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: 2004

U.S. GEOLOGICAL SURVEY

OPEN FILE REPORT 2005-1279

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: 2004

Edward Moon, Michelle K. Shouse, Francis Parchaso, Janet K. Thompson, Samuel N. Luoma, Daniel J. Cain and Michelle I. Hornberger

---

U.S. GEOLOGICAL SURVEY

OPEN FILE REPORT 2005-1279

Prepared in cooperation with the
CITY OF PALO ALTO, CALIFORNIA

Menlo Park, California

U.S. DEPARTMENT OF THE INTERIOR
GALE NORTON, Secretary

U.S. GEOLOGICAL SURVEY
CHARLES GROAT, Director

For Additional Information
Write to:

Samuel N. Luoma, MS 465
U.S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025

Copies of this report may be
obtained from the authors or

U.S. Geological Survey
Information Center
Box 25286, MS 517
Denver Federal Center
Denver, CO 80225

Table of contents

List of figures

List of tables

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: 2004

Edward Moon, Michelle K. Shouse, Francis Parchaso, Janet K. Thompson, Samuel N. Luoma, Daniel J. Cain and Michelle I. Hornberger

Abstract

Trace elements in sediments and clams (*Macoma petalum*) (formerly reported as *Macoma balthica* (Cohen and Carlton 1995)), clam reproductive activity and benthic community structure are reported for a mudflat one kilometer south of the discharge of the Palo Alto Regional Water Quality Control Plant in South San Francisco Bay. This report serves as a continuation of the Near-Field Receiving Water Monitoring Study, which began in 1974. Prior to this report, trace metal and reproductive activity/community structure data were reported separately (see Moon *et al.* 2004 and Shouse *et. al.* 2004). The data for 2004, herein, are interpreted within that context and are consistent with those previously reported.

Metal concentrations in both sediments and clam tissue samples are within the range of values previously observed due to seasonal variability. Copper and zinc concentrations in sediment and bivalve tissue display continued decreases over the last decade. In 2004, copper in sediment was observed to drop below the ERL (Effects Range-Low) concentration for the fourth consecutive year. The concentration of zinc in sediment never exceeded the ERL. Yearly average concentrations of copper, zinc and silver in *Macoma petalum* for 2004 are some of the lowest recorded since monitoring for metals began in 1975. The concentrations of mercury and selenium, during April and January 2004, respectively, were the highest values observed for these elements during this study. However, the concentrations of these elements in sediments and clams at Palo Alto were similar to concentrations observed elsewhere in the San Francisco Bay.

Analyses of the benthic community structure of a mudflat in South San Francisco Bay over a 31-year period show that changes in the community have occurred concurrent with reduced concentrations of metals in the sediment and in the tissues of the biosentinal clam *Macoma petalum* from the same area. Analysis of the reproductive activity of *Macoma 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 reproducing during the two reproductive seasons (spring and fall) 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 could be indicative of a more stable community that is subjected to less stress. In addition, two of the opportunistic species (*Ampelisca abdita* and *Streblospio benedicti*) that brood their young and live on the surface of the sediment in tubes have shown a continual decline in dominance coincident with the decline in metals. *Heteromastus filiformis*, a subsurface polychaete worm that lives in the sediment, consumes sediment and organic particles residing in the sediment, and reproduces by laying their eggs on or in the sediment has shown a concurrent increase in dominance. These changes in species dominance reflect a change in the community from one dominated by surface dwelling, brooding species to one with species with varying life history characteristics.

Introduction

Environmental Monitoring

Determining spatial distributions and temporal trends of metals in sediments and benthic organisms is one method used to monitor environmental contamination and the associated ecological implications. Another common method of environmental monitoring is to examine the community structure of sediment dwelling benthic organisms (Simon 2002). Integrating both approaches can provide a more complete view of anthropogenic disturbances and the associated effects on ecosystem health.

Trace Metals

Sediment particles strongly bind metals, effectively removing them from solution. As a result, sediments may retain metals released to the environment. Thus, concentrations of metals in sediments serve as a record of metal exposure 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 bottom sediments and suspended particulate materials. However, the route through which organisms assimilate bioavailable sediment-bound metal is not well understood. 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 *et al.*, USGS, unpublished data).

Benthic Community 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 changes in predator/prey interactions, changes in competition for available resources, and overall shifts in species abundance. Changes in the benthic community can ultimately result in changes at the ecosystem level due to their importance in the cycling of carbon in aquatic environments (see Alpine and Cloern 1992 for a local example).

In the environment, benthic organisms are exposed to contaminants at all life stages through a variety of routes - sediment, water and food (see Wang and Fisher 1999 for a summary of the potential transport of trace elements through food). An organism can be exposed to high or low levels of contaminants for short or long periods of time. Even at low contaminant levels, long-term exposure can impact benthic organisms. The added complexity of synergistic effects between different contaminants and between contaminants and natural stressors makes the determination of causal relationships difficult at best. However, a time-integrated picture of ecosystem response to contaminant loading can be provided by field studies which link exposure to long-term changes at individual, population and community level.

RWQCB and NPDES

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

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

Objectives

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

- Provide data to assess seasonal and annual trends in trace element concentrations in sediments and clams, reproductive activity of clams and benthic community structure at a site designated in the RWQCB's Self-Monitoring Program guidelines for PARWQCP
- Present the data within the context of historical changes in South Bay 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 *et al*. 2000) 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.

Analysis of trace element concentrations in the tissues of *Macoma petalum* provides a measure of exposure to bioavailable pollutants. This does not, however, examine the physiological effects of metal exposure on *Macoma petalum*. Biological response of the benthic community to pollution was examined at the three levels of organization: individual, population, and community.

At the individual level, concentrations of metals in the tissues of *Macoma petalum* were compared with physiological indicators. Two common animal responses to environmental stress are reduced reproductive activity and reduced growth. Earlier studies (Hornberger *et al.* 2000) have shown that reproductive activity of *Macoma petalum* has increased with declining metal concentrations in animals from this location. Therefore, reproductive activity of *Macoma petalum* appears to be a useful indicator of physiological stress by pollutants at this location. At the population level, trends of the dominant benthic species were examined to see if certain species have been more affected than others. It has been shown that most taxonomic groups have species that are sensitive to elevated silver (Luoma *et al*. 1995) and that some crustacean and polychaete species are particularly sensitive to elevated copper (Morrisey *et al*. 1996, Rygg 1985). Finally, the benthic community was examined for changes in community structure. Prior studies have shown that more opportunistic species are likely to persist in highly disturbed environments (see Nichols and Thompson 1985a). It was hypothesized that a shift in community composition would result from changes in the concentrations of specific metals or shifts in the composite of all contaminants.

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

Study Site

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

The sediment and biological samples from this location reflect a response of the receiving waters to the effluent just beyond the location of discharge. Earlier studies (Thomson *et al*. 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 *et al.* (1984) (also reported by Hornberger *et al.* 2000; Luoma *et al.* 1991; 1992; 1993; 1995; 1996; 1997; 1998; Wellise *et al.* 1999; David *et al.* 2002; Moon *et al.* 2003; Moon *et al.* 2004; Shouse *et al.* 2003; Shouse *et al.* 2004; Thompson *et al*. 2002). Earlier work by Thomson *et al.* (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 *et al.* 1984; Cain and Luoma 1990). Metal concentrations in sediments and clams (*M. petalum*), especially Cu and Ag, have declined substantially since the original studies as more efficient treatment processes and source control were employed (Hornberger *et al.* 2000). However, frequent sampling each year was necessary to characterize those trends since there was significant seasonal variability (Cain and Luoma 1990; Luoma *et al.* 1985). This report characterizes data for the year 2004, employing the methods described in the succeeding section.

Previous reports (Luoma *et al.* 1995; 1996; 1997; 1998; Wellise *et al.* 1999) included a study area in addition to the Palo Alto sampling site. This area was located in a region 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. Used as a reference, the SJ site allowed differentiation of local and regional long-term metal trends.

Methods

Sampling Frequency

In dynamic systems such as San Francisco Bay, the environmental effects of anthropogenic stressors are difficult to distinguish from natural seasonal changes. Frequent sampling increases the probability that anthropogenic effects can be identified. Analyses of early data (1974 through 1983; Nichols and Thompson 1985a, 1985b) showed that, when differences are small, benthic samples need to be collected near monthly to make the distinction between natural and anthropogenic effects. Therefore, samples were collected, with a few minor exceptions, on a monthly basis from the exposed mudflat at low tide between January and December 2004. 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.

Sediment

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

To provide a measure of bulk sediment characteristics at a site, and thus provide some comparability with bulk sediment determination such as that employed in the Regional Monitoring Program – San Francisco Estuary Institute (SFEI 1997), the fraction of sediment that did not pass through the sieve was determined. This fraction is termed sand fraction. Bulk sediment samples were assessed to determine a percent sand (>100 μm) and a percent silt/clay (<100 μm) (Appendix A).

The percentage of the bulk sediment sample with grain size >100 μm (percent sand) was determined by weighing the fraction of sediment that did not pass through the sieve and dividing that weight into the total weight of the bulk sample (Appendix A). The percentage of silt/clay in the sediment was determined similarly by weighing the sediment that passed through the sieve (grain size <100 The <100 μm fraction was dried at 60º C, weighed, and then measured into 0.4 to 0.6 gram aliquots in replicates for analysis. The samples were again dried at 60º C before re-weighing and extraction. The replicate sub-samples were digested for near-total metal analysis by refluxing in 10 ml of concentrated nitric acid until the digest was clear. This method is comparable with the recommended procedures of the U.S. Environmental Protection Agency (USEPA) and with the procedures employed in the Regional Monitoring Program. It also provides data comparable to the historical data available on San Francisco Bay sediments. While near-total analysis does not result in 100% recovery of all metals, recent comparisons between this method and more rigorous complete decomposition show that trends in the two types of data are very similar (Hornberger *et al.* 1999). After decomposition, samples were evaporated until dry and reconstituted in dilute hydrochloric acid for analysis. The hydrochloric acid matrix was specifically chosen because it mobilizes silver (Ag) into solution through the creation of Ag-chloro complexes. Sediment samples were also subjected to a partial weak acid extraction in 0.6 N Hydrochloric acid (HCl) to obtain a crude chemical estimate of bioavailable metal. These sub samples were extracted for 2 hours with 12 ml of acid at room temperature. The extract was pressure filtered through a 0.45 μm membrane filter before analysis.

Percent organic carbon, percent organic nitrogen, $^{13}\delta C$ and $^{15}\delta$ N were determined using a continuous flow isotope ratio mass spectrometer (IRMS) (Appendix A). Prior to analysis, samples were acidified with concentrated HCl vapor to remove inorganic carbon.

Clams

More than 60 individuals of *M. petalum* were collected by hand on each sampling occasion. When possible, the range of sizes (shell length) was maximized by intensive field sampling. Salinity was determined for surface water and the mantle water of clams at the time of collection using a refractometer. Mantle water and surface water salinity were typically within 1 ppt (‰) of each other. Only surface water values are reported. Clams were returned to the laboratory and held for 48 hours in ocean water diluted to the ambient salinity at the time of sampling to depurate undigested material from their digestive tracts. After depuration, individual clams were separated into 1 mm size classes, based on maximum shell length. Soft tissues from all of the individuals in a size class were collected to constitute a single sample for analysis. Samples for each date were thus composed of six to eight replicate composites, with each composite consisting of 2 to 19 clams of a similar shell length. Clam tissue samples were oven dried, weighed and refluxed in concentrated nitric acid until the digest was clear. Digests were then dried and reconstituted in dilute 0.6 N hydrochloric acid for trace metal analysis. Tissue dry weights and the average shell length for a particular size class sample were used to evaluate condition index (CI).

Metals Analysis

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

100º C in aqua regia, re-digested in 10 percent nitric acid plus potassium dichromate and then reduced at the time of the hydride analysis (Elrick and Horowitz 1985).

All glassware and field collection apparatus used were acid washed, thoroughly rinsed in ultra-clean deionized water (18 mΩ), dried in a dust-free positive pressure environment, sealed and stored in a dust free cabinet. Quality control was maintained by frequent analysis of blanks and analysis of National Institute of Standards and Technology (NIST) standard reference materials (tissues and sediments). Within each analytical run, analysis was calibrated using a two point calibration curve. Calibration was followed by quality control checks with prepared quality control standards before, during (approximately every 10 samples) and after each analytical run. A full QA/QC plan is available upon request. Analyses of NIST reference materials (oyster tissue, San Joaquin soils) were within the acceptable range of certified values reported by NIST or were consistent where the nitric acid digest did not completely decompose the sediment samples (Appendix E). For sediment and clam analysis, method limits of detection (LOD) and minimum levels of quantification (LOQ) were evaluated using the procedures outlined by the USEPA (2004) and Glasser *et. al.* (1981). To account for matrix effects, NIST SRM 2711 and NIST SRM 2976 were used (Appendix F).

Reproductive Activity

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

Community Analysis

Samples for benthic community analysis were collected with an 8.5 cm diameter x 20 cm deep hand-held core. Three replicate samples were arbitrarily taken, within a one m^2 area, during each sampling date.

Benthic community samples were washed on a 0.5 mm screen, fixed in 10% formalin and then later preserved in 70% ethanol. Samples were stained with rose bengal solution. All animals in all samples were sorted to species level where possible (some groups are still not well defined in the bay, such as the oligochaetes), and individuals for each species were enumerated. Taxonomic work was performed in conjunction with a private contractor familiar with the taxonomy of San Francisco Bay invertebrates (Susan McCormick, Colfax, CA) (Appendix H). S. McCormick also compared and verified her identifications with previously identified samples.

Results and Discussion

Salinity

The weather in San Francisco Bay is characterized by a winter rainy season and a summer dry season (Figure 2). Precipitation within San Francisco Bay is reported at San Francisco Airport (California Data Exchange Center 2005). Since we began this study in 1974, average rainfall has been 23.1 inches per water year. The precipitation recorded in the 2003-2004 water year was below that average, 20.4 inches. During the 2003-2004 wet season, precipitation occurred over a 5-month period, November 2003 thru March 2004 compared to our long-term study average of a 7+ month period (as determined by months with rainfall amounts greater than 0.25 inches).

Surface water salinity values show a seasonal pattern governed by wet and dry seasons (Figure 3, Table 1). In the winter of 2004, salinities exhibited a typical seasonal decrease. This decrease is attributed to an elevated influx of freshwater from surface water runoff generated by winter storm precipitation. The salinity minimum in 2004 (14.0 parts per thousand (ppt). In the summer of 2004, salinities were among the highest recorded during this study. In October 2004, salinity peaked at 28 ppt. Similar salinity maxima were observed in 1994 and 1997. Only in 2002 was a higher salinity observed (30 ppt).

Sediments

Percent silt/clay in sediments indicates particle size distributions before sediments were sieved. At Palo Alto, percent silt/clay, Al, and Fe typically follow a seasonal cycle of increasing early in the year then declining to a minimum by September or October. For this site, Thompson-Becker *et al.* (1985) suggested that fine sediments, accompanied by high Al and Fe concentrations, are dominant during the period of freshwater input (low salinities through April), reflecting annual terrigenous sediment inputs from runoff. Coarser sediments dominated later in the year because the seasonal diurnal winds progressively winnow the fine sediments into suspension through the summer. This pattern was observed in 2004. However, the winter maximum input of fine sediments was delayed. The maximum percent silt/clay was observed in June, three months after the last significant rainfall event. The percent silt/clay varied from 15 - 71% (Figure 4). Al and Fe concentrations changed directly with the proportion of clay-size (very fine) particles within the 100 µm fraction of the sediment after sieving (Figure 4, Table 1). The total organic carbon (TOC) content showed a slight seasonal fluctuation. TOC increase to a value of 1.7% in April 2004 then decreased through the summer to a value of 0.7%. In October 2004 the TOC in sediments was observed to be abnormally high, 8.1% (this value was verified by multiple re-analysis of the sample). The content of carbon in the sediment returned to a normal value in December. Excluding the high value observed in October 2004, sediments had an average organic carbon content of 1.20% (Table 1) in 2004.

The metals Cr, Ni and V are strongly 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 *et al.*, 1999). Typically, concentrations of Cr, Ni and V exhibit seasonal variability with the highest concentrations early in the year (winter maximum) and the lowest concentrations in September-November. In 2004, concentrations of nickel continued to exhibit this pattern (Figure 5, Table 2). However, 2004 was distinct in that some of the lowest concentrations to date were observed for Ni. In October of 2004, the concentration of Ni decreased to 51.7µg/g, the lowest value observed during the study period. Nickel concentration increased through the winter to maximum of 91.6µg/g. This was the lowest winter maximum observed for Ni during the study period. Nickel exhibited a typical seasonal pattern. The patterns for Cr and V were less obvious. The maximum concentration of V was observed in March (147.0µg/g) and the minimum concentration was observed in October (85.7µg/g). The concentration of Cr was highest in the winter; however there was no obvious peak. The concentration of Cr was observed to decrease into the fall to a minimum of 91.8µg/g. The minimum was similar to those observed in previous years.

Copper also exhibits a strong seasonal variability (Figure 6, Table 2) with concentrations peaking in the winter then decreasing to a summer/fall minimum. The minimum concentration of near-total Cu in 2004 dropped to the lowest value observed during this study (21.3µg/g). From June thru December 2004, the near-total copper in sediments remained below the effects range-low (ERL) guidelines set by the National Oceanic and Atmospheric Administration (Long *et al.*, 1995). Long *et al.* (1995) defined values between ERL (Effects Range-Low) and ERM (Effects Range-Median) as concentrations that are occasionally associated with adverse effects (21 - 47% of the time for different metals). Values greater than the ERM were frequently associated with adverse effects (42% - 93% of the time for different metals). It must be remembered, however, that these effects levels were derived mostly from bioassay data and are not accurate estimates of sediment toxicity. Over the study period, with only minor exceptions, the near-total and partial-extractable concentrations of Cu have been tightly coupled. The partial-extractable Cu concentrations observed in 2004 further substantiate this observation (Figure 6).

In 2004, near-total and partial extractable Zn concentrations never rose above the Zn ERL. Both wintertime maximum and summer/fall minimum concentrations were observed to decrease from the previous year's highs (Figure 7, Table 2). Partial-extractable Zn also decreased from the previous year.

The concentration of partial-extractable Ag remained well below the Ag ERL. However, silver concentrations remained above the established concentration for uncontaminated sediments in San Francisco Bay (Hornberger *et al.*, 1999). Unlike previous years, a distinct winter maximum was not observed (Figure 8, Table 2). The minimum Ag concentration seen in the fall of 2004 (0.18 µg/g) was the lowest observed since 1999.

The April 2004 concentration of Hg in the sediment (0.49 µg/g) was the highest observed in this study. Otherwise, Hg concentrations were within the bounds of earlier years at an enrichment level typical of San Francisco Bay as a whole (0.2 - 0.4 µg/g) (Figure 9, Table 2).

The highest concentration we have observed of Se in the sediment at the Palo Alto site also occurred in 2004 (Figure 9, Table 2). This concentration, 0.78 µg/g in February 2004, was comparable to the highest concentrations observed in sediments anywhere in the San Francisco Bay (Hornberger *et al.*, 1999).

Metals in Clams

Exposures to Cu and Ag at Palo Alto, as reflected in clam tissues, have been of special interest due to the high concentrations observed in the 1970s and 1980s (Figure 10 and Figure 11, Table 3 and Table 4, respectively). Exposures to both metals were lower throughout the 1990s than in the years prior to 1988. Minimum concentrations in clam tissues were observed in 1991, but a five-year period of slightly increased concentrations followed. Concentrations of both metals in clams declined in 1997 and have remained relatively constant through 2004.

Intra-annual variations in Cu concentrations in clam soft tissues display a consistent seasonal signal, with fall/winter maxima and spring/summer minima (Figure 12). The winter maxima and the amplitude of the seasonal cycle were greater between 1994 through 1996 than in subsequent years. Ag also displayed the same long-term seasonal pattern as Cu in clam tissue (Figure 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).

Seasonal cycles were also exhibited in the concentrations of Cr (Figure 14, Table 5), Ni (Figure 15, Table 5) and Zn (Figure 16, Table 5) in clam tissue. Wellise *et al.* (1999) observed that the trends of these metals in Palo Alto clam samples were similar to those from the San Jose site, suggesting that regional-scale processes may be more important than treatment plant inputs in controlling seasonality and bioavailability of these elements. The seasonal signal continued in 2004 wherein the highest Cr, Ni, and Zn concentrations were observed during winter (December-March), and the minima typically occurred during summer (June-September). In 2003, both Cr and Ni showed an increase in winter-maximum tissue concentration. These were the highest Cr and Ni concentrations observed in seven and six years respectively. For the years 2002-2004, winter-maximum for Zn showed a slight increasing trend. However, despite this short term increase, there appears to still be a general decreasing trend in winter maxima concentrations of Zn since 1996.

In 1996, there was a decrease in mercury concentrations in clam tissues (Figure 17). Since 1996, lower levels of Hg have persisted. In 2004, Hg concentrations remained low compared to the pre-1996 (Figure 17). Selenium concentrations also show a seasonal pattern (Figure 18, Table 5), which is stronger in some years that in others. In 2004, Se concentration reached a maximum of 5.5 µg/g and the annual low Se concentration in summer was higher than previously seen.

Condition index (CI) is a measure of physiological "fatness", the tissue weight of a clam for a given length. It is an index of the clams' well-being and is linked to the seasonal reproductive cycle. Seasonally, a clam of a given shell length will increase somatic tissue weight as a part of growth and reproductive tissue during the early stages of reproduction. The latter weight is then lost during and after reproduction. Other stressors such as pollutant exposure, salinity extremes or lack of food can also reduce condition index. Condition index has been monitored throughout this study (Figure 19).

Reproduction of Macoma petalum

As seen in previous years (Hornberger et al. 1999, and Shouse et al. 2004), reproduction in *Macoma petalum* continues to reflect the concentration of silver found in the tissue of this clam. The time series of reproductive activity (Figure 20) shows that *M. petalum* continues to be highly reproductive relative to the 1970's with a high percentage of the animals being reproductively active at any one time and with normal seasonal cycling of reproduction beginning in fall and spawning occurring during the following spring (Figure 21) (see Appendix H for detailed reproduction data for 2004).

Benthic Community

The simplest metrics that are used in assessing environmental stress on biological communities are estimates of species diversity and total animal abundance. Species diversity, as estimated by a time series of number of species for each month, showed no significant trend in this study, (Figure 22) nor did total animal abundance (Figure 23). The difficulty with these types of metrics is that they do not consider the possibility that one species can take the place of another. Depending on the characteristics of the new species, the community structure and function may change as a result of this exchange of species. The details of changes in species composition are important because these changes may reflect the relative ability of species to accommodate environmental stress.

Three common bivalves (*Macoma petalum*, *Mya aremaria*, and *Gemma gemma*) did not show any consistent trend over the 29-year period (Figure 24, Figure 25, and Figure 26). In all cases, there is significant seasonal and inter-annual variability in species abundances. There were, however, six species that did show trends in their abundance throughout the study. The first, *Ampelisca abdita*, a small crustacean that lives above the surface of the mudflat in a tube built from selected sediment particles showed a general decline in both the annual average abundances and annual maximum abundances (seasonal peaks in abundance; Figure 27). The second species to 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* exhibited a decline in annual maximum abundances as well as annual average abundances (Figure 28). The small burrowing crustacean *Grandiderella japonica*, a deposit feeder, initially shows a declining trend followed by increasing seasonal maximum abundances in recent years (Figure 29). *Neanthes succinea*, a burrowing polychaete that feeds on surface deposits and scavenges, similarly shows an initial decrease in annual maximum abundances, followed by an increase in both annual average abundances and annual maximum abundances (Figure 30). There are two species that show an increase in abundance through the time series. The first is the polychaete worm *Heteromastus filiformis* (Figure 31), a deposit feeding, burrowing species that lives deep in the sediment (usually 5-20 cm below the surface of the mudflat). The second is an introduced species, *Nippoleucon hinumensis*, a small burrowing crustacean, which appeared in the dataset in 1988 (Figure 32) and was introduced into the bay in 1986 (Cohen and Carlton 1995).

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 et al. 2002). Therefore, this update will only consider those metals (recent data, 2002 through 2003, taken from Moon et al. 2004). This comparison can be made by plotting the metals and individual species together over the period of the study. The worm *H. filiformis* has increased in abundance with the decrease in silver and copper through time (Figure 33). Because the natural spatial variability (i.e. the large standard deviations around the monthly means) and seasonal variability of invertebrate abundance and metal concentration can be quite large, the annual average abundances for *H. filiformis* and annual average metal concentrations are shown (Figure 34 and Figure 35). To interpret these plots, we must first examine the life history characteristics of this species and determine if there is some mechanism by which this organism could be responding to a decrease in silver or copper in the environment. *H. filiformis* has continual tissue contact with the sediment both at the exterior of its body, as well as within its body, due to its life style of burrowing through the sediment and consuming a diet of mud and organic particles. In addition, this is one of the few species in the present community that reproduces exclusively by laying its eggs in the sediment. The larvae hatch after two to three days and spend two to three days in the plankton before settling back to the mud as juvenile worms (Rasmussen 1956). One hypothesis as to why *H. filiformis* increased in abundance may be that either the adult worms or the eggs are less stressed in the present environment. Because of its mode of reproduction and short planktonic larval period, this species is not likely to move into an area quickly after the environment becomes acceptable. Therefore, it is not possible to identify either the identity of the metal or the threshold concentration of the metal to which the animal is responding without laboratory tests. However, other investigators have shown that silver can adversely affect reproduction in invertebrates and that adult *H. filiformis* can tolerate high levels of copper (Ahn et al.1995). The gradual increase in *H. filiformis* abundance through 1984 may be a response to the gradual reduction of metals in the environment or may indicate that it took several years for the population to build up in the area. The large abundance increase in 1985 and 1986, followed by a decline and leveling out of abundance, may be an example of the "boom and bust" principle whereby a species rises to levels too high for the habitat to support, and then declines in abundance until it levels out to a habitat-supportable abundance (Begon et al. 1986). It is unclear, based on only seven years of data since the early 1990's, if this species has established a stable abundance.

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

Summary

Long-term Observations

Since 1974, USGS personnel have monitored and researched the benthic sediments and 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 *et al.* 1991; 1992; 1993; 1995; 1996; 1997; 1998; Wellise *et al.* 1999; David *et al.* 2002; Moon *et al.* 2003; Moon *et al.* 2004; Shouse *et al.* 2003; Shouse *et al.* 2004; Thompson et al. 2002) with additional data from January 2004 through December 2004, to create a dataset spanning 31 years. This long-term dataset includes sediment chemistry, metal concentrations in *M. petalum*, reproductive activity of *M. petalum* and benthic community populations. The time series of benthic data is of particular interest because it encompasses the period when exceptionally high concentrations of copper and silver were found in the benthic animals (1970's) and the period when those concentrations declined (after 1981).

In the early 1980's, the point-source metal loading from the nearby Palo Alto Regional Water Quality Control Plant significantly declined. Coincident with declines in metal loadings, concentrations of metals in the sediment and in a biosentinel clam (*M. petalum*) also declined as previously described by Hornberger *et al*. (2000). Hornberger *et al.*1999 and 2000 correlated these coincident declines and illustrated that the reduction of metal discharge by the PARWQCP resulted in a rapid reduction (within a year) in near-field contamination in both the sediment and benthic organisms of San Francisco Bay.

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

While the benthic community response to reduced metal output is likely to take longer, a response at the organismal level (i.e. reproductive activity, a manifestation of a cellular or physiological change) was observed within a year or two, and a response at the population and community levels was observed soon thereafter. Due to the natural intra-annual variability of benthic community dynamics, stable changes in the benthic community can take some time to be expressed. The community is continually evolving in response to natural and anthropogenic disturbances. It is therefore critical to examine the changes in the community in the context of time, to account for seasonal and inter-annual variability. Thus, this study highlights the importance of long time series data that incorporate seasonal and inter-annual variability in studies of contaminant effects.

2004

In 2004, Cu and Ag concentrations in sediments and clam tissues continued to reflect the decrease in the loading of these metals from the treatment plant. For many other elements of regulatory interest, including Cr, V, Ni, and Zn, regional scale factors appeared to influence sedimentary and bioavailable concentrations. Other variables such as precipitation and accelerated erosion of salt marsh banks in recent years that may influence the seasonal and year to year patterns in sedimentary and tissue concentrations should still be investigated.

The current dataset demonstrates the adverse impacts of contaminants on benthic organisms. Decreasing trace metals in the local environment have been reflected in the increased reproductive activity in the clam *Macoma petalum*. Reproductive data from 2004 is consistent with data from the previous years. The abundances of individual species showed little variability during the year 2004. This reflects a more stable community in the absence of metal stressors. All dominant species in the community, with the exception of *G. gemma*, have abundances similar to those seen in previous years. The lower abundances exhibited by *G. gemma* in 2004 are found elsewhere in the dataseries, and could be due to a number factors. The interpretation that shifts in species abundance at Palo Alto were a response to decreasing contaminants continue to be supported by the most recent community data.

Value of Long-Term Monitoring

Long-term monitoring has made it possible to describe trends, identify previously undocumented phenomena, and pose otherwise unrecognized hypotheses that might guide detailed explanatory studies. Monitoring studies cannot always unambiguously determine the causes of trends in metal concentrations or benthic community structure. The strength of this study is the integrated analysis of metal exposure and biological response at intra- and inter-annual scales. The frequency of sampling allows long-term trends to be identified within the context of repeating seasonal cycles and unrelated inter-annual variation. Through interpreting time series data, it has been possible to separate anthropogenic effects from natural annual and inter-annual variability. Changes and trends in community structure that may be related to anthropogenic stressors, such as was seen in this study, can only be established given a study of sufficient length in time and frequency of sampling so that the natural stressors can be characterized and separated from those introduced by man.

References

Ahn, I. Y., Y. C. Kang, and J.W. Choi. 1995. The influence of industrial effluents on the intertidal benthic communities in Panweol, Kyeonggi Bay (Yellow Sea) on the west coast of Korea. Marine Pollution Bulletin, 30:200-206

Alpine, A. E. and J.E. Cloern. 1992. Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary. Limnology and Oceanography, 37:946-955.

Begon, M., J.L. Harper and C.R. Townsend. 1986. Ecology: Individuals, Populations and Communities. Sinauer Associates Inc., Sunderland, Massachusetts.

Cain, D. J. and Luoma, S. N., 1990, Influence of seasonal growth, age and environmental exposure on Cu and Ag in a bivalve indicator, *Macoma balthica* in San Francisco Bay: Marine Ecology Progress Series 60, p. 45-55.

California Data Exchange Center. 2005. San Francisco WB AP. California Department of Water Resources Division of Flood Management. http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=SFF.

Cohen, A.N. and J.T. Carlton. 1995. Biological Study. Nonindigenous aquatic species in a United States Estuary: A case study of the biological invasions of the San Francisco Bay and Delta. U.S. Fish and Wildlife Service, Washington D. C.

David, C. P. C., Luoma, S. N, Brown, C, Cain, D. J, Hornberger, M. and Lavigne, I. R. 2002. Near field receiving water monitoring of trace metals in clams (*Macoma balthica*) and sediments near the Palo Alto Water Quality Control Plant in South San Francisco Bay, California: 1999-2001. U. S. Geological Survey Open File Report 02-453. Menlo Park, California. 105pp.

Elrick, K. A. and Horowitz, A. J. 1985. Analysis of rocks and sediments for arsenic, antimony, and selenium, by wet digestion and hydride atomic absorption. U. S. Geological Survey Open File Report 85-497. Doraville, Georgia. 14pp.

Glaser, J.A., Foerst, D.L., Mckee, G.D., Quave, S.A., Budde, W.L. (1981) Trace analyses for wastewaters, Environmental Science and Technology, Vol. 15, No. 12, pp 1426-1435.

Hornberger, M. I., Luoma, S. N., Van Geen, A., Fuller, C. C., and Anima, R. 1999, Historical trends of metals in the sediments of San Francisco Bay, California. Marine Chemistry 64, p. 39-55.

Hornberger, M.I., Luoma, S. N., Cain, D., Parchaso, F., Brown, C., Bouse, R., Wellise, C.J., Thompson, J., 2000, Bioaccumulation of metals by the bivalve *Macoma balthica* at a site in South San Francisco Bay between 1977 and 1997: Long-term trends and associated biological effects with changing pollutant loadings. U. S. Geological Survey Open File Report 99-55. Menlo Park, California. 42pp.

Hornberger, M., S. Luoma, D. Cain, F. Parchaso, C. Brown, R. Bouse, C. Wellise, and J. Thompson. 2000. Linkage of bioaccumulation and biological effects to changes in pollutant loads in South San Francisco Bay. Environmental Science and Technology, 34:2401-2409.

Kennish, J.K. 1998. *Pollution impacts on marine biotic communities*. CRC Press, New York. 310 pp.

Long, E. R., MacDonald, D. D., Smith, S. L., and Calder, F. D., 1995, Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments: Environmental Management, v. 19, p. 81-97.

Luoma, S. N., Cain, D. J., and Johansson, C., 1985, Temporal Fluctuations of Silver, Copper and Zinc in the Bivalve *Macoma balthica* at Five Stations in South San Francisco Bay: Hydrobiologia 129:109_120, 1985.

Luoma, S. N., Cain, D. J., Brown, C. and Axtmann, E. V., 1991, Trace Metals in Clams (*Macoma balthica*) and sediments at the Palo Alto Mudflat in South San Francisco Bay: April, 1990 - April, 1991. U. S. Geological Survey Open File Report 91-460. Menlo Park, California. 47pp.

Luoma, S. N., Cain, D. J., Brown, C. and Hornberger, M., 1992, Trace Metals in Clams (*Macoma balthica*) and sediments at the Palo Alto Mudflat in South San Francisco Bay: May 1991 - May 1992. U. S. Geological Survey Open File Report 92-456. Menlo Park, California. 51pp.

Luoma, S. N., Cain, D. J., Brown, C. and Hornberger, M., 1993, Trace Metals in Clams (*Macoma balthica*) and sediments at the Palo Alto Mudflat in South San Francisco Bay: June 1992 - June 1993. U. S. Geological Survey Open File Report 93-500. Menlo Park, California. 52pp.

Luoma, S. N., Cain, D. J., Brown, C. and Hornberger, M., 1995, Near Field Receiving Water Monitoring of Trace Metals in Clams (*Macoma balthica*) and sediments near the Palo Alto and San Jose/Sunnyvale Water Quality Control Plants in South San Francisco Bay: June 1993 - October 1994. U. S. Geological Survey Open File Report 95-299. Menlo Park, California. 83pp.

Luoma, S. N., Cain, D. J., Brown, C., Hornberger, M., and Bouse, R. 1996, Near Field Receiving Water Monitoring of Trace Metals in Clams (*Macoma balthica*) and sediments near the Palo Alto and San Jose/Sunnyvale Water Quality Control Plants in South San Francisco Bay: December 1994 - December 1995 U. S. Geological Survey Open File Report 96-203. Menlo Park, California. 90pp.

Luoma, S. N., Cain, D. J., Brown, C., Hornberger, M., and Bouse, R. 1997, Near Field Receiving Water Monitoring of Trace Metals in Clams (*Macoma balthica*) and sediments near the Palo Alto and San Jose/Sunnyvale Water Quality Control Plants in South San Francisco Bay: 1996 U. S. Geological Survey Open File Report 97-585. Menlo Park, California. 91pp.

Luoma, S.N., Y.B. Ho, and G. W. Bryan. 1995. Fate, bioavailability and toxicity of silver in estuarine environments. Marine Pollution Bulletin, 31:44-54.

Luoma, S. N., Wellise, C, Cain, D. J., Brown, C., Hornberger, M., and Bouse, R. 1998, Near Field Receiving Water Monitoring of Trace Metals in Clams (*Macoma balthica*) and sediments near the Palo Alto and San Jose/Sunnyvale Water Quality Control Plants in South San Francisco Bay: 1997 U. S. Geological Survey Open File Report 98-563. Menlo Park, California. 88pp.

Morrisey, D.J., A.J. Underwood, and L. Howitt. 1996. Effects of copper on the faunas of marine soft-sediments: an experimental field study. Marine Biology 125:199-213.

Moon, E., David, C. P. C., Luoma, S. N, Cain, D. J, Hornberger, M. and Lavigne, I. R. 2003. Near field receiving water monitoring of trace metals in clams (*Macoma balthica*) and sediments near the Palo Alto Water Quality Control Plant in South San Francisco Bay, California: 2002. U.S. Geological Survey Open File Report 03-339. Menlo Park, California. 78pp.

Moon, E., Luoma, S. N, Cain, D. J, Hornberger, M. and ., David, C. P. C. 2004. Near field receiving water monitoring of trace metals in clams (*Macoma balthica*) and sediments near the Palo Alto Water Quality Control Plant in South San Francisco Bay, California: 2003. U.S. Geological Survey Open File Report 2004-1213. Menlo Park, California. 84pp.

Nichols, F.N, and J.K. Thompson. 1985a. Persistence of an introduced mudflat community in South San Francisco Bay, California. Marine Ecology Progress Series, 24:83-97.

