0.117	0.751	0.708
					Concentration, µg/g								
Tot1					49831	124	36.7	42145	1038	89.0	21.5	135	131
Tot2					55715	141	41.8	48634	1189	97.2	23.7	152	143
				Average	52773	133	39.2	45390	1114	93.1	22.6	143	137
				Std	4161	12	3.6	4589	107	5.8	1.6	12	8

5/21/2008: 81.3% < 100 µm					Concentration, µg/mL								
Sample	Weight (g)	Recon. (ml)	Dil. Factor		Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	0.499	10	10		296	0.753	0.216	247	2.88	0.477	0.107	0.819	0.719
Tot2	0.1045	10	1		434	1.114	0.335	372	4.43	0.809	0.193	1.369	1.275
					Concentration, µg/g								
Tot1					59359	151	43.3	49439	578	95.5	21.5	164	144
Tot2					41569	107	32.0	35627	424	77.4	18.5	131	122
				Average	50464	129	37.7	42533	501	86.5	20.0	148	133
				Std	12579	31	8.0	9767	109	12.8	2.1	23	16

6/24/2008: 73.4% <100 µm					Concentration, µg/mL								
Sample	Weight (g)	Recon. (ml)	Dil. Factor		Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	0.4636	10	10		190	0.509	0.143	170	2.53	0.357	0.085	0.571	0.520
Tot2	0.4467	10	10		184	0.513	0.135	159	2.38	0.339	0.080	0.553	0.496
					Concentration, µg/g								
Tot1					40897	110	30.8	36756	546	77.1	18.4	123	112
Tot2					41124	115	30.3	35617	532	75.8	17.8	124	111
				Average	41011	112	30.6	36186	539	76.4	18.1	123	112
				Std	160	4	0.4	805	10	0.9	0.4	0	1

Near-total metal extractions, continued

9/16/2008: 40.6% <100 µm					Concentration, µg/mL								
Sample	Weight (g)	Recon. (ml)	Dil. Factor		Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	lost												
Tot2	0.4326	10	10		175	0.520	0.126	162	3.95	0.311	0.079	0.523	0.470
					Concentration, µg/g								
Tot2					40499	120.134	29.057	37332	912.16	71.798	18.354	120.851	108.692
				Average	40499	120	29.1	37332	912	71.8	18.4	121	109
				Std									

10/27/2008: 82.0% <100 µm					Concentration, µg/mL								
Sample	Weight (g)	Recon. (ml)	Dil. Factor		Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	0.5175	10	10		240	0.635	0.188	216	5.21	0.425	0.106	0.692	0.649
Tot2	0.5459	10	10		221	0.593	0.174	205	5.02	0.420	0.103	0.638	0.642
					Concentration, µg/g								
Tot1					46435	123	36.2	41778	1006	82.2	20.5	134	125
Tot2					40520	109	31.8	37498	920	76.9	18.8	117	118
				Average	43478	116	34.0	39638	963	79.5	19.6	125	121
				Std	4182	10	3.1	3026	61	3.7	1.2	12	5

12/10/2008: 84.9% <100 µm					Concentration, µg/mL								
Sample	Weight (g)	Recon. (ml)	Dil. Factor		Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	0.5311	10	10		252	0.653	0.185	225	6.82	0.444	0.108	0.711	0.681
Tot2	0.5507	10	10		247	0.648	0.189	226	6.86	0.464	0.113	0.707	0.710
					Concentration, µg/g								
Tot1					47505	123	34.9	42290	1285	83.6	20.4	134	128
Tot2					44816	118	34.3	40966	1246	84.3	20.6	128	129
				Average	46160	120	34.6	41628	1265	83.9	20.5	131	129
				Std	1902	4	0.4	936	28	0.5	0.1	4	1

Partial metal extraction

1/16/2008				Concentration, µg/mL									
Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.5274	10		0.0100	82.9	0.213	0.723	212	31.2	0.276	0.849	0.397	1.655
HCL2	0.5230	10		0.0097	104	0.259	0.911	265	38.7	0.333	1.035	0.487	2.015
				Concentration, µg/g									
HCl1				0.19	1572	4.03	13.7	4022	592	5.24	16.1	7.52	31.4
HCl2				0.19	1989	4.94	17.4	5059	739	6.37	19.8	9.31	38.5
			Average	0.19	1780	4.49	15.6	4540	666	5.80	17.9	8.41	35.0
			Std	0.002	208	0.45	1.9	519	73	0.56	1.8	0.89	3.6

2/12/2008				Concentration, µg/mL									
Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.5484	10		0.0093	103	0.256	0.880	257	34.0	0.326	0.970	0.497	1.989
HCL2	0.5286	10		0.0091	102	0.256	0.862	255	34.1	0.321	0.956	0.487	1.964
				Concentration, µg/g									
HCl1				0.17	1884	4.67	16.1	4685	619	5.94	17.7	9.06	36.3
HCl2				0.17	1937	4.84	16.3	4824	644	6.07	18.1	9.21	37.2
			Average	0.17	1910	4.76	16.2	4754	632	6.01	17.9	9.13	36.7
			Std	**0.001**	**27**	**0.08**	**0.1**	**70**	**13**	**0.07**	**0.2**	**0.08**	**0.4**

3/25/2008				Concentration, µg/mL									
Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.5293	10		0.0120	92.7	0.253	0.807	259	28.8	0.335	0.910	0.441	1.94
HCL2	0.5134	10		0.0114	80.5	0.226	0.691	226	24.9	0.293	0.800	0.386	1.70
				Concentration, µg/g									
HCl1				0.227	1751	4.77	15.2	4899	544	6.32	17.2	8.33	36.6
HCl2				0.222	1568	4.40	13.5	4400	485	5.71	15.6	7.52	33.1
			Average	0.22	1660	4.59	14.4	4650	515	6.01	16.4	7.93	34.8
			Std	0.002	91	0.18	0.9	249	29	0.31	0.8	0.40	1.8

Partial metal extraction, continued

4/21/2008				Concentration, µg/mL									
Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.5348	10		0.0115	77.5	0.209	0.658	200	26.2	0.261	0.768	0.358	1.53
HCL2	0.3143	10		0.0074	75.3	0.200	0.651	194	25.5	0.255	0.758	0.349	1.56
				Concentration, µg/g									
HCl1				0.215	1449	3.91	12.3	3743	490	4.87	14.4	6.68	28.6
HCl2				0.235	2396	6.35	20.7	6176	812	8.13	24.1	11.11	49.7
			Average	0.23	1923	5.13	16.5	4960	651	6.50	19.2	8.90	39.2
			Std	0.01	473	1.22	4.2	1216	161	1.63	4.9	2.21	10.5

5/21/2008				Concentration, µg/mL									
Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.4427	10		0.0085	66.6	0.170	0.654	174	6.21	0.218	0.689	0.307	1.49
HCL2	0.5326	10		0.0105	79.5	0.199	0.810	207	7.53	0.260	0.816	0.371	1.78
				Concentration, µg/g									
HCl1				0.192	1504	3.84	14.8	3919	140	4.93	15.6	6.94	33.6
HCl2				0.196	1493	3.73	15.2	3892	141	4.88	15.3	6.97	33.3
			Average	0.19	1498	3.78	15.0	3906	141	4.91	15.4	6.95	33.5
			Std	0.002	5	0.06	0.2	13	1	0.02	0.1	0.01	0.1

6/24/2008				Concentration, µg/mL									
Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.5046	10		0.0073	65.7	0.167	0.594	164	10.4	0.231	0.640	0.310	1.41
HCl2	0.5241	10		0.0068	67.3	0.171	0.606	169	10.6	0.232	0.661	0.312	1.39
				Concentration, µg/g									
HCl1				0.145	1303	3.31	11.8	3256	206	4.57	12.7	6.15	27.9
HCl2				0.130	1285	3.26	11.6	3219	202	4.43	12.6	5.95	26.5
			Average	0.14	1294	3.28	11.7	3237	204	4.50	12.7	6.05	27.2
			Std	0.01	9	0.03	0.1	19	2	0.07	0.0	0.10	0.7

Partial metal extraction, continued

9/16/2008				Concentration, µg/mL									
Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.5158	10		0.0105	62.3	0.143	0.555	154	21.6	0.234	0.665	0.281	1.32
HCl2	0.5163	10		0.0105	62.7	0.155	0.574	156	22.3	0.233	0.674	0.282	1.34
				Concentration, µg/g									
HCl1				0.203	1208	2.77	10.8	2986	419	4.53	12.9	5.46	25.5
HCl2				0.204	1215	3.00	11.1	3016	433	4.51	13.0	5.46	26.0
			Average	0.20	1211	2.89	10.9	3001	426	4.52	13.0	5.46	25.7
			Std	0.001	4	0.11	0.2	15	7	0.01	0.1	0.00	0.2

10/27/2008				Concentration, µg/mL									
Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.5209	10		0.0121	61.1	0.154	0.597	142	21.5	0.205	0.690	0.275	1.27
HCl2	0.5338	10		0.0117	64.2	0.145	0.627	149	22.9	0.214	0.716	0.286	1.34
				Concentration, µg/g									
HCl1				0.232	1173	2.95	11.5	2726	414	3.93	13.2	5.27	24.4
HCl2				0.219	1203	2.71	11.7	2788	429	4.01	13.4	5.35	25.1
			Average	0.23	1188	2.83	11.6	2757	421	3.97	13.3	5.31	24.8
			Std	0.01	15	0.12	0.1	31	8	0.04	0.1	0.04	0.4

12/10/2008				Concentration, µg/mL									
Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.529	10		0.0119	74.9	0.189	0.664	190	33.8	0.255	0.786	0.353	1.568
HCl2	0.291	10		0.0069	43.9	0.103	0.374	113	19.0	0.158	0.470	0.206	0.927
				Concentration, µg/g									
HCl1				0.225	1415	3.58	12.5	3590	639	4.81	14.9	6.68	29.6
HCl2				0.239	1507	3.53	12.8	3887	653	5.42	16.1	7.09	31.9
			Average	0.23	1461	3.56	12.7	3738	646	5.12	15.5	6.89	30.8
			Std	0.01	46	0.02	0.1	148	7	0.30	0.6	0.21	1.1

Appendix D. 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 the following 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 100 mg 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 20-mm and 25-mm animals, respectively.

