4.0 Bivalve Monitoring

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4.1 Background

The purpose of monitoring contaminant concentrations in bivalve tissue for the RMP is two-fold. First, bivalves integrate the bioavailable portion of contaminants in the water column over time, and second, for many contaminants, bivalves are good indicators of contaminant transfer from water into the food web. Bivalves accumulate certain contaminants in concentrations much greater than those found in ambient water (Vinogradov, 1959). This phenomenon is a result of the limited ability of bivalves to regulate the concentrations of most contaminants in their tissues. This method of active biomonitoring has been widely applied by the California State Mussel Watch Program (Phillips, 1988; Rasmussen, 1994) and other studies (Young *et al.*, 1976; Wu and Levings, 1980; Hummel *et al.*, 1990; Martincic *et al.*, 1992). The RMP is extending the long-term database of the State Mussel Watch Program at several stations in the Bay. For reviews of bioaccumulation monitoring, see Luoma and Linville (1996) and Gunther and Davis (1997).

In 2000, bivalves were collected from two potentially uncontaminated sites; mussels from Bodega Head and oysters from Tomales Bay, for deployment at a total of 12 sites within the Estuary. The transplant studies were conducted with bagged and caged bivalves during the dry season (July through September). Caged bivalves were used in addition to the bagged ones to develop a method that would lower predation and would require less maintenance. The study area ranged from Coyote Creek (BA10) in the South Bay to the Napa River (BD50) in the North Bay.

A *Corbicula fluminea* reference site was not available, since a sufficient number of clams could no longer be found at "clean" sites. Consequently, resident species were collected for analysis from the Sacramento and the San Joaquin river stations, and the Grizzly Bay site (BF20) was discontinued. All bivalves were kept on ice after collection and deployed within 72†hours. Multiple species were deployed at several stations due to uncertain salinity regimes and tolerances. The effects of high short-term flows of freshwater on the transplanted bivalves west of Carquinez Strait were minimized by deploying the bivalves near the bottom, where density gradients tend to maintain higher salinities. Unlike in previous years, a full set of oysters and only 40 mussels were deployed at Dumbarton Bridge (BA30). All chemical analyses were performed on the full deployment of oysters. Detailed sampling and analysis methods are included in the *Description of Methods*. Data are tabulated in the *Data Tables*.

Contaminant concentrations in tissue were measured before deployment (referred to as time zero [T-0] or background) and at the end of the 90-100 day deployment period. Survival and biological condition indices were also measured. Because of the variability between each individual bivalve organism and the small tissue mass in individual bivalves, composite samples of tissue were made from T-0 organisms and from surviving organisms from each deployment site (up to 45 individuals) for analyses of trace contaminants.

Samples were analyzed for up to 12 trace metals (Table 19) and 85 synthetic organic chemicals, including PAHs (Table 20), PCBs (Table 21), and pesticides (Table 22). Aluminum in bivalves is measured as a surrogate for sediment retained in the bivalve gut and is not depicted in the graphs. Tissue concentrations of trace metals and organic chemicals are reported on a dry weight basis to reduce data variability due to moisture content.

Overall, the bivalve bioaccumulation and condition study objectives for 2000 were met.

The RMP Design Integration Workshop determined that it is sufficient to analyze tissue concentrations in bivalves only once per year during the dry season, when Estuary conditions are more consistent on an interannual basis.

4.2 Accumulation Factors

In addition to comparing the absolute tissue concentrations prior to and after each deployment period, this report uses accumulation factors (AF) to indicate accumulation or depuration (loss of constituents from bivalve tissue) during the 90-100 day deployment period of mussels and oysters. The accumulation factor is calculated by dividing the contaminant concentration in transplants by the initial bivalve concentration at T-0. For example, an accumulation factor of 1.0 indicates that the concentration of a specific contaminant remained the same during the deployment period compared to the initial contaminant level prior to transplanting the bivalve sample to the Estuary. An AF less than 1 indicates that the bivalves decreased in contaminant concentration during the deployment period, while an AF above 1 indicates accumulation. Accumulation factors can no longer be calculated to *Corbicula fluminea*, since they are collected as resident clams and not transplanted from a clean site.

4.3 Guidelines

California Screening Values (SVs) were specifically calculated for fish tissue in a study from two California Lakes (Brodberg, 1999). Screening values are defined as concentrations of target analytes in fish or shellfish tissue that are of potential public health concern. Exceedance of screening values should be taken as an indication that more intensive site-specific monitoring and/or evaluation of human health risk should be conducted. The calculations were based on a 70 kg adult using a cancer risk of 10^{-5} for carcinogens. A consumption rate of 21 g/day was used.

The screening values are used for comparison purposes only and do not suggest a possible public health concern, since the bagged bivalves in the RMP are temporary residents of the Estuary and are used as indicators of bioaccumulative contaminants for status and trends analyses. No follow-up action is triggered when bivalve values are above guidelines. Since bivalve contaminant concentrations can complement fish data in detecting the bioavailability of contaminants to the food web, Bay segments of higher risk can be identified by using the consumption advisories.

Tissue guidelines are generally expressed in wet weight, while the RMP tissue data are reported in dry weight. A wet-to-dry weight conversion was applied to the guideline values for comparative purposes, using a multiplication factor of 7. This value is based on average moisture content in bivalves of 85% (1998 RMP data). SVs for those parameters reported by the RMP have been converted to dry weight and are listed in Table 4.1.