Nichols, F.N, and J.K. Thompson. 1985b. Time scales of change in the San Francisco Bay benthos. Hydrobiologia. 129:121-138

Parchaso, F. 1993. Seasonal reproduction of *Potamocorbula amurensis* in San Francisco Bay, California. M.S. Thesis, San Francisco State University, San Francisco.

Rasmussen, E. 1956. The reproduction and larval development of some polychaetes for the Isefjord, with some faunistic notes. Biol. Meddr., 23(1):1-84.

Rygg, B. 1985. Effect of sediment copper on benthic fauna. Mar. Ecol. Prog. Ser. 25:83-89.

San Francisco Estuary Inst. 1997, RMP, Regional Monitoring Program for Trace Substances: 1996. Richmond, CA. 349 pp.

Shouse, Michelle K. 2002. The effects of decreasing trace metal concentrations on benthic community structure. Master's Thesis, San Francisco State University. 177pp.

Shouse, M.K., F. Parchaso, and J.K. Thompson. 2004. Near-field receiving water monitoring of benthic community near the Palo Alto Water Quality Control Plant in South San Francisco Bay: February 1974 through December 2003. U.S. Geological Survey Open File Report 2004-1210, Menlo Park, California, 39pp.

Shouse, M.K., F. Parchaso, and J.K. Thompson. 2003. Near-field receiving water monitoring of benthic community near the Palo Alto Water Quality Control Plant in South San Francisco Bay: February 1974 through December 2002. U.S. Geological Survey Open File Report 03-224, Menlo Park, California, 52pp.

Simon, T.P. 2002. *Biological response signatures*. CRC Press, Boca Raton, Florida, U.S.

Thomson, E. A., Luoma, S. N., Johansson, C. E., and Cain, D. J., 1984, Comparison of sediments and organisms in identifying sources of biologically available trace metal contamination: Water Research, v. 18, p. 755-765.

Thompson, J.K., Parchaso, F., and Shouse, M.K. 2002. Near field receiving water monitoring of benthic community near the Palo Alto Water Quality Control Plant in South San Francisco Bay: February 1974 through December 2000. U.S. Geological Survey Open File Report 02-394, 117pp.

Thomson-Becker, E. A., and Luoma, S. N., 1985. Temporal fluctuations in grain size, organic materials and iron concentrations in intertidal surface sediment. Hydrobiologia, v. 129, p. 91-109.

U.S. Environmental Protection Agency Office of Water, 2004, Revised Assessment of Detection and Quantitation Approaches, EPA-821-B-04-005, U.S. Environmental Protection Agency, 1200 Pennsylvania Avenue, NW Washington, DC 20460, pp 254.

van Geen, A and Luoma, S.N. 1999. A record of estuarine water contamination from the Cd content of foraminiferal tests in San Francisco Bay, California. Marine Chemistry 64, p. 57-69.

Wang, W. and Fisher, N. S. 1999. Delineating metal accumulation pathways for marine invertebrates. The Science of the Total Environment. 237:459-472.

Wellise, C., Luoma, S. N., Cain, D. J., Brown, C., Hornberger, M., and Bouse, R. 1999, Near Field Receiving Water Monitoring of Trace Metals in Clams (Macoma balthica) and sediments near the Palo Alto and San Jose/Sunnyvale Water Quality Control Plants in South San Francisco Bay: 1998 U.S. Geological Survey Open File Report 99-455. Menlo Park, California. 101pp.

Zar, J.H. 1996. Biostatistical Analysis. Prentice-Hall Inc. Upper Saddle River, New Jersey, USA.

Figures

-

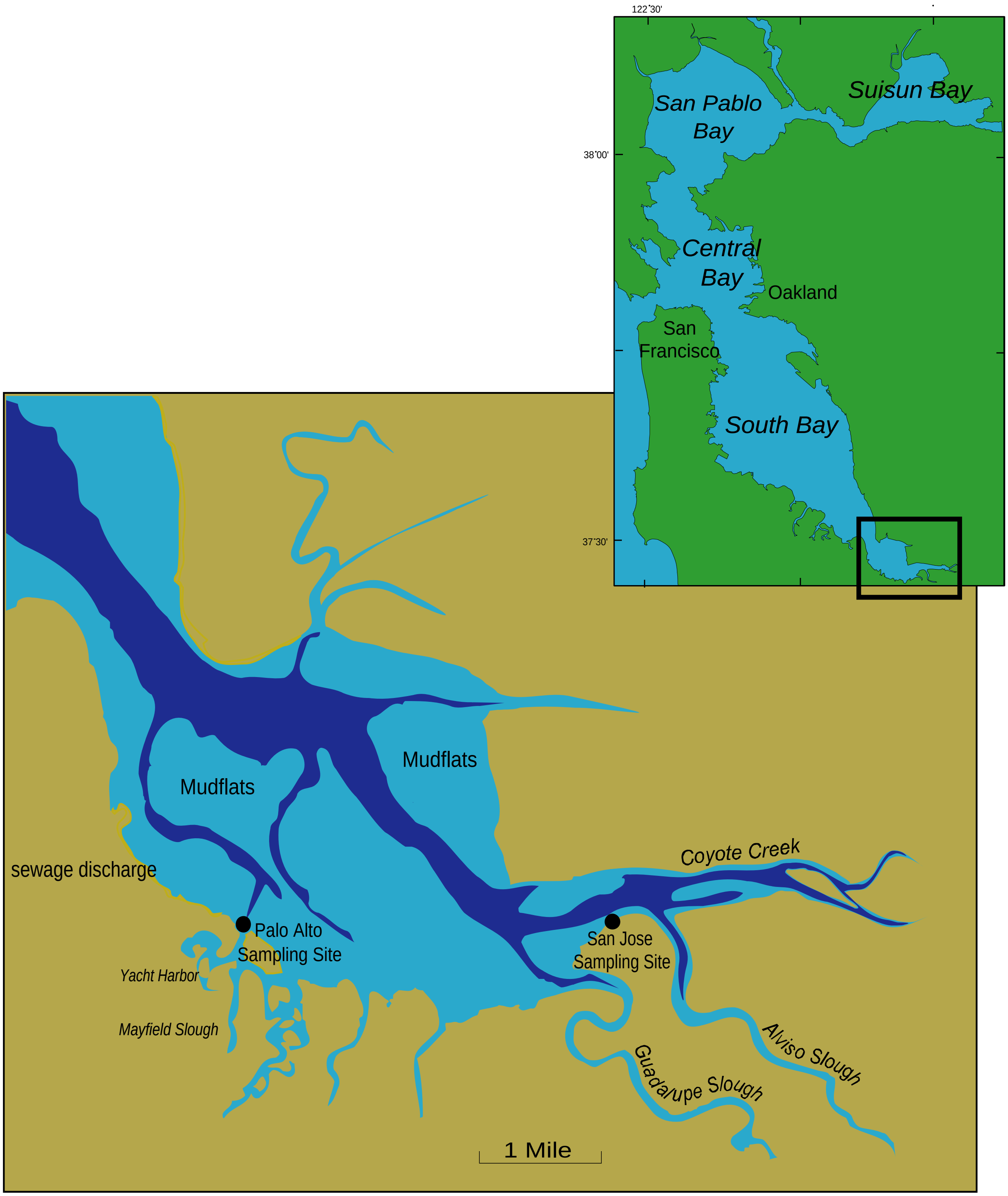


Figure 1. Location of the Palo Alto sampling station in South San Francisco Bay.

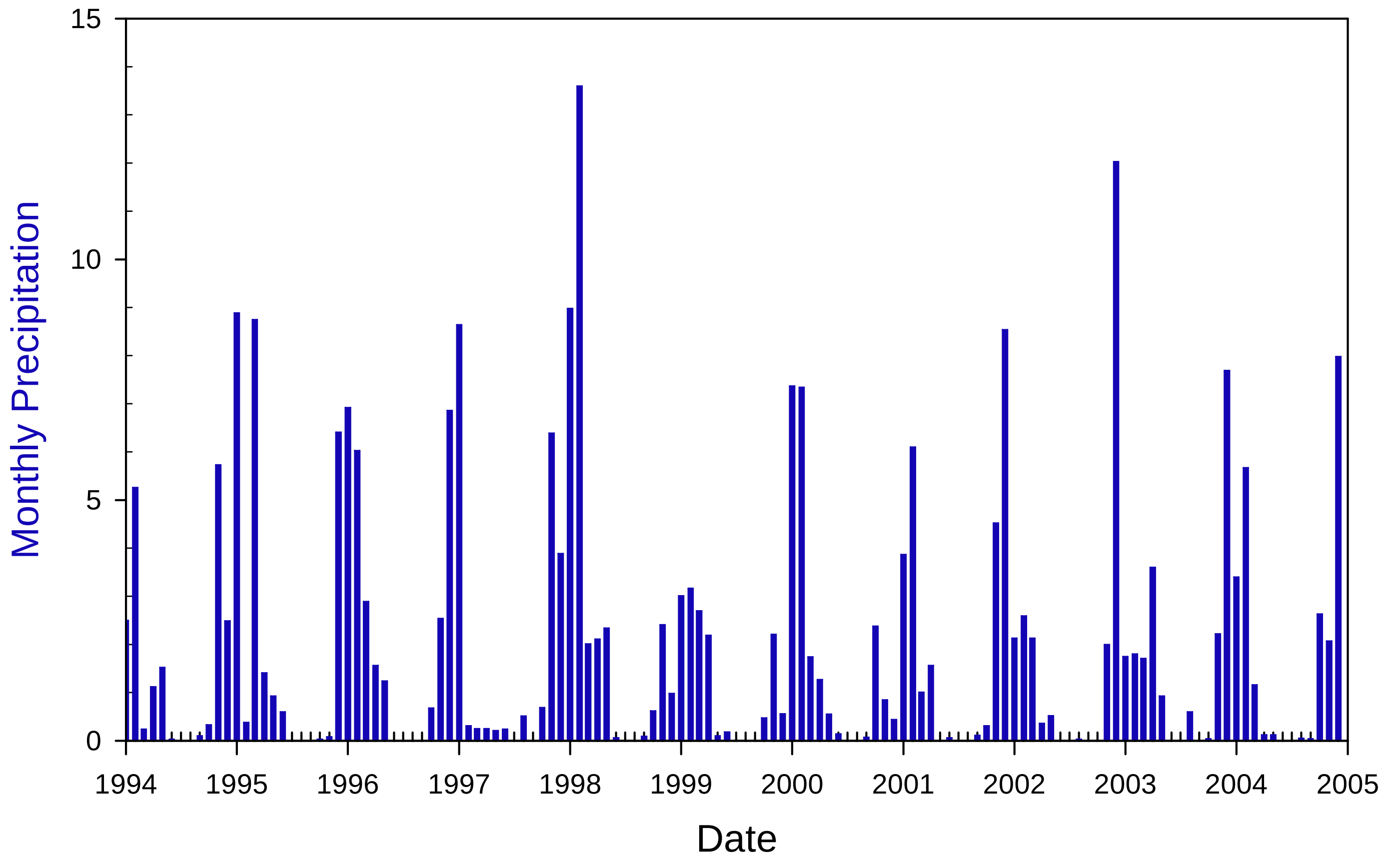


Figure 2. Precipitation

Data from San Mateo gauge station is for period from 1994 through 2004. Precipitation is in inches.

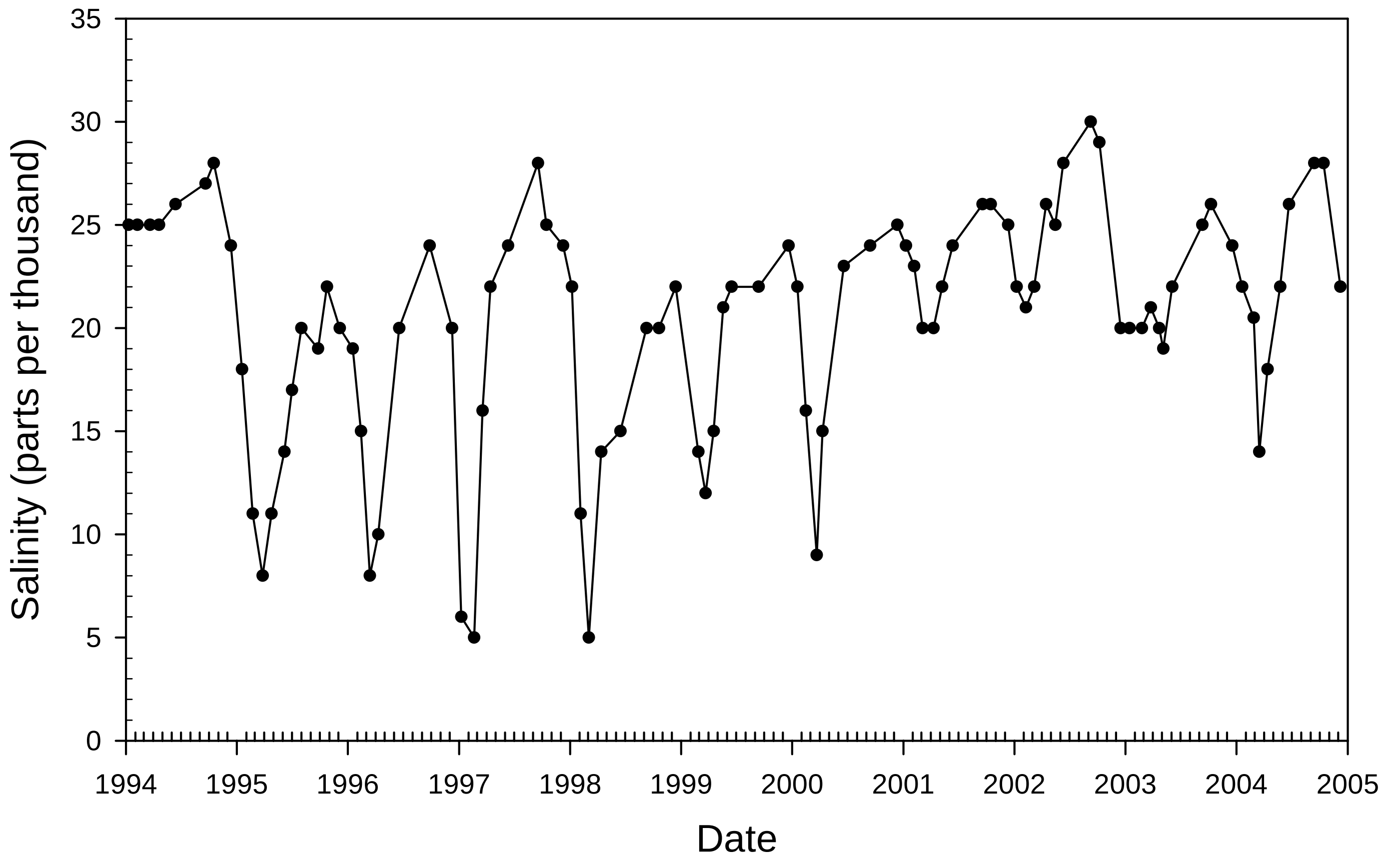


Figure 3. Water column salinity

Data from Palo Alto site is for period from 1994 through 2004.

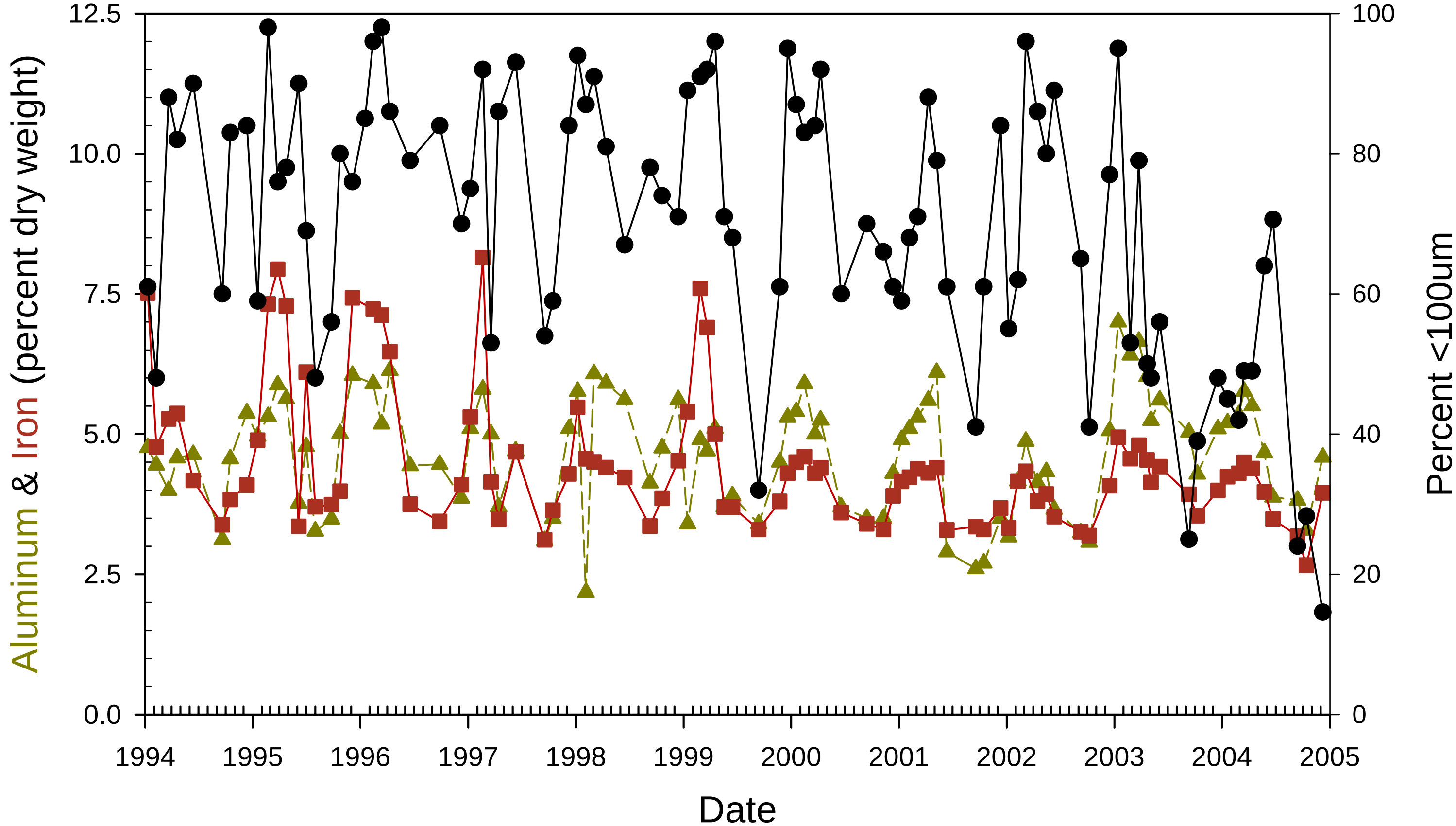


Figure 4. Aluminum, iron and silt/clay in sediments

Data from Palo Alto site is for period from 1994 through 2004. Percent aluminum (▲), iron (■) and silt/clay (●).

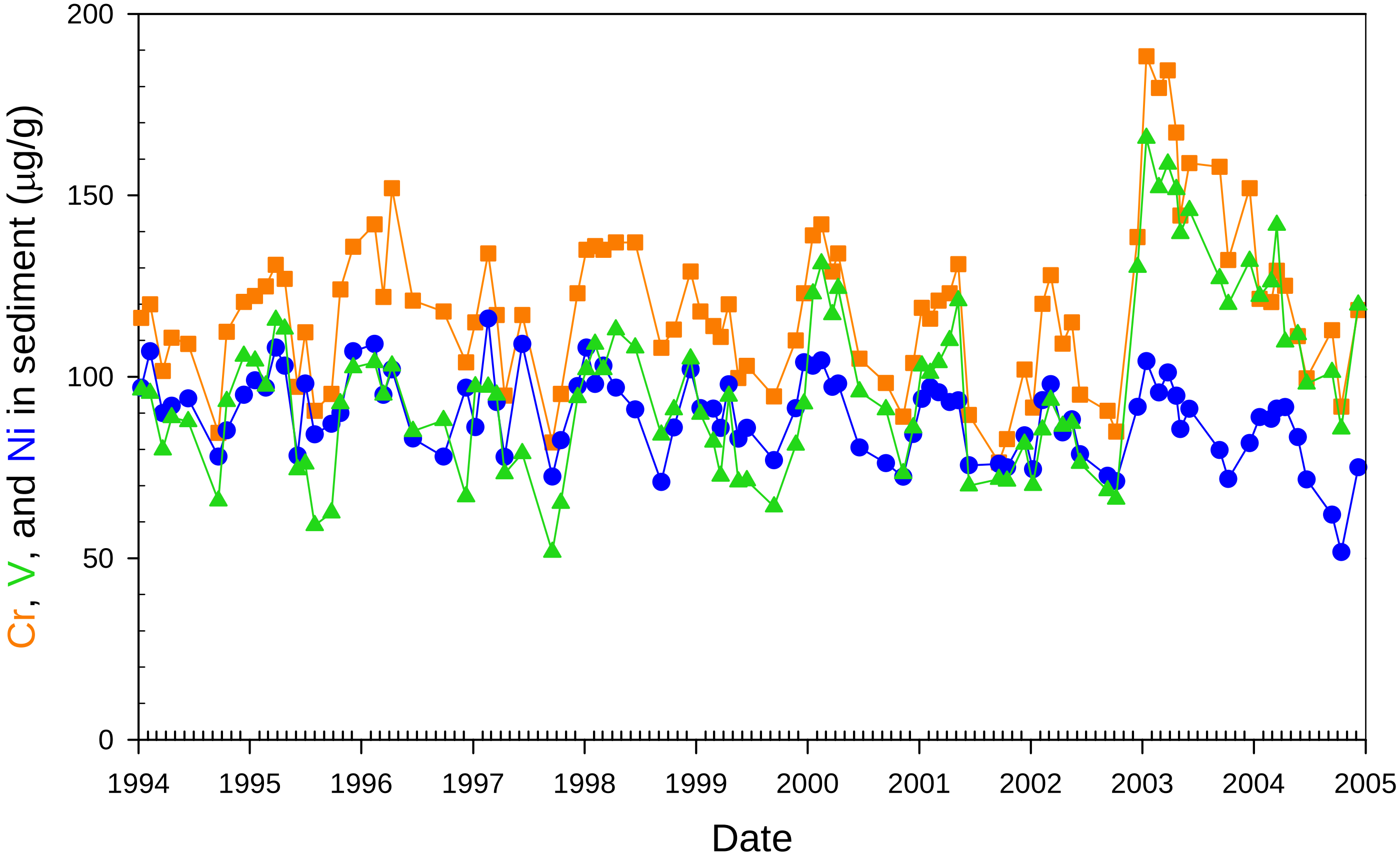


Figure 5. Chromium, nickel and vanadium in sediments

Data from Palo Alto site is for period from 1994 through 2004. Near-total extraction concentrations of chromium (Cr) (■), nickel (Ni) (●) and vanadium (V) (▲).

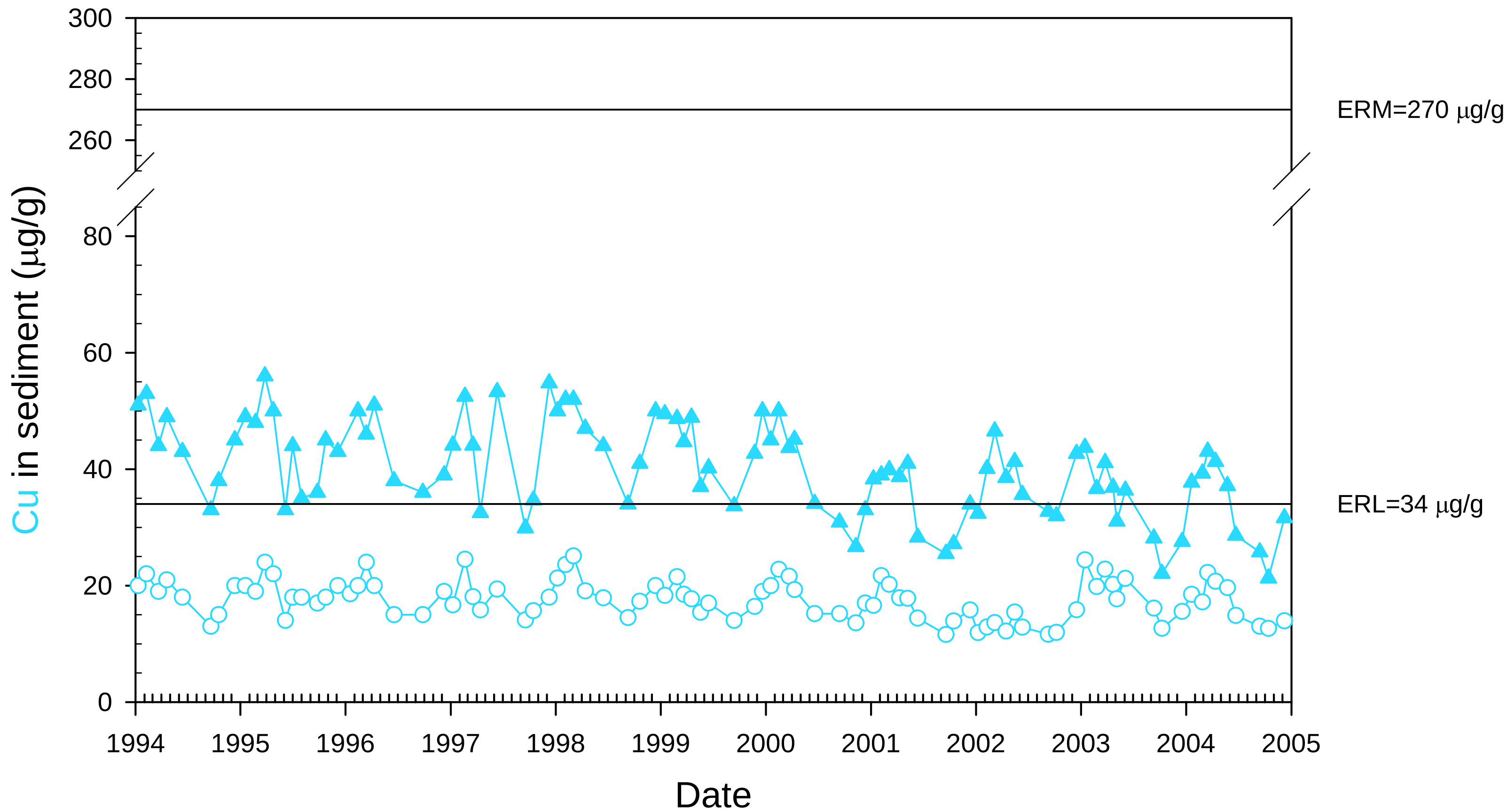


Figure 6. Copper in sediments

Data from Palo Alto site is for period from 1994 through 2004. Near-total (▲) and partial-extractable (○) copper.

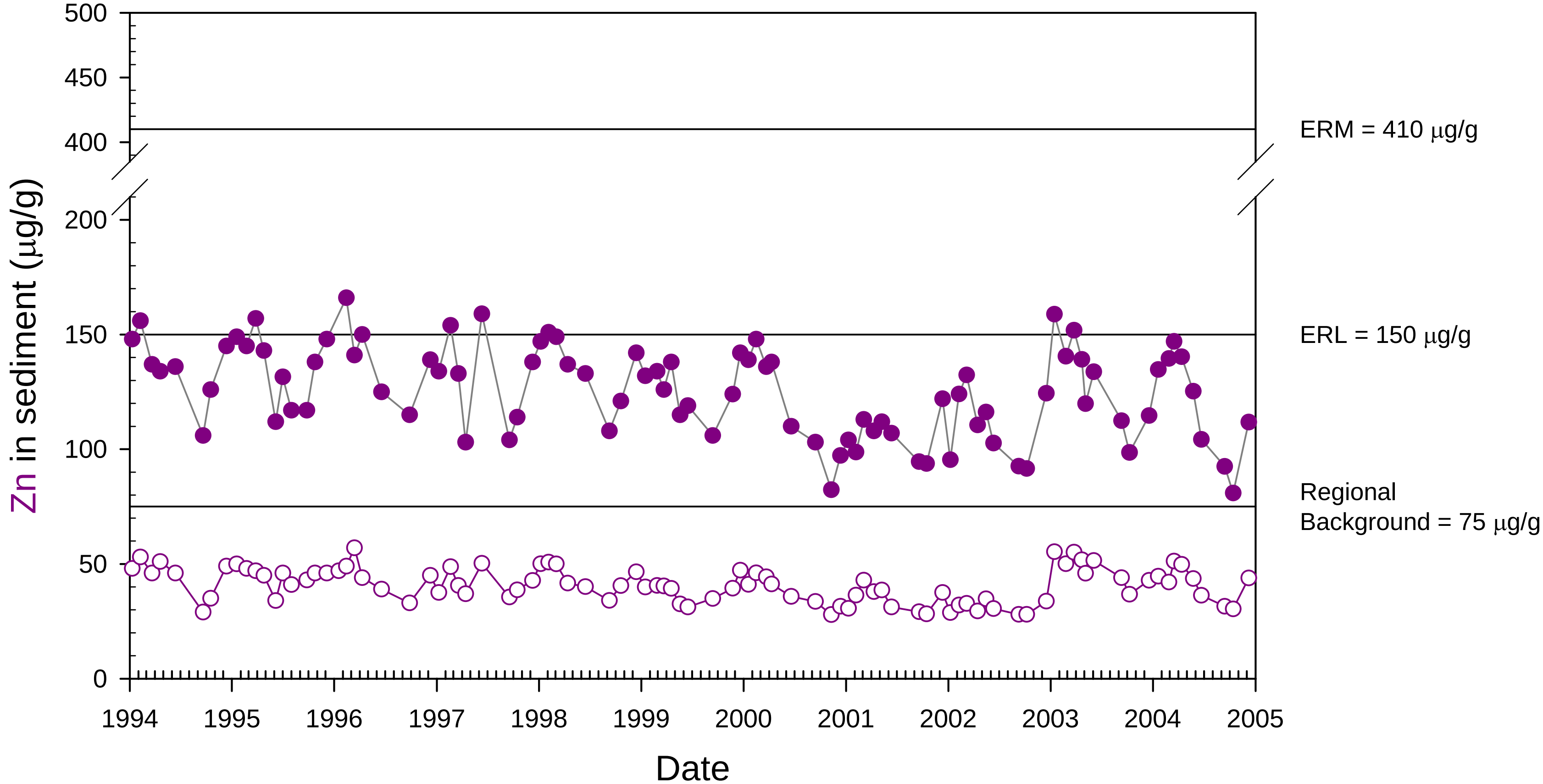


Figure 7. Zinc in sediments

Data from Palo Alto site is for period from 1994 through 2004. Near-total (●) and partial-extractable (○) zinc.

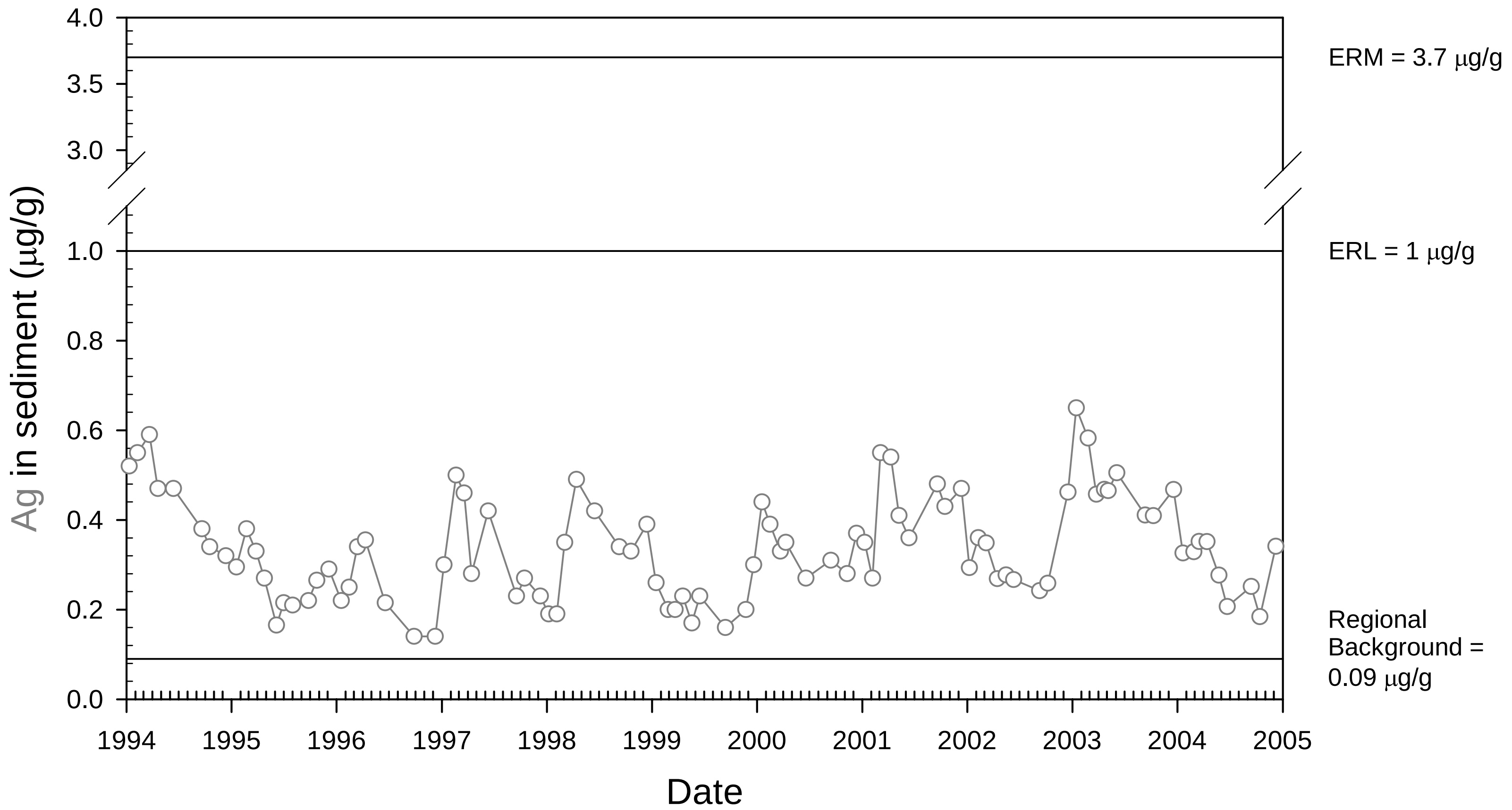


Figure 8. Silver in sediments

Data from Palo Alto site is for period from 1994 through 2004. Concentrations are for acid-extractable silver. Extractions were conducted with 0.6 N hydrochloric acid.

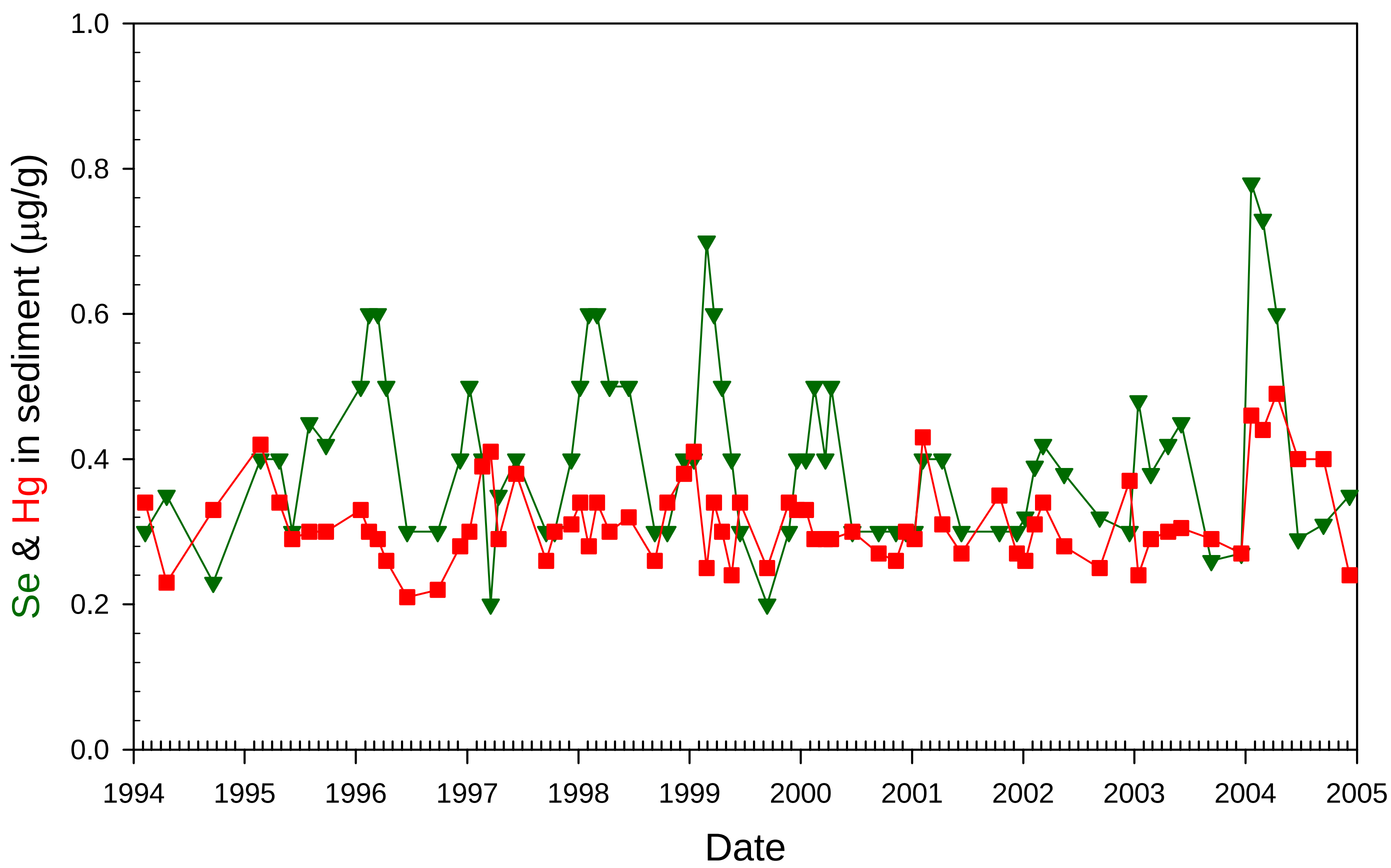


Figure 9. Selenium and mercury in sediments

Data from Palo Alto site is for period from 1994 through 2004. Selenium (▼) and mercury (■).