Soft-tissue weights for animals having shell lengths of 15, 20, and 25mm shell length were predicted from a linear regression of log tissue dry weight vs. log average shell length for each monthly collection. Predicted tissue weights for a 25-mm clam defined the condition index (CI), which was used to interpret the physiological condition of the population Content (a measure of metal bioaccumulation that is standardized to tissue mass) is shown for 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: 1/16/2008

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	2.8157	0.2630	4.0778	44.1707	7.1185	1.8119	3.5524	362.6492
STD	0.9772	0.0299	1.1033	17.7626	1.6096	0.3037	0.9458	63.6198
SEM	0.309	0.009	0.349	5.617	0.509	0.096	0.299	20.118
CV%	34.704	11.368	27.057	40.214	22.612	16.759	26.625	17.543
n	10	10	10	10	10	10	10	10
r wt x [ ]	0.353	0.372	0.405	0.356	0.417	0.383	0.418	0.365
X 100mg	1.965	0.193	2.500	31.177	4.848	1.232	2.401	291.451
r l x [ ]	0.417	0.449	0.485	0.413	0.495	0.456	0.496	0.436
X 20mm	4.487	0.382	5.778	69.269	9.567	2.638	4.770	510.481
X 25mm	1.528	0.152	1.855	25.963	3.999	0.972	1.974	248.895

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

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
20mm	0.1279	0.0123	0.1747	2.0276	0.3169	0.0828	0.1563	17.2968
25mm	0.2301	0.0217	0.2915	3.6986	0.5433	0.1443	0.2670	31.3923

Estimated weight for 15mm clam

0.017 g
17.032 mg

Estimated weight for 20mm clam

0.047 g
46.580 mg

Estimated weight for 25mm clam

0.102 g
101.650 mg

Station: Palo Alto

Date: 1/16/2008

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (g)	Average Dry Wt (g)	Recon Vol (mL)	Concentration (ug/ml) - Blank Corrected from ICP-AES Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mp1	8.44	0.03	0.0060	10	0.0108	0.0008	0.0126	0.1602	0.0180	0.0057	0.0090	0.9551
Mp2	9.46	0.1167	0.0058	10	0.0261	0.0035	0.0721	0.5660	0.1110	0.0273	0.0633	4.7950
Mp3	10.60	0.0964	0.0080	10	0.0233	0.0028	0.0441	0.3046	0.0809	0.0188	0.0401	4.0810
Mp4	11.25	0.1233	0.0103	10	0.0266	0.0033	0.0502	0.3553	0.0978	0.0202	0.0434	4.0810
Mp5	12.96	0.1157	0.0129	10	0.0393	0.0033	0.0610	0.4898	0.1078	0.0240	0.0508	4.3640
Mp6	20.38	0.1397	0.0466	10	0.0666	0.0041	0.0473	1.2430	0.0906	0.0279	0.0437	4.2830
Mp7	23.62	0.2227	0.0742	10	0.0779	0.0052	0.0963	0.9958	0.1612	0.0396	0.0901	8.9330
Mp8	24.56	0.1546	0.0773	10	0.0219	0.0036	0.0464	0.6102	0.0784	0.0259	0.0424	7.2890
Mp9	25.36	0.2012	0.1006	10	0.0488	0.0043	0.0501	0.6873	0.1179	0.0269	0.0468	5.4180
Mp10	26.86	0.1378	0.1378	10	0.0309	0.0034	0.0452	0.4098	0.0741	0.0197	0.0384	4.3720
				LOD	0.0006644	0.0001293	0.0043649	0.0081328	0.0003005	0.0009378	0.000368	0.0029356
				LOQ	0.0013288	0.0002586	0.0087299	0.0162655	0.000601	0.0018756	0.000736	0.0058712

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	Mp1	3.6000	0.2667	4.2000	53.4000	6.0000	1.9000	3.0000	318.367
	Mp2	2.2365	0.2999	6.1782	48.5004	9.5116	2.3393	5.4242	410.883
	Mp3	2.4170	0.2905	4.5747	31.5975	8.3921	1.9502	4.1598	423.340
	Mp4	2.1573	0.2676	4.0714	28.8159	7.9319	1.6383	3.5199	330.981
	Mp5	3.3967	0.2852	5.2723	42.3336	9.3172	2.0743	4.3907	377.182
	Mp6	4.7674	0.2935	3.3858	88.9764	6.4853	1.9971	3.1281	306.586
	Mp7	3.4980	0.2335	4.3242	44.7149	7.2384	1.7782	4.0458	401.123
	Mp8	1.4166	0.2329	3.0013	39.4696	5.0712	1.6753	2.7426	471.475
	Mp9	2.4254	0.2137	2.4901	34.1600	5.8598	1.3370	2.3260	269.284
	Mp10	2.2424	0.2467	3.2801	29.7388	5.3774	1.4296	2.7866	317.271

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	Mp1	0.0216	0.0016	0.0252	0.3204	0.0360	0.0114	0.0180	1.9102
	Mp2	0.0131	0.0018	0.0361	0.2830	0.0555	0.0137	0.0317	2.3975
	Mp3	0.0194	0.0023	0.0368	0.2538	0.0674	0.0157	0.0334	3.4008
	Mp4	0.0222	0.0028	0.0418	0.2961	0.0815	0.0168	0.0362	3.4008
	Mp5	0.0437	0.0037	0.0678	0.5442	0.1198	0.0267	0.0564	4.8489
	Mp6	0.2220	0.0137	0.1577	4.1433	0.3020	0.0930	0.1457	14.2767
	Mp7	0.2597	0.0173	0.3210	3.3193	0.5373	0.1320	0.3003	29.7767
	Mp8	0.1095	0.0180	0.2320	3.0510	0.3920	0.1295	0.2120	36.4450
	Mp9	0.2440	0.0215	0.2505	3.4365	0.5895	0.1345	0.2340	27.0900
	Mp10	0.3090	0.0340	0.4520	4.0980	0.7410	0.1970	0.3840	43.7200

Station: Palo Alto

Date: 2/12/2008

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	3.0293	0.2538	4.6026	33.0413	8.1307	1.7234	4.1999	369.3157
STD	1.0449	0.0328	1.7462	7.5605	1.8330	0.6873	1.5630	105.4908
SEM	0.315	0.010	0.526	2.280	0.553	0.207	0.471	31.807
CV%	34.492	12.922	37.940	22.882	22.544	39.880	37.215	28.564
n	11	11	11	11	11	11	11	11
r wt x [ ]	0.556	0.415	0.555	0.259	0.132	0.120	0.544	0.538
X 100mg	3.434	0.244	3.927	34.405	7.962	1.666	3.607	329.728
r l x [ ]	0.691	0.356	0.474	0.390	0.011	0.024	0.458	0.422
X 20mm	3.139	0.252	4.477	33.488	8.134	1.726	4.092	362.582
X 25mm	3.677	0.243	3.861	35.685	8.149	1.738	3.559	329.463

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

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
20mm	0.1651	0.0133	0.2093	1.7713	0.4229	0.0852	0.1915	18.0971
25mm	0.3739	0.0253	0.3586	3.6481	0.8247	0.1625	0.3301	32.5578

Estimated weight for 15mm clam	Estimated weight for 20mm clam
0.022 g	0.054 g
22.345 mg	53.595 mg

Estimated weight for 25mm clam

0.106 g
105.643 mg

Station: Palo Alto

Date: 2/12/2008

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (g)	Average Dry Wt (g)	Recon Vol (mL)	Concentration (ug/ml) - Blank Corrected from ICP-AES: Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mp1	10.20	0.1109	0.0074	10	0.0274	0.0032	0.0590	0.3682	0.0939	0.0193	0.0533	5.2730
Mp2	11.39	0.1221	0.0094	10	0.0287	0.0032	0.0491	0.3323	0.0842	0.0164	0.0424	4.9110
Mp3	12.56	0.1345	0.0122	10	0.0305	0.0035	0.0731	0.3828	0.1073	0.0243	0.0711	5.4420
Mp4	13.29	0.1548	0.0155	10	0.0330	0.0040	0.0885	0.4687	0.1319	0.0280	0.0820	5.7600
Mp5	14.67	0.132	0.0220	10	0.0212	0.0034	0.0950	0.3793	0.1193	0.0271	0.0806	4.4370
Mp6	19.15	0.1654	0.0414	10	0.0601	0.0046	0.0815	0.6547	0.1462	0.0289	0.0768	7.6630
Mp7	23.23	0.0914	0.0914	10	0.0390	0.0017	0.0157	0.2184	0.0473	0.0102	0.0134	3.7960
Mp8	24.56	0.1181	0.1181	10	0.0370	0.0024	0.0618	0.4193	0.0965	0.0174	0.0566	2.8760
Mp9	25.78	0.1069	0.1069	10	0.0495	0.0031	0.0369	0.5219	0.0971	0.0172	0.0359	2.5030
Mp10	26.64	0.1087	0.1087	10	0.0479	0.0029	0.0651	0.4480	0.1285	0.0379	0.0593	5.6300
Mp11	27.34	0.1538	0.1538	10	0.0373	0.0037	0.0249	0.4083	0.0838	0.0119	0.0233	3.0410

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
LOD	0.0006644	0.0001293	0.0043649	0.0081328	0.0003005	0.0009378	0.000368	0.0029356
LOQ	0.0013288	0.0002586	0.0087299	0.0162655	0.000601	0.0018756	0.000736	0.0058712

Concentration (ug/g) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mp1	2.4707	0.2885	5.3201	33.2011	8.4671	1.7403	4.8061	475.473
Mp2	2.3505	0.2621	4.0213	27.2154	6.8960	1.3432	3.4726	402.211
Mp3	2.2677	0.2602	5.4349	28.4610	7.9777	1.8067	5.2862	404.610
Mp4	2.1318	0.2584	5.7171	30.2778	8.5207	1.8088	5.2972	372.093
Mp5	1.6061	0.2576	7.1970	28.7348	9.0379	2.0530	6.1061	336.136
Mp6	3.6336	0.2781	4.9274	39.5828	8.8392	1.7473	4.6433	463.301
Mp7	4.2670	0.1860	1.7177	23.8950	5.1751	1.1160	1.4661	415.317
Mp8	3.1329	0.2032	5.2329	35.5038	8.1710	1.4733	4.7925	243.522
Mp9	4.6305	0.2900	3.4518	48.8213	9.0833	1.6090	3.3583	234.144
Mp10	4.4066	0.2668	5.9890	41.2144	11.8215	3.4867	5.4554	517.939
Mp11	2.4252	0.2406	1.6190	26.5475	5.4486	0.7737	1.5150	197.724