4.4 Biological Condition and Survival

The biological condition index (expressed as the ratio of dry tissue weight to shell cavity volume) and the survival rates of the transplanted bivalves (following exposure to Estuary water) are used as general health indicators (Figure 4.14-4.15). However, the data on survival and condition of the transplants indicate that certain sites are generating non-contaminant related, physiological stress in the animals at certain times, which confounds the interpretation of bioaccumulation data and interferes with the bivalves• usefulness as biomonitors. Since the winter cruise of 1999, comparisons between the traditionally used *Mytilus californianus* and the hybrid Bay mussel (*Mytilus galloprovincialis / trossulus / edulis*) have been conducted. This comparison evaluates potential artifacts introduced by using an open-ocean intertidal mussel (*Mytilus californianus*) as an indicator organism versus a related species adapted to more variable estuarine conditions.

4.5 Bivalve Trends

Transplanted bivalves are valuable in assessing long-term trends because they provide an integrated measure of contamination over a three-month period. This interval is more appropriate for assessment of interannual trends than the •snapshotŽ represented by RMP water samples, which are more subject to short-term hydrological variations and other disturbances, or by sediment samples that represent the mixed and highly dynamic sediment layer reflecting approximately 20 years of contaminant deposits. Bivalves have been shown to complement fish tissue contaminant concentration data in detecting relatively quickly and reliably any changes in contaminant availability to the food web (Russell and Gobas, 1989).

Figures 4.16-4.26 present plots of RMP bivalve bioaccumulation data for trace elements and trace organics from 1993 to 2000. Trends for *Corbicula fluminea* are not depicted due to the shift from transplanted to resident organisms. Concentrations in these plots are expressed as net bioaccumulation or depuration during the deployment period (initial concentrations prior to deployment have been subtracted from final concentrations measured after deployment). Presented in this manner, the plots can show trends in bioaccumulation. The trace metals database accumulated so far is fairly noisy due to interannual variation in trace metal data, and significant trends in trace metal bioaccumulation are not yet discernable. In many cases (e.g., lead), there was either little accumulation or depuration during deployment. Over the past years, cadmium in mussels exhibited a consistent seasonal pattern, with higher concentrations in summer samples, most likely reflecting the prevalence of oceanic influences during the dry season. Since the wet season sampling was discontinued in 2000, seasonal patterns will no longer be monitored.

4.6 Discussion

Bivalve monitoring is conducted in the San Francisco Estuary to measure contaminant accumulation in bivalve tissue during the dry season and to assess the bioavailability of contaminants of concern throughout the Bay. It is also a valuable tool to indicate long-term contaminant trends.

As currently designed, this program component is unable to compare contaminant bioavailability and accumulation in different segments of the Estuary due to the different bioaccumulation characteristics of the two species deployed in segments with different salinities and the resident species from the Sacramento and the San Joaquin rivers (see *Description of Methods* and Gold and Bell, 1998).

Trace Organics

An overall decrease in trace organic tissue concentration was exhibited during the sampling season of 2000 compared to previous years (Figure 4.1-4.8). Assuming that during years of extremely heavy rainfalls (as was the case in 1998), deposits of CHC (chlorinated hydrocarbons, including PCBs, DDTs, chlordanes, and dieldrin) and PAH compounds are mobilized throughout the watershed, the consistent pattern of lower concentrations in the 1999 and 2000 dry season may reflect less contaminated runoff into the Estuary.

Oysters consistently showed higher PAH concentrations and higher accumulation during the entire course of the monitoring program (1993-2000) than the two other species (Figure 4.9). In 2000, the highest concentration was measured at Napa River in the dry season, about 36 times higher than the pre-deployment concentration.

Since chlorinated hydrocarbons are much more soluble in fat tissue than in water, they partition into the lipid-rich tissue of aquatic organisms (Stout *et al.*, 1981). Animals with higher proportions of lipid in their tissue usually have higher concentrations of chlorinated hydrocarbons (Phillips, 1980). Factors such as season, reproductive cycle, water temperature, condition of the organism, and species can affect the lipid levels of samples collected for analysis and can cause variability in results. Normalization to lipid weight may reduce this variability and the lipid-normalized results are more comparable regarding bioaccumulation of compounds. For viewing the compound concentration in relation to the percent lipids in the bivalve tissue, the sum of every organic compound per station is divided by the lipid concentration in percent.

The lipid-normalized data showed lower average PAH concentrations in *Corbicula fluminea* and *Crassostrea gigas* for the dry season compared to 1998 and 1999. Mussels, which had exhibited decreasing PAH concentrations from 1997 to 1999, were above the running mean from pervious years.

In contrast to 1999, mussels had higher mean accumulation factors for PCBs than oysters, although oysters showed higher overall concentrations during the sampling season. However, compared to 1999, mussels showed a distinct decrease in PCB accumulation. The highest accumulation factor was 6.7 times above the pre-deployment concentration in mussels, compared to an accumulation factor of 63 in 1999. The initial concentration in mussels and oysters was much higher in 2000 (21 μg/kg and 41 μg/kg, respectively) compared to 1.8 μg/kg and 1.1 μg/kg in 1999, which accounts for the variance in accumulation.

The PCB concentration patterns in oysters and mussels reflected correspondingly high concentrations in sediment (e.g., Dumbarton Bridge, Alameda) at the stations near their deployments. Compounds associated with suspended solids have longer residence times in the Bay ecosystem and also enter the food web via filter-feeding benthic organisms. A higher level of contaminant concentrations could also be caused by an intense mixing of the sediment due to strong tidal currents or winds.