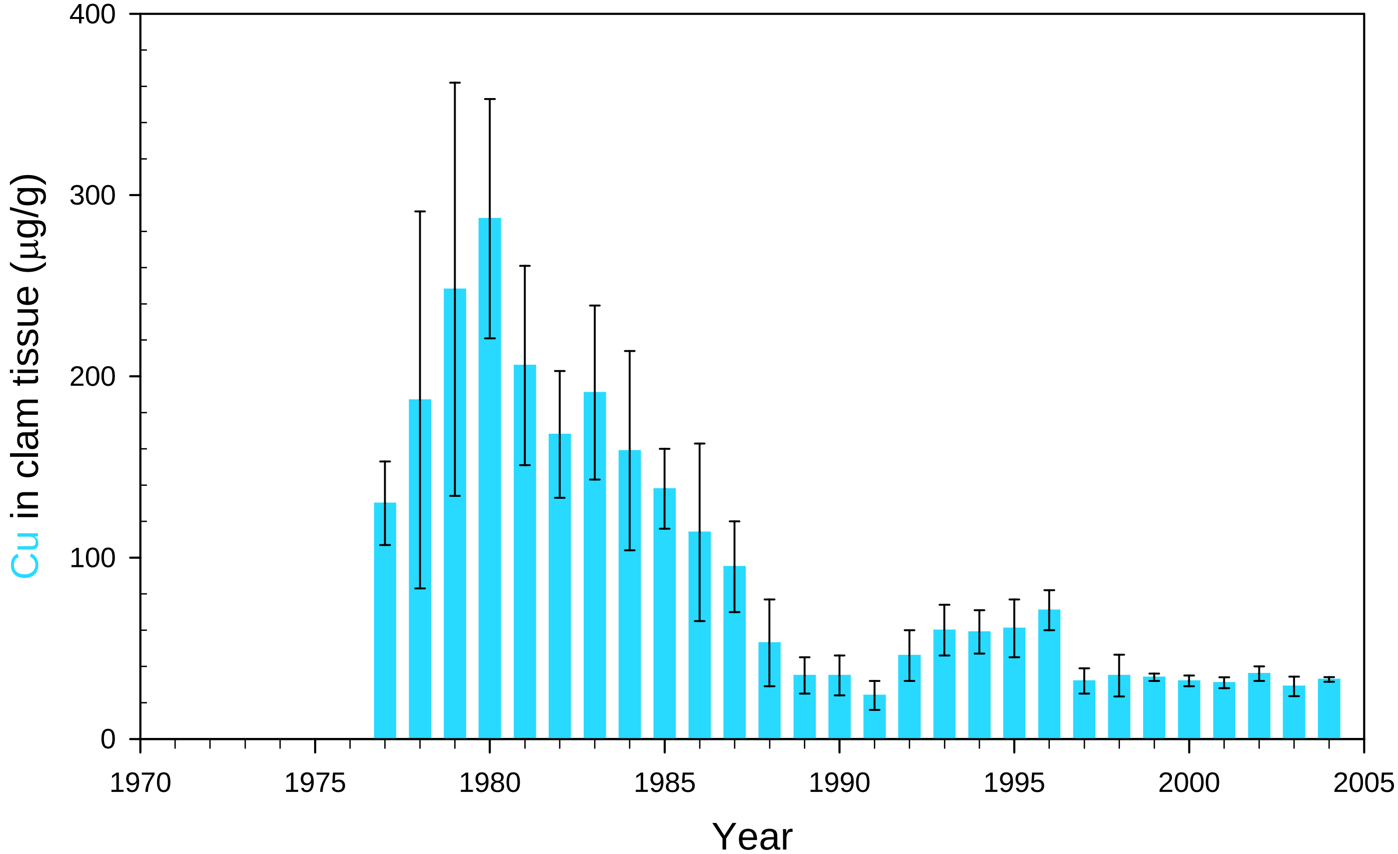


Figure 10. Annual mean copper in *Macoma petalum*

Data from Palo Alto site is for period from 1974 through 2004. Error bars are the standard error of the mean (SEM).

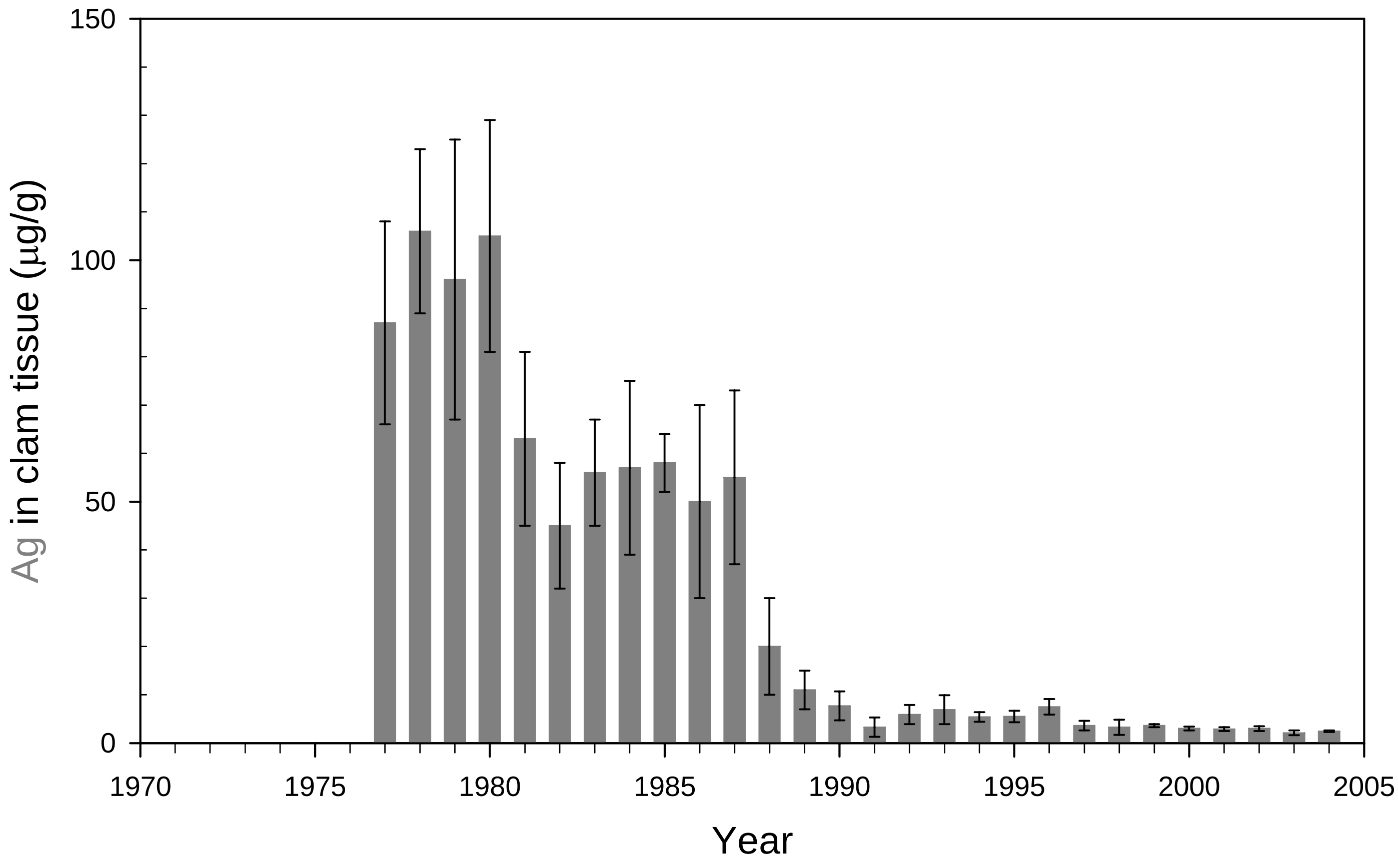


Figure 11. Annual mean silver in *Macoma petalum*

Data from Palo Alto site is for period from 1974 through 2004. Error bars are the standard error of the mean (SEM).

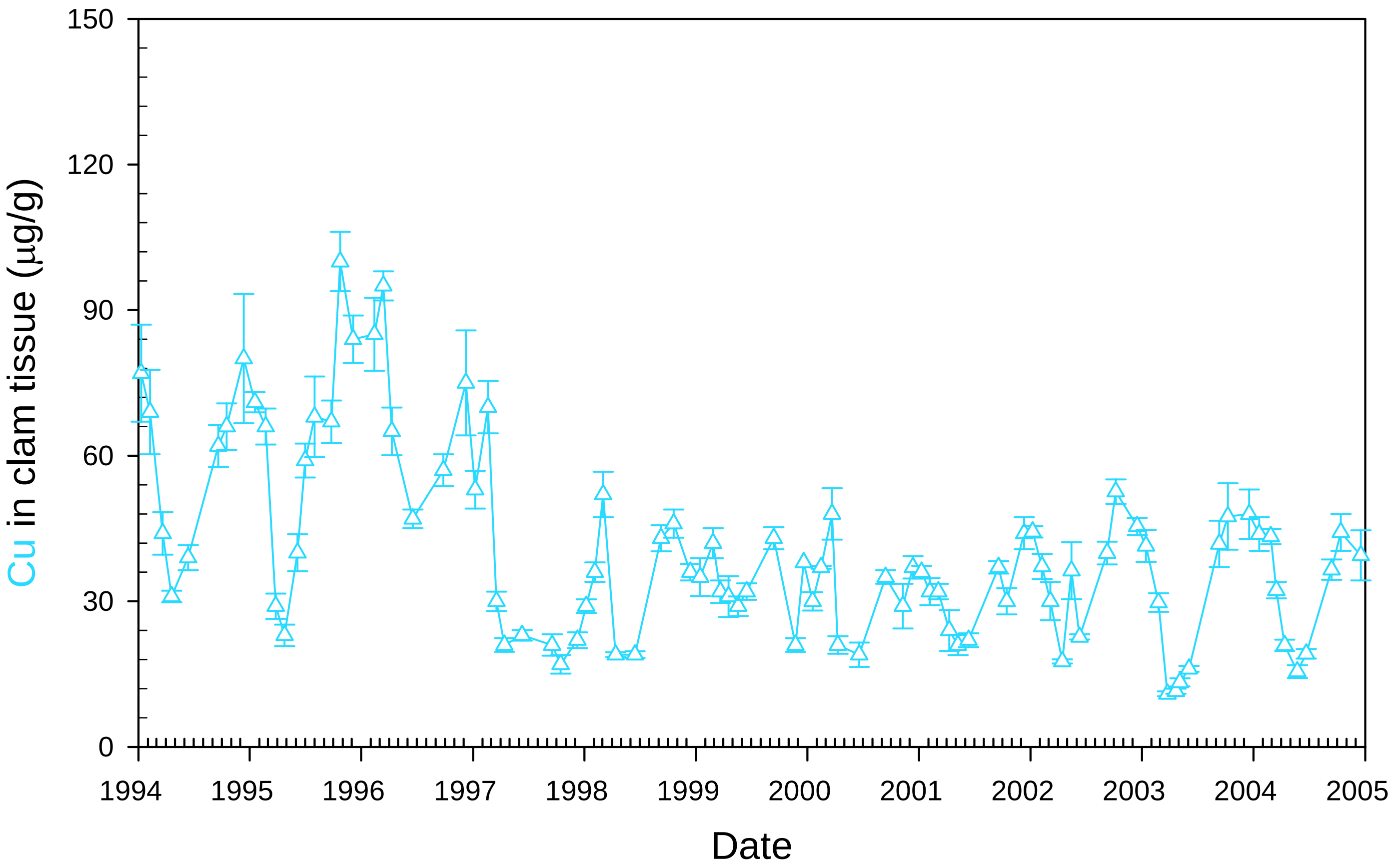


Figure 12. Copper in *Macoma petalum*

Data from Palo Alto site is for period from 1994 through 2004. Error bars are the standard error of the mean (SEM).

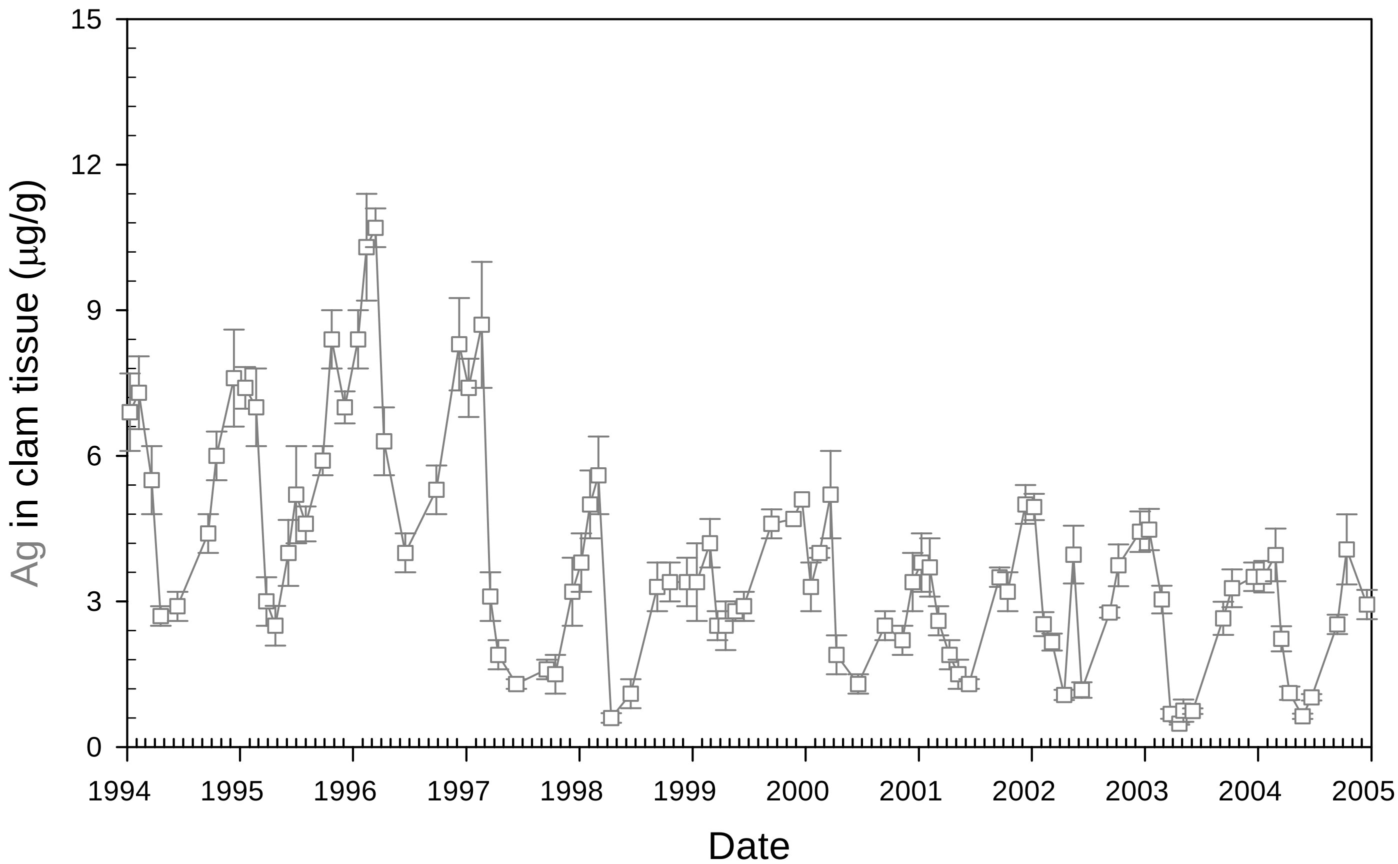


Figure 13. Silver in *Macoma petalum*

Data from Palo Alto site is for period from 1994 through 2004. Error bars are the standard error of the mean (SEM).

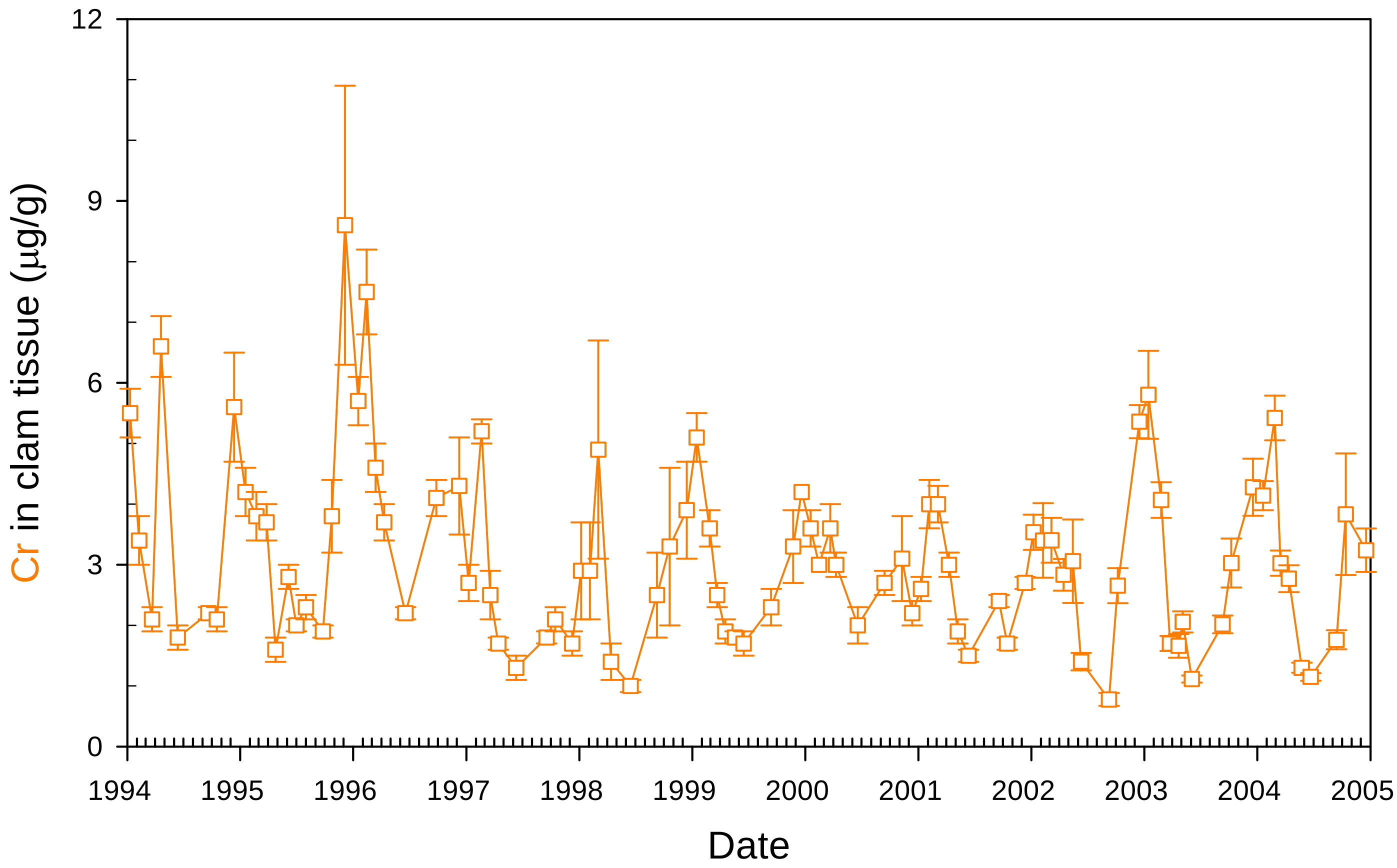


Figure 14. Chromium in *Macoma petalum*

Data from Palo Alto site is for period from 1994 through 2004. Error bars are the standard error of the mean (SEM).

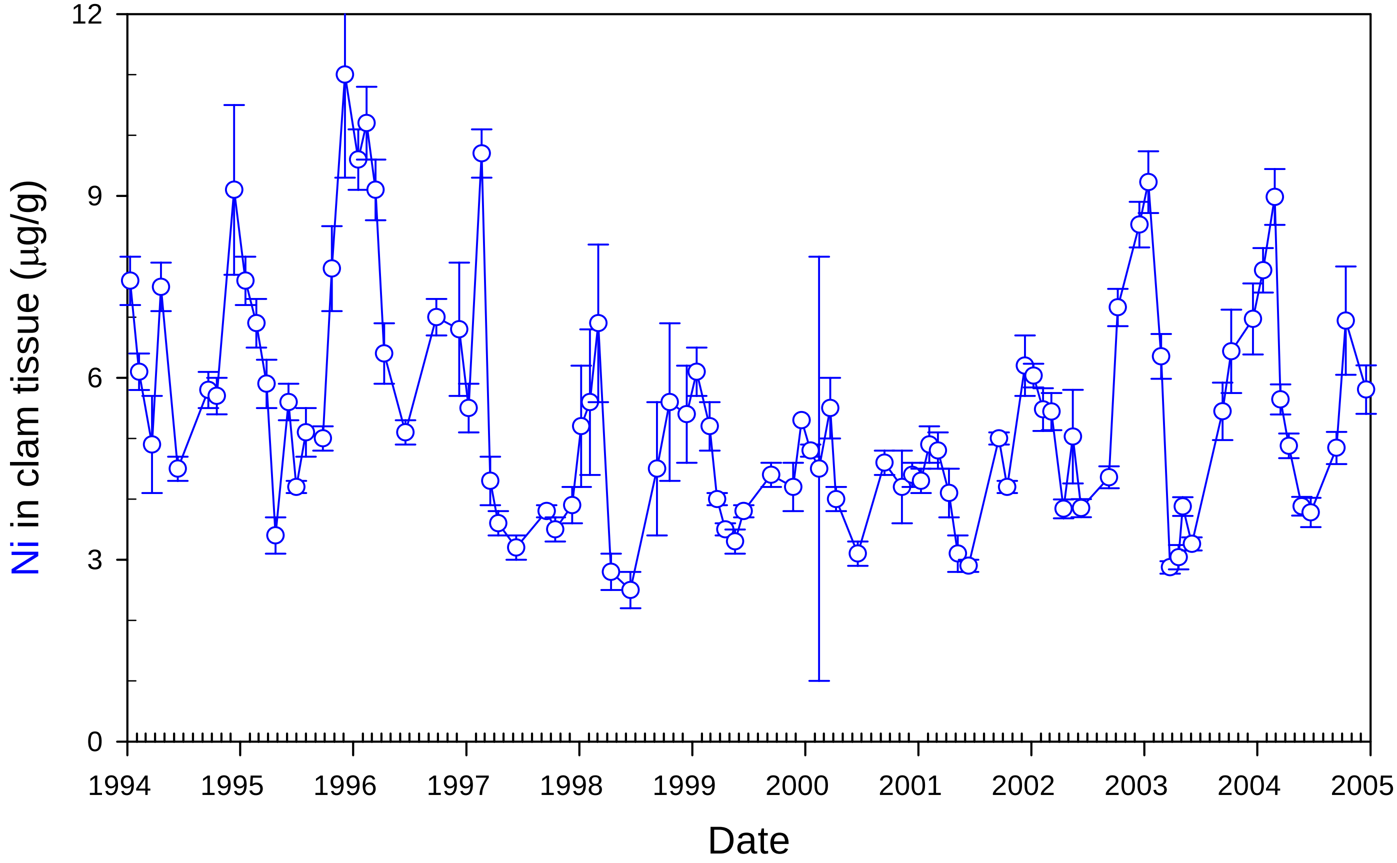


Figure 15. Nickel in *Macoma petalum*

Data from Palo Alto site is for period from 1994 through 2004. Error bars are the standard error of the mean (SEM).

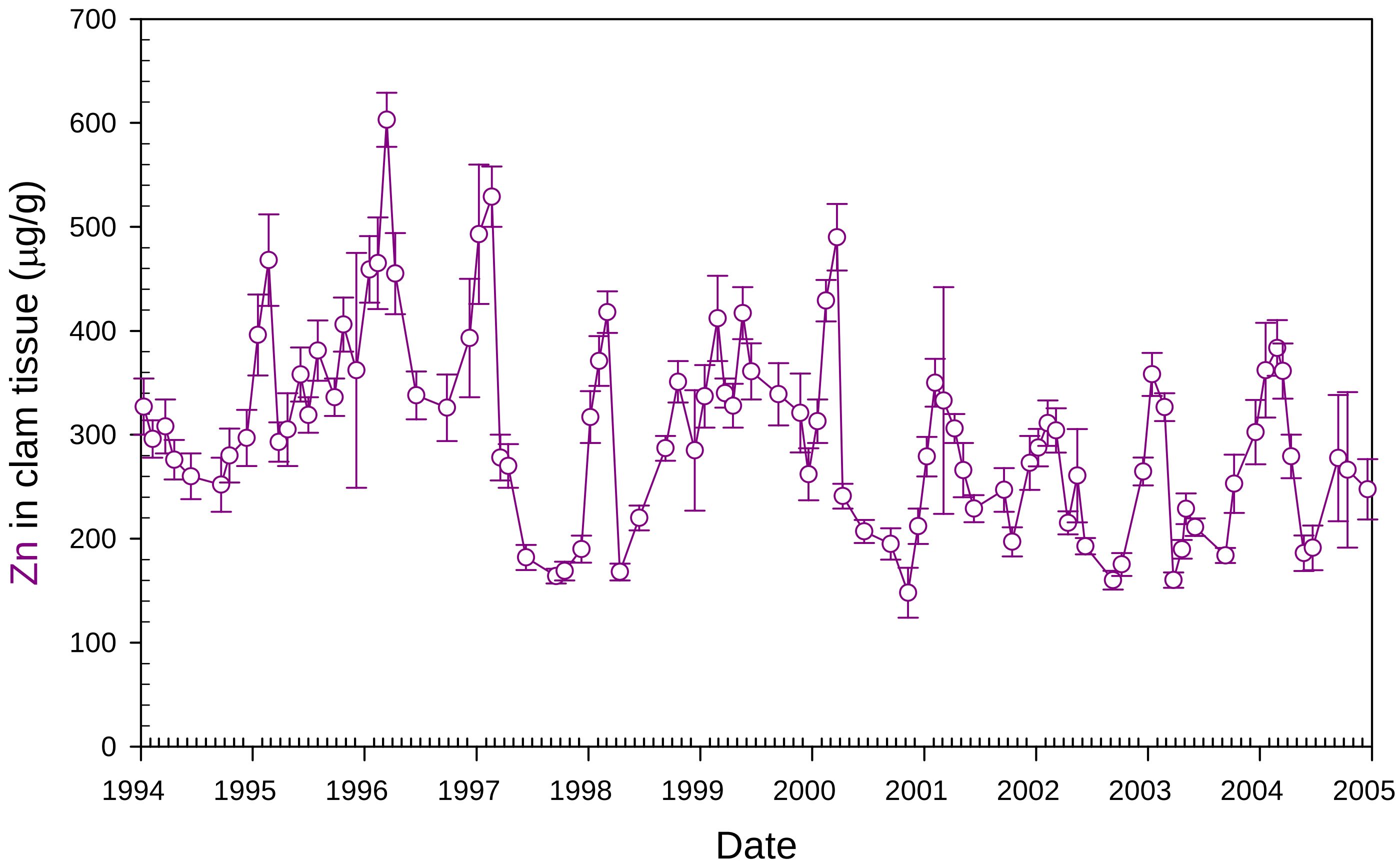


Figure 16. Zinc in *Macoma petalum*

Data from Palo Alto site is for period from 1994 through 2004. Error bars are the standard error of the mean (SEM).

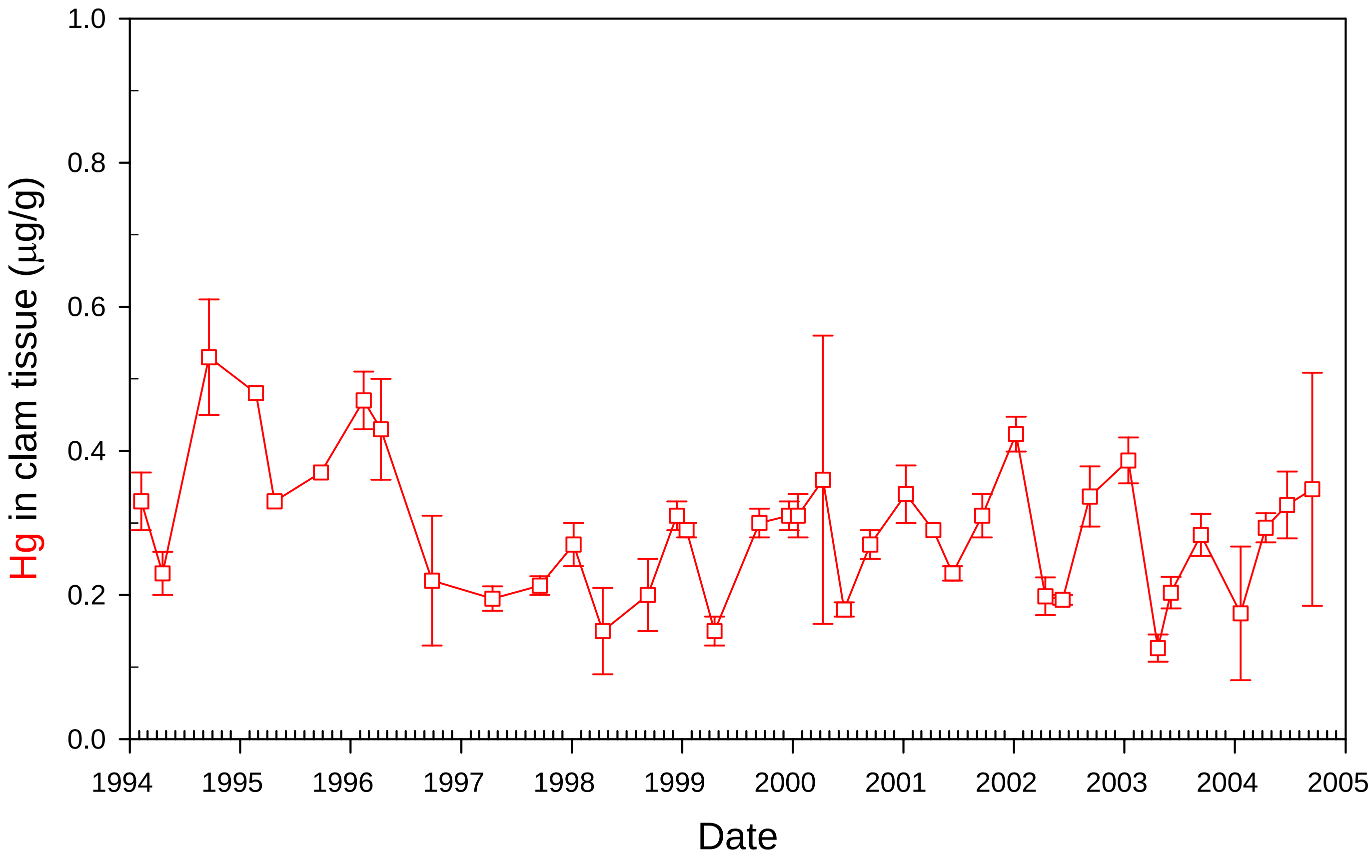


Figure 17. Mercury in *Macoma petalum*

Data from Palo Alto site is for period from 1994 through 2004. Error bars are the standard error of the mean (SEM).

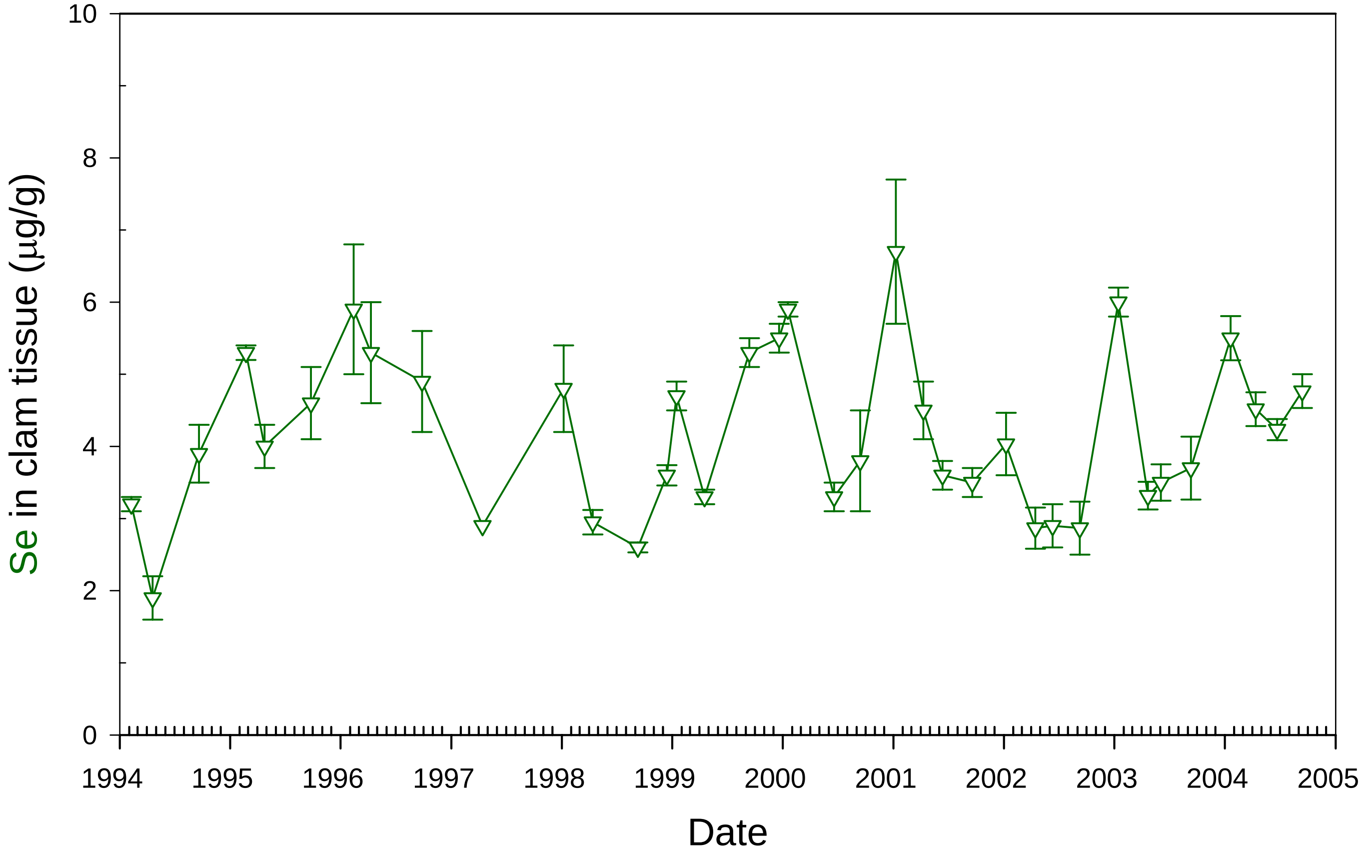


Figure 18. Selenium *Macoma petalum*

Data from Palo Alto site is for period from 1994 through 2004. Error bars are the standard error of the mean (SEM).