Content (ug) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mp1	0.0183	0.0021	0.0393	0.2455	0.0626	0.0129	0.0355	3.5153
Mp2	0.0221	0.0025	0.0378	0.2556	0.0648	0.0126	0.0326	3.7777
Mp3	0.0277	0.0032	0.0665	0.3480	0.0975	0.0221	0.0646	4.9473
Mp4	0.0330	0.0040	0.0885	0.4687	0.1319	0.0280	0.0820	5.7600
Mp5	0.0353	0.0057	0.1583	0.6322	0.1988	0.0452	0.1343	7.3950
Mp6	0.1503	0.0115	0.2038	1.6368	0.3655	0.0723	0.1920	19.1575
Mp7	0.3900	0.0170	0.1570	2.1840	0.4730	0.1020	0.1340	37.9600
Mp8	0.3700	0.0240	0.6180	4.1930	0.9650	0.1740	0.5660	28.7600
Mp9	0.4950	0.0310	0.3690	5.2190	0.9710	0.1720	0.3590	25.0300
Mp10	0.4790	0.0290	0.6510	4.4800	1.2850	0.3790	0.5930	56.3000
Mp11	0.3730	0.0370	0.2490	4.0830	0.8380	0.1190	0.2330	30.4100

Station: Palo Alto

Date: 3/25/2008

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	0.8716	0.1689	1.9969	19.7991	4.3074	0.9287	1.8367	232.2526
STD	0.3686	0.0196	0.7412	4.6180	0.5442	0.2059	0.6002	30.6878
SEM	0.102	0.005	0.206	1.281	0.151	0.057	0.166	8.511
CV%	42.287	11.596	37.116	23.324	12.633	22.168	32.677	13.213
n	13	13	13	13	13	13	13	13
r wt x [ ]	0.775	0.130	0.325	0.677	0.068	0.489	0.268	0.508
X 100mg	1.146	0.166	1.765	22.809	4.343	0.832	1.682	247.250
r l x [ ]	0.742	0.292	0.496	0.692	0.124	0.653	0.416	0.390
X 20mm	1.226	0.161	1.521	23.938	4.220	0.755	1.513	247.756
X 25mm	1.562	0.154	1.068	27.870	4.137	0.589	1.206	262.483

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

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
20mm	0.1130	0.0162	0.1381	2.4085	0.4216	0.0751	0.1414	24.8975
25mm	0.2698	0.0303	0.2175	5.3449	0.8008	0.1267	0.2371	50.2505

Estimated weight for 15mm clam	Estimated weight for 20mm clam
0.043 g	0.103 g
43.392 mg	103.041 mg

Estimated weight for 25mm clam

0.202 g
201.533 mg

Station: Palo Alto *Macoma petalum*

Date: 3/25/2008

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Concentration (ug/ml) - Blank Corrected from ICP-AES							
					Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mp1	10.37	0.0474	0.0158	10	0.0030	0.0008	0.0176	0.0792	0.0234	0.0064	0.0141	0.9433
Mp2	11.48	0.1226	0.0153	10	0.0098	0.0024	0.0205	0.1898	0.0484	0.0108	0.0149	3.1490
Mp3	11.43	0.1406	0.0176	10	0.0113	0.0027	0.0377	0.2456	0.0723	0.0172	0.0321	3.5810
Mp4	12.67	0.2313	0.0330	10	0.0125	0.0040	0.0569	0.4618	0.1045	0.0265	0.0581	5.2890
Mp5	12.51	0.1547	0.0221	10	0.0191	0.0029	0.0206	0.3886	0.0678	0.0147	0.0195	3.8510
Mp6	13.54	0.3498	0.0318	10	0.0284	0.0060	0.0758	0.6089	0.1472	0.0336	0.0725	8.4490
Mp7	13.44	0.3519	0.0320	10	0.0225	0.0057	0.0843	0.5363	0.1567	0.0330	0.0742	7.1200
Mp8	14.48	0.4216	0.0422	10	0.0290	0.0062	0.0742	0.8546	0.1530	0.0319	0.0676	8.8650
Mp9	14.36	0.3237	0.0360	10	0.0245	0.0056	0.0600	0.6275	0.1402	0.0290	0.0648	7.4840
Mp10	15.46	0.4699	0.0522	10	0.0411	0.0074	0.0814	0.9532	0.1869	0.0373	0.0750	9.9460
Mp11	16.40	0.2504	0.0626	10	0.0116	0.0039	0.0426	0.3530	0.1054	0.0192	0.0451	5.7770
Mp12	20.05	0.1905	0.09525	10	0.0242	0.0024	0.0112	0.5240	0.0616	0.0116	0.0126	3.7390
Mp13	25.39	0.2043	0.2043	10	0.0371	0.0038	0.0389	0.5813	0.1027	0.0164	0.0365	6.2750

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
LOD	0.0006644	0.0001293	0.0043649	0.0081328	0.0003005	0.0009378	0.000368	0.0029356
LOQ	0.0013288	0.0002586	0.0087299	0.0162655	0.000601	0.0018756	0.000736	0.0058712

Concentration (ug/g) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mp1	0.6329	0.1688	3.7131	16.7089	4.9367	1.3502	2.9747	199.008
Mp2	0.7993	0.1958	1.6721	15.4812	3.9478	0.8809	1.2153	256.852
Mp3	0.8037	0.1920	2.6814	17.4680	5.1422	1.2233	2.2831	254.694
Mp4	0.5404	0.1729	2.4600	19.9654	4.5179	1.1457	2.5119	228.664
Mp5	1.2346	0.1875	1.3316	25.1196	4.3827	0.9502	1.2605	248.933
Mp6	0.8119	0.1715	2.1670	17.4071	4.2081	0.9605	2.0726	241.538
Mp7	0.6394	0.1620	2.3956	15.2401	4.4530	0.9378	2.1086	202.330
Mp8	0.6879	0.1471	1.7600	20.2704	3.6290	0.7566	1.6034	210.270
Mp9	0.7569	0.1730	1.8536	19.3852	4.3312	0.8959	2.0019	231.202
Mp10	0.8747	0.1575	1.7323	20.2852	3.9774	0.7938	1.5961	211.662
Mp11	0.4633	0.1558	1.7013	14.0974	4.2093	0.7668	1.8011	230.711
Mp12	1.2703	0.1260	0.5879	27.5066	3.2336	0.6089	0.6614	196.273
Mp13	1.8160	0.1860	1.9041	28.4533	5.0269	0.8027	1.7866	307.146

Content (ug) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mp1	0.0100	0.0027	0.0587	0.2640	0.0780	0.0213	0.0470	3.1443
Mp2	0.0123	0.0030	0.0256	0.2373	0.0605	0.0135	0.0186	3.9363
Mp3	0.0141	0.0034	0.0471	0.3070	0.0904	0.0215	0.0401	4.4763
Mp4	0.0179	0.0057	0.0813	0.6597	0.1493	0.0379	0.0830	7.5557
Mp5	0.0273	0.0041	0.0294	0.5551	0.0969	0.0210	0.0279	5.5014
Mp6	0.0258	0.0055	0.0689	0.5535	0.1338	0.0305	0.0659	7.6809
Mp7	0.0205	0.0052	0.0766	0.4875	0.1425	0.0300	0.0675	6.4727
Mp8	0.0290	0.0062	0.0742	0.8546	0.1530	0.0319	0.0676	8.8650
Mp9	0.0272	0.0062	0.0667	0.6972	0.1558	0.0322	0.0720	8.3156
Mp10	0.0457	0.0082	0.0904	1.0591	0.2077	0.0414	0.0833	11.0511
Mp11	0.0290	0.0098	0.1065	0.8825	0.2635	0.0480	0.1128	14.4425
Mp12	0.1210	0.0120	0.0560	2.6200	0.3080	0.0580	0.0630	18.6950
Mp13	0.3710	0.0380	0.3890	5.8130	1.0270	0.1640	0.3650	62.7500

Station: Palo Alto

Date: 4/21/2008

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	0.8352	0.1294	1.1575	24.2411	3.0460	0.8447	1.0783	168.9062
STD	0.5438	0.0169	0.4990	14.4149	0.4933	0.1770	0.3983	10.8133
SEM	0.157	0.005	0.144	4.161	0.142	0.051	0.115	3.122
CV%	65.103	13.042	43.106	59.465	16.196	20.960	36.943	6.402
n	12	12	12	12	12	12	12	12
r wt x [ ]	0.769	0.122	0.369	0.682	0.026	0.246	0.400	0.265
X 100mg	1.027	0.130	1.073	28.757	3.040	0.825	1.005	170.223
r l x [ ]	0.792	0.165	0.278	0.756	0.117	0.116	0.319	0.269
X 20mm	1.257	0.132	1.022	34.915	3.103	0.824	0.954	171.751
X 25mm	1.955	0.137	0.796	52.593	3.197	0.791	0.747	176.463

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

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
20mm	0.1239	0.0148	0.1043	3.5270	0.3505	0.0919	0.1002	19.3883
25mm	0.4291	0.0298	0.1698	11.2444	0.7098	0.1750	0.1653	38.7115