Similar to previous years, the 2000 PAH and DDT tissue concentrations were positively correlated with lipid content of the bivalves (r^2=0.52 and p=0.002 for PAHs and r^2=0.40 and p=0.009 for DDTs). In general, lipid-normalization for CHCs and PAHs reveals patterns that are not otherwise obvious because of the highly lipid-soluble characteristics of these compounds. For example, DDT concentrations at Sacramento River, Napa River, Red Rock, Alameda, and Coyote Creek were higher than in 1999, but the lipid-normalized data for these stations indicated a decrease in DDTs for the year 2000.

The lipid-normalized DDT concentrations overall showed a noticeable decline compared to the previous years. In 2000, the lowest lipid-normalized DDT concentrations were measured since the inception of the RMP. Dieldrin concentrations continued to decline as well. Other chlorinated pesticides with PBT (persistent, bioaccumulative, and toxic) characteristics such as chlordanes, decreased in concentration compared to 1998 and 1999.

In 2000, PCB concentrations did not correlate significantly with total lipid contents (r^2=0.18; p=0.10).

In cases where lipids are very low, as in lean fish or mussels, the relationship can be very weak or non-existent. Lipid-normalization of PCB concentrations may not be an appropriate practice, especially when the organism has a relatively low total lipid content (<6% dry weight). Therefore, normalizing PCB concentrations may only work for animals with total concentrations above this limit (Bergen *et al.*, 2001).

Trace Metals

Arsenic, chromium, and mercury measurements were discontinued in 2000 because past results do not suggest that bioaccumulation of these trace metals occurred in significant amounts in transplanted bivalves. However, for other trace metals, oysters in general seem to have a much higher accumulation potential than mussels. Nickel, lead, and zinc concentrations in mussels decreased further in comparison to 1999. In 2000, the decrease in total concentrations, which was observed in previous years already, is reflected in the accumulation factor and due to a much lower initial concentration in 2000.

Also consistent with previous years, oysters accumulated cadmium to a higher degree, while mussels did not exhibit any substantial bioaccumulation. Oysters continued showing twice as high accumulation factors for copper during the sampling season than they did in 1997 and 1998. The running mean concentration for nickel in all species decreased slightly compared to 1999, as well as the silver and lead running mean concentration. Only in clams did the selenium concentration increase noticeably. The running mean concentration during the dry season was about 3.5 times higher than the year before and about 4.5 times as high as in 1998 and 1997. The selenium mean accumulation factor in oysters and mussels increased, as well as the selenium overall concentrations compared to previous years, including the initial concentrations. Although the use of tributyltins was regulated under the Organotin Antifouling Paint Control Act of 1988, there is no noticeable steady decline in bivalve tissue, and bivalve tissue concentrations may represent equilibrium conditions in the Estuary. They are about 20 times lower than concentrations at which adverse effects in bivalves have been reported. The accumulation factors were highest in *Crassostrea gigas* with 67 times the initial concentration during the dry season.

Condition and Survival

Condition, percent lipid, and percent moisture measurements were made prior to deployment and after the transplants were collected to show natural variables affecting condition, such as weight loss due to reproduction, which can also account for a decrease in contaminant accumulation. In addition, some water quality parameters in the Estuary were outside optimum conditions for the bivalve species during their deployment and may have affected bioaccumulation at certain times. For example, survival, condition, and percent lipid in mussels are significantly positively related to dissolved oxygen and salinity (Hardin *et al.*, 1999). At the sampling sites for *Crassostrea gigas*, which are located near the river-mouths (BD50, BD40, BD15), low salinity ranges can cause higher mortality rates in oysters. They are deployed at sites with lower expected salinities because the tolerance of the organism to freshwater exposure is higher than in mussels (as low as 10â), but their optimum salinity range for adult growth is reported at 35â (Mann *et al.*, 1994). While their natural habitat is the lower inter-tidal zone of estuaries, salinity values as low as 14â were measured at Napa River (BD50). Also, the ability to describe spatial concentration patterns throughout the Bay is confounded by other potential effects that dissolved oxygen, salinity, temperature, total suspended solids, and chlorophyll may have on the bioaccumulation of contaminants in bivalves.

In 2000, sturdy, low maintenance bivalve cage prototypes were deployed at the Redwood Creek, Yerba Buena Island, Horseshoe Bay, San Pablo Bay, and Napa River sites. Survival rates (Table 18) of bagged and caged bivalves showed evidence of less predation of caged bivalves.

Long-term contaminant trends in bivalves can only be compared among sites with the same species due to the very high spatial and temporal variations in water quality parameters in the San Francisco Estuary and the various biological differences of the bivalve species used.

4.7 References

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Table 4.1. California Screening Values calculated according to USEPA guidance (USEPA, 1995). Calculations were based on a 70 kg adult and a fish consumption value of 21 g/day. Guidelines were specifically developed for a fish study and should be used as reference values in bivalve tissue concentrations only. No follow-up actions are associated with bivalve tissue concentrations above these screening values. Screening values have been converted to dry weight using a conversion factor of 7, which is based on an 85% average moisture content in bivalves.