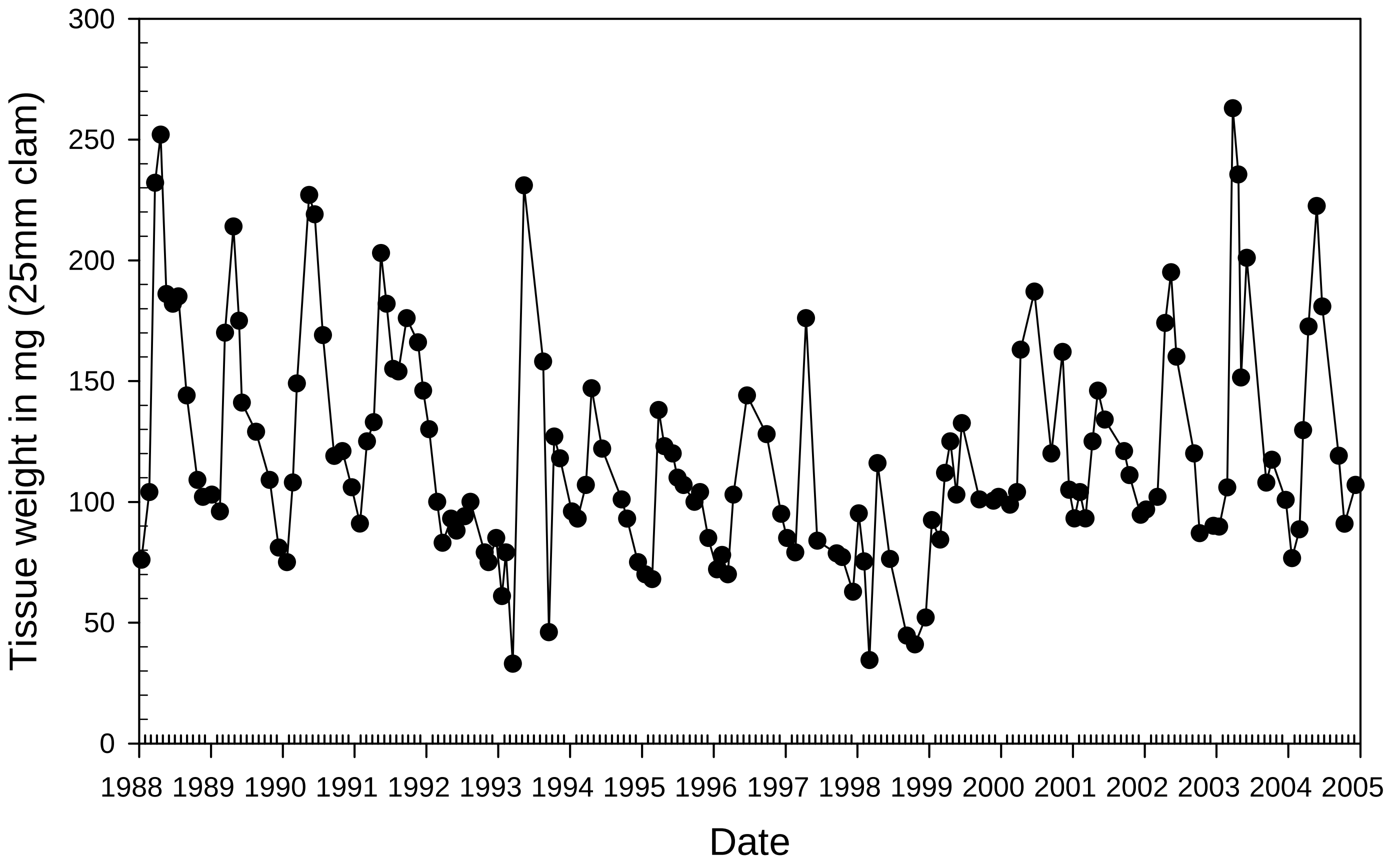


Figure 19. Condition index of *Macoma petalum*

Data from Palo Alto site is for period from 1988 through 2004. Condition index (CI) is defined as total weight of soft tissues of *Macoma petalum* having a shell length of 25 mm.

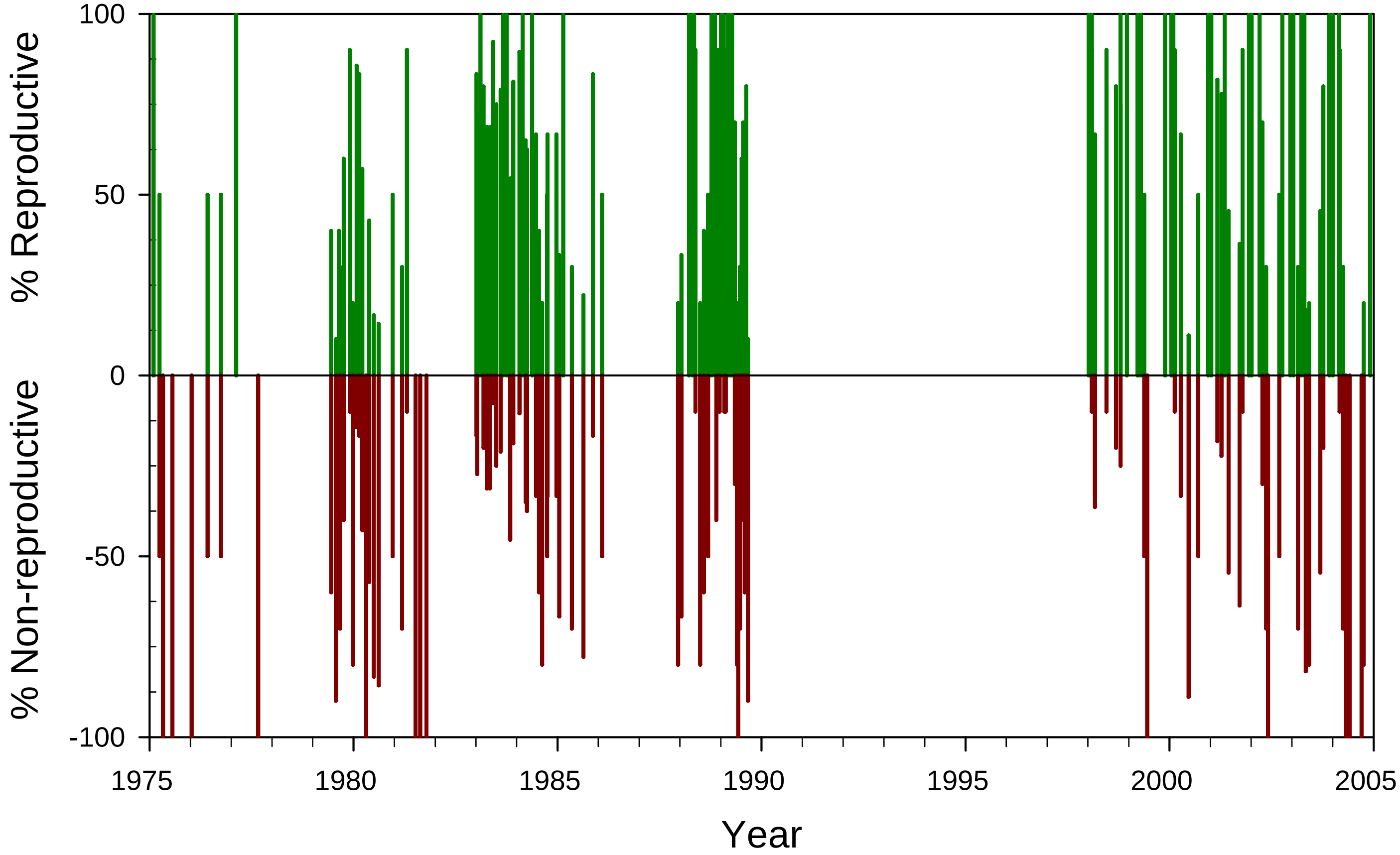


Figure 20. Reproductive activity of *Macoma petalum*

Data from Palo Alto site is for period from 1974 through 2004.

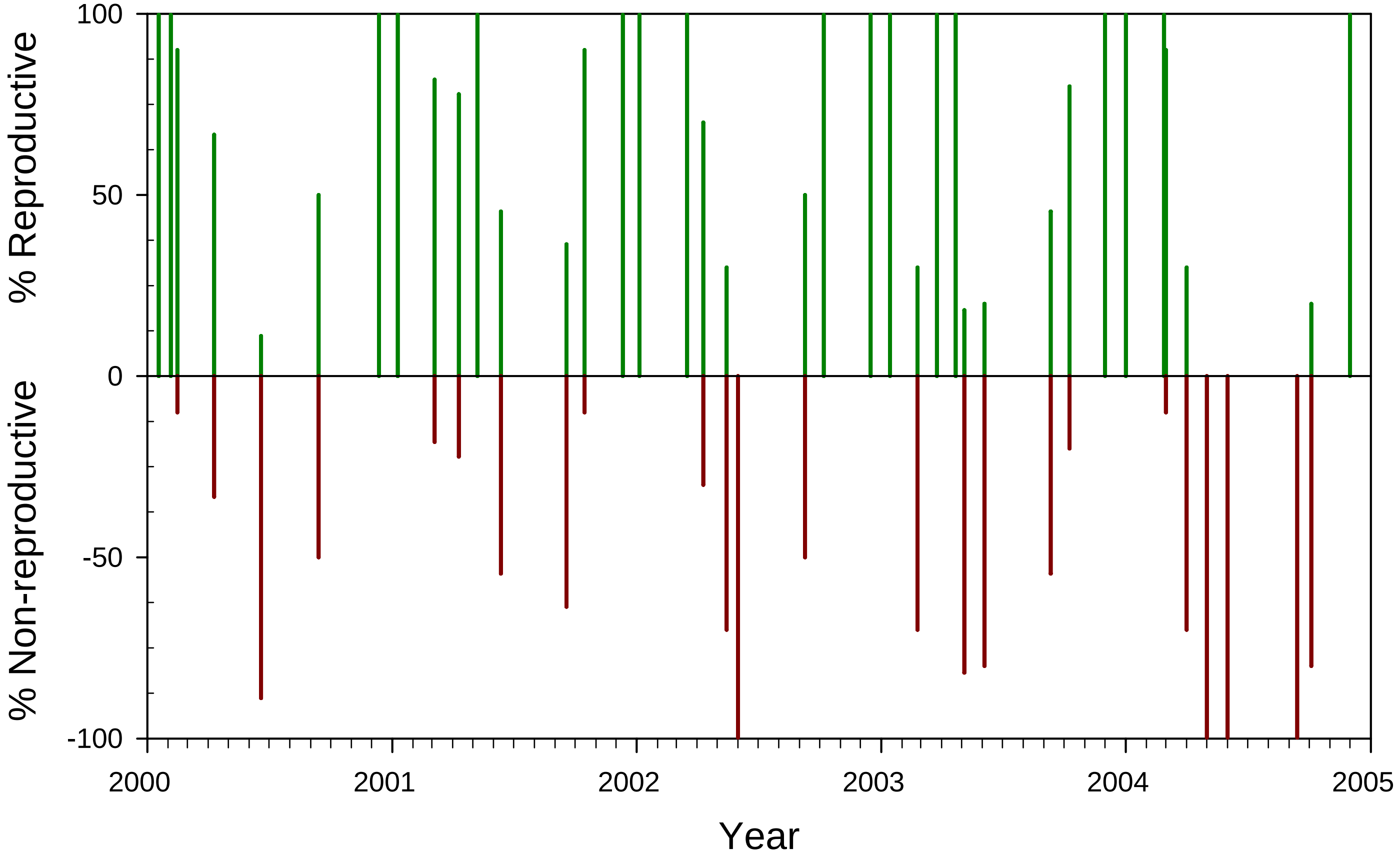


Figure 21. Reproductive activity of *Macoma petalum* 2000 thru 2004

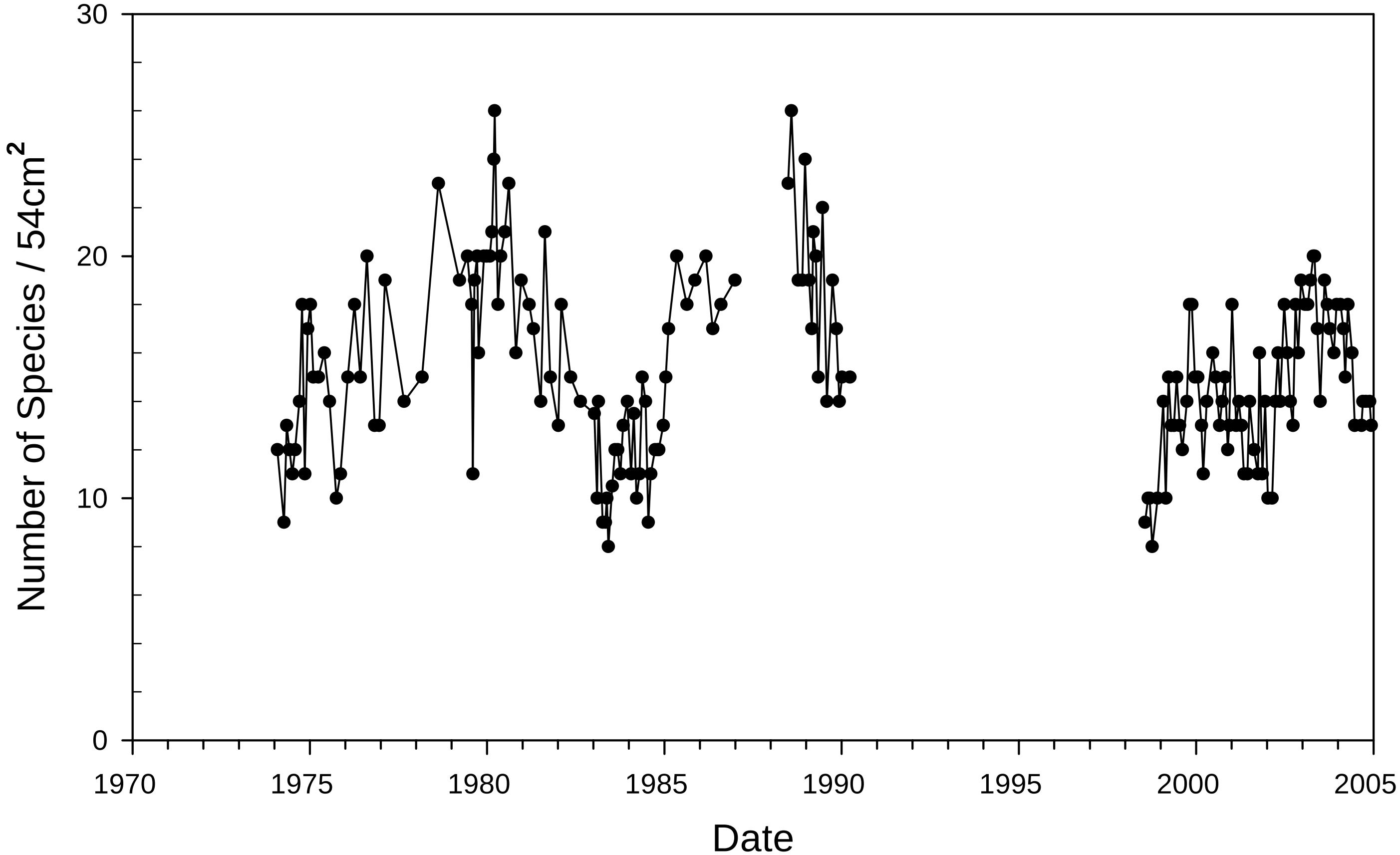


Figure 22. Total number of species present

Data from Palo Alto site is for period from 1974 through 2004

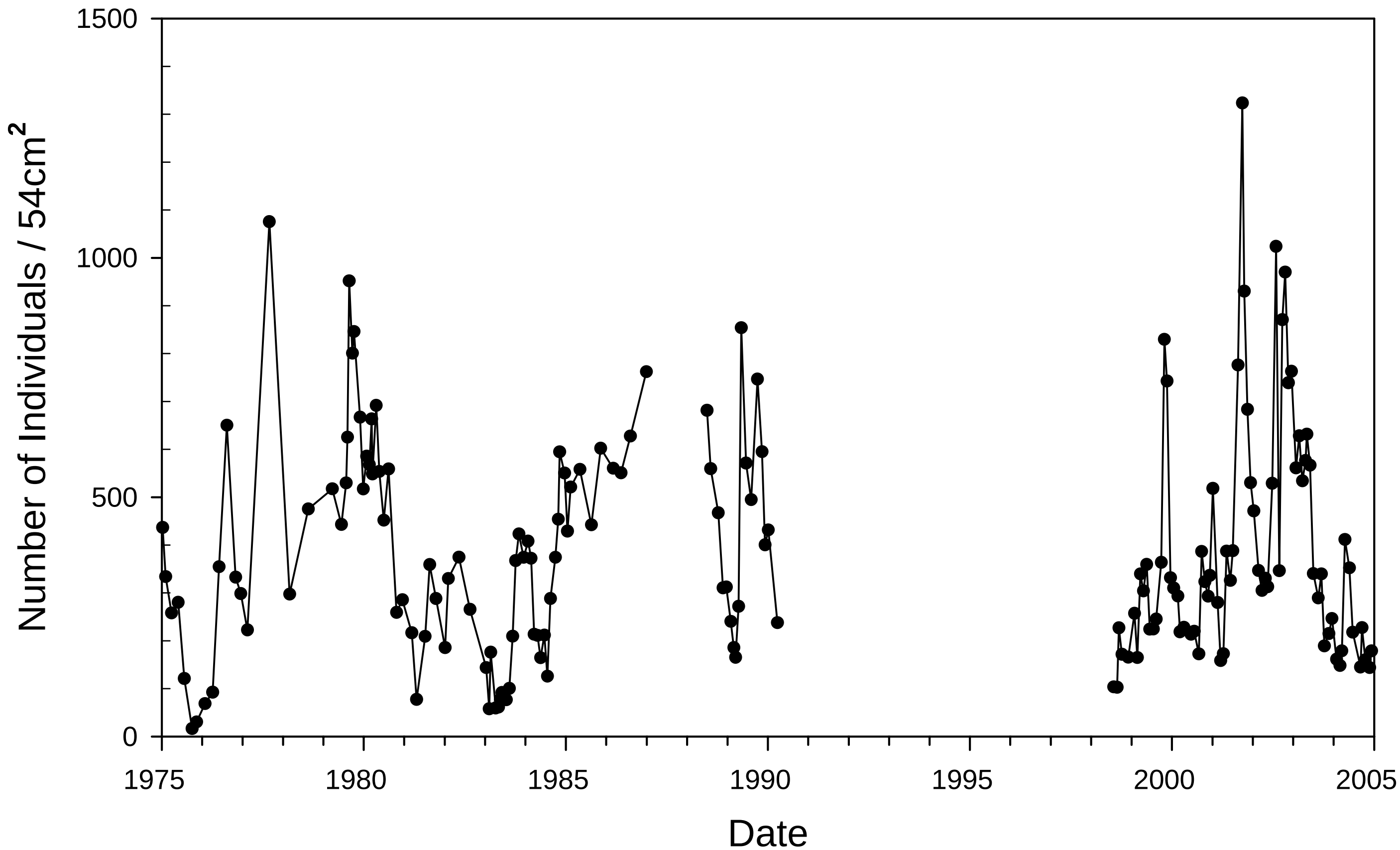


Figure 23. Total average number of individuals present

Data from Palo Alto site is for period from 1974 through 2004.

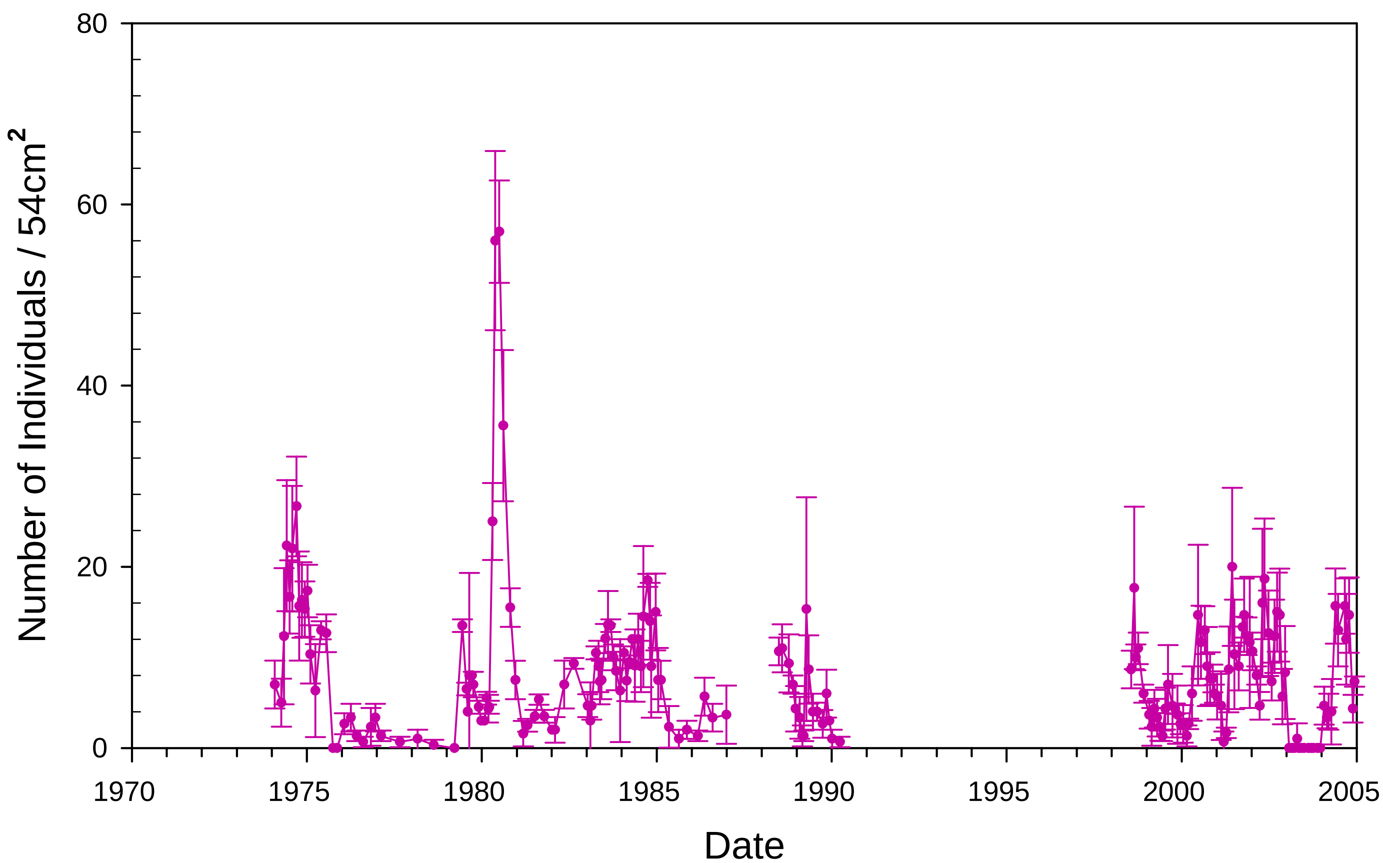


Figure 24. Average abundance of *Macoma petalum*

Data from Palo Alto site is for period from 1974 through 2004. Error bars represent standard deviation from 3 replicate samplings.

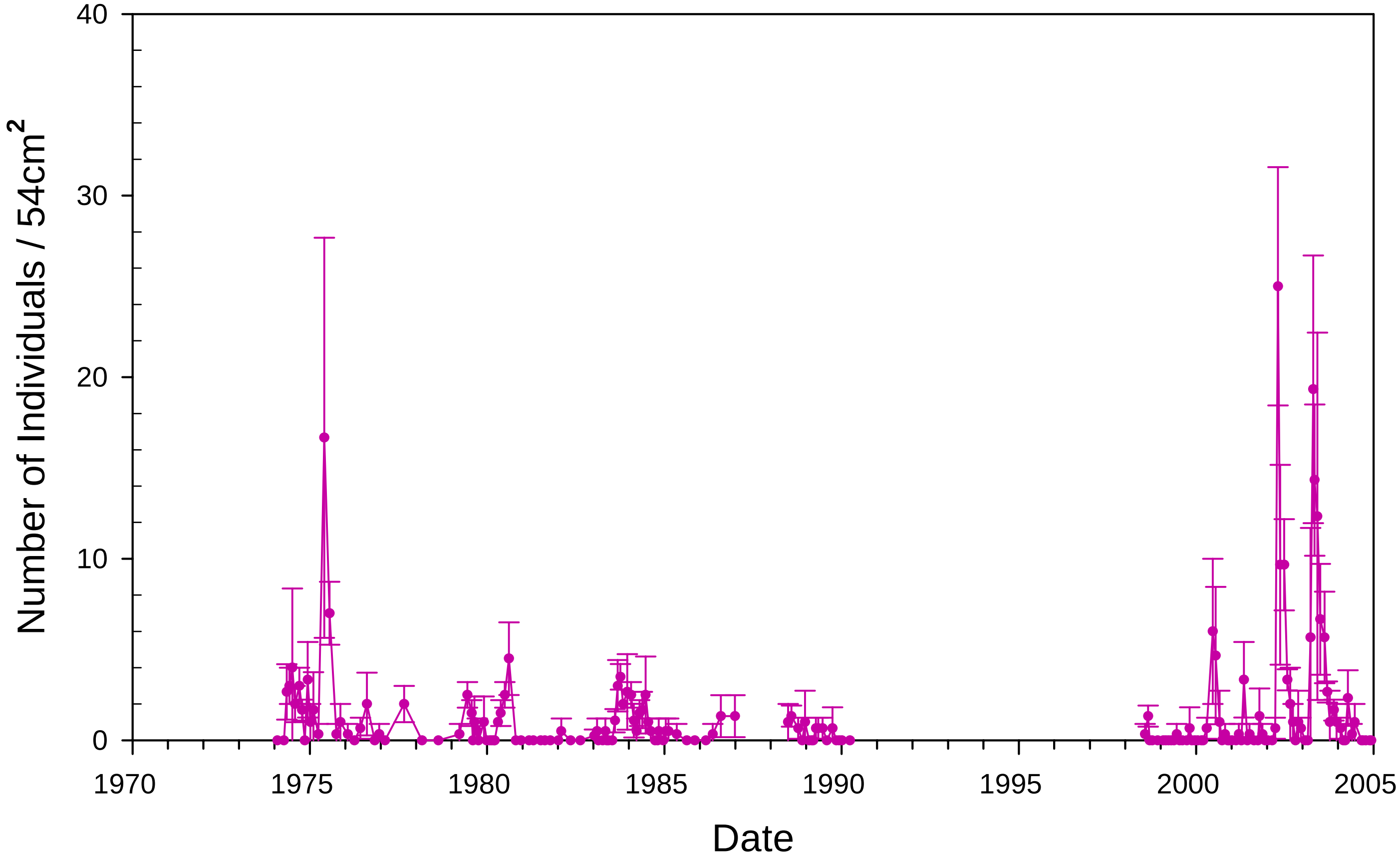


Figure 25. Average abundance of *Mya arenaira*

Data from Palo Alto site is for period from 1974 through 2004. Error bars represent standard deviation from 3 replicate samplings.

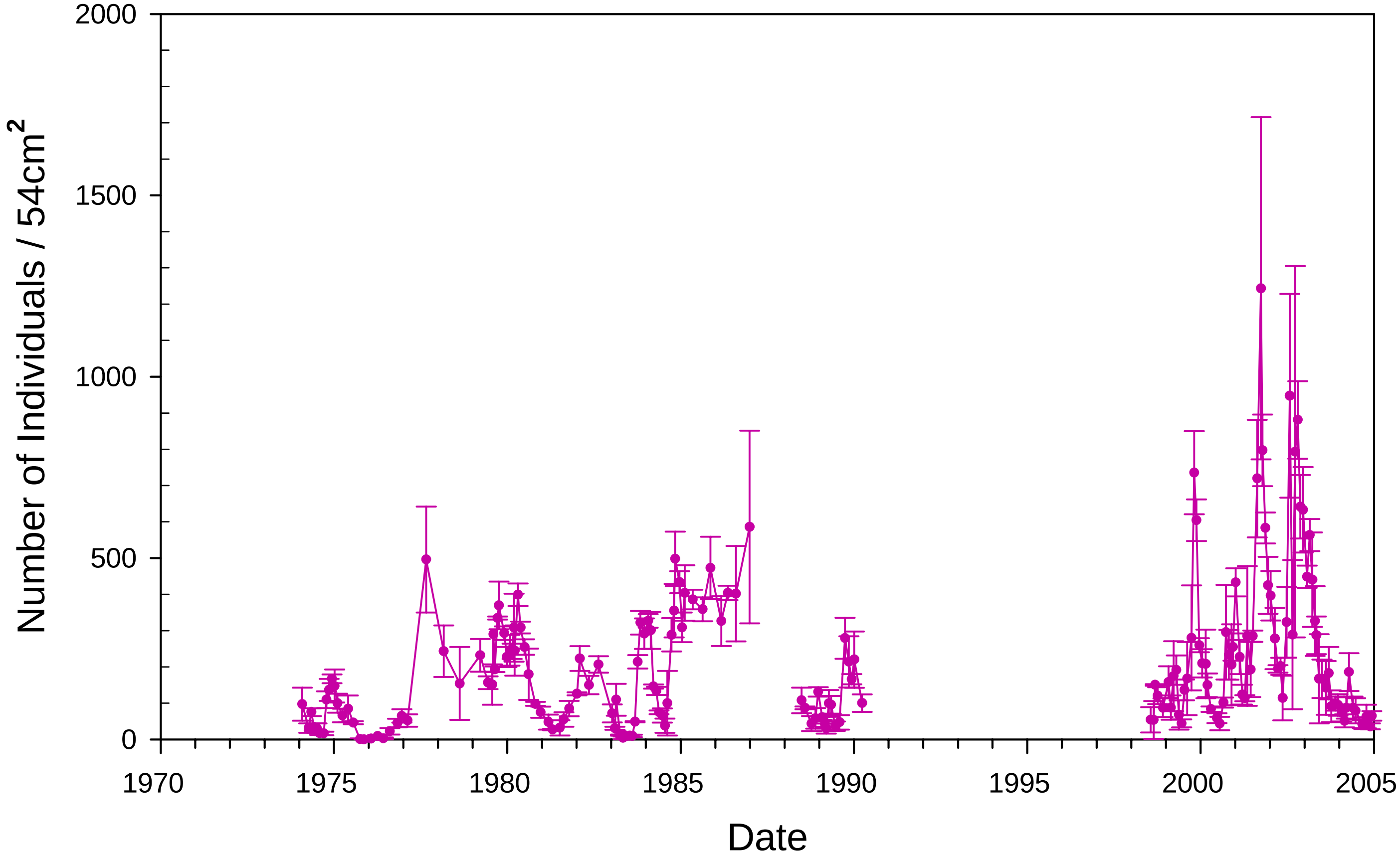


Figure 26. Average abundance of *Gemma gemma*

Data from Palo Alto site is for period from 1974 through 2004. Error bars represent standard deviation from 3 replicate samplings.

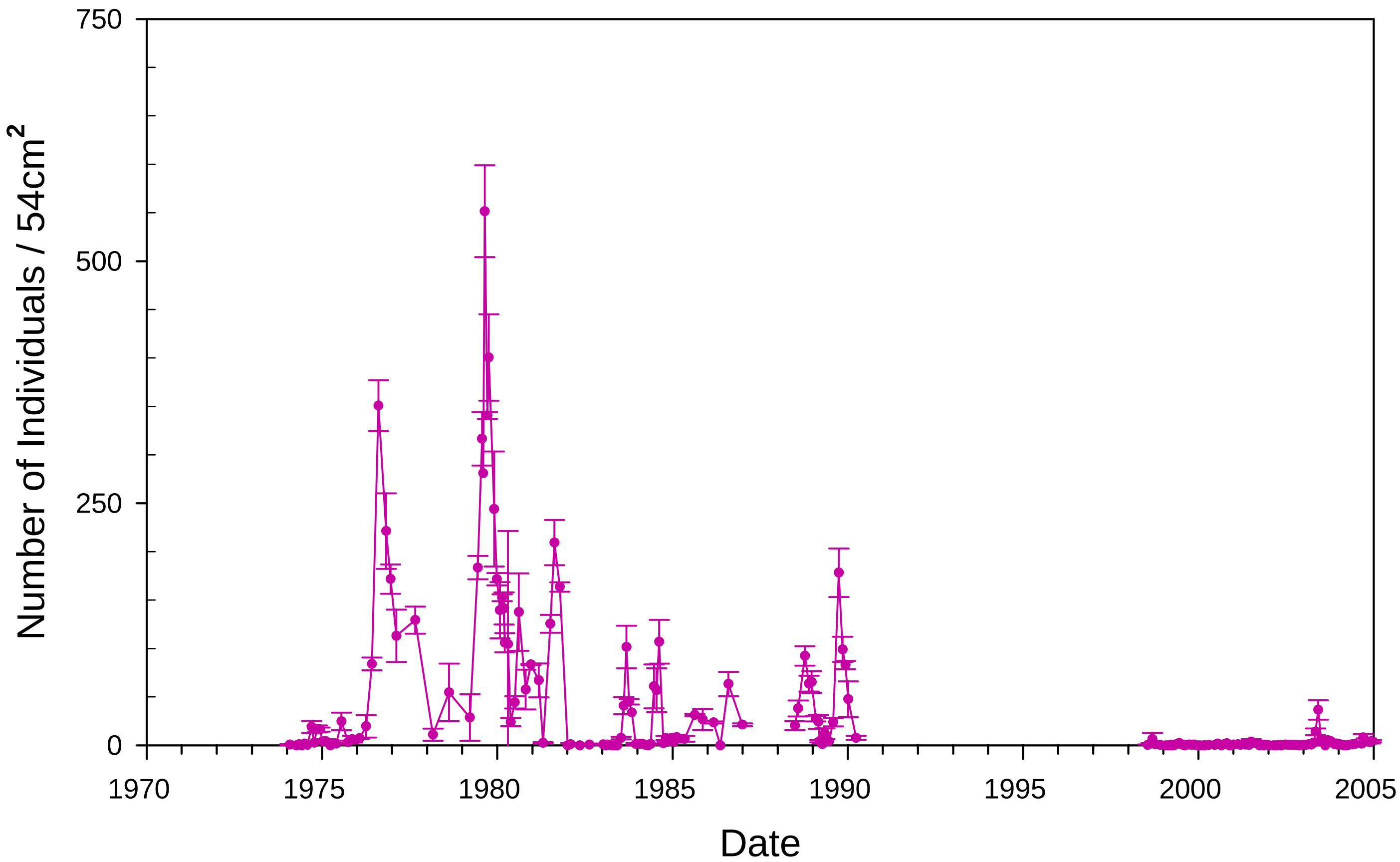


Figure 27. Average abundance of *Ampelisca abdita*

Data from Palo Alto site is for period from 1974 through 2004. Error bars represent standard deviation from 3 replicate samplings.

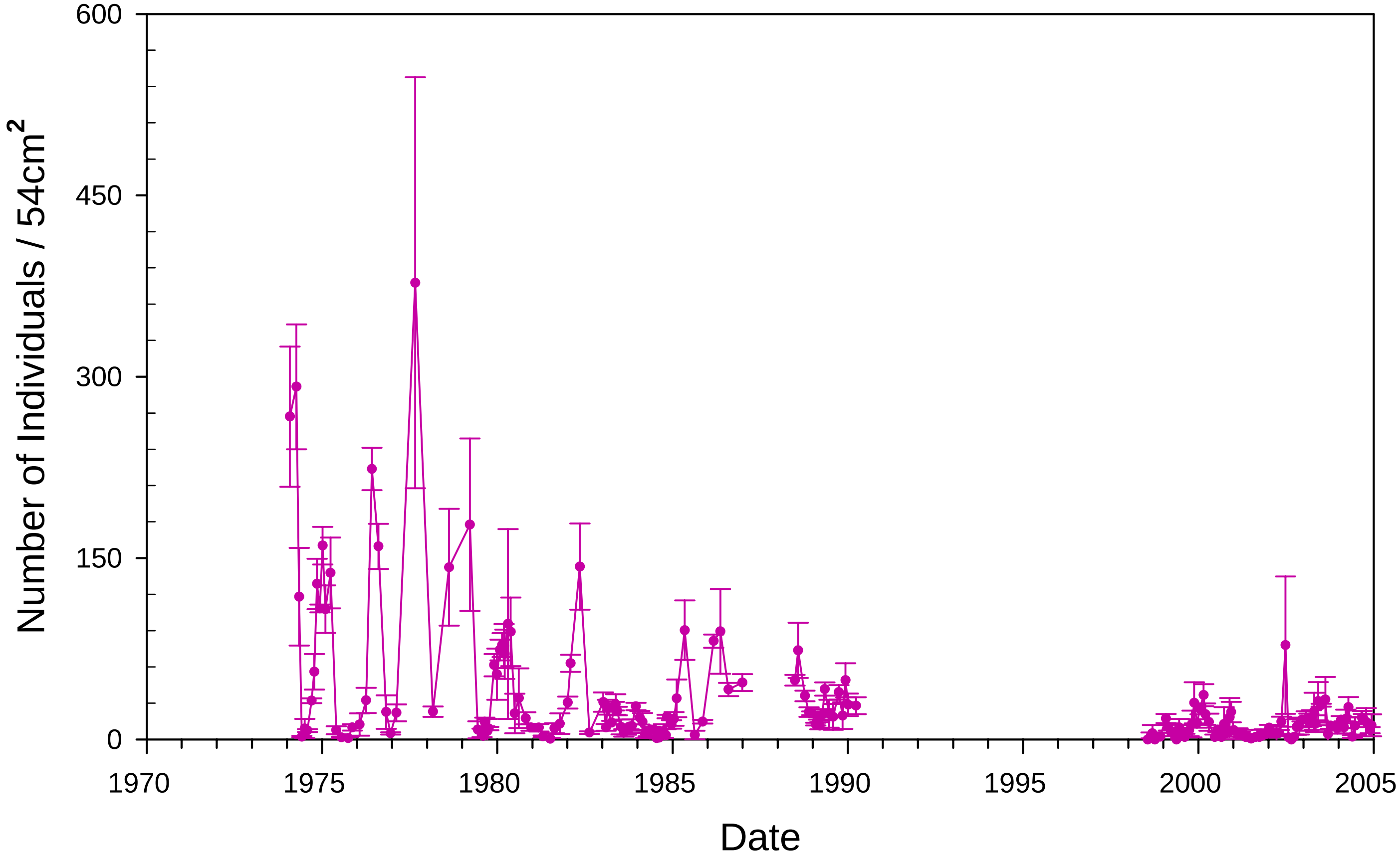


Figure 28. Average abundance of *Streblospio benedicti*

Data from Palo Alto site is for period from 1974 through 2004. Error bars represent standard deviation from 3 replicate samplings.