Estimated weight for 15mm clam

0.048 gm
47.583 mg

Estimated weight for 20mm clam

0.113 gm
113.365 mg

Estimated weight for 25mm clam

0.222 gm
222.290 mg

Station: Palo Alto *Macoma petalum*

Date: 3/25/2008

Sample #-n	Average Length (mm)	Total Dry Wt (g)	Average Dry Wt (g)	Recon Vol (mL)	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
					Concentration (ug/ml) - Blank Corrected from ICP-AES							
Mp1	10.37	0.0474	0.0158	10	0.0030	0.0008	0.0176	0.0792	0.0234	0.0064	0.0141	0.9433
Mp2	11.48	0.1226	0.0153	10	0.0098	0.0024	0.0205	0.1898	0.0484	0.0108	0.0149	3.1490
Mp3	11.43	0.1406	0.0176	10	0.0113	0.0027	0.0377	0.2456	0.0723	0.0172	0.0321	3.5810
Mp4	12.67	0.2313	0.0330	10	0.0125	0.0040	0.0569	0.4618	0.1045	0.0265	0.0581	5.2890
Mp5	12.51	0.1547	0.0221	10	0.0191	0.0029	0.0206	0.3886	0.0678	0.0147	0.0195	3.8510
Mp6	13.54	0.3498	0.0318	10	0.0284	0.0060	0.0758	0.6089	0.1472	0.0336	0.0725	8.4490
Mp7	13.44	0.3519	0.0320	10	0.0225	0.0057	0.0843	0.5363	0.1567	0.0330	0.0742	7.1200
Mp8	14.48	0.4216	0.0422	10	0.0290	0.0062	0.0742	0.8546	0.1530	0.0319	0.0676	8.8650
Mp9	14.36	0.3237	0.0360	10	0.0245	0.0056	0.0600	0.6275	0.1402	0.0290	0.0648	7.4840
Mp10	15.46	0.4699	0.0522	10	0.0411	0.0074	0.0814	0.9532	0.1869	0.0373	0.0750	9.9460
Mp11	16.40	0.2504	0.0626	10	0.0116	0.0039	0.0426	0.3530	0.1054	0.0192	0.0451	5.7770
Mp12	20.05	0.1905	0.09525	10	0.0242	0.0024	0.0112	0.5240	0.0616	0.0116	0.0126	3.7390
Mp13	25.39	0.2043	0.2043	10	0.0371	0.0038	0.0389	0.5813	0.1027	0.0164	0.0365	6.2750
				LOD	0.0006644	0.0001293	0.0043649	0.0081328	0.0003005	0.0009378	0.000368	0.0029356
				LOQ	0.0013288	0.0002586	0.0087299	0.0162655	0.000601	0.0018756	0.000736	0.0058712

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	Mp1	0.6329	0.1688	3.7131	16.7089	4.9367	1.3502	2.9747	199.008
	Mp2	0.7993	0.1958	1.6721	15.4812	3.9478	0.8809	1.2153	256.852
	Mp3	0.8037	0.1920	2.6814	17.4680	5.1422	1.2233	2.2831	254.694
	Mp4	0.5404	0.1729	2.4600	19.9654	4.5179	1.1457	2.5119	228.664
	Mp5	1.2346	0.1875	1.3316	25.1196	4.3827	0.9502	1.2605	248.933
	Mp6	0.8119	0.1715	2.1670	17.4071	4.2081	0.9605	2.0726	241.538
	Mp7	0.6394	0.1620	2.3956	15.2401	4.4530	0.9378	2.1086	202.330
	Mp8	0.6879	0.1471	1.7600	20.2704	3.6290	0.7566	1.6034	210.270
	Mp9	0.7569	0.1730	1.8536	19.3852	4.3312	0.8959	2.0019	231.202
	Mp10	0.8747	0.1575	1.7323	20.2852	3.9774	0.7938	1.5961	211.662
	Mp11	0.4633	0.1558	1.7013	14.0974	4.2093	0.7668	1.8011	230.711
	Mp12	1.2703	0.1260	0.5879	27.5066	3.2336	0.6089	0.6614	196.273
	Mp13	1.8160	0.1860	1.9041	28.4533	5.0269	0.8027	1.7866	307.146

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	Mp1	0.0100	0.0027	0.0587	0.2640	0.0780	0.0213	0.0470	3.1443
	Mp2	0.0123	0.0030	0.0256	0.2373	0.0605	0.0135	0.0186	3.9363
	Mp3	0.0141	0.0034	0.0471	0.3070	0.0904	0.0215	0.0401	4.4763
	Mp4	0.0179	0.0057	0.0813	0.6597	0.1493	0.0379	0.0830	7.5557
	Mp5	0.0273	0.0041	0.0294	0.5551	0.0969	0.0210	0.0279	5.5014
	Mp6	0.0258	0.0055	0.0689	0.5535	0.1338	0.0305	0.0659	7.6809
	Mp7	0.0205	0.0052	0.0766	0.4875	0.1425	0.0300	0.0675	6.4727
	Mp8	0.0290	0.0062	0.0742	0.8546	0.1530	0.0319	0.0676	8.8650
	Mp9	0.0272	0.0062	0.0667	0.6972	0.1558	0.0322	0.0720	8.3156
	Mp10	0.0457	0.0082	0.0904	1.0591	0.2077	0.0414	0.0833	11.0511
	Mp11	0.0290	0.0098	0.1065	0.8825	0.2635	0.0480	0.1128	14.4425
	Mp12	0.1210	0.0120	0.0560	2.6200	0.3080	0.0580	0.0630	18.6950
	Mp13	0.3710	0.0380	0.3890	5.8130	1.0270	0.1640	0.3650	62.7500

Station: Palo Alto

Date: 5/21/2008

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	0.7959	0.1260	1.2776	17.5016	3.3285	0.9858	1.2559	186.0585
STD	0.4950	0.0291	0.7414	2.4064	1.0875	0.3986	0.6799	54.5011
SEM	0.143	0.008	0.214	0.695	0.314	0.115	0.196	15.733
CV%	62.190	23.093	58.029	13.749	32.672	40.431	54.136	29.292
n	12	12	12	12	12	12	12	12
r wt x [ ]	0.752	0.515	0.717	0.282	0.588	0.793	0.685	0.235
X 100mg	0.678	0.131	1.446	17.287	3.531	1.086	1.403	190.110
r l x [ ]	0.649	0.670	0.840	0.121	0.770	0.911	0.826	0.305
X 20mm	0.718	0.131	1.428	17.431	3.532	1.074	1.392	190.090
X 25mm	1.088	0.108	0.711	17.767	2.565	0.655	0.744	170.905

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

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
20mm	0.0589	0.0112	0.1061	1.5402	0.2930	0.0858	0.1062	16.0370
25mm	0.1712	0.0214	0.1525	3.4228	0.5179	0.1356	0.1603	31.3131

Estimated weight for 15mm clam	Estimated weight for 20mm clam
0.032 g	0.089 g
31.990 mg	88.826 mg

Estimated weight for 25mm clam

0.196 g
196.142 mg

Station: Palo Alto

Date: 5/21/2008

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (g)	Average Dry Wt (g)	Recon Vol (ml)	Concentration (ug/ml) - Blank Corrected from ICP-AES Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mp1	12.17	0.1786	0.0162	10	0.0131	0.0037	0.0572	0.3699	0.1144	0.0359	0.0561	4.4660
Mp2	16.41	0.4637	0.0422	10	0.0190	0.0065	0.0787	0.7471	0.1846	0.0595	0.0732	9.5170
Mp3	18.43	0.4098	0.0585	10	0.0225	0.0054	0.0546	0.6524	0.1454	0.0437	0.0528	7.9510
Mp4	19.50	0.4835	0.0806	10	0.0234	0.0057	0.0422	0.7737	0.1416	0.0400	0.0421	8.7560
Mp5	19.35	0.4378	0.0876	10	0.0212	0.0044	0.0481	0.6603	0.1222	0.0454	0.0460	6.6170
Mp6	20.23	0.3459	0.0865	10	0.0183	0.0038	0.0697	0.5496	0.1088	0.0421	0.0599	7.4860
Mp7	21.31	0.7811	0.1116	15	0.0235	0.0062	0.0655	0.7475	0.1758	0.0470	0.0645	9.9390
Mp8	22.44	0.2831	0.1416	10	0.0113	0.0033	0.0291	0.5733	0.0819	0.0274	0.0297	5.2400
Mp9	23.88	0.1560	0.1560	10	0.0198	0.0020	0.0095	0.3156	0.0331	0.0098	0.0112	1.3100
Mp10	25.61	0.2337	0.2337	10	0.0187	0.0023	0.0172	0.4919	0.0656	0.0132	0.0170	2.5740
Mp11	26.27	0.4478	0.2239	10	0.0751	0.0062	0.0396	0.7461	0.1534	0.0306	0.0445	12.7500
Mp12	27.01	0.2680	0.268	10	0.0473	0.0028	0.0160	0.4759	0.0675	0.0172	0.0183	4.8220

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
LOD	0.0006644	0.0001293	0.0043649	0.0081328	0.0003005	0.0009378	0.000368	0.0029356
LOQ	0.0013288	0.0002586	0.0087299	0.0162655	0.000601	0.0018756	0.000736	0.0058712

Concentration (ug/g) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mp1	0.7335	0.2072	3.2027	20.7111	6.4054	2.0101	3.1411	250.056
Mp2	0.4097	0.1402	1.6972	16.1117	3.9810	1.2832	1.5786	205.240
Mp3	0.5490	0.1318	1.3324	15.9200	3.5481	1.0664	1.2884	194.021
Mp4	0.4840	0.1179	0.8728	16.0021	2.9286	0.8273	0.8707	181.096
Mp5	0.4842	0.1005	1.0987	15.0822	2.7912	1.0370	1.0507	151.142
Mp6	0.5291	0.1099	2.0150	15.8890	3.1454	1.2171	1.7317	216.421
Mp7	0.4513	0.1191	1.2578	14.3548	3.3760	0.9026	1.2386	190.865
Mp8	0.3992	0.1166	1.0279	20.2508	2.8930	0.9679	1.0491	185.094
Mp9	1.2692	0.1282	0.6090	20.2308	2.1218	0.6282	0.7179	83.974
Mp10	0.8002	0.0984	0.7360	21.0484	2.8070	0.5648	0.7274	110.141
Mp11	1.6771	0.1385	0.8843	16.6615	3.4256	0.6833	0.9937	284.725
Mp12	1.7649	0.1045	0.5970	17.7575	2.5187	0.6418	0.6828	179.925

Content (ug) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mp1	0.0119	0.0034	0.0520	0.3363	0.1040	0.0326	0.0510	4.0600
Mp2	0.0173	0.0059	0.0715	0.6792	0.1678	0.0541	0.0665	8.6518
Mp3	0.0321	0.0077	0.0780	0.9320	0.2077	0.0624	0.0754	11.3586
Mp4	0.0390	0.0095	0.0703	1.2895	0.2360	0.0667	0.0702	14.5933
Mp5	0.0424	0.0088	0.0962	1.3206	0.2444	0.0908	0.0920	13.2340
Mp6	0.0458	0.0095	0.1743	1.3740	0.2720	0.1053	0.1498	18.7150
Mp7	0.0504	0.0133	0.1404	1.6018	0.3767	0.1007	0.1382	21.2979
Mp8	0.0565	0.0165	0.1455	2.8665	0.4095	0.1370	0.1485	26.2000
Mp9	0.1980	0.0200	0.0950	3.1560	0.3310	0.0980	0.1120	13.1000
Mp10	0.1870	0.0230	0.1720	4.9190	0.6560	0.1320	0.1700	25.7400
Mp11	0.3755	0.0310	0.1980	3.7305	0.7670	0.1530	0.2225	63.7500
Mp12	0.4730	0.0280	0.1600	4.7590	0.6750	0.1720	0.1830	48.2200