PARAMETER	**Screening Value dry weight**	**dry unit**
Cd	**21**	ppm
Se	**140**	ppm
Dieldrin	**14**	ppb
Endrin	**7,000**	ppb
gamma-HCH	**210**	ppb
Heptachlor Epoxide	**28**	ppb
Hexachlorobenzene	**140**	ppb
Total Chlordanes (SFEI)	**210**	ppb
Total DDTs (SFEI)	**700**	ppb
Total PCBs (SFEI)	**140**	ppb

Cadmium in Bivalves, September 2000

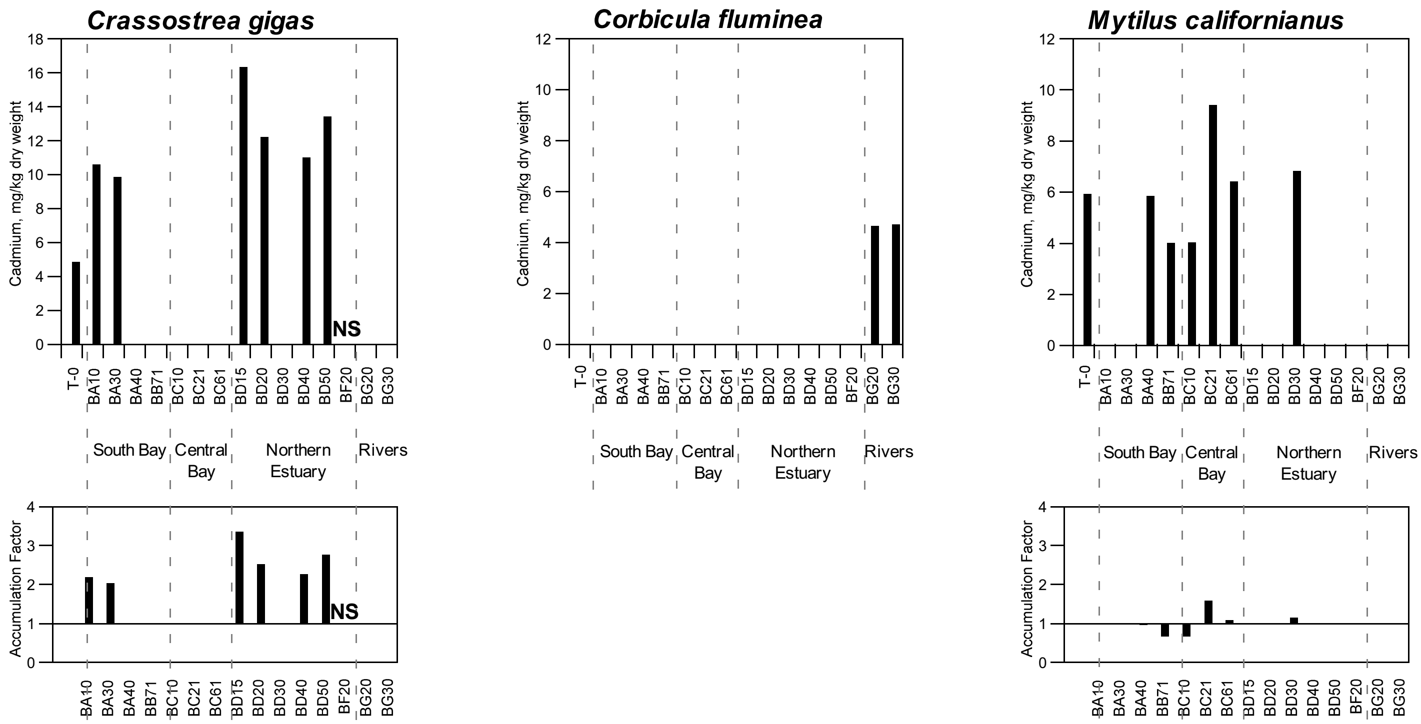


Figure 4.1. Cadmium concentrations in parts per million dry weight (ppm) in two transplanted and one native bivalve species at 15 RMP stations during the wet season sampling period. NS = not sampled. Note different y-axis scales. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 0.68 (depuration) to 3.36. Median concentrations were highest in *C. gigas,* intermediate in *M. californianus*, and lowest in *C. fluminea*. The highest measured concentration was in *C. gigas*, at Petaluma River (BD15).