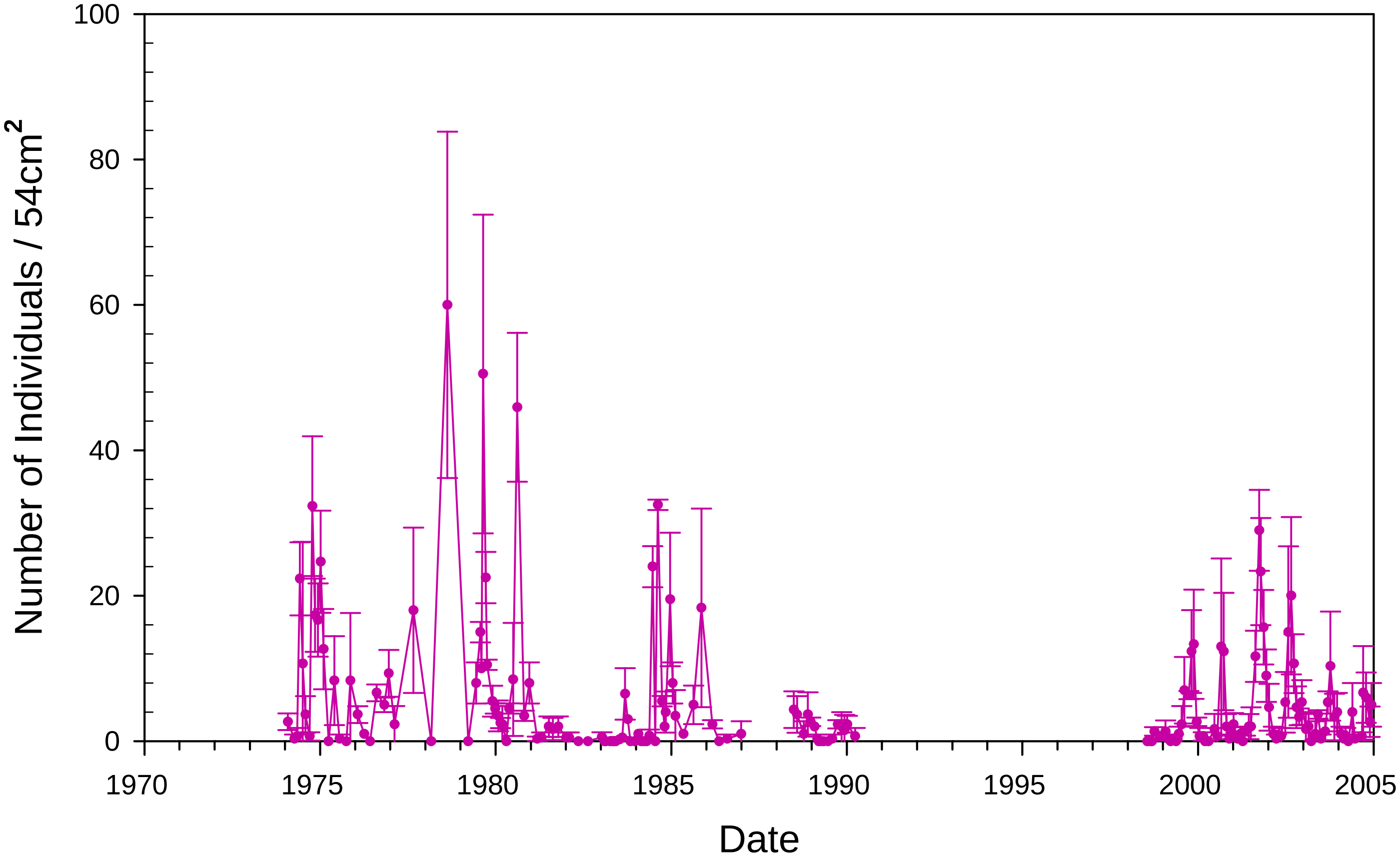


Figure 29. Average abundance of *Grandiderella japonica*

Data from Palo Alto site is for period from 1974 through 2004. Error bars represent standard deviation from 3 replicate samplings.

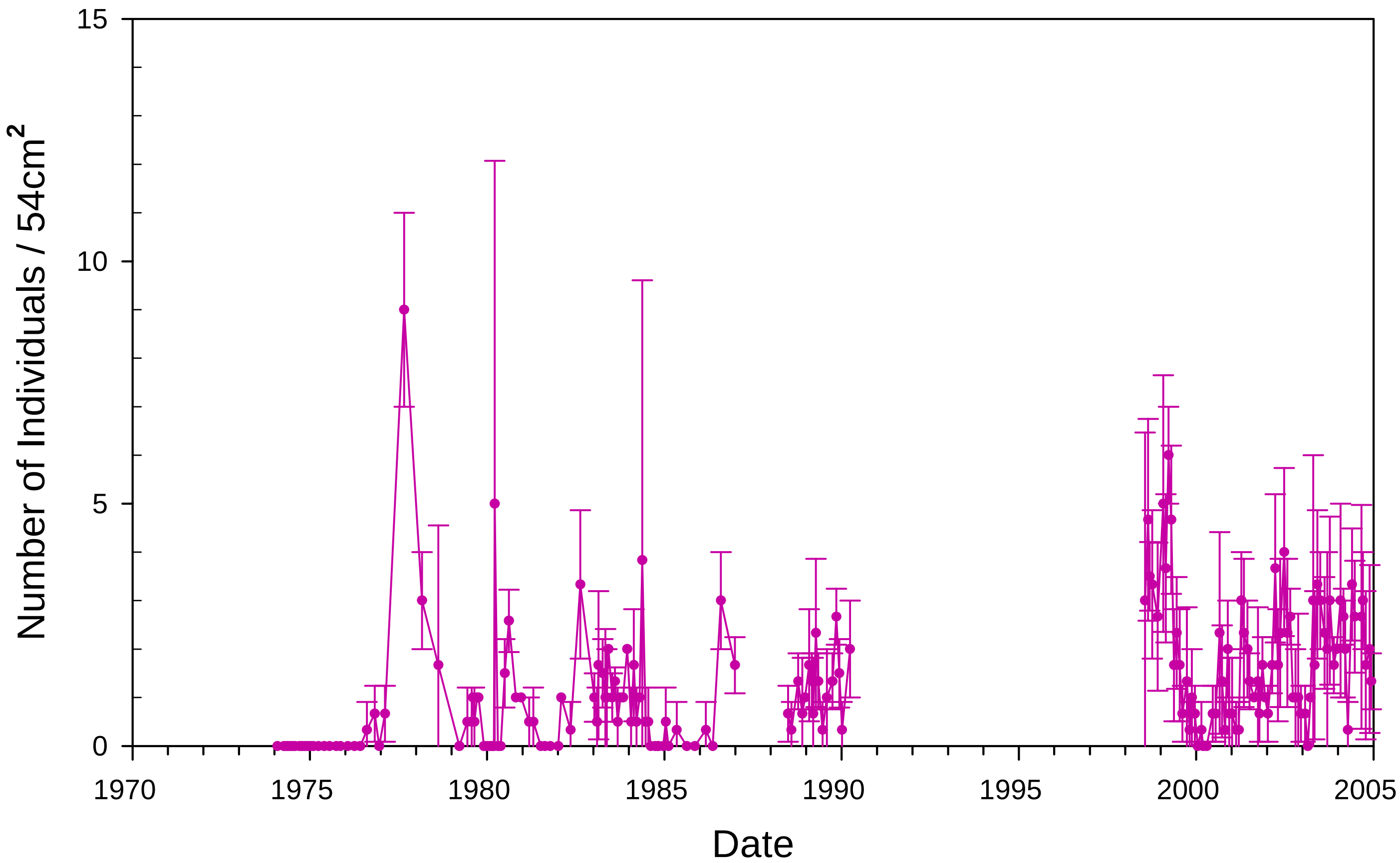


Figure 30. Average abundance of *Neanthes succinea*

Data from Palo Alto site is for period from 1974 through 2004. Error bars represent standard deviation from 3 replicate samplings.

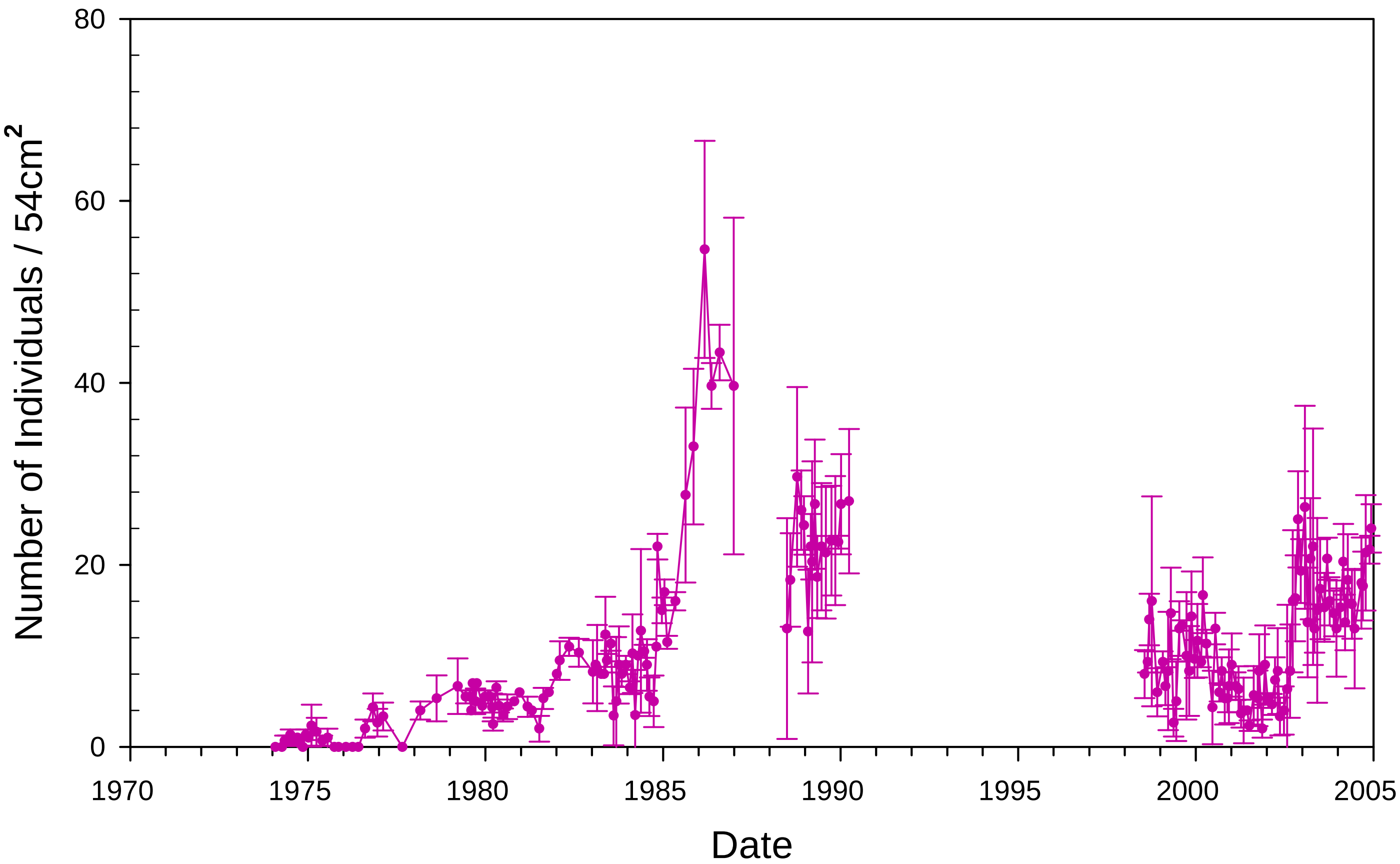


Figure 31. Average abundance of *Hetermastus filiformis*

Data from Palo Alto site is for period from 1974 through 2004. Error bars represent standard deviation from 3 replicate samplings.

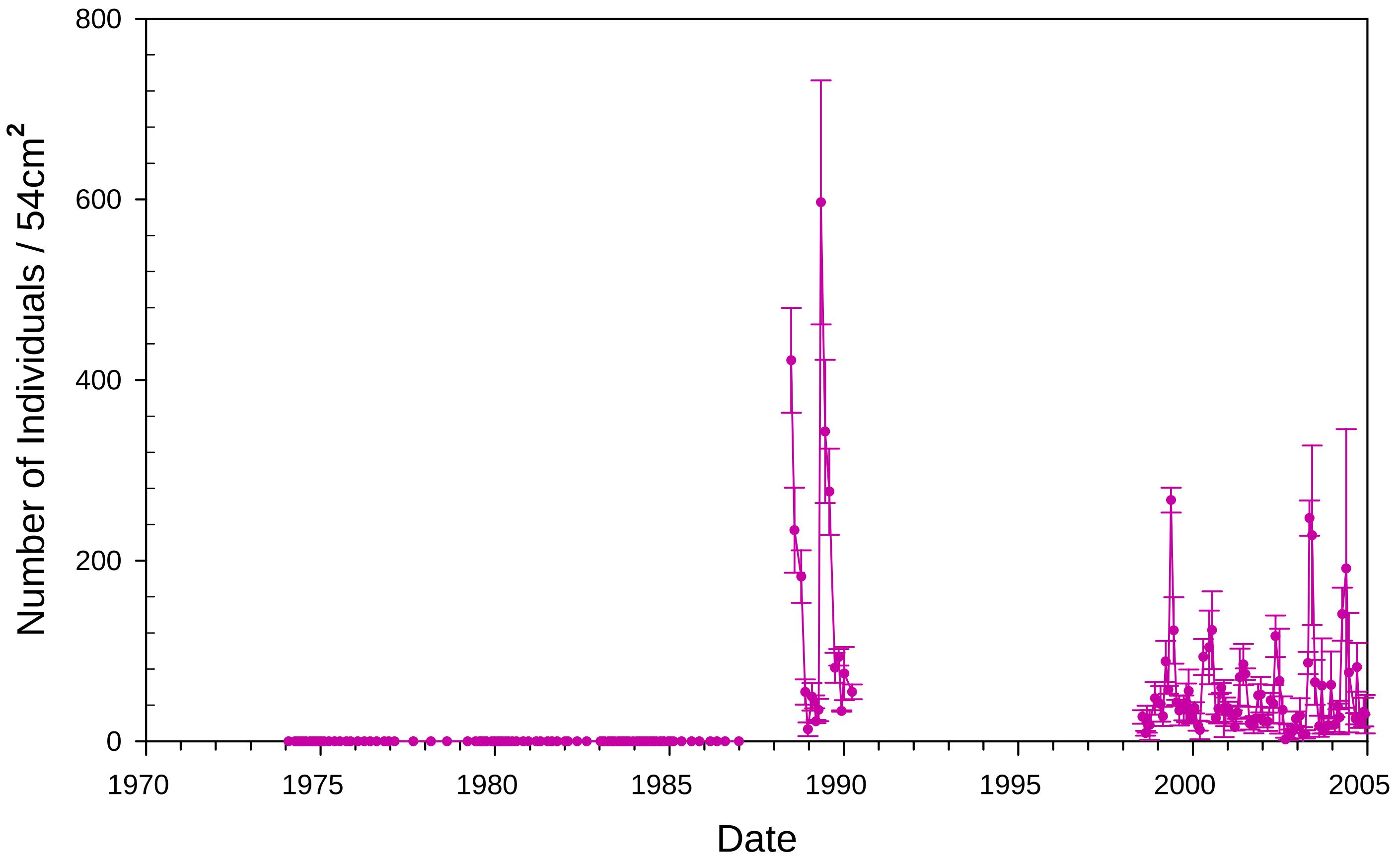


Figure 32. Average abundance of *Nippoleucon hinumensis*

Data from Palo Alto site is for period from 1974 through 2004. Error bars represent standard deviation from 3 replicate samplings.

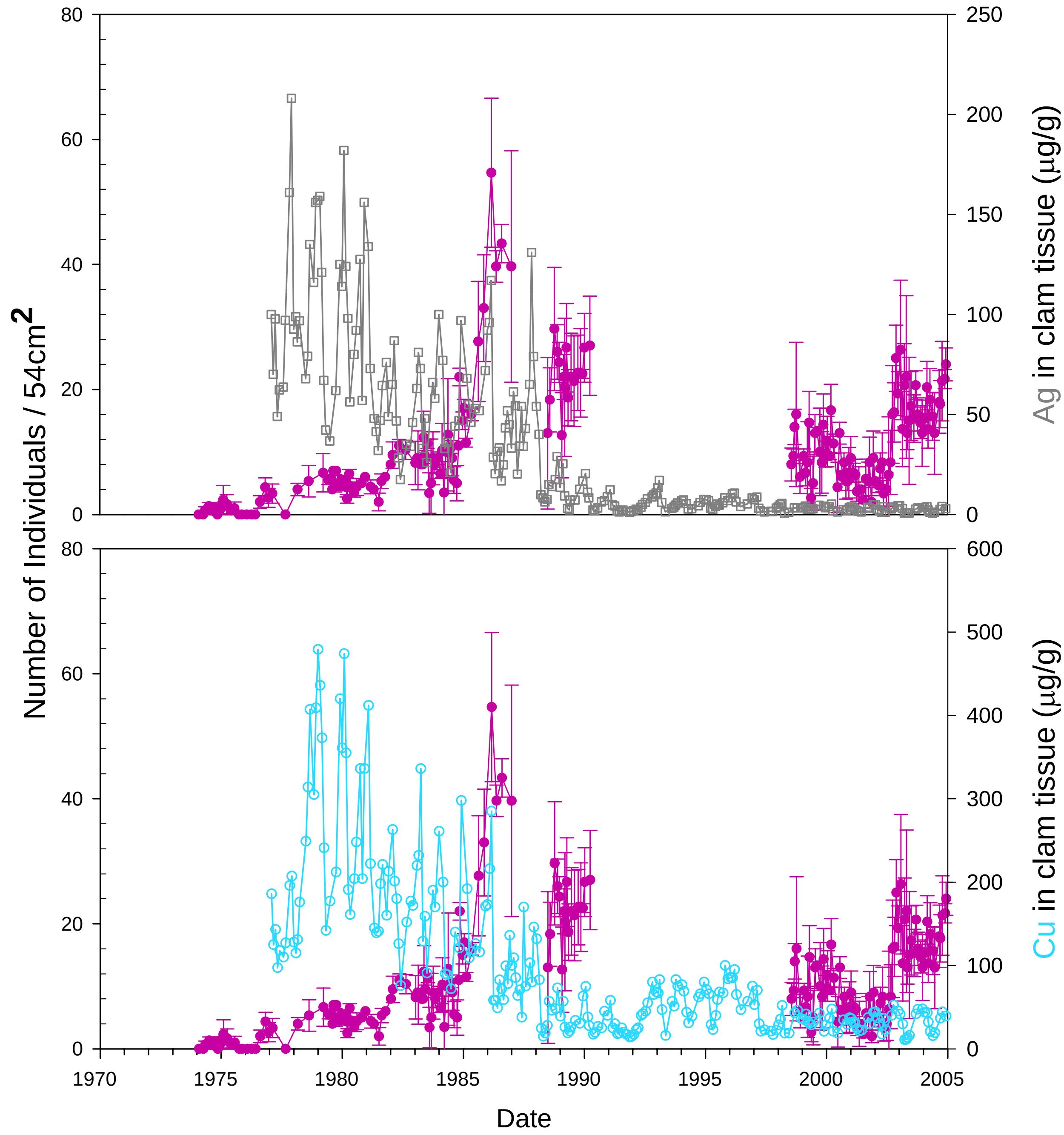


Figure 33. *Heteromastus filiformis* abundance with silver and copper in *M. petalum*

Data from Palo Alto site is for period from 1974 through 2004. Error bars represent standard deviation from 3 replicate samplings.Number of individuals (●) with silver (□) and copper (○) tissue concentrations in *Macoma petalum*

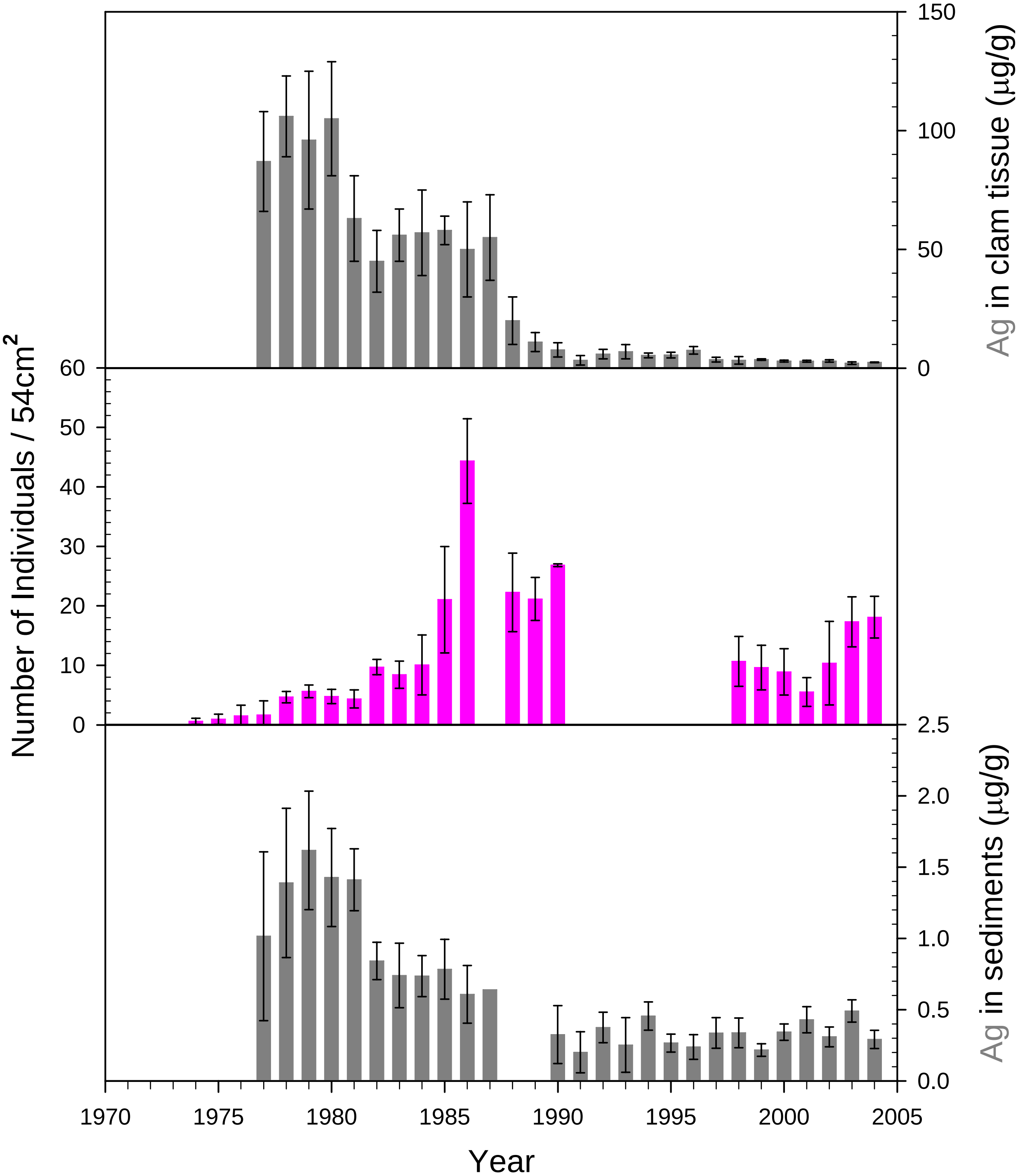


Figure 34. *Heteromastus filiformis* annual abundance with silver in *M. petalum* and sediment

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

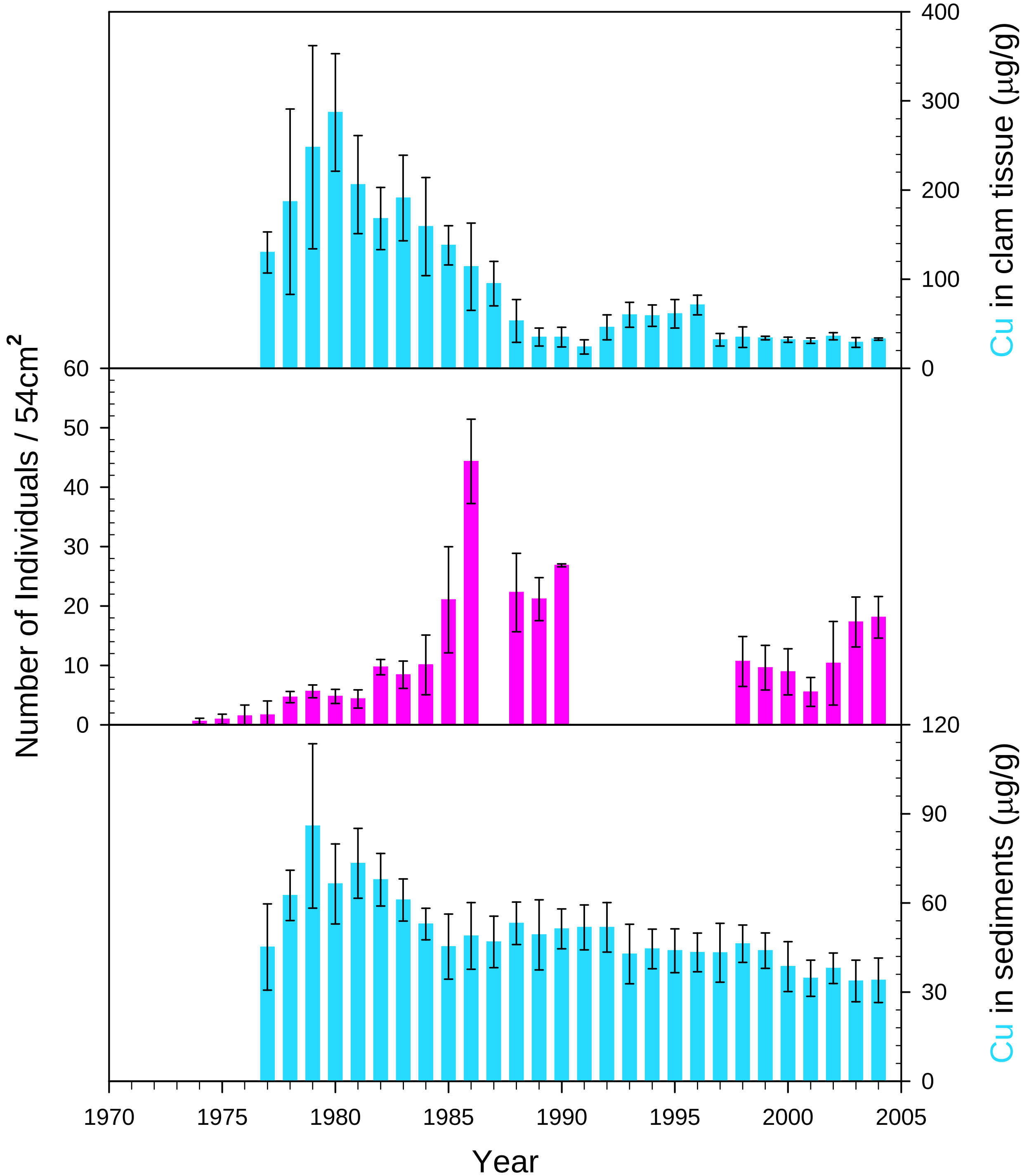


Figure 35. *Heteromastus filiformis* annual abundance with copper in *M. petalum* and sediment

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

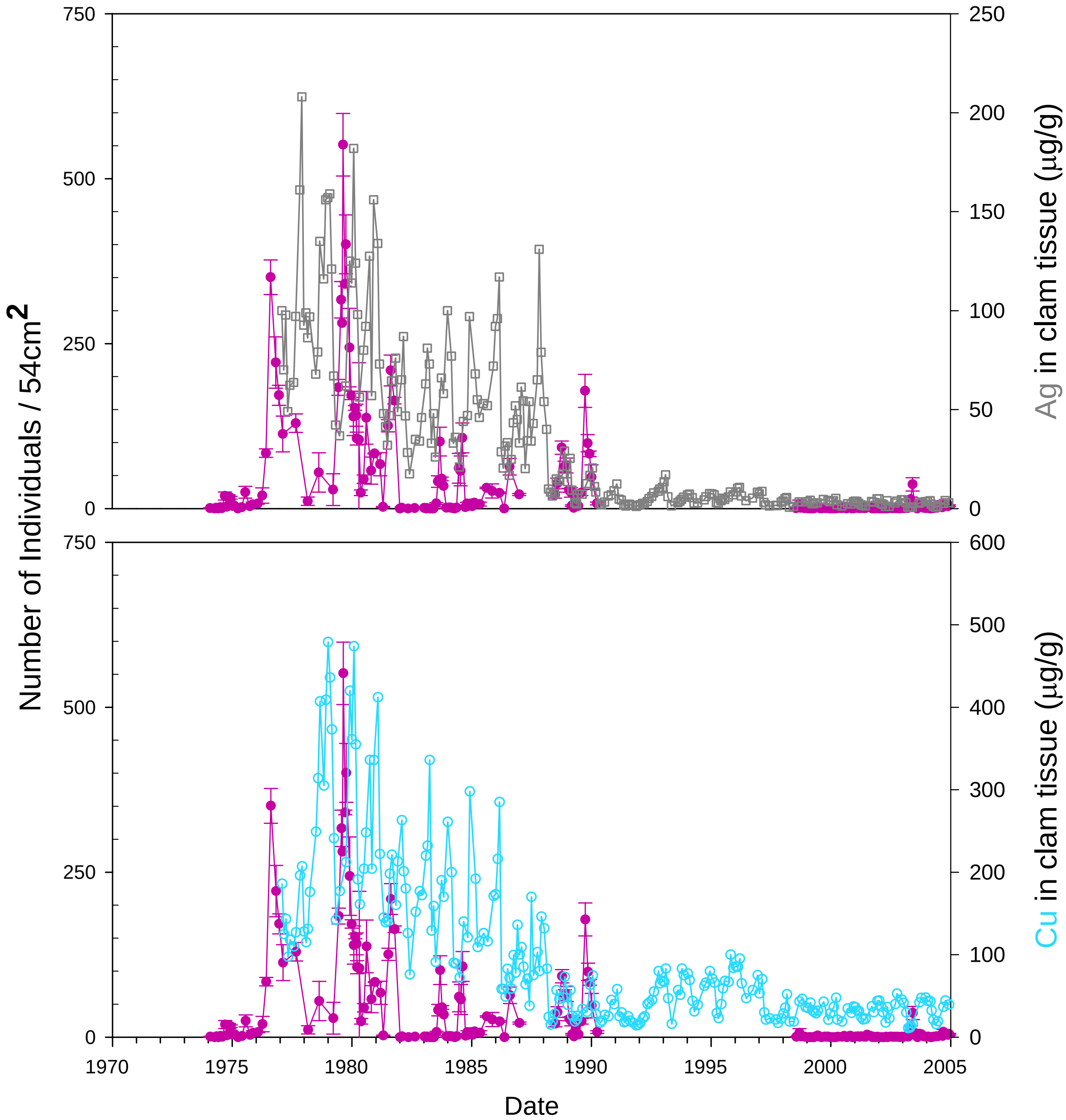


Figure 36. *Ampelisca abdita* abundance with silver and copper in *M. petalum*

Data from Palo Alto site is for period from 1974 through 2004. Error bars represent standard deviation from 3 replicate samplings. Number of individuals (●) with silver (□) and copper (○) tissue concentrations in *Macoma petalum*

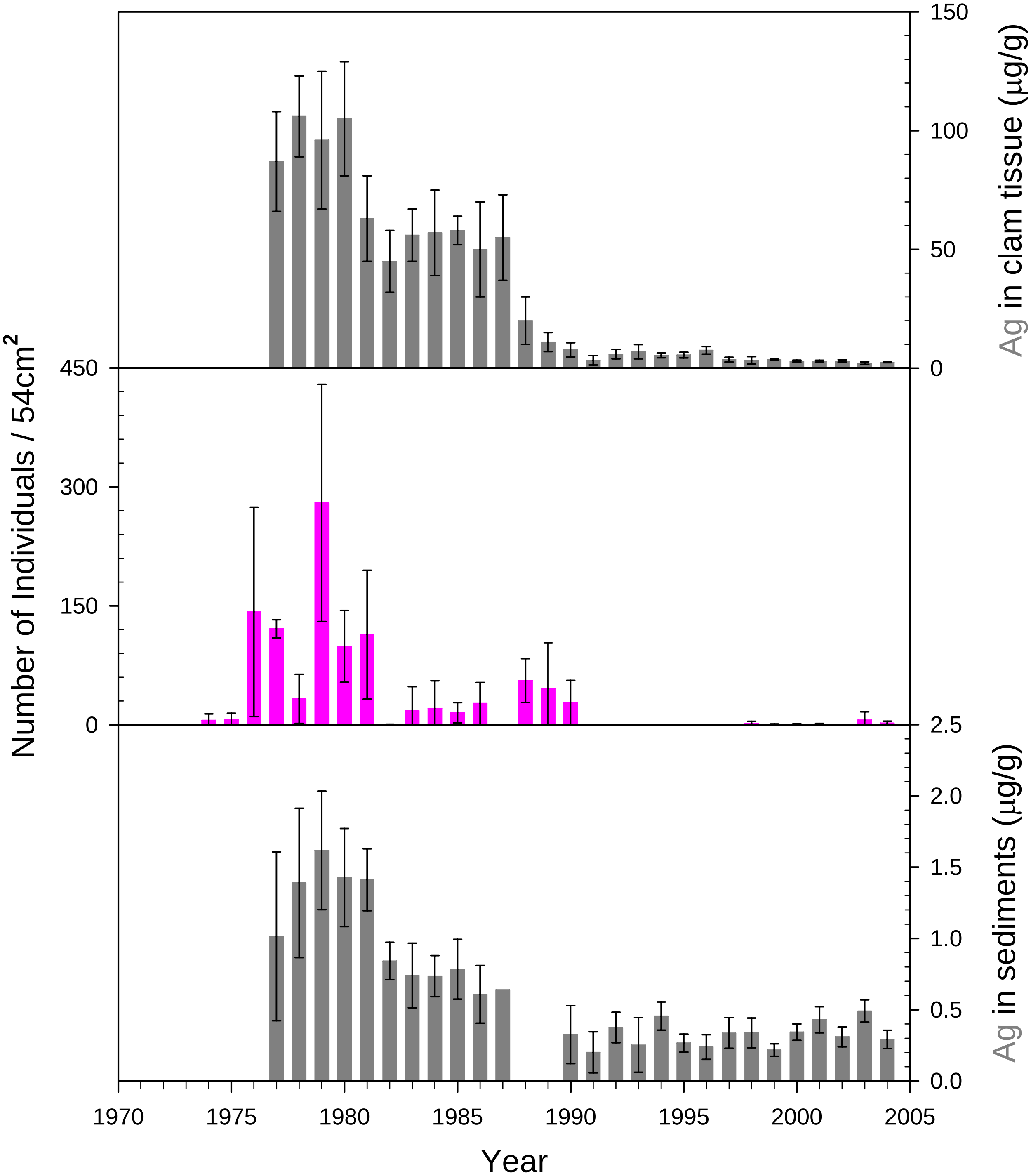


Figure 37. *Ampelisca abdita* annual abundance with silver in *M. petalum* and sediment