Station: Palo Alto

Date: 6/24/2008

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	0.9976	0.2015	1.8014	21.8280	4.6271	1.2867	1.4974	183.7600
STD	0.7132	0.0848	1.4254	4.8883	1.7364	0.7549	1.1641	39.2734
SEM	0.226	0.027	0.451	1.546	0.549	0.239	0.368	12.419
CV%	71.491	42.107	79.127	22.394	37.527	58.665	77.742	21.372
n	10	10	10	10	10	10	10	10
r wt x [ ]	0.774	0.376	0.733	0.256	0.627	0.807	0.676	0.643
X 100mg	1.485	0.173	0.880	22.932	3.666	0.749	0.803	161.473
r l x [ ]	0.550	0.599	0.882	0.024	0.798	0.936	0.840	0.629
X 20mm	1.285	0.164	0.881	21.744	3.614	0.769	0.782	165.697
X 25mm	1.647	0.117	-0.282	21.637	2.332	0.116	-0.123	142.861

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

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
20mm	0.0838	0.0126	0.0704	1.7344	0.2938	0.0617	0.0624	13.4044
25mm	0.2170	0.0237	0.1037	3.7703	0.5474	0.0988	0.0953	27.2107

Estimated weight for 15mm clam

0.030 g
29.848 mg

Estimated weight for 20mm clam

0.083 g
83.153 mg

Estimated weight for 25mm clam

0.184 g
184.084 mg

Station: Palo Alto

Date: 6/24/2008

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (g)	Average Dry Wt (g)	Recon Vol (mL)	Concentration (ug/ml) - Blank Corrected from ICP-AES Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mp1	8.57	0.0544	0.0039	10	0.0056	0.0018	0.0252	0.1428	0.0459	0.0140	0.0211	1.3590
Mp2	9.54	0.0609	0.0068	10	0.0041	0.0019	0.0221	0.1153	0.0366	0.0138	0.0191	1.1550
Mp3	10.33	0.0639	0.0071	10	0.0025	0.0016	0.0192	0.1683	0.0397	0.0137	0.0137	1.4110
Mp4	12.28	0.1071	0.0153	10	0.0062	0.0019	0.0169	0.2329	0.0470	0.0146	0.0132	1.9710
Mp5	16.70	0.2351	0.0470	10	0.0238	0.0031	0.0180	0.3956	0.0707	0.0199	0.0163	3.6030
Mp6	18.15	0.1721	0.0574	10	0.0101	0.0020	0.0140	0.2758	0.0552	0.0120	0.0102	2.7140
Mp7	19.64	0.2164	0.0721	10	0.0107	0.0029	0.0252	0.3596	0.0713	0.0195	0.0189	4.0240
Mp8	20.46	0.3077	0.0769	10	0.0193	0.0042	0.0261	0.6058	0.1291	0.0234	0.0247	6.4200
Mp9	22.50	0.2629	0.1315	10	0.0630	0.0076	0.0236	0.7602	0.1017	0.0195	0.0262	4.7470
Mp10	22.29	0.1395	0.1395	10	0.0305	0.0019	0.0095	0.3758	0.0509	0.0080	0.0087	1.4950
				LOD	0.0006644	0.0001293	0.0043649	0.0081328	0.0003005	0.0009378	0.000368	0.0029356
				LOQ	0.0013288	0.0002586	0.0087299	0.0162655	0.000601	0.0018756	0.000736	0.0058712

Concentration (ug/g) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mp1	1.0294	0.3309	4.6324	26.2500	8.4375	2.5735	3.8787	249.816
Mp2	0.6732	0.3120	3.6289	18.9327	6.0099	2.2660	3.1363	189.655
Mp3	0.3912	0.2504	3.0047	26.3380	6.2128	2.1440	2.1440	220.814
Mp4	0.5789	0.1774	1.5780	21.7460	4.3884	1.3632	1.2325	184.034
Mp5	1.0123	0.1319	0.7656	16.8269	3.0072	0.8464	0.6933	153.254
Mp6	0.5869	0.1162	0.8135	16.0256	3.2074	0.6973	0.5927	157.699
Mp7	0.4945	0.1340	1.1645	16.6174	3.2948	0.9011	0.8734	185.952
Mp8	0.6272	0.1365	0.8482	19.6880	4.1956	0.7605	0.8027	208.645
Mp9	2.3963	0.2891	0.8977	28.9159	3.8684	0.7417	0.9966	180.563
Mp10	2.1864	0.1362	0.6810	26.9391	3.6487	0.5735	0.6237	107.168

Content (ug) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mp1	0.0040	0.0013	0.0180	0.1020	0.0328	0.0100	0.0151	0.9707
Mp2	0.0046	0.0021	0.0246	0.1281	0.0407	0.0153	0.0212	1.2833
Mp3	0.0028	0.0018	0.0213	0.1870	0.0441	0.0152	0.0152	1.5678
Mp4	0.0089	0.0027	0.0241	0.3327	0.0671	0.0209	0.0189	2.8157
Mp5	0.0476	0.0062	0.0360	0.7912	0.1414	0.0398	0.0326	7.2060
Mp6	0.0337	0.0067	0.0467	0.9193	0.1840	0.0400	0.0340	9.0467
Mp7	0.0357	0.0097	0.0840	1.1987	0.2377	0.0650	0.0630	13.4133
Mp8	0.0483	0.0105	0.0653	1.5145	0.3228	0.0585	0.0618	16.0500
Mp9	0.3150	0.0380	0.1180	3.8010	0.5085	0.0975	0.1310	23.7350
Mp10	0.3050	0.0190	0.0950	3.7580	0.5090	0.0800	0.0870	14.9500

Station: Palo Alto

Date: 9/16/2008

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	1.9552	0.2527	2.8705	27.9913	6.2740	1.5135	2.7160	239.0895
STD	0.6384	0.1075	1.5744	6.1206	2.1095	0.6146	1.4025	77.1197
SEM	0.192	0.032	0.475	1.845	0.636	0.185	0.423	23.252
CV%	32.652	42.530	54.847	21.866	33.624	40.607	51.637	32.256
n	11	11	11	11	11	11	11	11
r wt x [ ]	0.203	0.706	0.722	0.592	0.684	0.825	0.747	0.376
X 100mg	1.902	0.221	2.401	26.496	5.678	1.304	2.284	227.100
r l x [ ]	0.323	0.848	0.838	0.436	0.815	0.922	0.854	0.440
X 20mm	1.947	0.249	2.821	27.890	6.209	1.492	2.671	237.808
X 25mm	1.799	0.184	1.872	25.972	4.972	1.084	1.809	213.429

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

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
20mm	0.0961	0.0117	0.1206	1.4366	0.3018	0.0695	0.1157	11.7780
25mm	0.1778	0.0190	0.1831	2.7132	0.5138	0.1118	0.1772	21.3798

Estimated weight for 15mm clam

0.022 g
22.027 mg

Estimated weight for 20mm clam

0.053 g
53.272 mg

Estimated weight for 25mm clam

0.106 g
105.681 mg

Station: Palo Alto *Macoma petalum*

Date: 9/16/2008

Sample #-n	Average Length (mm)	Total Dry Wt (g)	Average Dry Wt (g)	Recon Vol (mL)	Concentration (ug/ml) - Blank Corrected from ICP-AES Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mp1	9.60	0.0572	0.0064	10	0.0177	0.0023	0.0350	0.1766	0.0585	0.0153	0.0308	2.2560
Mp2	10.50	0.0668	0.0074	10	0.0134	0.0024	0.0341	0.2004	0.0615	0.0154	0.0306	1.9310
Mp3	11.79	0.0517	0.0103	10	0.0117	0.0024	0.0161	0.1300	0.0427	0.0102	0.0182	1.2580
Mp4	17.42	0.0853	0.0284	10	0.0149	0.0019	0.0261	0.3643	0.0467	0.0157	0.0248	1.6220
Mp5	18.61	0.3282	0.0410	10	0.0387	0.0068	0.1025	0.8872	0.1834	0.0445	0.0944	6.7600
Mp7	20.61	0.2619	0.0655	10	0.0223	0.0044	0.0524	0.6020	0.1143	0.0286	0.0425	3.6530
Mp8	21.72	0.2370	0.0790	10	0.0541	0.0042	0.0296	0.6766	0.1026	0.0253	0.0281	4.2770
Mp9	22.60	0.1701	0.0567	10	0.0423	0.0045	0.0499	0.5410	0.1109	0.0260	0.0525	4.9210
Mp10	26.49	0.2218	0.1109	10	0.0405	0.0042	0.0449	0.5770	0.1411	0.0256	0.0422	6.9210
Mp11	28.56	0.3776	0.1888	10	0.0881	0.0069	0.0300	0.8725	0.1504	0.0282	0.0326	8.9450
Mp12	29.20	0.1968	0.1968	10	0.0283	0.0028	0.0404	0.3874	0.0925	0.0179	0.0383	2.9300
				LOD	0.0006644	0.0001293	0.0043649	0.0081328	0.0003005	0.0009378	0.000368	0.0029356
				LOQ	0.0013288	0.0002586	0.0087299	0.0162655	0.000601	0.0018756	0.000736	0.0058712

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	Mp1	3.0944	0.4021	6.1189	30.8741	10.2273	2.6748	5.3846	394.406
	Mp2	2.0060	0.3593	5.1048	30.0000	9.2066	2.3054	4.5808	289.072
	Mp3	2.2631	0.4642	3.1141	25.1451	8.2592	1.9729	3.5203	243.327
	Mp4	1.7468	0.2227	3.0598	42.7081	5.4748	1.8406	2.9074	190.152
	Mp5	1.1792	0.2072	3.1231	27.0323	5.5881	1.3559	2.8763	205.972
	Mp7	0.8515	0.1680	2.0008	22.9859	4.3643	1.0920	1.6228	139.481
	Mp8	2.2827	0.1772	1.2489	28.5485	4.3291	1.0675	1.1857	180.464
	Mp9	2.4868	0.2646	2.9336	31.8048	6.5197	1.5285	3.0864	289.300
	Mp10	1.8260	0.1894	2.0243	26.0144	6.3616	1.1542	1.9026	312.038
	Mp11	2.3332	0.1827	0.7945	23.1065	3.9831	0.7468	0.8633	236.891
	Mp12	1.4380	0.1423	2.0528	19.6850	4.7002	0.9096	1.9461	148.882