Source Data:
See Data
Table 19

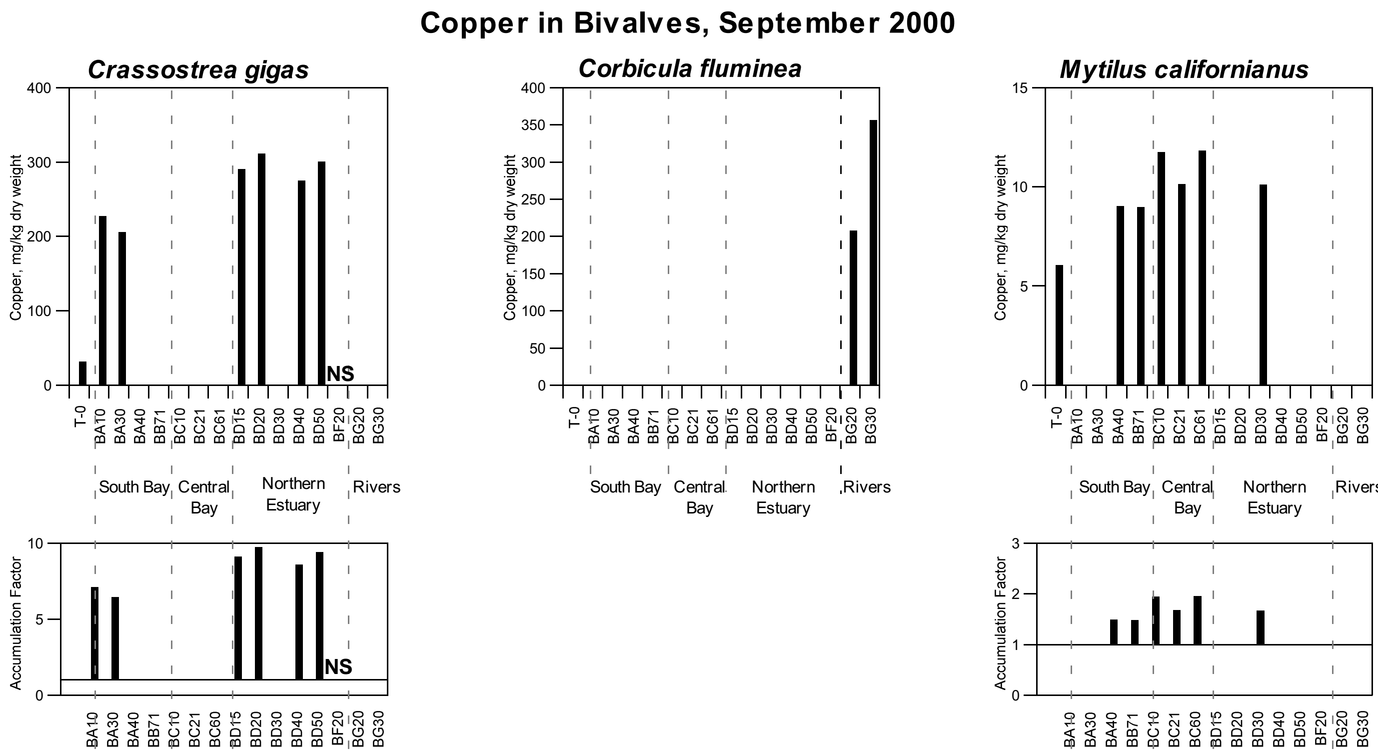


Figure 4.2. Copper concentrations in parts per million dry weight (ppm) in two transplanted and one native bivalve species at 15 RMP stations during the dry-season sampling periods. NS = Not sampled. Note different y-axis scales. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 1.48 to 9.74. Median concentrations were highest in *C. gigas*, intermediate in *C. fluminea*, and lowest in *M. californianus*. The highest measured concentration was in *C. fluminea*, at San Joaquin River (BG30).

Source Data:
See Data
Table 19

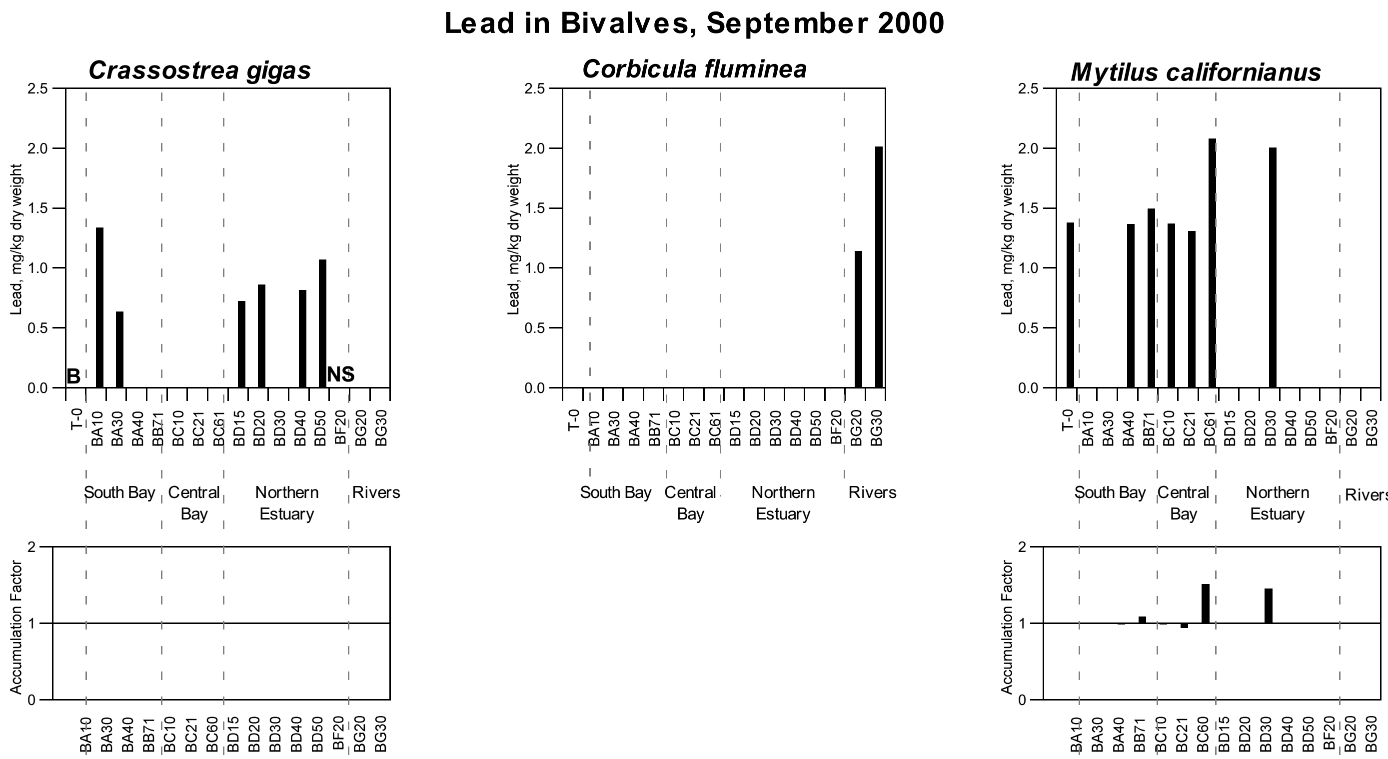


Figure 4.3. Lead concentrations in parts per million dry weight (ppm) in two transplanted and one native bivalve species at 15 RMP stations during the dry-season sampling period. NS = not sampled, B = blank contamination > 30% of measured concentartion. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 0.95 to 1.51 in *M. californianus*. Due to blank contamination in the T-0 sample for *C. gigas*, no accumulation factors could be calculated. Median concentrations were highest in *C. fluminea*, intermediate in *M. californianus,* and lowest in *C. gigas*. The highest measured concentration was in *M. californianus*, at Red Rock (BC61).