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

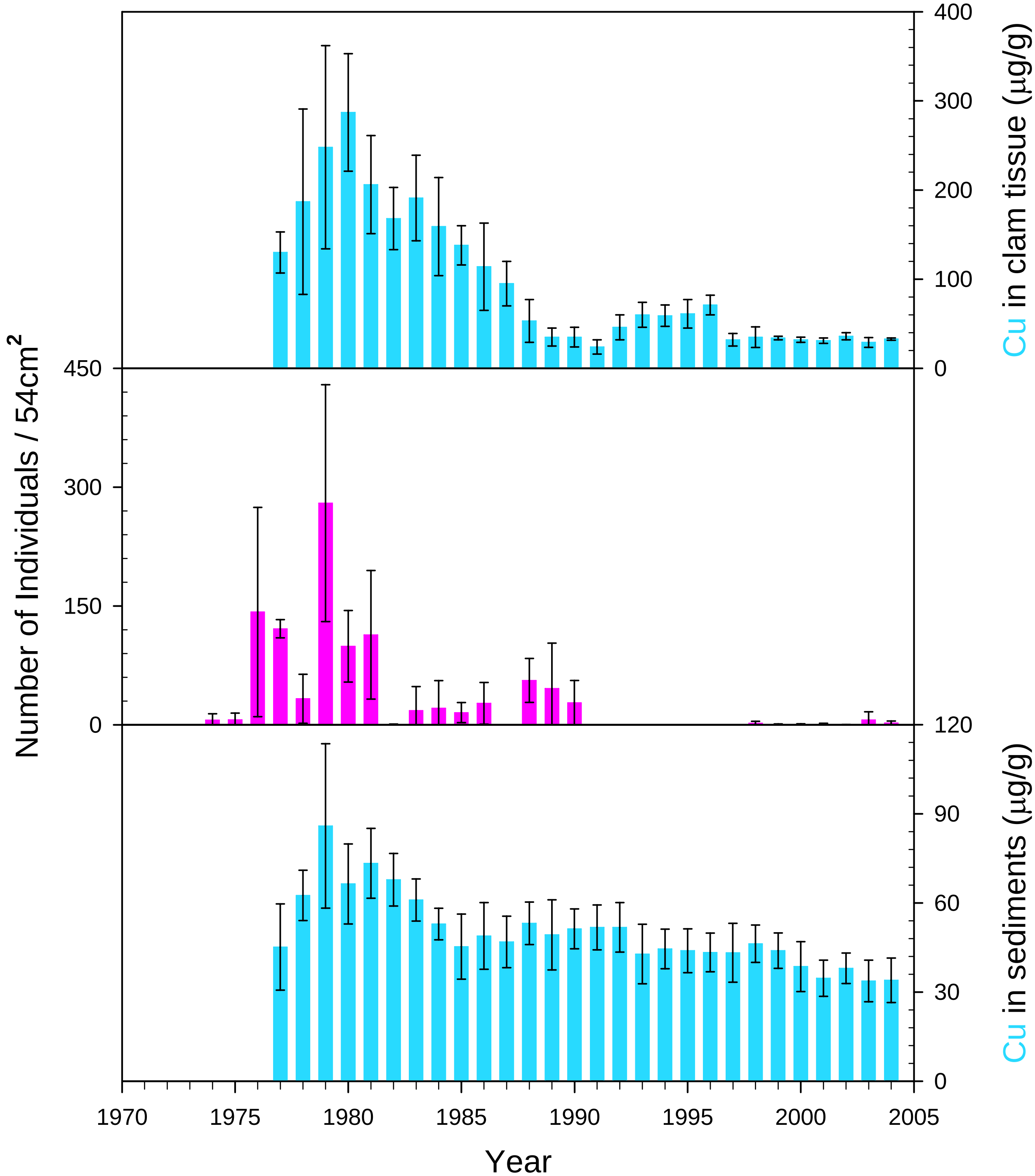


Figure 38. *Ampelisca abdita* annual abundance with copper in *M. petalum* and sediment

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

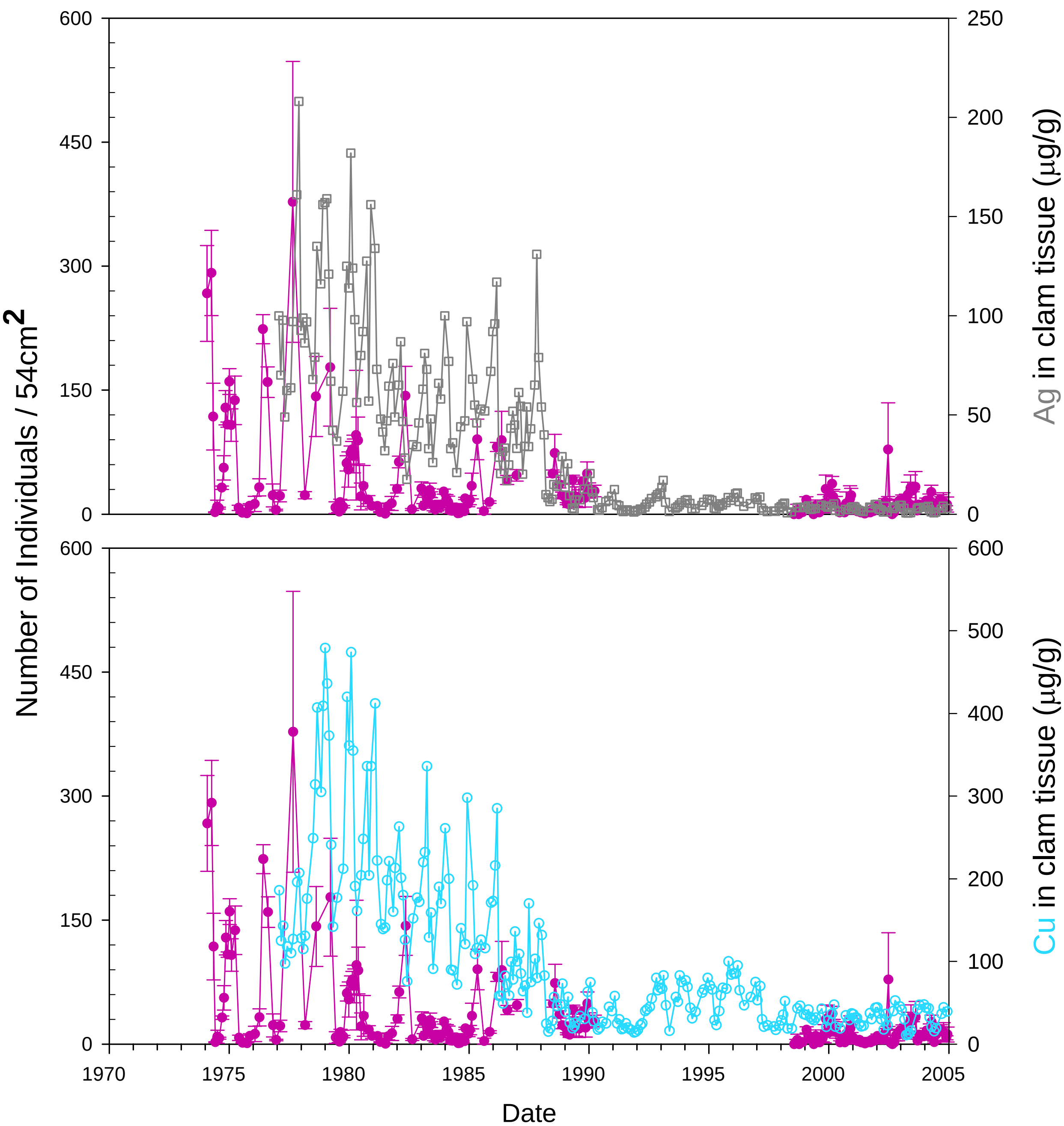


Figure 39. *Streblospio benedicti* abundance with silver and copper in *M. petalum*

Data from Palo Alto site is for period from 1974 through 2004. Error bars represent standard deviation from 3 replicate samplings. Number of individuals (●) with silver (□) and copper (○) tissue concentrations in *Macoma petalum*

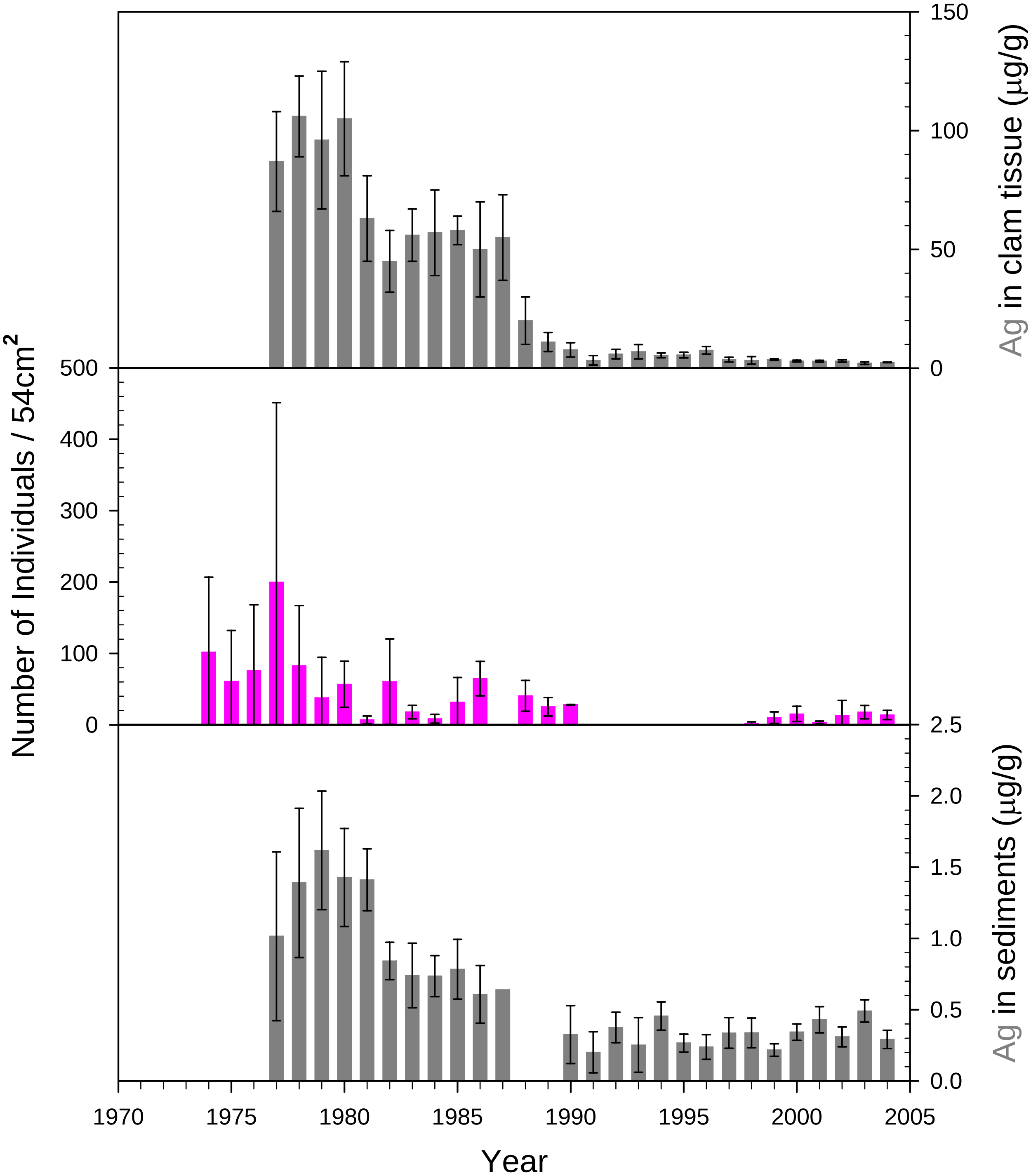


Figure 40. *Streblospio benedicti* annual abundance with silver in *M. petalum* and sediment

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

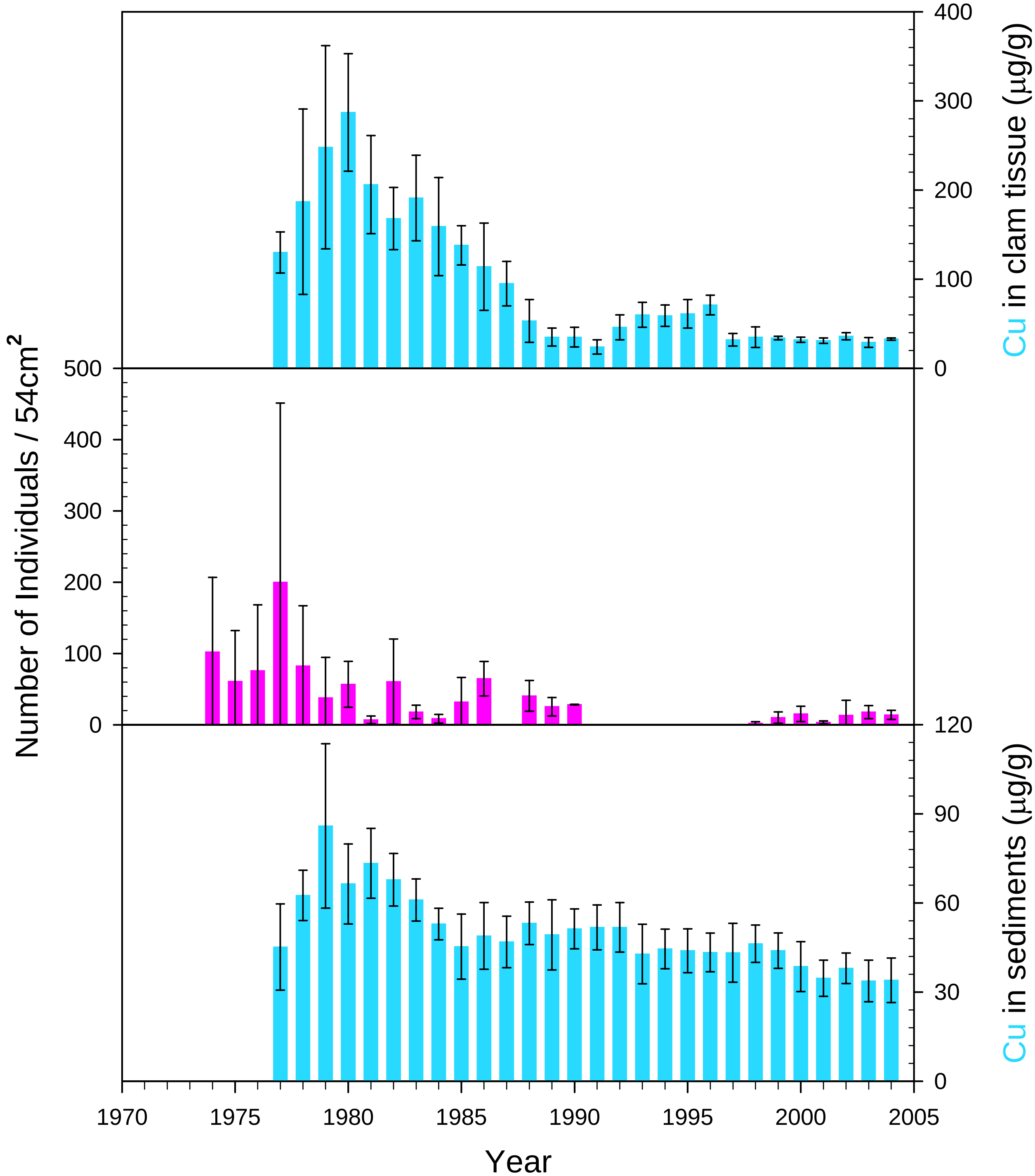


Figure 41. *Streblospio benedicti* annual abundance with copper in *M. petalum* and sediment

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

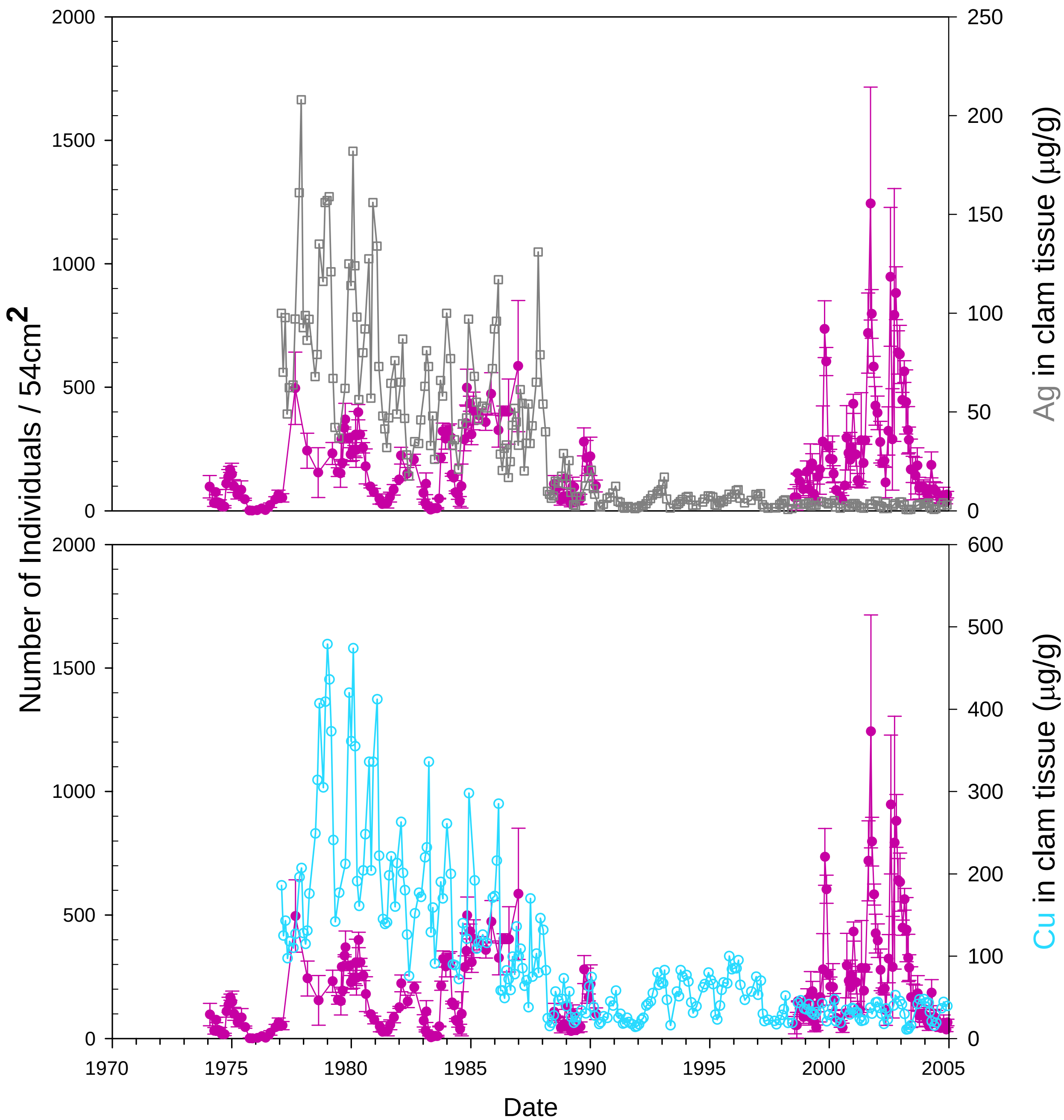


Figure 42. *Gemma gemma* abundance with silver and copper in *M. petalum*

Data from Palo Alto site is for period from 1974 through 2004. Error bars represent standard deviation from 3 replicate samplings. Number of individuals (●) with silver (□) and copper (○) tissue concentrations in *Macoma petalum*

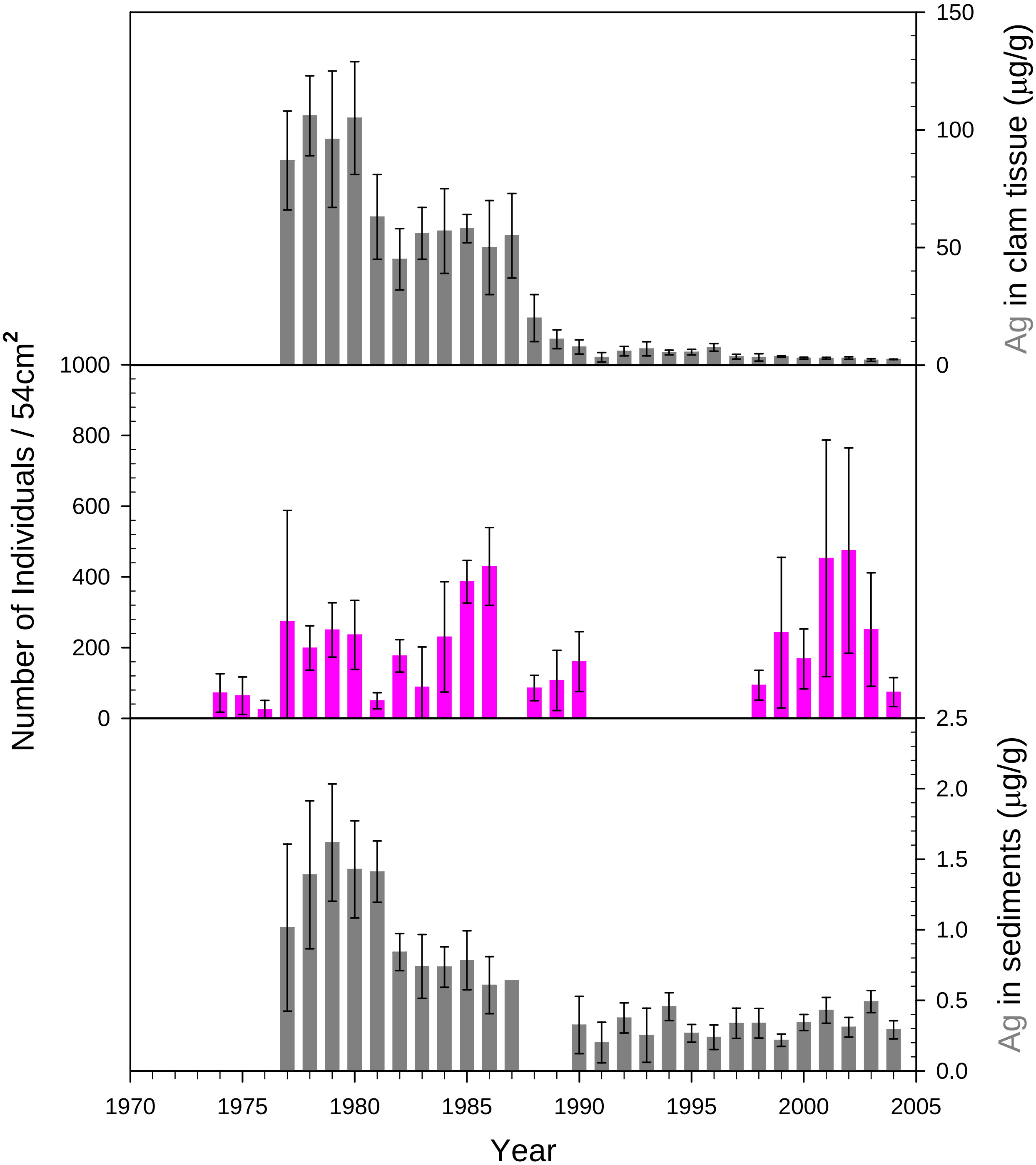


Figure 43. *Gemma gemma* annual abundance with silver in *M. petalum* and sediment

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

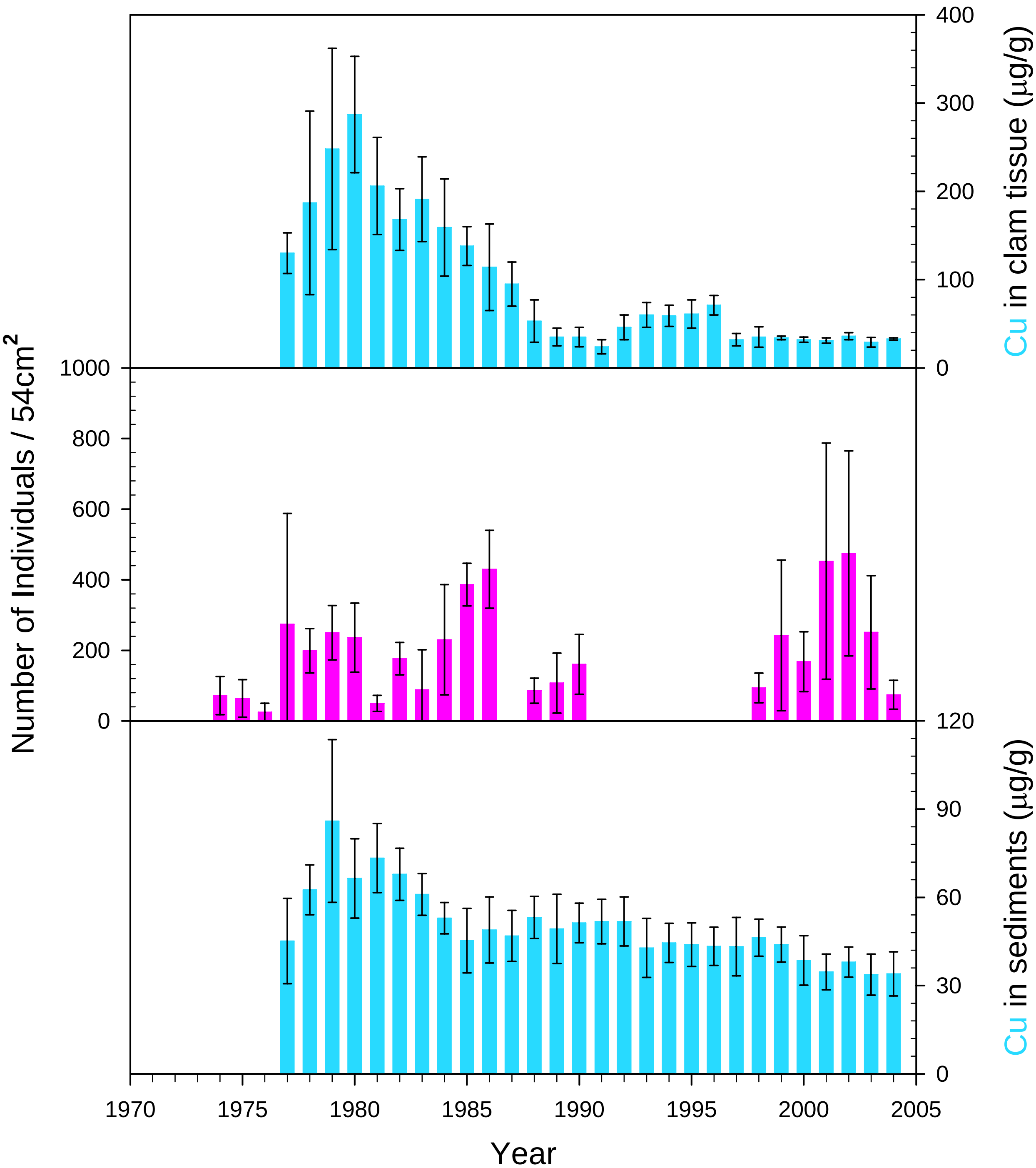


Figure 44. *Gemma gemma* annual abundance with copper in *M. petalum* and sediment

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

Tables

Table 1. Sediment and environmental characteristics in 2004

Units for Al, Fe, total organic carbon (TOC) and sand are percent dry weight. Monthly data are the mean ± standard deviation (std) for replicate subsamples (n=2). Means are summarized as the annual mean (the average of monthly means) and the standard error of the monthly means (SEM) (n=9). Percent sand is calculated as the percent sediment that does not pass through a 100 um screen

Date	**Al** (percent)		**Fe** (percent)		**TOC** (percent)	**Sand** (percent)	**Salinity** (ppt)
	mean	std	mean	std			
January 20, 2004	5.2	0.4	4.2	0.1	1.3	55	22
February 27, 2004	5.3	0.3	4.3	0.0	1.4	58	21
March 16, 2004	5.8	0.2	4.5	0.1	1.5	51	14
April 12, 2004	5.5	0.5	4.4	0.2	1.7	51	18
May 24, 2004	4.7	0.0	4.0	0.1	1.2	36	22
June 22, 2004	3.9	0.1	3.5	0.1	0.9	29	26
September 13, 2004	3.8	0.0	3.2	0.1	0.7	76	28
October 13, 2004	3.3	0.0	2.7	0.0	8.1	72	28
December 8, 2004	4.6	0.0	4.0	0.0	0.9	85	22
Annual Mean:	**4.7**		**3.9**		**1.96**	**57**	**22**
SEM:	*0.3*		*0.2*		*0.77*	*6*	*2*

Table 2. Concentrations of trace elements in sediments in 2004

Units are micrograms per gram dry weight. Monthly data are the mean ± standard deviation (std) for replicate subsamples (n=2). 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 except for silver (Ag) are based on near-total extracts (See Methods). Silver values are partial extracts.

Date	**Ag**		**Cr**		**Cu**		**Hg**	**Ni**		**Se**	**V**		**Zn**	
	mean	*STD*	*mean*	*STD*	*mean*	*STD*	*mean*	*mean*	*STD*	*mean*	*mean*	*STD*	*mean*	*STD*
January 20, 2004	0.33	0.00	121	9	38	0.7	0.46	89	2.6	0.78	122	4	135	2
February 27, 2004	0.33	0.01	121	8	39	0.5	0.44	88	0.3	0.73	126	2.7	140	2
March 16, 2004	0.35	0.00	129	2	43	0.7	-	91	0.2	-	142	2	147	0
April 12, 2004	0.35	0.01	125	10	41	3	0.49	92	1	0.60	110	18	140	3
May 24, 2004	0.28	0.00	111	0	37	0.3	-	83	1.0	-	112	2	125	1
June 22, 2004	0.21	0.00	100	3	29	0.5	0.40	72	1.2	0.29	98	4	104	3
September 13, 2004	0.25	0.01	113	1	26	0.4	0.40	62	0.50	0.31	101	1	93	1
October 13, 2004	0.18	0.01	92	7	21	0	-	52	1.2	-	86	1	81	2
December 8, 2004	0.34	0.01	118	2	32	0.5	0.24	75	0.2	0.35	120	1	112	1
Annual Mean:	**0.29**		**114**		**34**		**0.41**	**78**		**0.51**	**113**		**120**	
SEM:	***0.02***		***4***		***3***		***0.04***	***5***		***0.09***	***6***		***8***	

Table 3. Annual mean copper in *Macoma petalum* and sediments 1977 through 2004

Values are annual means from 7 to 12 collections per year and standard errors of those means for the year. Means are calculated between January and December. Units are microgram per gram dry weight of soft tissue for clams (*Macoma petalum*) and microgram per gram dry weight for sediment.

Year	Copper in sediment HCl	Copper in sediment Total	Copper in clams
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

Table 4. Annual mean silver in *Macoma petalum* and sediments 1977 through 2004

Values are annual means from 7 to 12 collections per year and standard errors of those means for the year. Means are calculated between January and December. Units are microgram per gram dry weight of soft tissue for clams (*Macoma petalum*) and microgram per gram dry weight for sediment.

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 ± 0.08	2.1 ± 1.5
2004	0.29 ± 0.06	2.4 ± 1.3

Table 5. Concentrations of trace elements in *Macoma petalum* in 2004

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

Date		Ag	Cr	Cu	Hg	Ni	Se	Zn	Condition Index
January 20, 2004	*mean*	3.5	4.1	44	0.17	7.8	5.5	362	77
	**SEM*	0.3	0.2	3	0.09	0.4	0.3	46	
February 27, 2004	*mean*	4.0	5.4	43		9.0		383	89
	**SEM*	0.5	0.4	2		0.5		27	
March 16, 2004	*mean*	2.2	3.0	32		5.6		361	130
	**SEM*	0.3	0.2	2		0.2		27	
April 12, 2004	*mean*	1.1	2.8	21	0.29	4.9	4.5	279	173
	**SEM*	0.1	0.2	1	0.02	0.2	0.2	21	
May 24, 2004	*mean*	0.6	1.3	16		3.9		186	222
	**SEM*	0.1	0.1	1		0.2		17	
June 22, 2004	*mean*	1.0	1.2	19	0.33	3.8	4.2	191	181
	**SEM*	0.1	0.1	1	0.05	0.2	0.1	21	
September 13, 2004	*mean*	2.5	1.8	37	0.35	4.8	4.8	278	119
	**SEM*	0.2	0.2	2	0.16	0.3	0.2	61	
October 13, 2004	*mean*	4.1	3.8	44		6.9		266	91
	**SEM*	0.7	1.0	4		0.9		75	
December 8, 2004	*mean*	2.9	3.2	39		5.8		248	107
	**SEM*	0.3	0.4	5		0.4		29	
Annual Mean:		2.4	3.0	33	0.28	5.8	4.8	284	132
SEM:		0.4	0.5	4	0.04	0.6	0.3	24	17

Appendix A

Grain size (p. A-2) and total organic carbon (p. A-4) data.

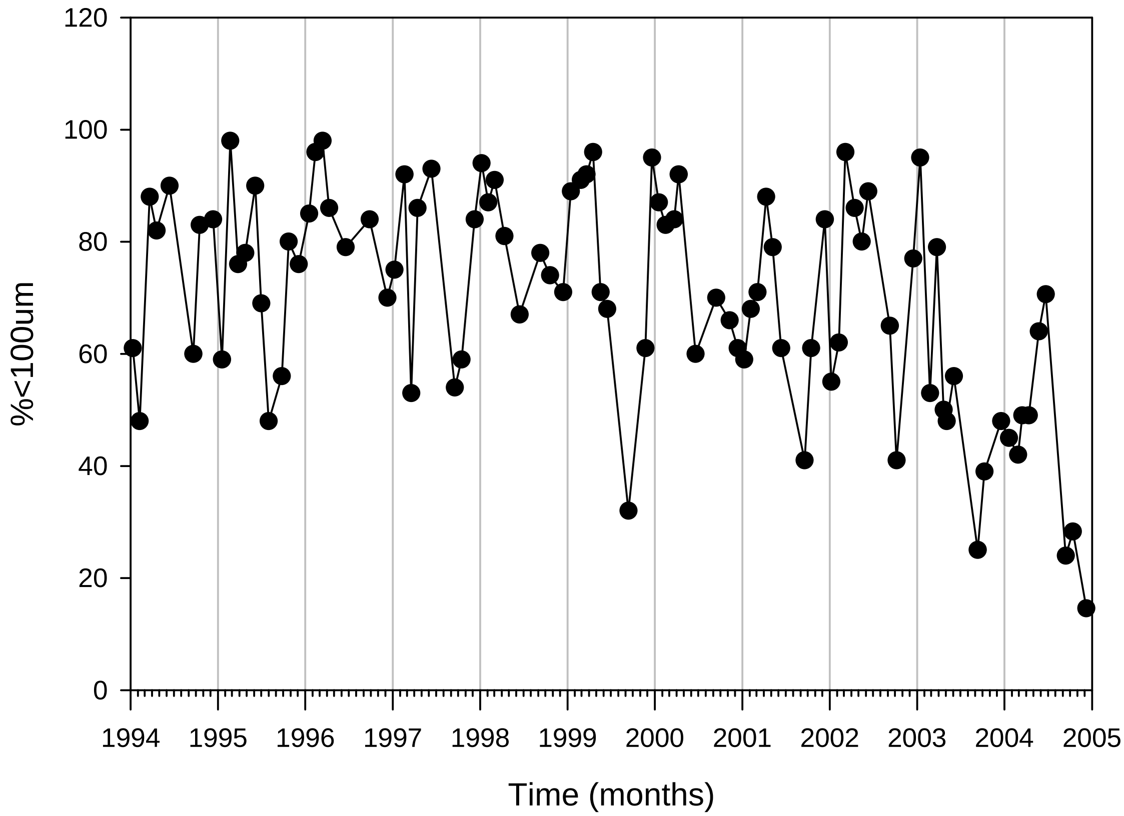
PALTO ALTO GRAIN SIZE DATA: <100um

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

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

Year	Date	%<100um
2004	01/20/04	45
	02/27/04	42
	03/16/04	49
	04/12/04	49
	05/24/04	64
	06/22/04	71
	09/13/04	24
	10/13/04	28
	12/08/04	15

Palo Alto Grain Size: Sieved <100um



Carbon and Nitrogen analysis for 2004 Palo Alto surface sediments

Date	**%C**	**%N**	**d13C**	**d15N**
January 20, 2004	1.3	0.2	-23.9	9.4
February 27, 2004	1.4	0.2	-23.9	9.0
March 16, 2004	1.5	0.2	-24.0	9.3
April 12, 2004	1.7	0.2	-23.3	10.1
May 24, 2004	1.2	0.1	-23.4	9.3
June 22, 2004	0.9	0.1	-23.4	9.0
September 13, 2004	0.7	0.1	-23.6	7.7
October 13, 2004	8.1	0.8	-31.2	-0.7
December 8, 2004	0.9	0.1	-23.5	10.3

Appendix B

Metal concentrations determined by ICP-OES in sediments collected at the Palo Alto mudflat. Each monthly collection is reported on a separate page. Concentrations observed in the reconstituted samples or extracts (in micrograms per milliliter or µg/ml) are reported at the top of each page, along with the sediment weight and dilution factor. The latter are used to calculate concentrations in sediments (reported as microgram per gram dry sediment or µg/g). Replicate subsamples were analyzed from each collection. Mean and standard deviation for the replicate samples are reported for the near-total and hydrochloric acid extracts.