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	Mp1	0.0197	0.0026	0.0389	0.1962	0.0650	0.0170	0.0342	2.5067
	Mp2	0.0149	0.0027	0.0379	0.2227	0.0683	0.0171	0.0340	2.1456
	Mp3	0.0234	0.0048	0.0322	0.2600	0.0854	0.0204	0.0364	2.5160
	Mp4	0.0497	0.0063	0.0870	1.2143	0.1557	0.0523	0.0827	5.4067
	Mp5	0.0484	0.0085	0.1281	1.1090	0.2293	0.0556	0.1180	8.4500
	Mp7	0.0558	0.0110	0.1310	1.5050	0.2858	0.0715	0.1063	9.1325
	Mp8	0.1803	0.0140	0.0987	2.2553	0.3420	0.0843	0.0937	14.2567
	Mp9	0.1410	0.0150	0.1663	1.8033	0.3697	0.0867	0.1750	16.4033
	Mp10	0.2025	0.0210	0.2245	2.8850	0.7055	0.1280	0.2110	34.6050
	Mp11	0.4405	0.0345	0.1500	4.3625	0.7520	0.1410	0.1630	44.7250
	Mp12	0.2830	0.0280	0.4040	3.8740	0.9250	0.1790	0.3830	29.3000

Station: Palo Alto

Date: 10/27/2008

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	2.3833	0.2223	4.1134	31.1051	6.6063	1.5859	3.6839	230.2087
STD	0.7199	0.0260	1.0285	6.8975	0.7907	0.2056	0.8802	77.4460
SEM	0.208	0.007	0.297	1.991	0.228	0.059	0.254	22.357
CV%	30.205	11.678	25.004	22.175	11.970	12.963	23.892	33.642
n	12	12	12	12	12	12	12	12
r wt x [ ]	0.261	0.596	0.656	0.546	0.571	0.401	0.552	0.024
X 100mg	2.693	0.197	3.003	37.306	5.862	1.450	2.883	227.104
r l x [ ]	0.204	0.690	0.733	0.547	0.704	0.587	0.651	0.149
X 20mm	2.414	0.218	3.954	31.904	6.488	1.560	3.562	227.759
X 25mm	2.596	0.196	3.024	36.552	5.802	1.412	2.856	213.496

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

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
20mm	0.1175	0.0111	0.1951	1.6128	0.3289	0.0791	0.1768	10.9385
25mm	0.2267	0.0192	0.3088	3.3631	0.5707	0.1384	0.2881	18.7022

Estimated weight for 15mm clam

0.023 g
22.646 mg

Estimated weight for 20mm clam

0.051 g
51.369 mg

Estimated weight for 25mm clam

0.097 g
96.962 mg

Station: Palo Alto *Macoma petalum*

Date: 10/27/2008

Sample #-n	Average Length (mm)	Total Dry Wt (g)	Average Dry Wt (g)	Recon Vol (mL)	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
					Concentration (ug/ml) - Blank Corrected from ICP-AES							
Mp1	11.28	0.1808	0.0113	10	0.0369	0.0048	0.1169	0.4325	0.1504	0.0391	0.1047	4.9270
Mp2	14.39	0.1306	0.0187	10	0.0362	0.0033	0.0531	0.3953	0.0921	0.0215	0.0439	4.8320
Mp3	16.59	0.1156	0.0289	10	0.0294	0.0027	0.0411	0.2811	0.0783	0.0161	0.0377	2.7230
Mp4	17.52	0.2252	0.0322	10	0.0745	0.0057	0.1146	0.8138	0.1611	0.0363	0.0938	5.1960
Mp5	18.51	0.3098	0.0387	10	0.0618	0.0068	0.1240	1.0700	0.1928	0.0518	0.1117	6.6740
Mp6	19.42	0.3035	0.0434	10	0.0602	0.0068	0.0938	0.9302	0.1639	0.0411	0.0799	6.2990
Mp7	19.50	0.3485	0.0498	10	0.0888	0.0076	0.1716	1.2340	0.2463	0.0541	0.1538	6.9010
Mp8	20.61	0.2827	0.0565	10	0.0689	0.0059	0.1191	0.8832	0.1685	0.0450	0.1057	6.0030
Mp9	20.46	0.3360	0.0560	10	0.0434	0.0063	0.1335	0.8826	0.2287	0.0504	0.1239	5.7030
Mp10	21.44	0.2737	0.0684	10	0.0337	0.0050	0.1141	0.7463	0.1850	0.0417	0.1103	3.7600
Mp11	22.85	0.2465	0.0822	10	0.0703	0.0049	0.0790	0.6163	0.1403	0.0359	0.0734	3.3650
Mp12	27.13	0.2419	0.12095	10	0.0870	0.0054	0.0631	1.1670	0.1468	0.0379	0.0615	9.1140
				LOD	0.0006644	0.0001293	0.0043649	0.0081328	0.0003005	0.0009378	0.000368	0.0029356
				LOQ	0.0013288	0.0002586	0.0087299	0.0162655	0.000601	0.0018756	0.000736	0.0058712

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	Mp1	2.0409	0.2655	6.4657	23.9215	8.3186	2.1626	5.7909	272.511
	Mp2	2.7718	0.2527	4.0658	30.2680	7.0521	1.6462	3.3614	369.985
	Mp3	2.5433	0.2336	3.5554	24.3166	6.7734	1.3927	3.2612	235.554
	Mp4	3.3082	0.2531	5.0888	36.1368	7.1536	1.6119	4.1652	230.728
	Mp5	1.9948	0.2195	4.0026	34.5384	6.2234	1.6720	3.6056	215.429
	Mp6	1.9835	0.2241	3.0906	30.6491	5.4003	1.3542	2.6326	207.545
	Mp7	2.5481	0.2181	4.9240	35.4089	7.0674	1.5524	4.4132	198.020
	Mp8	2.4372	0.2087	4.2129	31.2416	5.9604	1.5918	3.7389	212.345
	Mp9	1.2917	0.1875	3.9732	26.2679	6.8065	1.5000	3.6875	169.732
	Mp10	1.2313	0.1827	4.1688	27.2671	6.7592	1.5236	4.0300	137.377
	Mp11	2.8519	0.1988	3.2049	25.0020	5.6917	1.4564	2.9777	136.511
	Mp12	3.5965	0.2232	2.6085	48.2431	6.0686	1.5668	2.5424	376.767

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	Mp1	0.0231	0.0030	0.0731	0.2703	0.0940	0.0244	0.0654	3.0794
	Mp2	0.0517	0.0047	0.0759	0.5647	0.1316	0.0307	0.0627	6.9029
	Mp3	0.0735	0.0068	0.1028	0.7028	0.1958	0.0403	0.0943	6.8075
	Mp4	0.1064	0.0081	0.1637	1.1626	0.2301	0.0519	0.1340	7.4229
	Mp5	0.0773	0.0085	0.1550	1.3375	0.2410	0.0648	0.1396	8.3425
	Mp6	0.0860	0.0097	0.1340	1.3289	0.2341	0.0587	0.1141	8.9986
	Mp7	0.1269	0.0109	0.2451	1.7629	0.3519	0.0773	0.2197	9.8586
	Mp8	0.1378	0.0118	0.2382	1.7664	0.3370	0.0900	0.2114	12.0060
	Mp9	0.0723	0.0105	0.2225	1.4710	0.3812	0.0840	0.2065	9.5050
	Mp10	0.0843	0.0125	0.2853	1.8658	0.4625	0.1043	0.2758	9.4000
	Mp11	0.2343	0.0163	0.2633	2.0543	0.4677	0.1197	0.2447	11.2167
	Mp12	0.4350	0.0270	0.3155	5.8350	0.7340	0.1895	0.3075	45.5700

Station: Palo Alto

Date: 12/10/2008

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	2.7365	0.2558	4.7767	28.5860	7.0124	1.6090	4.0827	285.9464
STD	0.5673	0.0532	1.7349	4.3662	1.8735	0.3767	1.4110	74.3431
SEM	0.171	0.016	0.523	1.316	0.565	0.114	0.425	22.415
CV%	20.730	20.795	36.321	15.274	26.716	23.414	34.561	25.999
n	11	11	11	11	11	11	11	11
r wt x [ ]	0.437	0.850	0.852	0.119	0.944	0.891	0.788	0.809
X 100mg	1.877	0.099	-0.342	30.379	0.889	0.447	0.233	77.805
r l x [ ]	0.472	0.865	0.837	0.111	0.932	0.870	0.759	0.825
X 20mm	2.386	0.196	2.873	29.222	4.725	1.179	2.679	205.553
X 25mm	2.077	0.142	1.195	29.783	2.707	0.801	1.442	134.646

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

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
20mm	0.1459	0.0123	0.1850	1.7457	0.3013	0.0740	0.1671	13.0028
25mm	0.2578	0.0204	0.2779	3.3284	0.4734	0.1204	0.2585	21.0683

Estimated weight for 15mm clam

0.027 g
26.764 mg

Estimated weight for 20mm clam

0.061 g
60.800 mg

Estimated weight for 25mm clam

0.115 g
114.897 mg

Station: Palo Alto

Macoma petalum

Date: 12/10/2008

Sample #-n	Average Length (mm)	Total Dry Wt (g)	Average Dry Wt (g)	Recon Vol (mL)	Concentration (ug/ml) - Blank Corrected from ICP-AES							
					Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mp1	8.64	0.0444	0.0049	10	0.0187	0.0016	0.0283	0.1580	0.0439	0.0092	0.0230	1.8730
Mp2	9.57	0.0730	0.0073	10	0.0212	0.0023	0.0460	0.2205	0.0607	0.0148	0.0332	2.7180
Mp3	10.56	0.0825	0.0103	10	0.0199	0.0022	0.0420	0.1907	0.0658	0.0144	0.0384	2.0600
Mp4	10.35	0.0856	0.0107	10	0.0209	0.0023	0.0627	0.1957	0.0746	0.0165	0.0520	2.8110
Mp5	11.81	0.1253	0.0125	10	0.0364	0.0037	0.0567	0.3457	0.0980	0.0202	0.0475	4.2180
Mp6	14.26	0.0930	0.0233	10	0.0266	0.0023	0.0645	0.2938	0.0771	0.0188	0.0584	2.9750
Mp7	16.61	0.1552	0.0388	10	0.0307	0.0038	0.0642	0.3683	0.1006	0.0225	0.0621	3.6890
Mp8	17.55	0.1382	0.0461	10	0.0382	0.0025	0.0445	0.3771	0.0698	0.0153	0.0406	3.2880
Mp9	18.43	0.2319	0.0464	10	0.0582	0.0047	0.0736	0.7185	0.1247	0.0333	0.0630	4.0810
Mp10	19.35	0.1647	0.0549	10	0.0387	0.0034	0.0407	0.4471	0.0663	0.0177	0.0339	3.7360
Mp11	20.50	0.3508	0.0585	10	0.0970	0.0079	0.1049	1.2050	0.1823	0.0430	0.0936	8.3560
				LOD	0.0006644	0.0001293	0.0043649	0.0081328	0.0003005	0.0009378	0.000368	0.0029356
				LOQ	0.0013288	0.0002586	0.0087299	0.0162655	0.000601	0.0018756	0.000736	0.0058712