Source Data:
See Data
Table 19

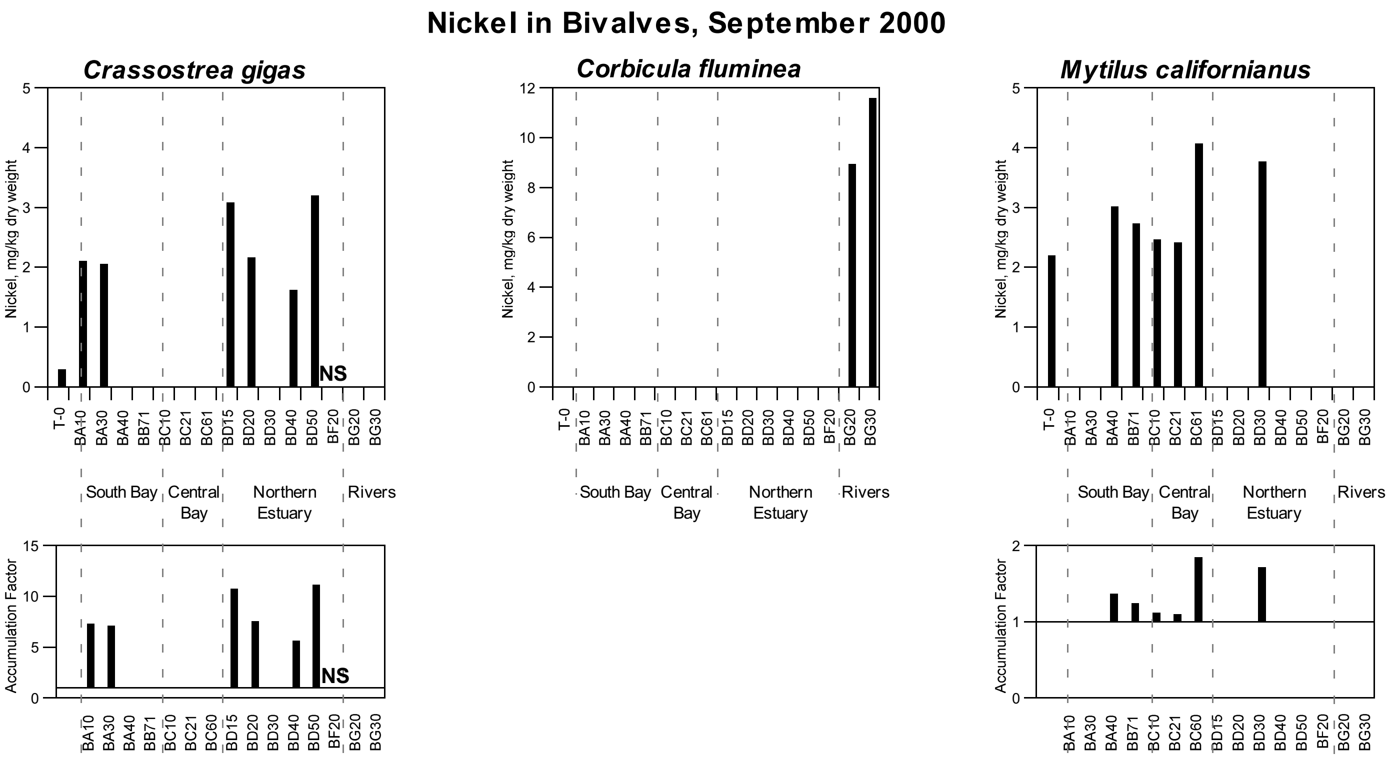


Figure 4.4. Nickel concentrations in parts per million dry weight (ppm) in two transplanted and one native bivalve species at 15 RMP stations during the dry-season sampling period. NS = Not sampled. Note different y-axis scales. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 1.10 to 11.16. Median concentrations were highest in *C. fluminea*, intermediate in *M. californianus,* and lowest in *C. gigas.* The highest measured concentration was in *C. fluminea*, at San Joaquin River (BG30).