Palo Alto Total Extracts: 2004

1/20/2004: 45% < 100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	0.5405	10	10	265.8	0.62	0.20	224.70	6.450	0.470	0.172	0.644	0.720
Tot2	0.5115	10	10	280.8	0.65	0.20	221.30	6.283	0.464	0.158	0.641	0.698
				49177	115	37	41573	1193	87.0	31.8	119	133
				54897	128	38	43265	1228	90.7	30.8	125	136
			Average	**52037**	**121**	**38**	**42419**	**1211**	**88.9**	**31.3**	**122**	**135**
			Std	**4045**	**9**	**1**	**1197**	**25**	**2.6**	**0.7**	**4**	**2**

2/27/2004: 42% < 100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	0.5064	10	10	280.8	0.64	0.20	218.00	5.798	0.449	0.158	0.649	0.712
Tot2	0.523	10	10	269.0	0.60	0.21	224.70	6.047	0.461	0.172	0.650	0.724
				55450	126	39	43049	1145	88.6	31.1	128	141
				51434	115	40	42964	1156	88.2	32.9	124	138
			Average	**53442**	**121**	**39**	**43006**	**1151**	**88.4**	**32.0**	**126**	**140**
			Std	**2840**	**8**	**0**	**60**	**8**	**0.3**	**1.3**	**3**	**2**

3/16/2004: 49% < 100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	0.5442	10	10	304.7	0.69	0.23	241.20	5.953	0.495	0.180	0.762	0.798
Tot2	0.5456	10	10	323.5	0.71	0.24	248.80	6.093	0.499	0.176	0.783	0.804
				55990	128	43	44322	1094	91.0	33.1	140	147
				59293	131	44	45601	1117	91.4	32.2	144	147
			Average	**57641**	**129**	**43**	**44962**	**1105**	**91.2**	**32.6**	**142**	**147**
			Std	**2335**	**2**	**1**	**905**	**16**	**0.2**	**0.6**	**2**	**0**

4/12/2004: 49% < 100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	0.5295	10	10	308.8	0.70	0.23	238.70	7.163	0.491	0.178	0.512	0.756
Tot2	0.4945	10	10	256.0	0.58	0.19	210.80	6.541	0.448	0.168	0.607	0.682
				58319	132	43	45080	1353	92.6	33.6	96.6	143
				51769	118	39	42629	1323	90.6	34.0	123	138
			Average	**55044**	**125**	**41**	**43855**	**1338**	**91.6**	**33.8**	**110**	**140**
			Std	**4631**	**10**	**3**	**1733**	**21**	**1.4**	**0.3**	**18**	**3**

5/24/2004: 64% < 100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	0.5242	10	10	244.0	0.58	0.20	210.00	3.684	0.441	0.161	0.577	0.660
Tot2	0.5405	10	10	252.9	0.60	0.20	212.50	3.723	0.447	0.152	0.612	0.674
				46547	111	37	40061	702.8	84.1	30.6	110	126
				46790	111	37	39315	688.8	82.7	28.2	113	125
			Average	**46669**	**111**	**37**	**39688**	**695.8**	**83.4**	**29.4**	**112**	**125**
			Std	**172**	**0**	**0**	**527**	**9.9**	**1.0**	**1.7**	**2**	**1**

6/22/2004: 70.6% < 100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	0.5513	10	10	219.4	0.56	0.16	194.60	3.231	0.400	0.139	0.555	0.587
Tot2	0.5341	10	10	201.7	0.52	0.15	184.30	3.061	0.378	0.135	0.510	0.545
				39797	102	29	35298	586.1	72.5	25.2	101	107
				37764	97	28	34507	573.1	70.8	25.2	95.4	102
			Average	**38781**	**100**	**29**	**34903**	**579.6**	**71.7**	**25.2**	**98**	**104**
			Std	**1437**	**3**	**1**	**560**	**9.2**	**1.2**	**0.1**	**4**	**3**

9/13/2004: 24% < 100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	0.5088	10	10	195.9	0.58	0.13	163.80	2.832	0.317	0.120	0.520	0.468
Tot2	0.5734	10	10	217.2	0.64	0.15	180.30	3.143	0.353	0.134	0.575	0.533
				38502	113	26	32193	556.6	62.3	23.5	102	92.0
				37879	112	26	31444	548.1	61.6	23.4	100	93.0
			Average	**38191**	**113**	**26**	**31819**	**552.4**	**62.0**	**23.4**	**101**	**92.5**
			Std	**441**	**1**	**0**	**530**	**6.0**	**0.5**	**0.1**	**1**	**0.7**

10/13/2004: 28.3% < 100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	0.5502	10	10	179.3	0.48	0.12	146.40	2.374	0.280	0.103	0.469	0.435
Tot2	0.5097	10	10	169.1	0.49	0.11	136.00	2.226	0.268	0.096	0.439	0.421
				32588	87	21	26609	431.5	50.9	18.7	85.2	79.1
				33176	97	21	26682	436.7	52.5	18.9	86.1	82.6
			Average	**32882**	**92**	**21**	**26645**	**434.1**	**51.7**	**18.8**	**85.7**	**80.8**
			Std	**416**	**7**	**0**	**52**	**3.7**	**1.2**	**0.1**	**0.6**	**2.4**

12/8/2004: 14.6% < 100 µm

Sample	Weight (g)	Recon. (ml)	Dil. Factor	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Tot1	0.4992	10	10	227.7	0.58	0.16	197.50	4.340	0.374	0.148	0.595	0.555
Tot2	0.509	10	10	235.0	0.61	0.16	200.90	4.477	0.383	0.147	0.613	0.572
				45613	117	31	39563	869.4	74.9	29.7	119	111
				46169	120	32	39470	879.6	75.1	29.0	120	112
			Average	**45891**	**118**	**32**	**39516**	**874.5**	**75.0**	**29.3**	**120**	**112**
			Std	**393**	**2**	**1**	**66**	**7.2**	**0.2**	**0.5**	**1**	**1**

Palo Alto HCl Extracts: 2004

1/20/2004: 45% < 100 µm

Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.5498	10		0.018	127.50	0.282	1.02	284.000	47.1800	0.4161	1.011	0.551	2.468
HCl2	0.5602	10		0.018	127.40	0.282	1.03	283.800	47.8700	0.4178	1.024	0.555	2.483
				0.33	2319	5.13	18.6	5165.51	858.130	7.568	18.39	10.0	44.89
				0.33	2274	5.04	18.4	5066.05	854.516	7.458	18.28	9.91	44.32
			Average	**0.33**	**2297**	**5.08**	**18.5**	**5115.78**	**856.323**	**7.513**	**18.33**	**9.96**	**44.61**
			Std	**0.00**	**22**	**0.04**	**0.1**	**49.73**	**1.807**	**0.055**	**0.05**	**0.06**	**0.28**

2/27/2004: 42% < 100 µm

Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.4971	10		0.017	113.60	0.244	0.86	238.100	38.8900	0.3732	0.921	0.507	2.115
HCl2	0.5003	10		0.016	110.40	0.233	0.85	231.000	38.7500	0.3622	0.923	0.496	2.080
				0.34	2285.3	4.91	17	4789.78	782.338	7.508	18.54	10.2	42.55
				0.32	2207	4.65	17	4617.23	774.535	7.240	18.45	9.92	41.58
			Average	**0.33**	**2246**	**4.78**	**17**	**4703.51**	**778.436**	**7.374**	**18.49**	**10.05**	**42.06**
			Std	**0.01**	**39**	**0.13**	**0**	**86.28**	**3.901**	**0.134**	**0.04**	**0.14**	**0.49**

3/16/2004: 49% < 100 µm

Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.4861	10		0.017	119.50	0.269	1.08	283.500	36.9300	0.4273	0.951	0.531	2.483
HCl2	0.4775	10		0.017	117.60	0.269	1.06	280.800	36.1800	0.4255	0.934	0.526	2.452
				0.35	2458.3	5.52	22.2	5832.13	759.720	8.790	19.56	10.9	51.08
				0.35	2463	5.63	22.2	5880.63	757.696	8.911	19.57	11.01	51.35
			Average	**0.35**	**2461**	**5.58**	**22.2**	**5856.38**	**758.708**	**8.851**	**19.56**	**10.96**	**51.22**
			Std	**0.00**	**2**	**0.05**	**0.0**	**24.25**	**1.012**	**0.060**	**0.01**	**0.04**	**0.14**

4/12/2004: 49% < 100 µm

Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.4274	10		0.016	104.20	0.245	0.89	241.700	42.4400	0.3421	0.834	0.477	2.145
HCl2	0.4968	10		0.017	120.10	0.278	1.03	272.000	48.4400	0.3875	0.933	0.546	2.455
				0.36	2438	5.72	21	5655.12	992.981	8.004	19.51	11.2	50.19
				0.34	2417	5.59	20.7	5475.04	975.040	7.800	18.79	11.0	49.42
			Average	**0.35**	**2428**	**5.66**	**21**	**5565.08**	**984.011**	**7.902**	**19.15**	**11.1**	**49.80**
			Std	**0.01**	**10**	**0.07**	**0**	**90.04**	**8.970**	**0.102**	**0.36**	**0.1**	**0.39**

5/24/2004: 64% < 100 µm

Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.5484	10		0.015	116.10	0.275	1.08	286.000	22.2700	0.4047	0.968	0.493	2.389
HCl2	0.5290	10		0.015	112.60	0.267	1.04	279.000	21.5000	0.3957	0.945	0.477	2.312
				0.27	2117.1	5.02	19.7	5215.17	406.090	7.380	17.64	8.99	43.56
				0.28	2129	5.05	19.6	5274.10	406.427	7.480	17.87	9.02	43.71
			Average	**0.28**	**2123**	**5.03**	**19.6**	**5244.64**	**406.259**	**7.430**	**17.76**	**9.00**	**43.63**
			Std	**0.00**	**6**	**0.02**	**0.0**	**29.47**	**0.168**	**0.050**	**0.11**	**0.01**	**0.07**

6/22/2004: 70.6% < 100 µm

Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.4930	10		0.010	93.12	0.215	0.74	228.600	16.2400	0.3295	0.733	0.382	1.807
HCl2	0.5138	10		0.011	94.80	0.219	0.76	234.300	16.7900	0.3364	0.757	0.395	1.848
				0.21	1888.8	4.37	15	4636.92	329.412	6.684	14.86	7.75	36.65
				0.20	1845	4.26	15	4560.14	326.781	6.547	14.73	7.69	35.97
			Average	**0.21**	**1867**	**4.31**	**15**	**4598.53**	**328.096**	**6.615**	**14.79**	**7.72**	**36.31**
			Std	**0.00**	**22**	**0.05**	**0**	**38.39**	**1.315**	**0.068**	**0.07**	**0.03**	**0.34**

9/13/2004: 24% < 100 µm

Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.5044	10		0.012	75.48	0.175	0.65	192.000	15.3500	0.2774	0.697	0.314	1.577
HCl2	0.5492	10		0.014	83.15	0.189	0.72	208.300	16.6900	0.3002	0.761	0.337	1.744
				0.25	1496.4	3.46	13	3806.50	304.322	5.500	13.81	6.22	31.26
				0.26	1514	3.45	13	3792.79	303.897	5.466	13.85	6.14	31.76
			Average	**0.25**	**1505**	**3.45**	**13**	**3799.65**	**304.109**	**5.483**	**13.83**	**6.18**	**31.51**
			Std	**0.01**	**9**	**0.01**	**0**	**6.86**	**0.213**	**0.017**	**0.02**	**0.04**	**0.25**

10/13/2004: 28.3% < 100 µm

Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.5346	10		0.009	68.75	0.191	0.66	205.900	12.1300	0.3277	0.257	0.292	1.588
HCl2	0.4992	10		0.010	68.12	0.190	0.64	201.200	11.6000	0.3261	0.256	0.285	1.547
				0.17	1286	3.58	12	3851.48	226.899	6.130	4.80	5.46	29.70
				0.19	1365	3.81	13	4030.45	232.372	6.532	5.12	5.71	30.99
			Average	**0.18**	**1325**	**3.69**	**13**	**3940.96**	**229.635**	**6.331**	**4.96**	**5.58**	**30.35**
			Std	**0.01**	**39**	**0.11**	**0**	**89.49**	**2.737**	**0.201**	**0.16**	**0.12**	**0.64**

12/8/2004: 14.6% < 100 µm

Sample	Weight (g)	Recon. (ml)		Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
HCl1	0.4912	10		0.017	113.10	0.293	0.69	290.100	26.9100	0.4172	0.825	0.455	2.171
HCl2	0.5005	10		0.017	113.90	0.298	0.69	287.000	27.6900	0.4270	0.835	0.456	2.174
				0.35	2302.5	5.96	14	5905.94	547.842	8.493	16.79	9.26	44.20
				0.33	2276	5.95	14	5734.27	553.247	8.531	16.68	9.11	43.44
			Average	**0.34**	**2289**	**5.95**	**14**	**5820.11**	**550.544**	**8.512**	**16.74**	**9.18**	**43.82**
			Std	**0.01**	**13**	**0.01**	**0**	**85.84**	**2.702**	**0.019**	**0.06**	**0.08**	**0.38**

Appendix C

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

- Mean concentrations in microgram per gram dry tissue weight (µg/g).
- STD is the standard deviation of the mean.
- SEM is the standard error of the mean.
- CV percent is the coefficient of variation.
- r wt x [] is the correlation coefficient for the concentration versus weight correlation for each element.
- X 100mg is the concentration interpolated from the above regression for a 100 mg animal.
- r l x [] is the correlation coefficient for the concentration versus shell length regression.
- X 20 mm and X 25 mm are concentrations interpolated from the regression for 20mm and 25 mm animals.

Condition index (CI) is an estimate of the tissue dry weight of a clam having 25 mm shell length. This index, along with weights for animals of 15 mm and 20 mm shell length, was estimated from a plot of log tissue dry weight vs. log average shell length for a particular size replicate.

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

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

Station: Palo Alto

Date: 1/20/2004

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	3.510	0.370	4.140	43.874	7.772	2.196	4.882	362.127
STD	0.926	0.040	0.676	9.850	1.039	0.268	0.816	128.930
SEM	0.328	0.014	0.239	3.482	0.367	0.095	0.288	45.584
CV%	26.394	10.847	16.326	22.451	13.369	12.215	16.707	35.604
n	8	8	8	8	8	8	8	8
r wt x [ ]	0.409	0.848	0.646	0.146	0.161	0.926	0.610	0.643
X 100mg	4.370	0.293	3.149	47.131	8.151	1.632	3.753	550.202
r l x [ ]	0.408	0.821	0.670	0.252	0.137	0.910	0.632	0.549
X 15mm	2.943	0.420	4.820	40.157	7.559	2.562	5.655	256.069
X 20mm	3.444	0.376	4.219	43.441	7.748	2.239	4.972	349.779
X 25mm	3.945	0.332	3.619	46.725	7.936	1.915	4.289	443.489

Estimated content (μg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.055	0.008	0.092	0.737	0.142	0.049	0.108	4.985
20mm	0.140	0.015	0.172	1.773	0.320	0.091	0.202	14.125
25mm	0.290	0.026	0.278	3.504	0.599	0.148	0.328	31.686

Estimated weight for 15mm clam

0.019 gm
18.823 mg

Estimated weight for 20mm clam

0.042 gm
41.505 mg

Estimated weight for 25mm clam

0.077 gm
76.643 mg

Station: Palo Alto

Date: 1/20/2004

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Concentration (ug/ml) - Blank Corrected from ICP-AES Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
mb1	14.92	0.2283	0.0176	10	0.0791	0.0097	0.1152	1.1080	0.1957	0.0584	0.1351	6.6310
mb2	16.78	0.2597	0.0260	10	0.0771	0.0106	0.1228	0.8842	0.2021	0.0654	0.1418	7.7420
mb3	18.48	0.2611	0.0373	10	0.0703	0.0095	0.0998	0.8969	0.1670	0.0571	0.1191	8.8810
mb4	20.23	0.2625	0.0438	10	0.0648	0.0094	0.1010	0.9061	0.1687	0.0564	0.1213	6.6100
mb5	21.39	0.2274	0.0455	10	0.1132	0.0094	0.1092	1.3940	0.2048	0.0537	0.1312	6.1820
mb6	23.38	0.1844	0.0615	10	0.0575	0.0061	0.0604	0.9648	0.1298	0.0374	0.0674	9.4240
mb7	24.55	0.1586	0.0793	10	0.0760	0.0054	0.0676	0.6541	0.1389	0.0313	0.0802	9.7080
mb8	25.53	0.1555	0.0778	10	0.0559	0.0050	0.0519	0.6947	0.1275	0.0279	0.0624	4.9990

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
LOD	0.0004	0.0001	0.0018	0.0041	0.0008	0.0036	0.0019	0.0012
LOQ	0.0022	0.0007	0.0061	0.0154	0.0027	0.0125	0.0034	0.0063

Concentration (ug/g) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
mb1	3.4647	0.4249	5.0460	48.5326	8.5721	2.5580	5.9177	290.4512
mb2	2.9688	0.4082	4.7285	34.0470	7.7821	2.5183	5.4601	298.1132
mb3	2.6925	0.3638	3.8223	34.3508	6.3960	2.1869	4.5615	340.1379
mb4	2.4686	0.3581	3.8476	34.5181	6.4267	2.1486	4.6210	251.8095
mb5	4.9780	0.4134	4.8021	61.3017	9.0062	2.3615	5.7696	271.8558
mb6	3.1182	0.3308	3.2755	52.3210	7.0390	2.0282	3.6551	511.0629
mb7	4.7919	0.3405	4.2623	41.2421	8.7579	1.9735	5.0567	612.1059
mb8	3.5949	0.3215	3.3376	44.6752	8.1994	1.7942	4.0129	321.4791

Content (ug) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
mb1	0.0608	0.0075	0.0886	0.8523	0.1505	0.0449	0.1039	5.1008
mb2	0.0771	0.0106	0.1228	0.8842	0.2021	0.0654	0.1418	7.7420
mb3	0.1004	0.0136	0.1426	1.2813	0.2386	0.0816	0.1701	12.6871
mb4	0.1080	0.0157	0.1683	1.5102	0.2812	0.0940	0.2022	11.0167
mb5	0.2264	0.0188	0.2184	2.7880	0.4096	0.1074	0.2624	12.3640
mb6	0.1917	0.0203	0.2013	3.2160	0.4327	0.1247	0.2247	31.4133
mb7	0.3800	0.0270	0.3380	3.2705	0.6945	0.1565	0.4010	48.5400
mb8	0.2795	0.0250	0.2595	3.4735	0.6375	0.1395	0.3120	24.9950

Station: Palo Alto

Date: 2/27/2004

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	3.957	0.456	5.420	43.358	8.983	2.569	6.243	383.491
STD	1.802	0.072	1.224	5.226	1.523	0.422	1.575	88.976
SEM	0.543	0.022	0.369	1.576	0.459	0.127	0.475	26.827
CV%	45.531	15.742	22.593	12.053	16.952	16.438	25.231	23.201
n	11	11	11	11	11	11	11	11
r wt x [ ]	0.684	0.105	0.210	0.154	0.459	0.004	0.307	0.729
X 100mg	4.920	0.450	5.620	43.987	9.529	2.570	6.621	332.826
r l x [ ]	0.706	0.111	0.205	0.212	0.485	0.008	0.308	0.642
X 15mm	2.203	0.467	5.073	41.830	7.964	2.564	5.575	462.252
X 20mm	3.492	0.459	5.328	42.954	8.713	2.567	6.066	404.351
X 25mm	4.782	0.451	5.583	44.077	9.462	2.571	6.557	346.450

Estimated content (µg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.052	0.010	0.111	0.912	0.174	0.056	0.122	10.223
20mm	0.161	0.022	0.252	2.055	0.418	0.122	0.287	18.622
25mm	0.390	0.039	0.476	3.857	0.822	0.222	0.555	29.652

Estimated weight for 15mm clam

0.022 gm
21.648 mg

Estimated weight for 20mm clam

0.048 gm
47.866 mg

Estimated weight for 25mm clam

0.089 gm
88.580 mg

Station: Palo Alto

Date: 2/27/04

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
					Concentration (ug/ml) - Blank Corrected from ICP-AES							
mb1	14.14	0.2455	0.0205	10	0.0925	0.0135	0.1595	1.0500	0.2338	0.0740	0.1823	9.1400
mb2	16.76	0.2245	0.0249	10	0.0436	0.0107	0.1227	0.9235	0.1958	0.0578	0.1354	8.8590
mb3	17.92	0.2878	0.0360	10	0.0870	0.0129	0.1520	1.2980	0.2272	0.0781	0.1695	12.6800
mb4	18.62	0.269	0.0384	10	0.0807	0.0119	0.1249	1.2170	0.2146	0.0650	0.1361	13.1100
mb5	19.95	0.2798	0.0466	10	0.0821	0.0111	0.1083	1.1090	0.2061	0.0626	0.1233	13.6500
mb6	21.29	0.3507	0.0585	10	0.0768	0.0165	0.1948	1.5680	0.2944	0.0883	0.2174	15.6900
mb7	22.79	0.3746	0.0749	10	0.1254	0.0149	0.1583	1.5790	0.2996	0.0768	0.1759	16.7100
mb8	24.26	0.2218	0.0739	10	0.1508	0.0113	0.1513	0.9035	0.2490	0.0667	0.1856	7.1320
Mb9	25.98	0.2103	0.1052	10	0.0786	0.0066	0.0811	0.8725	0.1698	0.0399	0.0958	5.5170
Mb10	28.64	0.2815	0.1408	10	0.1515	0.0126	0.1629	1.0360	0.2642	0.0715	0.1950	6.3560
Mb11	29.46	0.1275	0.1275	10	0.0944	0.0072	0.0971	0.7289	0.1562	0.0419	0.1162	4.2400

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
LOD	0.0004	0.0001	0.0018	0.0041	0.0008	0.0036	0.0019	0.0012
LOQ	0.0022	0.0007	0.0061	0.0154	0.0027	0.0125	0.0034	0.0063

Concentration (ug/g) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
mb1	3.7678	0.5499	6.4969	42.7699	9.5234	3.0143	7.4257	372.3014
mb2	1.9421	0.4766	5.4655	41.1359	8.7216	2.5746	6.0312	394.6102
mb3	3.0229	0.4482	5.2814	45.1008	7.8944	2.7137	5.8895	440.5837
mb4	3.0000	0.4424	4.6431	45.2416	7.9777	2.4164	5.0595	487.3606
mb5	2.9342	0.3967	3.8706	39.6355	7.3660	2.2373	4.4067	487.8485
mb6	2.1899	0.4705	5.5546	44.7106	8.3946	2.5178	6.1990	447.3909
mb7	3.3476	0.3978	4.2258	42.1516	7.9979	2.0502	4.6957	446.0758
mb8	6.7989	0.5095	6.8215	40.7349	11.2263	3.0072	8.3679	321.5509
Mb9	3.7375	0.3138	3.8564	41.4883	8.0742	1.8973	4.5554	262.3395
Mb10	5.3819	0.4476	5.7869	36.8028	9.3854	2.5400	6.9272	225.7904
Mb11	7.4039	0.5647	7.6157	57.1686	12.2510	3.2863	9.1137	332.5490

Content (ug) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
mb1	0.0771	0.0113	0.1329	0.8750	0.1948	0.0617	0.1519	7.6167
mb2	0.0484	0.0119	0.1363	1.0261	0.2176	0.0642	0.1504	9.8433
mb3	0.1088	0.0161	0.1900	1.6225	0.2840	0.0976	0.2119	15.8500
mb4	0.1153	0.0170	0.1784	1.7386	0.3066	0.0929	0.1944	18.7286
mb5	0.1368	0.0185	0.1805	1.8483	0.3435	0.1043	0.2055	22.7500
mb6	0.1280	0.0275	0.3247	2.6133	0.4907	0.1472	0.3623	26.1500
mb7	0.2508	0.0298	0.3166	3.1580	0.5992	0.1536	0.3518	33.4200
mb8	0.5027	0.0377	0.5043	3.0117	0.8300	0.2223	0.6187	23.7733
Mb9	0.3930	0.0330	0.4055	4.3625	0.8490	0.1995	0.4790	27.5850
Mb10	0.7575	0.0630	0.8145	5.1800	1.3210	0.3575	0.9750	31.7800
Mb11	0.9440	0.0720	0.9710	7.2890	1.5620	0.4190	1.1620	42.4000

Station: Palo Alto

Date: 3/16/2004

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	2.230	0.310	3.026	32.277	5.643	1.293	3.304	361.355
STD	0.857	0.032	0.689	5.584	0.820	0.239	0.712	88.073
SEM	0.258	0.010	0.208	1.684	0.247	0.072	0.215	26.555
CV%	38.432	10.460	22.766	17.300	14.525	18.480	21.553	24.373
n	11	11	11	11	11	11	11	11
r wt x [ ]	0.649	0.235	0.110	0.735	0.686	0.147	0.185	0.673
X 100mg	2.156	0.311	3.015	31.731	5.568	1.288	3.287	369.240
r l x [ ]	0.689	0.252	0.070	0.806	0.708	0.080	0.134	0.603
X 15mm	1.116	0.326	2.934	23.783	4.548	1.257	3.125	461.500
X 20mm	1.834	0.316	2.993	29.257	5.254	1.280	3.240	396.971
X 25mm	2.551	0.306	3.052	34.730	5.960	1.303	3.356	332.441

Estimated content (μg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.037	0.010	0.088	0.708	0.139	0.038	0.094	16.126
20mm	0.124	0.022	0.203	2.012	0.365	0.088	0.221	27.288
25mm	0.321	0.039	0.388	4.522	0.771	0.167	0.428	41.037

Estimated weight for 15mm clam

0.031 gm
31.379 mg

Estimated weight for 20mm clam

0.070 gm
69.764 mg

Estimated weight for 25mm clam

0.130 gm
129.651 mg

Station: Palo Alto

Date: 3/16/2004

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
					Concentration (ug/ml) - Blank Corrected from ICP-AES							
mb1	17.17	0.4791	0.0479	15	0.0479	0.0110	0.1255	0.8351	0.1855	0.0503	0.1342	11.5000
mb2	18.34	0.5474	0.0547	15	0.0445	0.0106	0.0822	0.7824	0.1594	0.0346	0.0892	15.0200
mb3	19.62	0.4894	0.0612	15	0.0676	0.0104	0.0896	1.0020	0.1571	0.0415	0.1012	12.1200
mb4	20.54	0.4295	0.0716	15	0.0534	0.0086	0.0744	0.8248	0.1484	0.0340	0.0823	9.6760
mb5	21.52	0.3683	0.0921	10	0.0696	0.0114	0.1052	1.3010	0.1995	0.0502	0.1140	14.5500
mb6	22.27	0.3739	0.0935	10	0.0789	0.0109	0.0748	1.1980	0.1741	0.0362	0.0822	19.1900
mb7	22.91	0.4552	0.1138	15	0.0683	0.0106	0.1296	0.9783	0.1787	0.0528	0.1391	11.4700
mb8	23.79	0.4107	0.1027	15	0.0674	0.0086	0.0956	0.8916	0.1791	0.0359	0.0985	12.4000
Mb9	25.68	0.2683	0.1342	10	0.0519	0.0094	0.0883	1.0150	0.1776	0.0354	0.0975	8.3560
Mb10	27.32	0.3368	0.1684	10	0.1512	0.0080	0.0898	1.3960	0.2044	0.0375	0.1007	7.5100
Mb11	31.21	0.2448	0.2448	10	0.0669	0.0075	0.0778	0.8936	0.1643	0.0349	0.0888	5.3930
				LOD	0.0004	0.0001	0.0018	0.0041	0.0008	0.0036	0.0019	0.0012
				LOQ	0.0022	0.0007	0.0061	0.0154	0.0027	0.0125	0.0034	0.0063

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	mb1	1.4997	0.3444	3.9292	26.1459	5.8078	1.5748	4.2016	360.0501
	mb2	1.2194	0.2905	2.2525	21.4395	4.3679	0.9481	2.4443	411.5820
	mb3	2.0719	0.3188	2.7462	30.7111	4.8151	1.2720	3.1018	371.4753
	mb4	1.8650	0.3003	2.5984	28.8056	5.1828	1.1874	2.8743	337.9278
	mb5	1.8898	0.3095	2.8564	35.3245	5.4168	1.3630	3.0953	395.0584
	mb6	2.1102	0.2915	2.0005	32.0407	4.6563	0.9682	2.1984	513.2388
	mb7	2.2507	0.3493	4.2707	32.2375	5.8886	1.7399	4.5837	377.9657
	mb8	2.4617	0.3141	3.4916	32.5639	6.5413	1.3112	3.5975	452.8853
	Mb9	1.9344	0.3504	3.2911	37.8308	6.6195	1.3194	3.6340	311.4424
	Mb10	4.4893	0.2375	2.6663	41.4489	6.0689	1.1134	2.9899	222.9810
	Mb11	2.7328	0.3064	3.1781	36.5033	6.7116	1.4257	3.6275	220.3023

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	mb1	0.0719	0.0165	0.1883	1.2527	0.2783	0.0755	0.2013	17.2500
	mb2	0.0668	0.0159	0.1233	1.1736	0.2391	0.0519	0.1338	22.5300
	mb3	0.1268	0.0195	0.1680	1.8788	0.2946	0.0778	0.1898	22.7250
	mb4	0.1335	0.0215	0.1860	2.0620	0.3710	0.0850	0.2058	24.1900
	mb5	0.1740	0.0285	0.2630	3.2525	0.4988	0.1255	0.2850	36.3750
	mb6	0.1973	0.0273	0.1870	2.9950	0.4353	0.0905	0.2055	47.9750
	mb7	0.2561	0.0398	0.4860	3.6686	0.6701	0.1980	0.5216	43.0125
	mb8	0.2528	0.0323	0.3585	3.3435	0.6716	0.1346	0.3694	46.5000
	Mb9	0.2595	0.0470	0.4415	5.0750	0.8880	0.1770	0.4875	41.7800
	Mb10	0.7560	0.0400	0.4490	6.9800	1.0220	0.1875	0.5035	37.5500
	Mb11	0.6690	0.0750	0.7780	8.9360	1.6430	0.3490	0.8880	53.9300

Station: Palo Alto

Date: 4/12/2004

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	1.110	0.288	2.771	20.943	4.878	1.333	2.797	279.224
STD	0.387	0.032	0.630	3.277	0.572	0.242	0.607	59.020
SEM	0.137	0.011	0.223	1.159	0.202	0.086	0.214	20.867
CV%	34.836	11.234	22.735	15.649	11.731	18.166	21.686	21.137
n	8	8	8	8	8	8	8	8
r wt x [ ]	0.727	0.231	0.256	0.480	0.174	0.149	0.191	0.892
X 100mg	1.213	0.285	2.713	21.515	4.914	1.320	2.755	298.365
r l x [ ]	0.537	0.420	0.264	0.264	0.050	0.120	0.197	0.954
X 15mm	1.006	0.295	2.855	20.510	4.864	1.348	2.857	251.014
X 20mm	1.198	0.282	2.701	21.307	4.890	1.321	2.746	302.888
X 25mm	1.389	0.270	2.548	22.105	4.916	1.295	2.636	354.762

Estimated content (μg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.034	0.010	0.092	0.686	0.162	0.044	0.092	8.411
20mm	0.095	0.023	0.220	1.760	0.408	0.109	0.225	25.604
25mm	0.212	0.046	0.433	3.655	0.836	0.220	0.449	60.721

Estimated weight for 15mm clam

0.033 gm
33.325 mg

Estimated weight for 20mm clam

0.084 gm
84.142 mg

Estimated weight for 25mm clam

0.173 gm
172.590 mg

Station: Palo Alto

Date: 4/12/2004

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
					on (ug/ml) - Blank Corrected from ICP-AES							
mb1	11.28	0.1630	0.0125	10	0.0165	0.0053	0.0543	0.3657	0.0891	0.0216	0.0534	3.7400
mb2	12.58	0.1960	0.0196	10	0.0186	0.0062	0.0598	0.3887	0.0972	0.0273	0.0609	4.2810
mb3	13.98	0.2144	0.0268	10	0.0206	0.0070	0.0723	0.4243	0.1122	0.0361	0.0722	4.6220
mb4	14.56	0.2256	0.0322	10	0.0276	0.0056	0.0386	0.4869	0.0869	0.0235	0.0361	5.6280
mb5	19.61	0.3777	0.0755	10	0.0309	0.0097	0.0908	0.7947	0.1566	0.0450	0.0992	11.7400
mb6	20.84	0.3922	0.0981	10	0.0425	0.0102	0.0976	0.7275	0.1940	0.0447	0.1011	11.6600
mb7	22.15	0.3331	0.1110	10	0.0275	0.0091	0.1158	0.5537	0.1730	0.0562	0.1116	11.7200
mb8	26.75	0.4418	0.2209	15	0.0592	0.0088	0.0688	0.8157	0.1539	0.0355	0.0727	10.6300
				LOD	0.0004	0.0001	0.0018	0.0041	0.0008	0.0036	0.0019	0.0012
				LOQ	0.0022	0.0007	0.0061	0.0154	0.0027	0.0125	0.0034	0.0063

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	mb1	1.0123	0.3252	3.3313	22.4356	5.4663	1.3252	3.2761	229.4479
	mb2	0.9490	0.3163	3.0510	19.8316	4.9592	1.3929	3.1071	218.4184
	mb3	0.9608	0.3265	3.3722	19.7901	5.2332	1.6838	3.3675	215.5784
	mb4	1.2234	0.2482	1.7110	21.5824	3.8520	1.0417	1.6002	249.4681
	mb5	0.8181	0.2568	2.4040	21.0405	4.1461	1.1914	2.6264	310.8287
	mb6	1.0836	0.2601	2.4885	18.5492	4.9465	1.1397	2.5778	297.2973
	mb7	0.8256	0.2732	3.4764	16.6226	5.1936	1.6872	3.3503	351.8463
	mb8	2.0100	0.2988	2.3359	27.6947	5.2252	1.2053	2.4683	360.9099

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	mb1	0.0127	0.0041	0.0418	0.2813	0.0685	0.0166	0.0411	2.8769
	mb2	0.0186	0.0062	0.0598	0.3887	0.0972	0.0273	0.0609	4.2810
	mb3	0.0258	0.0088	0.0904	0.5304	0.1403	0.0451	0.0903	5.7775
	mb4	0.0394	0.0080	0.0551	0.6956	0.1241	0.0336	0.0516	8.0400
	mb5	0.0618	0.0194	0.1816	1.5894	0.3132	0.0900	0.1984	23.4800
	mb6	0.1063	0.0255	0.2440	1.8188	0.4850	0.1118	0.2528	29.1500
	mb7	0.0917	0.0303	0.3860	1.8457	0.5767	0.1873	0.3720	39.0667
	mb8	0.4440	0.0660	0.5160	6.1178	1.1543	0.2663	0.5453	79.7250

Station: Palo Alto

Date: 5/24/2004

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	0.634	0.152	1.301	15.534	3.881	1.234	1.240	186.089
STD	0.162	0.029	0.254	3.945	0.464	0.288	0.255	51.194
SEM	0.054	0.010	0.085	1.315	0.155	0.096	0.085	17.065
CV%	25.590	19.399	19.540	25.398	11.950	23.320	20.588	27.511
n	9	9	9	9	9	9	9	9
r wt x [ ]	0.444	0.468	0.798	0.175	0.447	0.547	0.720	0.280
X 100mg	0.493	0.125	0.903	14.179	3.474	0.925	0.880	214.208
r l x [ ]	0.401	0.514	0.768	0.101	0.414	0.538	0.727	0.204
X 15mm	0.720	0.172	1.561	16.063	4.137	1.440	1.487	172.228
X 20mm	0.518	0.125	0.954	14.827	3.540	0.959	0.910	204.637
X 25mm	0.316	0.078	0.347	13.592	2.943	0.477	0.334	237.047

Estimated content (μg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.023	0.006	0.052	0.510	0.135	0.047	0.049	5.650
20mm	0.050	0.012	0.095	1.400	0.341	0.093	0.090	18.177
25mm	0.091	0.022	0.151	3.065	0.699	0.158	0.144	44.992

Estimated weight for 15mm clam		Estimated weight for 20mm clam	
0.033	gm	0.096	gm
32.667	mg	96.234	mg

Estimated weight for 25mm clam	
0.222	gm
222.477	mg

Station: Palo Alto

Date: 5/24/2004

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	n (ug/ml) - Blank Corrected from ICP-AES Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
mb1	14.73	0.3557	0.0356	10	0.0237	0.0065	0.0553	0.5129	0.1456	0.0492	0.0566	6.4070
mb2	15.51	0.4034	0.0367	15	0.0160	0.0041	0.0337	0.3895	0.0987	0.0356	0.0312	4.7930
mb3	16.20	0.369	0.0410	10	0.0281	0.0054	0.0593	0.5732	0.1497	0.0457	0.0495	6.4690
mb4	16.51	0.3751	0.0417	15	0.0245	0.0049	0.0359	0.6135	0.1161	0.0444	0.0327	6.4640
mb5	17.05	0.4459	0.0495	15	0.0190	0.0052	0.0476	0.4751	0.1301	0.0433	0.0476	5.3110
mb6	17.59	0.4766	0.0596	10	0.0197	0.0051	0.0548	0.4424	0.1596	0.0426	0.0609	5.0700
mb7	18.12	0.3951	0.0659	10	0.0215	0.0055	0.0452	0.5622	0.1475	0.0378	0.0413	6.5850
mb8	18.67	0.3013	0.0753	10	0.0156	0.0035	0.0299	0.4810	0.0964	0.0282	0.0268	4.7100
Mb9	19.87	0.3086	0.1029	10	0.0182	0.0046	0.0301	0.4747	0.1176	0.0353	0.0293	8.4750