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	Mp1	4.2117	0.3604	6.3739	35.5856	9.8874	2.0721	5.1802	421.847
	Mp2	2.9041	0.3151	6.3014	30.2055	8.3151	2.0274	4.5479	372.329
	Mp3	2.4121	0.2667	5.0909	23.1152	7.9758	1.7455	4.6545	249.697
	Mp4	2.4416	0.2687	7.3248	22.8621	8.7150	1.9276	6.0748	328.388
	Mp5	2.9050	0.2953	4.5251	27.5898	7.8212	1.6121	3.7909	336.632
	Mp6	2.8602	0.2473	6.9355	31.5914	8.2903	2.0215	6.2796	319.892
	Mp7	1.9781	0.2448	4.1366	23.7307	6.4820	1.4497	4.0013	237.693
	Mp8	2.7641	0.1809	3.2200	27.2865	5.0507	1.1071	2.9378	237.916
	Mp9	2.5097	0.2027	3.1738	30.9832	5.3773	1.4360	2.7167	175.981
	Mp10	2.3497	0.2064	2.4712	27.1463	4.0255	1.0747	2.0583	226.837
	Mp11	2.7651	0.2252	2.9903	34.3501	5.1967	1.2258	2.6682	238.198

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	Mp1	0.0208	0.0018	0.0314	0.1756	0.0488	0.0102	0.0256	2.0811
	Mp2	0.0212	0.0023	0.0460	0.2205	0.0607	0.0148	0.0332	2.7180
	Mp3	0.0249	0.0028	0.0525	0.2384	0.0823	0.0180	0.0480	2.5750
	Mp4	0.0261	0.0029	0.0784	0.2446	0.0933	0.0206	0.0650	3.5138
	Mp5	0.0364	0.0037	0.0567	0.3457	0.0980	0.0202	0.0475	4.2180
	Mp6	0.0665	0.0058	0.1613	0.7345	0.1928	0.0470	0.1460	7.4375
	Mp7	0.0768	0.0095	0.1605	0.9208	0.2515	0.0563	0.1553	9.2225
	Mp8	0.1273	0.0083	0.1483	1.2570	0.2327	0.0510	0.1353	10.9600
	Mp9	0.1164	0.0094	0.1472	1.4370	0.2494	0.0666	0.1260	8.1620
	Mp10	0.1290	0.0113	0.1357	1.4903	0.2210	0.0590	0.1130	12.4533
	Mp11	0.1617	0.0132	0.1748	2.0083	0.3038	0.0717	0.1560	13.9267

Appendix E. Mercury and selenium concentrations (µg/g dry weight) determined in surface sediments and *Macoma petalum*, 2008.

[Analyses were conducted on homogenized sediment. Values for *Macoma petalum* are the mean and 1 std (n=2-3).]

Date	Sediment		*M. petalum*	
	mercury	selenium	mercury	selenium
1/16/2008	0.62	0.8	0.34 ± 0.02	5.9 ± 0.1
2/12/2008	0.26	0.7	0.42 ± 0.06	5.7 ± 0.7
4/21/2008	0.27	1.0	0.30 ± 0.06	3.4 ± 0.2
6/24/2008	0.26	0.8	0.36 ± 0.13	4.4 ± 1.4
9/16/2008	0.23	0.6	0.40 ± 0.06	4.2 ± 0.6
12/10/2008	0.21	0.7	0.41 ± 0.07	5.4 ± 0.5

Appendix F. Mercury and selenium concentrations (µg/g dry weight) determined in sample splits of surface sediments and *Macoma petalum* collected in June and September 2008.

Date	Sediment		*M. petalum*	
	mercury	selenium	mercury	selenium
4/21/2008	0.29 \ 0.24	1 \ 0.9	0.27 \ 0.26	3.9 \ 4.1
12/10/2008	NA	NA	0.34 \ 0.3	5.1 \ 5.2

Appendix G. Observed and certified concentrations of mercury and selenium in standard reference materials (SRM) analyzed in 2008.

[The certified concentration as reported by National Research Council Canada (CRC) and the National Institute of Standards and Technology (NIST) are the mean and 95-percent confidence interval. Selenium in USGS GSP-2 has not been certified (N.D., signifies no data).]

SRM	Mercury		Selenium	
	Observed	Certified	Observed	Certified
NIST 2709	1.38	1.40±0.08	1.5	1.6±0.1
CRC MESS-3	0.09	0.09±0.009	0.8	0.72±0.05
CRC TORT-2	0.27	0.27±0.06	4.9	5.6±0.7
CRC DOLT-3	3.39	3.37±0.14	7	7.1±0.5
USGS SGR-1	0.25	0.31	3.7	3.5±0.3
USGS SCO-1	0.08	0.05	1	0.9±0.1
USGS GSP-2	0.02	0.02	0.1	N.D.
USGS QLO-1	0.02	0.01	<0.1	0.01

Appendix H. Results of the analyses of National Institute of Science and Technology (NIST) standard reference material 2709 (San Joaquin Soil) for elements, excluding selenium and mercury.

[Recoveries are reported as the observed concentrations (microgram per gram, dry weight (µg/g)) and the percent recoveries relative to the certified values for the standard.]

H. SRM 2709 Recoveries 2008

Month	Rep	Al	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
		Observed concentration										
1/16/2008	1	46824	14	0.63	108	30	35107	545	86	10.5	138	112
	2	47006	13	0.62	107	28	35960	560	84	11	133	110
2/12/2008	1	49544	14	0.64	111	32	38066	592	90	11	140	117
	2	45195	13	0.63	104	28	35488	554	86	11	132	112
3/25/2008	1	48852	14	0.66	112	30	38372	600	90	11	140	116
	2	47049	13	0.62	108	28	36553	572	86	11	136	112
4/21/2008	1	52817	14	0.66	123	32	39418	614	91	11	153	121
	2	45325	13	0.61	105	29	34155	533	82	10	135	107
5/21/2008	1	47153	14	0.64	109	29	36874	573	88	11	139	114
	2	47138	14	0.64	108	30	36995	576	88	11	139	115
6/24/2008	1	50365	14	0.67	118	31	38463	599	91	11	149	122
	2	46931	14	0.62	109	29	36040	559	87	11	139	113
9/16/2008	1	42532	13	0.58	98	26	33279	520	80	10	125	105
	2	45170	13	0.64	103	27	35238	550	85	11	133	110
10/27/2008	1	48388	15	0.67	112	30	38200	599	92	12	148	120
	2	41966	14	0.63	99	27	35339	556	88	11	130	112
12/10/2008	1	46798	14	0.64	108	29	36463	573	88	11	143	118
	2	46576	14	0.64	107	29	36272	570	88	11	144	117
		Certified concentration										
	Mean	75000	18	0.38	130	35	35000	538	88	19	112	106
	CI	0.06	1	0.01	4	1	0.11	17	5	1	5	3

Month	Rep	Al	As	Cd	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
		Percent recovery										
1/16/2008	1	62	77	167	83	86	100	101	98	55	123	105
	2	63	74	163	82	82	103	104	95	56	118	103
2/12/2008	1	66	79	169	85	91	109	110	102	59	125	110
	2	60	75	166	80	82	101	103	98	57	118	105
3/25/2008	1	65	78	173	86	87	110	112	102	61	125	110
	2	63	76	164	83	82	104	106	98	57	122	106
4/21/2008	1	70	80	173	94	92	113	114	103	60	136	114
	2	60	74	160	81	83	98	99	93	54	120	101
5/21/2008	1	63	79	168	84	85	105	107	100	57	124	107
	2	63	78	169	83	86	106	107	100	60	124	108

6/24/2008	1	67	81	176	91	89	110	111	103	60	133	115
	2	63	78	162	84	82	103	104	99	59	124	107
9/16/2008	1	57	71	153	75	76	95	97	91	54	112	99
	2	60	74	169	80	79	101	102	96	56	119	104
10/27/2008	1	65	84	176	86	85	109	111	104	61	132	113
	2	56	76	166	76	78	101	103	100	60	116	106
12/10/2008	1	62	81	168	83	83	104	106	100	59	128	111
	Mean	63	77	167	83	84	104	106	99	58	124	107
	STD	4	3	6	5	4	5	5	4	2	6	4

Appendix I. Observed and certified values for inorganic elements in NIST Standard Reference Material 2976 (mussel tissue) prepared in 2008.

Observed Concentrations in NIST SRM 2976 in 2008. Concentration unit is µg/g (dry weight). Observed concentrations for different dates are the mean and 1 standard deviation.
Certified concentrations are the mean and 95% confidence interval.