Source Data:
See Data
Table 19

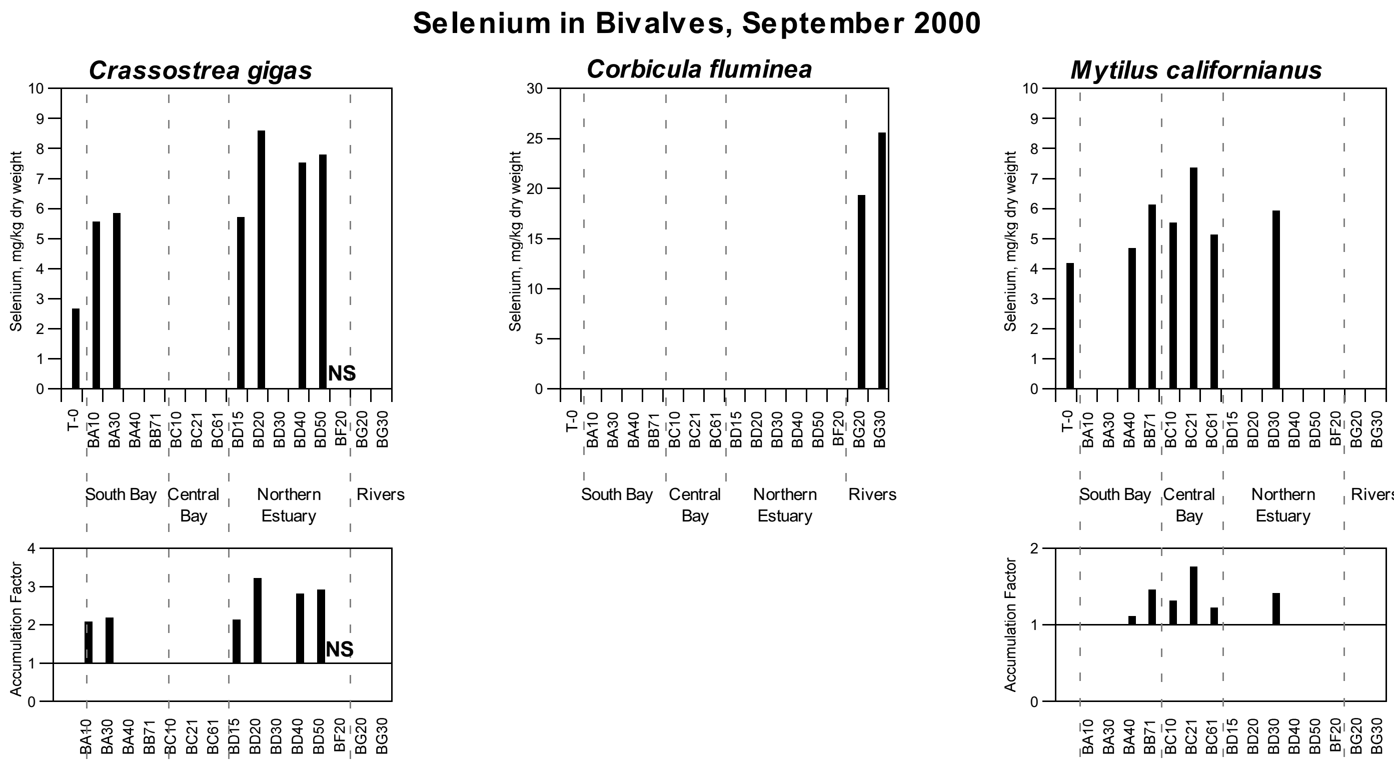


Figure 4.5. Selenium concentrations in parts per million dry weight (ppm) in two transplanted and one native bivalve species at 15 RMP stations during the dry-season sampling period. NS = not sampled. Note different y-axis scales. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 1.12 to 3.22. Median concentrations were highest in *C. fluminea*, intermediate in *C. gigas*, and lowest in *M. californianus.* The highest measured concentration was in *C. fluminea*, at San Joaquin River (BG30).