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
LOD	0.0004	0.0001	0.0018	0.0041	0.0008	0.0036	0.0019	0.0012
LOQ	0.0022	0.0007	0.0061	0.0154	0.0027	0.0125	0.0034	0.0063

Concentration (ug/g) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
mb1	0.6663	0.1827	1.5547	14.4195	4.0933	1.3832	1.5912	180.1237
mb2	0.5949	0.1525	1.2531	14.4831	3.6701	1.3237	1.1601	178.2226
mb3	0.7615	0.1463	1.6070	15.5339	4.0569	1.2385	1.3415	175.3117
mb4	0.9797	0.1959	1.4356	24.5335	4.6428	1.7755	1.3077	258.4911
mb5	0.6392	0.1749	1.6013	15.9823	4.3765	1.4566	1.6013	178.6611
mb6	0.4133	0.1070	1.1498	9.2824	3.3487	0.8938	1.2778	106.3785
mb7	0.5442	0.1392	1.1440	14.2293	3.7332	0.9567	1.0453	166.6667
mb8	0.5178	0.1162	0.9924	15.9642	3.1995	0.9359	0.8895	156.3226
mb9	0.5898	0.1491	0.9754	15.3824	3.8108	1.1439	0.9494	274.6273

Content (ug) ==>

Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
mb1	0.0237	0.0065	0.0553	0.5129	0.1456	0.0492	0.0566	6.4070
mb2	0.0218	0.0056	0.0460	0.5311	0.1346	0.0485	0.0425	6.5359
mb3	0.0312	0.0060	0.0659	0.6369	0.1663	0.0508	0.0550	7.1878
mb4	0.0408	0.0082	0.0598	1.0225	0.1935	0.0740	0.0545	10.7733
mb5	0.0317	0.0087	0.0793	0.7918	0.2168	0.0722	0.0793	8.8517
mb6	0.0246	0.0064	0.0685	0.5530	0.1995	0.0533	0.0761	6.3375
mb7	0.0358	0.0092	0.0753	0.9370	0.2458	0.0630	0.0688	10.9750
mb8	0.0390	0.0088	0.0748	1.2025	0.2410	0.0705	0.0670	11.7750
mb9	0.0607	0.0153	0.1003	1.5823	0.3920	0.1177	0.0977	28.2500

Station: Palo Alto

Date: 6/22/2004

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	1.025	0.153	1.151	19.205	3.780	0.961	1.132	191.206
STD	0.185	0.023	0.179	2.814	0.685	0.170	0.168	60.491
SEM	0.065	0.008	0.063	0.995	0.242	0.060	0.059	21.387
CV%	18.065	15.247	15.592	14.652	18.119	17.702	14.825	31.637
n	8	8	8	8	8	8	8	8
r wt x [ ]	0.821	0.520	0.648	0.880	0.520	0.955	0.516	0.541
X 100mg	0.965	0.148	1.105	18.221	3.638	0.896	1.097	204.212
r l x [ ]	0.874	0.536	0.682	0.879	0.520	0.953	0.555	0.563
X 15mm	1.213	0.168	1.292	22.065	4.192	1.148	1.239	151.845
X 20mm	0.984	0.150	1.120	18.576	3.689	0.920	1.108	199.866
X 25mm	0.756	0.132	0.947	15.088	3.186	0.691	0.976	247.886

Estimated content (μg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.036	0.005	0.038	0.646	0.122	0.034	0.036	4.507
20mm	0.077	0.012	0.089	1.469	0.290	0.072	0.088	15.630
25mm	0.142	0.024	0.173	2.779	0.566	0.129	0.176	41.013

Estimated weight for 15mm clam

0.029 gm
28.637 mg

Estimated weight for 20mm clam

0.081 gm
80.862 mg

Estimated weight for 25mm clam

0.181 gm
180.895 mg

Station: Palo Alto

Date: 6/22/2004

Macoma balthica

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	n (ug/ml) - Blank Corrected from ICP-AES Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
mb1	15.20	0.3038	0.0304	10	0.0410	0.0054	0.0455	0.6953	0.1296	0.0324	0.0436	5.1480
mb2	15.90	0.3143	0.0349	10	0.0368	0.0053	0.0369	0.6337	0.1270	0.0369	0.0384	5.4050
mb3	16.60	0.2792	0.0399	10	0.0284	0.0045	0.0349	0.5914	0.1297	0.0295	0.0314	4.5370
mb4	17.74	0.3125	0.0521	10	0.0356	0.0052	0.0334	0.6666	0.1159	0.0321	0.0340	6.0060
mb5	19.09	0.3435	0.0687	10	0.0310	0.0044	0.0383	0.6706	0.1066	0.0319	0.0368	5.5390
mb6	19.68	0.2427	0.0809	10	0.0238	0.0035	0.0265	0.4130	0.0920	0.0247	0.0251	4.3120
mb7	24.00	0.4870	0.1623	15	0.0274	0.0036	0.0280	0.4658	0.0815	0.0237	0.0279	5.0740
mb8	24.58	0.3201	0.1601	10	0.0256	0.0054	0.0367	0.5504	0.1336	0.0220	0.0390	10.8300
				LOD	0.0004	0.0001	0.0018	0.0041	0.0008	0.0036	0.0019	0.0012
				LOQ	0.0022	0.0007	0.0061	0.0154	0.0027	0.0125	0.0034	0.0063

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	mb1	1.3496	0.1777	1.4977	22.8868	4.2660	1.0665	1.4352	169.4536
	mb2	1.1709	0.1686	1.1740	20.1623	4.0407	1.1740	1.2218	171.9695
	mb3	1.0172	0.1612	1.2500	21.1819	4.6454	1.0566	1.1246	162.5000
	mb4	1.1392	0.1664	1.0688	21.3312	3.7088	1.0272	1.0880	192.1920
	mb5	0.9025	0.1281	1.1150	19.5226	3.1033	0.9287	1.0713	161.2518
	mb6	0.9806	0.1442	1.0919	17.0169	3.7907	1.0177	1.0342	177.6679
	mb7	0.8439	0.1109	0.8624	14.3470	2.5103	0.7300	0.8593	156.2834
	mb8	0.7998	0.1687	1.1465	17.1946	4.1737	0.6873	1.2184	338.3318

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	mb1	0.0410	0.0054	0.0455	0.6953	0.1296	0.0324	0.0436	5.1480
	mb2	0.0409	0.0059	0.0410	0.7041	0.1411	0.0410	0.0427	6.0056
	mb3	0.0406	0.0064	0.0499	0.8449	0.1853	0.0421	0.0449	6.4814
	mb4	0.0593	0.0087	0.0557	1.1110	0.1932	0.0535	0.0567	10.0100
	mb5	0.0620	0.0088	0.0766	1.3412	0.2132	0.0638	0.0736	11.0780
	mb6	0.0793	0.0117	0.0883	1.3767	0.3067	0.0823	0.0837	14.3733
	mb7	0.1370	0.0180	0.1400	2.3290	0.4075	0.1185	0.1395	25.3700
	mb8	0.1280	0.0270	0.1835	2.7520	0.6680	0.1100	0.1950	54.1500

Station: Palo Alto

Date: 9/13/2004

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	2.527	0.321	1.762	36.512	4.844	1.300	2.012	277.584
STD	0.559	0.010	0.444	5.907	0.752	0.224	0.396	171.618
SEM	0.197	0.003	0.157	2.089	0.266	0.079	0.140	60.676
CV%	22.099	3.024	25.204	16.180	15.523	17.231	19.688	61.826
n	8	8	8	8	8	8	8	8
r wt x [ ]	0.946	0.857	0.120	0.673	0.326	0.749	0.112	0.632
X 100mg	2.928	0.315	1.802	39.525	5.030	1.173	2.046	359.859
r l x [ ]	0.881	0.865	0.102	0.702	0.384	0.865	0.036	0.797
X 15mm	1.896	0.332	1.704	31.193	4.473	1.549	1.994	102.192
X 20mm	2.505	0.322	1.760	36.320	4.831	1.309	2.011	271.250
X 25mm	3.113	0.311	1.816	41.447	5.188	1.070	2.029	440.307

Estimated content (μg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.039	0.007	0.034	0.647	0.092	0.034	0.041	3.045
20mm	0.139	0.018	0.096	2.015	0.267	0.071	0.110	14.004
25mm	0.368	0.037	0.213	4.862	0.609	0.126	0.238	45.733

Estimated weight for 15mm clam

0.021 gm
20.835 mg

Estimated weight for 20mm clam

0.056 gm
55.596 mg

Estimated weight for 25mm clam

0.119 gm
119.031 mg

Station: Palo Alto

Date: 9/13/2004

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
					on (ug/ml) - Blank Corrected from ICP-AES							
mb1	15.39	0.1655	0.0236	10	0.0343	0.0055	0.0239	0.6150	0.0717	0.0237	0.0307	3.3800
mb2	16.70	0.1782	0.0297	10	0.0363	0.0057	0.0446	0.5445	0.0902	0.0279	0.0434	3.1350
mb3	17.51	0.1562	0.0312	10	0.0334	0.0052	0.0213	0.5256	0.0654	0.0214	0.0277	2.6410
mb4	18.21	0.1515	0.0379	10	0.0329	0.0050	0.0254	0.4434	0.0892	0.0220	0.0293	2.8280
mb5	20.25	0.1743	0.0581	10	0.0455	0.0056	0.0229	0.7194	0.0648	0.0204	0.0263	4.9350
mb6	22.11	0.2790	0.0930	10	0.0694	0.0087	0.0652	0.9144	0.1355	0.0382	0.0770	7.8520
mb7	24.15	0.2674	0.1337	10	0.0954	0.0084	0.0429	1.1170	0.1322	0.0319	0.0513	6.2130
mb8	27.17	0.1235	0.1235	10	0.0387	0.0038	0.0229	0.5637	0.0712	0.0105	0.0236	8.4950
				LOD	0.0004	0.0001	0.0018	0.0041	0.0008	0.0036	0.0019	0.0012
				LOQ	0.0022	0.0007	0.0061	0.0154	0.0027	0.0125	0.0034	0.0063

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	mb1	2.0725	0.3323	1.4441	37.1601	4.3323	1.4320	1.8550	204.2296
	mb2	2.0370	0.3199	2.5028	30.5556	5.0617	1.5657	2.4355	175.9259
	mb3	2.1383	0.3329	1.3636	33.6492	4.1869	1.3700	1.7734	169.0781
	mb4	2.1716	0.3300	1.6766	29.2673	5.8878	1.4521	1.9340	186.6667
	mb5	2.6104	0.3213	1.3138	41.2737	3.7177	1.1704	1.5089	283.1325
	mb6	2.4875	0.3118	2.3369	32.7742	4.8566	1.3692	2.7599	281.4337
	mb7	3.5677	0.3141	1.6043	41.7726	4.9439	1.1930	1.9185	232.3485
	mb8	3.1336	0.3077	1.8543	45.6437	5.7652	0.8502	1.9109	687.8543

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	mb1	0.0490	0.0079	0.0341	0.8786	0.1024	0.0339	0.0439	4.8286
	mb2	0.0605	0.0095	0.0743	0.9075	0.1503	0.0465	0.0723	5.2250
	mb3	0.0668	0.0104	0.0426	1.0512	0.1308	0.0428	0.0554	5.2820
	mb4	0.0823	0.0125	0.0635	1.1085	0.2230	0.0550	0.0733	7.0700
	mb5	0.1517	0.0187	0.0763	2.3980	0.2160	0.0680	0.0877	16.4500
	mb6	0.2313	0.0290	0.2173	3.0480	0.4517	0.1273	0.2567	26.1733
	mb7	0.4770	0.0420	0.2145	5.5850	0.6610	0.1595	0.2565	31.0650
	mb8	0.3870	0.0380	0.2290	5.6370	0.7120	0.1050	0.2360	84.9500

Station: Palo Alto

Date: 10/13/2004

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	4.072	0.347	3.833	44.202	6.943	2.200	4.645	266.254
STD	2.043	0.062	2.838	10.717	2.525	1.060	3.387	211.688
SEM	0.722	0.022	1.003	3.789	0.893	0.375	1.197	74.843
CV%	50.182	17.915	74.038	24.246	36.370	48.203	72.913	79.506
n	8	8	8	8	8	8	8	8
r wt x [ ]	0.499	0.015	0.350	0.056	0.460	0.192	0.391	0.197
X 100mg	4.530	0.346	4.279	43.935	7.465	2.291	5.239	284.961
r l x [ ]	0.596	0.131	0.496	0.054	0.601	0.339	0.531	0.353
X 15mm	2.525	0.336	2.047	44.941	5.015	1.743	2.361	171.492
X 20mm	3.592	0.343	3.280	44.431	6.346	2.058	3.937	236.883
X 25mm	4.660	0.351	4.512	43.921	7.676	2.373	5.513	302.274

Estimated content (μg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.049	0.006	0.043	0.782	0.090	0.032	0.051	3.668
20mm	0.155	0.015	0.137	1.910	0.277	0.088	0.165	9.699
25mm	0.380	0.031	0.335	3.818	0.665	0.192	0.415	20.617

Estimated weight for 15mm clam

0.017 gm
17.227 mg

Estimated weight for 20mm clam

0.044 gm
43.957 mg

Estimated weight for 25mm clam

0.091 gm
90.906 mg

Station: Palo Alto

Date: 10/13/2004

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
					on (ug/ml) - Blank Corrected from ICP-AES							
mb1	15.47	0.2099	0.0161	10	0.0858	0.0081	0.0755	1.2200	0.1370	0.0517	0.0903	5.9510
mb2	17.07	0.2590	0.0259	10	0.0887	0.0090	0.0923	1.2200	0.1661	0.0595	0.1079	5.8800
mb3	17.94	0.2479	0.0310	10	0.0802	0.0087	0.0626	1.0830	0.1254	0.0456	0.0721	5.4090
mb4	19.54	0.2259	0.0452	10	0.0674	0.0067	0.0512	0.9487	0.1090	0.0350	0.0639	4.3150
mb5	23.10	0.2677	0.0892	10	0.0591	0.0082	0.0574	0.7068	0.1708	0.0346	0.0696	4.6010
mb6	24.72	0.1799	0.0900	10	0.0552	0.0058	0.0553	0.5820	0.1326	0.0344	0.0668	2.7600
mb7	29.94	0.1712	0.1712	10	0.0825	0.0049	0.0474	0.8377	0.1047	0.0274	0.0644	1.8960
mb8	30.20	0.1320	0.1320	10	0.1155	0.0063	0.1416	0.7263	0.1697	0.0613	0.1700	10.2200
				LOD	0.0004	0.0001	0.0018	0.0041	0.0008	0.0036	0.0019	0.0012
				LOQ	0.0022	0.0007	0.0061	0.0154	0.0027	0.0125	0.0034	0.0063

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Concentration (ug/g) ==>	mb1	4.0877	0.3859	3.5970	58.1229	6.5269	2.4631	4.3020	283.5160
	mb2	3.4247	0.3475	3.5637	47.1042	6.4131	2.2973	4.1660	227.0270
	mb3	3.2352	0.3509	2.5252	43.6870	5.0585	1.8395	2.9084	218.1928
	mb4	2.9836	0.2966	2.2665	41.9965	4.8251	1.5494	2.8287	191.0137
	mb5	2.2077	0.3063	2.1442	26.4027	6.3803	1.2925	2.5999	171.8715
	mb6	3.0684	0.3224	3.0739	32.3513	7.3708	1.9122	3.7132	153.4186
	mb7	4.8189	0.2862	2.7687	48.9311	6.1157	1.6005	3.7617	110.7477
	mb8	8.7500	0.4773	10.7273	55.0227	12.8561	4.6439	12.8788	774.2424

	Sample #	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Content (ug) ==>	mb1	0.0660	0.0062	0.0581	0.9385	0.1054	0.0398	0.0695	4.5777
	mb2	0.0887	0.0090	0.0923	1.2200	0.1661	0.0595	0.1079	5.8800
	mb3	0.1003	0.0109	0.0783	1.3538	0.1568	0.0570	0.0901	6.7613
	mb4	0.1348	0.0134	0.1024	1.8974	0.2180	0.0700	0.1278	8.6300
	mb5	0.1970	0.0273	0.1913	2.3560	0.5693	0.1153	0.2320	15.3367
	mb6	0.2760	0.0290	0.2765	2.9100	0.6630	0.1720	0.3340	13.8000
	mb7	0.8250	0.0490	0.4740	8.3770	1.0470	0.2740	0.6440	18.9600
	mb8	1.1550	0.0630	1.4160	7.2630	1.6970	0.6130	1.7000	102.2000

Station: Palo Alto

Date: 10/13/2004

Statistical Summary

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
Mean(ug/g)	2.938	0.296	3.239	39.445	5.805	1.730	3.721	247.612
STD	0.853	0.061	1.010	14.585	1.132	0.521	1.106	81.918
SEM	0.302	0.022	0.357	5.157	0.400	0.184	0.391	28.962
CV%	29.043	20.687	31.168	36.976	19.507	30.125	29.712	33.083
n	8	8	8	8	8	8	8	8
r wt x [ ]	0.472	0.718	0.782	0.445	0.621	0.847	0.795	0.472
X 100mg	3.018	0.287	3.082	40.738	5.665	1.642	3.546	255.312
r l x [ ]	0.412	0.801	0.849	0.414	0.696	0.895	0.860	0.430
X 15mm	2.371	0.375	4.620	29.720	7.074	2.481	5.253	190.945
X 20mm	2.740	0.323	3.723	36.040	6.249	1.993	4.258	227.770
X 25mm	3.108	0.272	2.825	42.360	5.425	1.505	3.262	264.594

Estimated content (μg) for 15mm, 20mm and 25mm clam

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
15mm	0.047	0.008	0.097	0.610	0.142	0.052	0.110	3.799
20mm	0.139	0.016	0.180	1.824	0.310	0.096	0.206	11.432
25mm	0.320	0.029	0.290	4.270	0.568	0.155	0.336	26.867

Estimated weight for 15mm clam

0.019 gm
19.416 mg

Estimated weight for 20mm clam

0.051 gm
50.768 mg

Estimated weight for 25mm clam

0.107 gm
106.998 mg

Station: Palo Alto

Date: 10/13/2004

Macoma petalum

Sample #-n	Average Length (mm)	Total Dry Wt (gm)	Average Dry Wt (gm)	Recon Amt (ml)	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
					Concentration (ug/ml) - Blank Corrected from ICP-AES							
mb1	16.20	0.1896	0.0237	10	0.0572	0.0078	0.0922	0.6818	0.1423	0.0497	0.1057	5.1430
mb2	17.70	0.2317	0.0331	10	0.0691	0.0086	0.1084	0.8946	0.1726	0.0557	0.1209	4.9760
mb3	19.10	0.3342	0.0477	10	0.0707	0.0095	0.1059	1.0600	0.1791	0.0554	0.1211	5.9830
mb4	21.90	0.3404	0.0681	10	0.0816	0.0093	0.1067	1.1620	0.1897	0.0598	0.1255	6.0210
mb5	23.99	0.3983	0.0996	10	0.1070	0.0102	0.1080	1.1580	0.1969	0.0607	0.1254	7.8780
mb6	25.49	0.3310	0.1103	10	0.0830	0.0080	0.0743	1.2310	0.1676	0.0440	0.0862	11.4700
mb7	28.25	0.3150	0.1575	10	0.1545	0.0082	0.0703	2.3550	0.1410	0.0365	0.0852	6.3430
mb8	28.93	0.3430	0.1715	10	0.0992	0.0092	0.0988	1.1700	0.2083	0.0476	0.1101	13.4900

		Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
	LOD	0.0004	0.0001	0.0018	0.0041	0.0008	0.0036	0.0019	0.0012
	LOQ	0.0022	0.0007	0.0061	0.0154	0.0027	0.0125	0.0034	0.0063
	Sample #								
Concentration (ug/g) ==>	mb1	3.0169	0.4114	4.8629	35.9599	7.5053	2.6213	5.5749	271.2553
	mb2	2.9823	0.3712	4.6785	38.6103	7.4493	2.4040	5.2180	214.7605
	mb3	2.1155	0.2843	3.1688	31.7175	5.3591	1.6577	3.6236	179.0245
	mb4	2.3972	0.2732	3.1345	34.1363	5.5729	1.7568	3.6868	176.8801
	mb5	2.6864	0.2561	2.7115	29.0736	4.9435	1.5240	3.1484	197.7906
	mb6	2.5076	0.2417	2.2447	37.1903	5.0634	1.3293	2.6042	346.5257
	mb7	4.9048	0.2603	2.2317	74.7619	4.4762	1.1587	2.7048	201.3651
	mb8	2.8921	0.2682	2.8805	34.1108	6.0729	1.3878	3.2099	393.2945
	Sample #								
Content (ug) ==>	mb1	0.0715	0.0098	0.1153	0.8523	0.1779	0.0621	0.1321	6.4288
	mb2	0.0987	0.0123	0.1549	1.2780	0.2466	0.0796	0.1727	7.1086
	mb3	0.1010	0.0136	0.1513	1.5143	0.2559	0.0791	0.1730	8.5471
	mb4	0.1632	0.0186	0.2134	2.3240	0.3794	0.1196	0.2510	12.0420
	mb5	0.2675	0.0255	0.2700	2.8950	0.4923	0.1518	0.3135	19.6950
	mb6	0.2767	0.0267	0.2477	4.1033	0.5587	0.1467	0.2873	38.2333
	mb7	0.7725	0.0410	0.3515	11.7750	0.7050	0.1825	0.4260	31.7150
	mb8	0.4960	0.0460	0.4940	5.8500	1.0415	0.2380	0.5505	67.4500

Appendix D

Concentrations of Hg and Se in surface sediments and clams from Palo Alto (D-2) and in standard reference materials (D-3).

Palo Alto surface sediments, Hg and Se analysis: 2004

Date	mean Hg (μg/g)	mean Se (μg/g)
January 20, 2004	0.46	0.78
February 27, 2004	0.44	0.73
April 12, 2004	0.49	0.60
June 22, 2004	0.40	0.29
September 13, 2004	0.40	0.31
December 18, 2004	0.24	0.35

Palo Alto *Macoma petalum*, Hg analysis: 2004

Sample ID	mean Hg (μg/g)	SEM
January 20, 2004	0.17	0.09
April 12, 2004	0.29	0.02
June 22, 2004	0.33	0.05
September 13, 2004	0.35	0.16

Palo Alto *Macoma petalum*, Se analysis: 2004

Sample ID	mean Se (μg/g)	SEM
January 20, 2004	5.50	0.31
April 12, 2004	4.52	0.24
June 22, 2004	4.23	0.15
September 13, 2004	4.77	0.23

Standard reference materials (SRM) with accepted and found concentrations. Se and Hg analysis 2004

SRM		Hg	Se
NRC-CNRC DORM-2	Accepted	4.6±0.3	1.40±0.1
	Found	4.50	1.50
NRC-CNRC TORT-2	Accepted	-	5.6±0.7
	Found	-	5.50
NIST 1566b	Accepted	0.04±0.01	2.1±0.2
	Found	0.04	2.40
NIST 1646A	Accepted	0.04	-
	Found	0.06	-
NIST 2709	Accepted	1.40±0.08	1.57±0.08
	Found	1.4	1.7
NIST 2711	Accepted	6.25±0.19	-
	Found	6.2	-
USGS MAG-1	Accepted	0.018	-
	Found	0.053	-
USGS SDO-1	Accepted	0.19±0.08	-
	Found	0.21	-
USGS SGR-1	Accepted	0.313	3.5±0.28
	Found	0.27	3.5

Appendix E

Analysis of (NIST) reference materials. 2003 SRM 2709 (San Joaquin Soil) recoveries (HNO_3 extraction) (E-2). Metal concentrations analyzed (at each sampling) in Standard Reference Material (NIST) 2976 (Mussel tissue) compared to certified mean, maximum and minimum values for that material (E-3)

2004 SRM 2709 Recoveries

Concentration, ug/g

Month	Rep	AG	AL	AS	CD	CR	CU	FE	MN	NI	PB	V	ZN
January	1	NA	38176	10.1	NA	86.1	24.1	29452	473	69.4	16.9	96.9	86.0
	2	NA	42357	10.9	NA	93.2	27.0	31719	512	74.3	18.1	105.3	93.9
February	1	NA	41147	11.7	NA	91.8	25.7	31181	506	73.8	18.0	105.2	92.5
	2	NA	39640	11.8	NA	87.5	24.6	31080	505	74.3	17.8	100.6	91.5
March	1	NA	42530	11.8	NA	95.3	27.4	31934	522	75.7	18.6	107.7	97.2
	2	NA	41596	12.2	NA	92.2	27.2	31197	509	74.3	17.9	106.0	95.4
April	1	NA	44560	11.5	NA	99.3	28.3	32770	534	77.7	18.9	111.3	98.2
	2	NA	41667	11.9	NA	92.0	26.0	31820	511	74.6	18.0	107.2	92.8
May	1	NA	39318	10.2	NA	86.2	26.0	30602	494	73.2	17.6	99.3	90.0
	2	NA	40558	11.6	NA	89.5	26.2	31250	512	74.4	17.5	104.7	93.1
June	1	NA	38987	11.1	NA	87.9	25.2	31042	504	74.3	17.8	100.6	91.1
	2	NA	41606	11.0	NA	93.8	26.1	31189	503	75.3	18.3	106.1	92.8
September	1	NA	43385	12.0	NA	98.0	26.7	32244	519	75.5	18.9	111.1	93.7
	2	NA	42909	11.7	NA	165.0	26.7	32172	548	74.2	18.7	no data	96.5
October	1	NA	42151	11.9	NA	98.8	26.5	31243	507	73.7	18.7	108.1	92.2
	2	NA	41554	11.6	NA	95.8	26.2	30951	495	72.2	18.1	106.0	90.8
December	1	NA	43474	10.7	NA	94.7	28.0	32898	516	75.8	20.1	111.8	93.8
	2	NA	41962	11.0	NA	92.6	27.9	31975	510	72.6	19.3	107.7	91.2
Certified Value, ug/g		**0.41**	**75000**	**17.7**	**NA**	**130.00**	**34.60**	**35000**	**538**	**88.0**	**18.9**	**112.0**	**106.0**
Standard Deviation		**0.03**	**0**	**0.8**	**NA**	**4.00**	**0.70**	**0**	**17**	**5.0**	**0.5**	**5.0**	**3.0**

Percent Recovery

Month	Rep	AG	AL	AS	CD	CR	CU	FE	MN	NI	PB	V	ZN
January	1	NA	51	57	NA	66	70	84	88	79	89	87	81
	2	NA	56	62	NA	72	78	91	95	84	96	94	89
February	1	NA	55	66	NA	71	74	89	94	84	95	94	87
	2	NA	53	67	NA	67	71	89	94	84	94	90	86
March	1	NA	57	66	NA	73	79	91	97	86	98	96	92
	2	NA	55	69	NA	71	79	89	95	84	94	95	90
April	1	NA	59	65	NA	76	82	94	99	88	100	99	93
	2	NA	56	67	NA	71	75	91	95	85	95	96	88
June	1	NA	52	57	NA	66	75	87	92	83	93	89	85
	2	NA	54	65	NA	69	76	89	95	85	93	93	88
September	1	NA	58	68	NA	75	77	92	96	86	100	99	88
	2	NA	57	66	NA	127	77	92	102	84	99	no data	91
October	1	NA	56	67	NA	76	77	89	94	84	99	97	87
	2	NA	55	66	NA	74	76	88	92	82	96	95	86
December	1	NA	58	61	NA	73	81	94	96	86	106	100	88
	2	NA	56	62	NA	71	81	91	95	82	102	96	86
Average % Recovery		**NA**	**56**	**64**	**NA**	**75**	**77**	**90**	**95**	**84**	**97**	**95**	**88**
Standard Deviation		**NA**	**2**	**4**	**NA**	**14**	**3**	**2**	**3**	**2**	**4**	**4**	**3**

2004 SRM 2976 Recoveries

Date	Cadmium	Chromium	Copper	Lead	Nickel	Silver	Vanadium	Zinc
January 14, 2003	0.77	0.56	3.34	1.06	0.72	0.019	0.73	134
February 24, 2003	0.77	0.55	3.35	0.98	0.74	0.019	0.70	135
March 25, 2003	0.77	0.55	3.28	0.98	0.74	0.025	0.72	133
April 22, 2003	0.74	0.62	3.73	0.99	0.72	0.021	0.71	131
May 5, 2003	0.87	0.62	3.77	1.06	0.75	0.021	0.72	135
June 4, 2003	0.76	0.59	3.35	1.01	0.72	0.020	0.71	134
September 11, 2003	0.79	0.61	3.62	1.02	0.73	0.021	0.71	133
October 9, 2003	0.81	0.61	3.58	1.03	0.73	0.021	0.72	134
December 18, 2003	0.79	0.60	3.52	1.02	0.73	0.020	0.71	134
Mean	0.79	0.59	3.50	1.02	0.73	0.02	0.72	133.62
STD	0.04	0.03	0.18	0.03	0.01	0.00	0.01	1.19

Certified Values

Mean	0.82	0.5	4.02	1.19	0.93	0.011	NA	137
Max.	0.98	0.66	4.35	1.37	1.05	0.016	NA	150
Min.	0.66	0.37	3.69	1.01	0.81	0.006	NA	124

Appendix F

Method limits of detection and limits of quantification. Limits were determined using serial dilutions of extracts of NIST SRM 2711 for the sediment methods and NIST SRM 2976 for the clam method.

Sediment Partial Extract Analysis:

	Ag	Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
LOD	0.0005	0.02	0.002	0.003	0.005	0.0005	0.0004	0.001	0.001	0.001
LOQ	0.002	0.06	0.007	0.01	0.02	0.002	0.001	0.004	0.003	0.004

Sediment Total Extract Analysis:

		Al	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
LOD		0.007	0.001	0.003	0.008	0.0008	0.0009	0.003	0.001	0.004
LOQ		0.02	0.004	0.01	0.02	0.002	0.003	0.009	0.004	0.01

Tissue Analysis:

	Ag	Cd	Cr	Cu	Ni	Pb	V	Zn
LOD	0.001	0.0002	0.001	0.010	0.0005	0.001	0.001	0.003
LOQ	0.005	0.0005	0.004	0.03	0.002	0.004	0.004	0.009

* All numbers are in units of μg/ml

Appendix G

Reproduction data for the year 2004 (H-2)

Date	Inactive	Active	Ripe	Spawning	Spent	Spawned	N	Reprocuctive	Non-reproductive
January 20, 2004	0	0	100	0	0		10	100	0
February 27, 2004	0	0	100	0	0		9	100	0
March 16, 2004	0	0	80	10	10		10	90	-10
April 12, 2004	0	0	0	30	70		10	30	-70
May 24, 2004	0	0	0	0	100		10	0	-100
June 22, 2004	100	0	0	0	0		10	0	-100
September 13, 2004	70	0	0	0	30		10	0	-100
October 13, 2004	80	20	0	0	0		10	20	-80
December 8, 2004	0	0	100	0	0		10	100	0

Appendix H

Complete list of benthic species found at Palo Alto in the year 2004 (I-2 thru I-4)

	1/27/2004		2/27/2004		3/16/2004		4/12/2004		5/24/2004		6/21/2004		8/31/2004		9/13/2004		10/13/2004		11/22/2004		12/9/2004	
Species	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
Acari	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ampelisca abdita	0.67	0.58	0	0	0	0	0.33	0.58	1.00	0	1.33	0.58	1.67	1.53	8.00	3.61	4.33	2.89	3.33	1.53	4.33	1.15
Amphipoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ampithoe spp.	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
Balanus ?aquila	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
Balanus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boonea bisuturalis	5.67	3.79	0.67	0.58	2.33	2.52	4.67	1.15	0	0	0	0	0	0	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
Callianassidae	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	0	0	0	0	0	0	0	0	0	0	0	0	0
Caprella californica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	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
Cirripedia	0	0	0	0	0	0	0	0	0.33	0.58	0.33	0.58	0	0	0	0	0	0	0	0	0	0
Corophium ?insidiosum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corophium acherusicum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corophium insidiosum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corophium spinicorne	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corophium spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0.58	0.67	0.58	1.67	2.08	3	1
Corophium spp. (female & juvenile)	0.67	1.15	0	0	0	0	0.33	0.58	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corophium spp. (male)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cumacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cumella vulgaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	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
Dynamenella spp.	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
Eteone ?californica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eteone lighti	0	0	3	1	1.67	1.15	4.67	1.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eteone spp.	0	0	0	0	0	0	0	0	6.67	1.53	6.67	1.53	2.00	1.00	1.33	1.53	1.67	1.15	1.67	2.08	2.67	0.58
Euchone limnicola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euchone spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eusarsiella zostericola	9.67	4.62	6.00	2.65	9.67	6.35	10.33	1.53	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gemma gemma	73.33	23.54	51.00	18.08	87.00	29.21	185.67	52.35	87.00	31.19	79.00	34.83	42.33	10.79	45.33	16.17	63.00	32.51	36.00	8.19	65.00	13.23
Glycera spp.	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
Glycinde polygnatha	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	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
Grandidierella japonica	1.00	1.00	0.33	0.58	0.67	1.15	0	0	4.00	4.00	0.33	0.58	0.67	0.58	6.67	6.43	6.00	3.46	2.67	2.08	5.00	3.00

	1/27/2004		2/27/2004		3/16/2004		4/12/2004		5/24/2004		6/21/2004		8/31/2004		9/13/2004		10/13/2004		11/22/2004		12/9/2004	
Species	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
Harmothoe imbricata	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
Hemigrapsus oregonensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	15.33	2.08	20.33	4.16	13.67	3.06	18.33	5.03	15.67	3.79	13.00	6.56	18.00	5.00	17.67	3.79	21.33	6.35	21.67	1.53	24.00	2.65
Ilyanassa obsoleta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macoma petalum	4.67	2.08	3.33	1.15	4.00	2.00	4.00	3.61	15.67	4.16	13.00	4.00	15.67	3.06	12.00	5.00	14.67	4.16	4.33	1.53	7.33	0.58
Macoma spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marphysa sanguinea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	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
Musculista senhousia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mya arenaria	0.67	0.58	0	0	0	0	2.33	1.53	0.33	0.58	1.00	1.00	0	0	0	0	0	0	0	0	0	0
Mysidacea	0	0	0.3333	0.58	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
Neanthes succinea	3.00	2.00	2.67	0.58	2.00	1.00	0.33	0.58	3.33	1.15	2.67	1.15	2.67	2.31	3.00	1.00	1.67	1.53	2.00	1.73	1.33	0.58
Nematoda	0	0	1.00	1.00	0.33	0.58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nippoleucon hinumensis	18.67	8.08	38.67	3.21	26.33	18.58	140.67	29.40	191.33	154.28	76.00	66.05	25.00	6.24	82.00	26.89	22.33	7.37	32.33	15.95	30.00	21.17
Odostomia fetella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Odostomia spp.	3.00	3.46	0.33	0.58	3.67	2.89	2.33	0.58	2.67	2.31	0	0	1.00	1.00	0.33	0.58	0	0	1.00	1.00	0.33	0.58
Oligochaeta	0	0	0.33	0.58	2.33	2.08	0	0	14.33	19.73	9.00	3.46	16.67	5.86	31.67	10.79	6.00	3.46	28.00	24.43	22.67	12.01
Planariidae A	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	1.33	1.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polydora spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Potamocorbula amurensis	0	0	0	0	0	0	0.33	0.58	1	1	0	0	0.33	0.58	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
Rochefortia grippi	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	0.67	0.58	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
Sphaeromatidae (juv.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerosyllis californiensis	0.33	0.58	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
Streblospio benedicti	16.33	3.06	10.00	5.00	17.00	7.55	26.67	8.39	2.33	1.15	11.33	7.23	18.00	5.57	17.33	3.79	14.33	11.68	7.67	2.52	11.67	9.07
Synidotea laevidorsalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tellinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tharyx spp. ?	0.67	0.58	0.33	0.58	0	0	0.67	0.58	0	0	0	0	0	0	0.33	0.58	0.33	0.58	1.00	1.00	0	0
Tubificidae	7	4.58	9.33	6.66	7.33	6.66	8	7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Turbellaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	1/27/2004		2/27/2004		3/16/2004		4/12/2004		5/24/2004		6/21/2004		8/31/2004		9/13/2004		10/13/2004		11/22/2004		12/9/2004	
Species	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev	Mean	Stdev
Unid. Actiniaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unid. amphipod	0.3333	0.5774	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unid. Balanomorpha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	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
Unid. Gastropoda	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	0.6667	1.15	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
Unid. Ostracoda	0.33	0.58	0.33	0.58	0	0	0.33	0.58	6.00	4.36	4.00	1.73	1.00	1.00	1.33	1.53	3.00	1.00	0.33	0.58	1.33	0.58
Unid. Polychaeta	0	0	0	0	0	0	0	0	0.67	1.15	0	0	0	0	0	0	0	0	0	0	0	0
Unid. Spionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unid. Syllidae	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
Urosalpinx cinerea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0