Date	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
				Observed Concentrations				
1/16/2008	<MRL	0.81 ± 0.01	0.40 ± 0.08	4.02 ± 0.02	0.66 ± 0.01	0.98 ± 0.02	0.56 ± 0.01	131 ± 0.4
2/12/2008	<MRL	0.81 ± 0.01	0.36 ± 0.04	3.91 ± 0.06	0.66 ± 0.01	1.01 ± 0.02	0.55 ± 0.02	130 ± 2.2
3/25/2008	<MRL	0.79 ± 0.003	0.37 ± 0.02	3.89 ± 0.04	0.65 ± 0.03	0.96 ± 0.02	0.54 ± 0.00	127 ± 0.6
4/21/2008	<MRL	0.81 ± 0.01	0.46 ± 0.06	3.72 ± 0.05	0.69 ± 0.01	0.98 ± 0.03	0.59 ± 0.03	130 ± 0.6
5/21/2008	<MRL	0.81 ± 0.003	0.43 ± 0.04	4.02 ± 0.13	0.68 ± 0.01	0.96 ± 0.01	0.58 ± 0.02	132 ± 0.7
6/24/2008	<MRL	0.81 ± 0.01	0.45 ± 0.03	3.79 ± 0.06	0.67 ± 0.02	0.97 ± 0.04	0.57 ± 0.03	131 ± 1.7
9/16/2008	<MRL	0.81 ± 0.004	0.54 ± 0.02	3.95 ± 0.10	0.68 ± 0.00	0.97 ± 0.02	0.60 ± 0.01	130 ± 0.9
10/27/2008	<MRL	0.83 ± 0.03	0.68 ± 0.06	3.73 ± 0.19	0.72 ± 0.02	1.02 ± 0.06	0.61 ± 0.02	132 ± 4.6
12/10/2008	<MRL	0.82 ± 0.01	0.55 ± 0.14	3.61 ± 0.15	0.68 ± 0.01	0.98 ± 0.04	0.58 ± 0.01	131 ± 1.7
Mean		0.81	0.47	3.85	0.68	0.98	0.58	131
Median		0.81	0.45	3.89	0.68	0.98	0.58	131
				Certified Concentrations				
	0.011	0.82 ± 0.16	0.5 ± 0.16	4.02 ± 0.33	0.93 ± 0.12	1.19 ± 0.18	nc	137 ± 13

Appendix J. Method detection limits (MDL) and reporting levels (MRL) for ICP-OES methods.

[Concentration is reported as microgram per milliliter (µg/mL).]

J. Method detection limit (MDL) and method reporting limits (MRL) for Inductively coupled plasma optical emission spectrophotometry methods. Units are reported in ug/ml

Method	Marker	Ag	Al	Cd	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Sediment	MDL	0.00081	0.01309	0.00010	0.00630	0.00707	0.00955	0.00155	0.00043	0.00073	0.00048	0.00025
	MRL	0.00161	0.02619	0.00020	0.01261	0.01414	0.01909	0.00311	0.00086	0.00146	0.00096	0.00049
Tissue	MDL	0.00066	0.00109	0.00013	0.00436	0.00813	0.01591	0.00127	0.00030	0.00094	0.00037	0.00294
	MRL	0.00133	0.00218	0.00026	0.00873	0.01627	0.03183	0.00254	0.00060	0.00188	0.00074	0.00587

Appendix K. Reproduction data for *Macoma petalum* for the year 2008.

Date	Inactive	Active	Ripe	Spawning	Spent	Spawned	N	Reproductive	Non-Reproductive
1/16/2008	0	22.2	77.8	0	0		9	100	0
2/12/2008	0	0	100	0	0		10	100	0
3/25/2008	0	0	50	50	0		10	100	0
4/21/2008	0	0	50	50	0		8	100	0
5/21/2008	0	0	10	80	10		10	90	-10
6/24/2008	0	0	0	10	90		10	10	-90
7/1/2008									
8/1/2008									
9/16/2008	80	20	0	0	0		10	20	-80
10/27/2008	22.2	77.8	0	0	0		9	77.8	-22.2
11/1/2008									
12/10/2008	0	20	80	0	0		10	100	0

Appendix L. Complete list of benthic species found at Palo Alto in the year 2008.

Species	1/17/2008		2/15/2008		3/14/2008		4/11/2008		5/20/2008		6/9/2008		7/22/2008		8/29/2008		9/26/2008		11/13/2008		12/9/2008	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Acari	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ampelisca abdita	0.3	0.6	0.0	0.0	0.7	0.6	4.7	1.5	14.3	7.2	95.3	8.3	14.3	4.5	18.3	3.8	57.0	6.1	58.7	11.6	39.3	15.3
Ampithoe spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	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	0.0	0.0	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	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Boonea bisuturalis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.6	0.0	0.0	0.0	0.0
Calinoida	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	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	0.0	1.0	1.7	0.0	0.0	0.7	1.2	0.0	0.0	0.3	0.6
Caprella californica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.6	0.0	0.0	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	0.0	0.0	1.7	1.2	0.0	0.0	0.3	0.6	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Corophium alienense	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.2	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.6	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	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Species	1/17/2008		2/15/2008		3/14/2008		4/11/2008		5/20/2008		6/9/2008		7/22/2008		8/29/2008		9/26/2008		11/13/2008		12/9/2008	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Dynamenella spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eteone ?californica	0.7	0.6	0.0	0.0	0.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eteone lighti	3.0	2.6	0.0	0.0	3.3	1.5	8.3	2.9	33.3	5.5	4.3	3.2	6.0	4.4	2.7	1.2	4.0	2.6	3.3	2.5	1.7	1.2
Eteone spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Euchone limnicola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.6	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eusarsiella zostericola	1.3	1.2	0.0	0.0	0.0	0.0	0.3	0.6	0.3	0.6	0.7	0.6	1.7	0.6	4.0	1.0	9.3	2.9	3.7	3.1	2.7	2.3
Gemma gemma	0.0	0.0	0.0	0.0	0.7	0.6	1.7	0.6	3.0	2.6	2.3	2.3	2.7	2.3	8.7	11.7	75.7	28.4	0.3	0.6	0.0	0.0
Glycera spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	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	0.0	0.0	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	0.0	0.3	0.6	3.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grandidierella japonica	6.3	2.3	0.0	0.0	0.3	0.6	2.3	0.6	11.0	10.1	14.0	11.5	8.0	3.6	18.0	17.1	16.0	3.6	15.3	7.5	6.7	4.0
Harmothoe imbricata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.6

Species	1/17/2008 Mean	1/17/2008 Std Dev	2/15/2008 Mean	2/15/2008 Std Dev	3/14/2008 Mean	3/14/2008 Std Dev	4/11/2008 Mean	4/11/2008 Std Dev	5/20/2008 Mean	5/20/2008 Std Dev	6/9/2008 Mean	6/9/2008 Std Dev	7/22/2008 Mean	7/22/2008 Std Dev	8/29/2008 Mean	8/29/2008 Std Dev	9/26/2008 Mean	9/26/2008 Std Dev	11/13/2008 Mean	11/13/2008 Std Dev	12/9/2008 Mean	12/9/2008 Std Dev
Hemigrapsus oregonensis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heteromastus filiformis	22.3	4.5	0.0	0.0	3.3	0.6	0.7	1.2	2.3	1.5	0.0	0.0	1.7	1.5	2.3	1.5	0.7	1.2	0.3	0.6	0.7	1.2
Ilyanassa obsoleta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.6	1.0	1.0	0.3	0.6	0.7	0.6	0.0	0.0	0.3	0.6	0.0	0.0
Macoma petalum	1.7	1.5	0.0	0.0	0.7	0.6	12.7	4.9	96.0	18.1	21.0	8.2	21.7	5.0	24.7	6.4	15.3	0.6	3.0	4.4	5.0	3.0
Macoma spp.	0.0	0.0	0.0	0.0	1.3	1.2	13.7	5.7	8.3	4.6	1.0	1.7	0.3	0.6	6.3	11.0	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	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monocorophium acherusicum	0.3	0.6	0.0	0.0	2.0	1.0	3.7	1.5	7.7	3.5	3.7	5.5	7.3	3.8	4.7	5.0	4.7	2.5	5.3	3.5	4.3	2.1
Monocorophium insidiosum	13.3	2.5	0.0	0.0	0.0	0.0	0.3	0.6	97.0	23.6	0.7	0.6	0.0	0.0	0.0	0.0	1.0	1.7	0.0	0.0	0.0	0.0
Monocorophium spp.	2.7	1.2	0.0	0.0	0.3	0.6	0.0	0.0	10.0	1.0	0.7	1.2	2.3	0.6	6.7	0.6	5.0	2.0	9.3	2.1	3.7	3.2
Musculista senhousia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	1.3	1.5	1.3	0.6	0.0	0.0	0.7	1.2	1.3	2.3	0.3	0.6	0.0	0.0	0.0	0.0
Mysidacea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Neanthes succinea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.6	1.0	1.0	1.0	1.0	2.0	0.0	2.0	1.7	0.7	0.6	0.7	0.6
Nematoda	0.7	1.2	0.0	0.0	1.7	1.5	0.7	0.6	3.0	2.6	0.0	0.0	1.0	0.0	4.3	0.6	6.0	4.0	5.3	8.4	13.3	5.5

Species	1/17/2008		2/15/2008		3/14/2008		4/11/2008		5/20/2008		6/9/2008		7/22/2008		8/29/2008		9/26/2008		11/13/2008		12/9/2008	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Nippoleucon hinumensis	62.0	21.4	3.0	2.0	4.7	4.5	77.0	24.3	66.3	41.7	52.7	21.1	29.3	6.4	13.3	9.3	9.7	2.3	2.7	1.5	32.7	33.7
Odostomia fetella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Odostomia spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oligochaeta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Planariidae A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polydora cornuta	0.0	0.0	0.0	0.0	0.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.6
Polydora spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	11.4	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.3	0.6	4.3	2.5	8.3	5.1	3.3	2.1	4.7	2.1	0.0	0.0	0.0	0.0
Pseudopolydora kempi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	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	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sinelobus stanfordi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	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	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Species	1/17/2008		2/15/2008		3/14/2008		4/11/2008		5/20/2008		6/9/2008		7/22/2008		8/29/2008		9/26/2008		11/13/2008		12/9/2008	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Streblospio benedicti	29.3	7.1	0.0	0.0	16.7	5.5	16.0	12.5	0.0	0.0	15.7	6.5	43.3	1.5	39.7	4.2	60.0	19.5	3.0	2.6	13.3	11.6
Synidotea laevidorsalis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.6	7.3	2.3	1.7	1.5	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tharyx spp. ?	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tubificidae	34.0	24.4	0.3	0.6	43.0	42.2	23.0	3.6	11.7	4.2	32.0	12.2	41.0	23.3	29.3	11.7	99.0	86.2	62.7	18.2	71.7	35.9
Turbellaria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unid. Amphipod	3.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.6	0.3	0.6
Unid. Balanomorpha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unid. Copepod	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	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	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unid. Malanidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	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	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Species	1/17/2008		2/15/2008		3/14/2008		4/11/2008		5/20/2008		6/9/2008		7/22/2008		8/29/2008		9/26/2008		11/13/2008		12/9/2008	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Unid. Spionidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.6
Unid. Syllidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0