Source Data:
See Data
Table 19

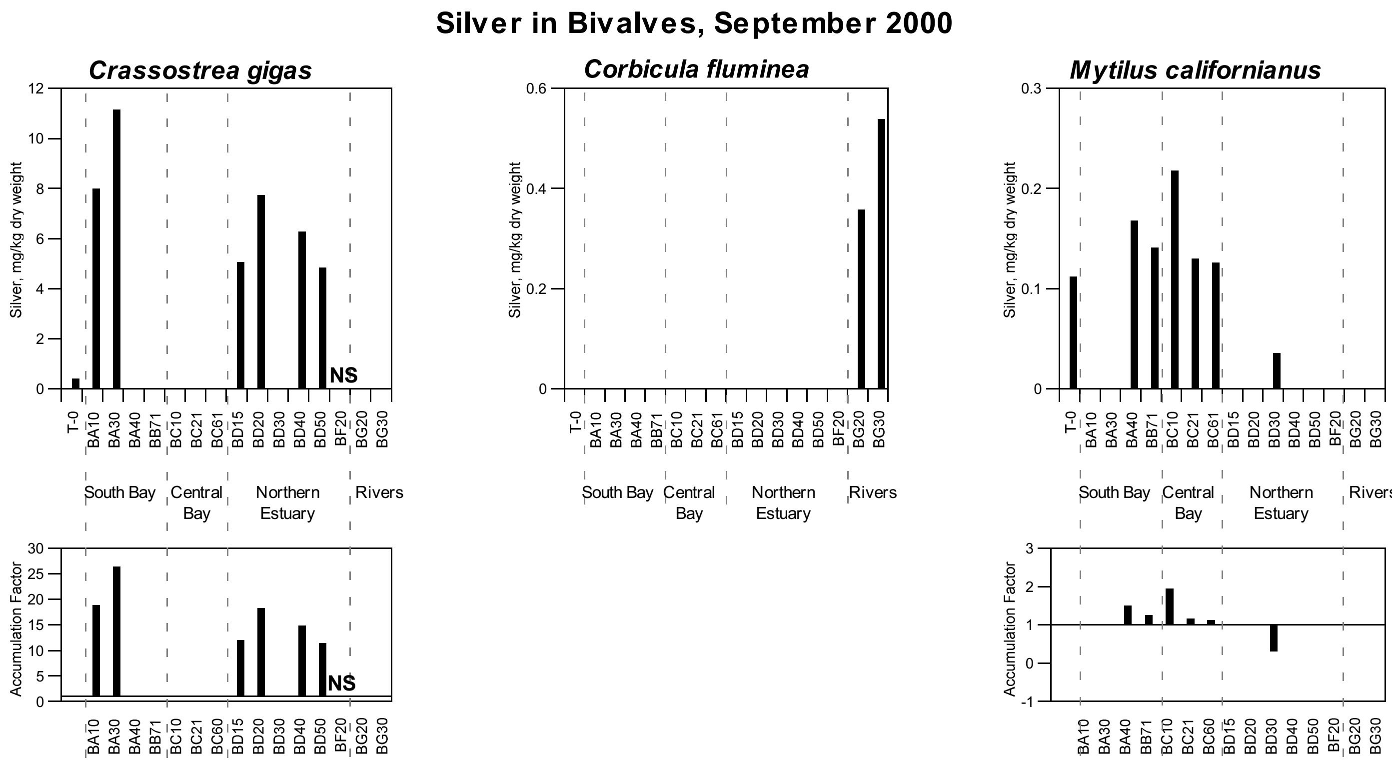


Figure 4.6. Silver concentrations in parts per million dry weight (ppm) in two transplanted and one native bivalve species at 15 RMP stations during the dry-season sampling period. NS = not sampled. Note different y-axis scales. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 0.32 (depuration) to 26.38. Median concentrations were highest in *C. gigas*, intermediate in *C. fluminea*, and lowest in *M. californianus.* The highest measured concentration was in *C. gigas*, at Coyote Creek (BA10).

Source Data:
See Data
Table 19

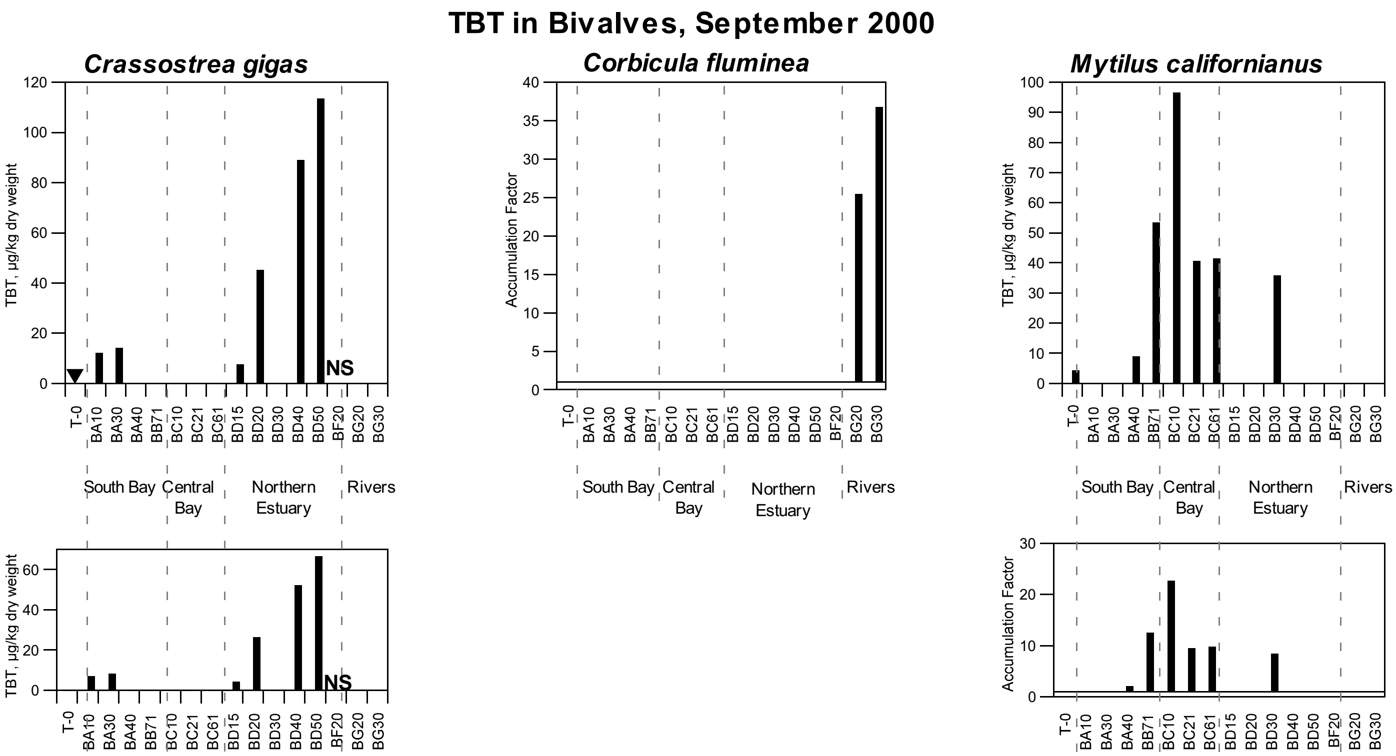


Figure 4.7. Tributyltin concentrations in parts per billion dry weight (ppb) in two transplanted and one native bivalve species at 15 RMP stations during the dry-season sampling period. ▼ = not detected, NS = not sampled. Note different y-axis scales. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 2.12 to 66.71. Median concentrations were highest in *M. californianus*, intermediate in *C. fluminea*, and lowest in *C. gigas*. The highest measured concentration was in *C. gigas*, at Napa River (BD50).

Source Data:
See Data
Table 19

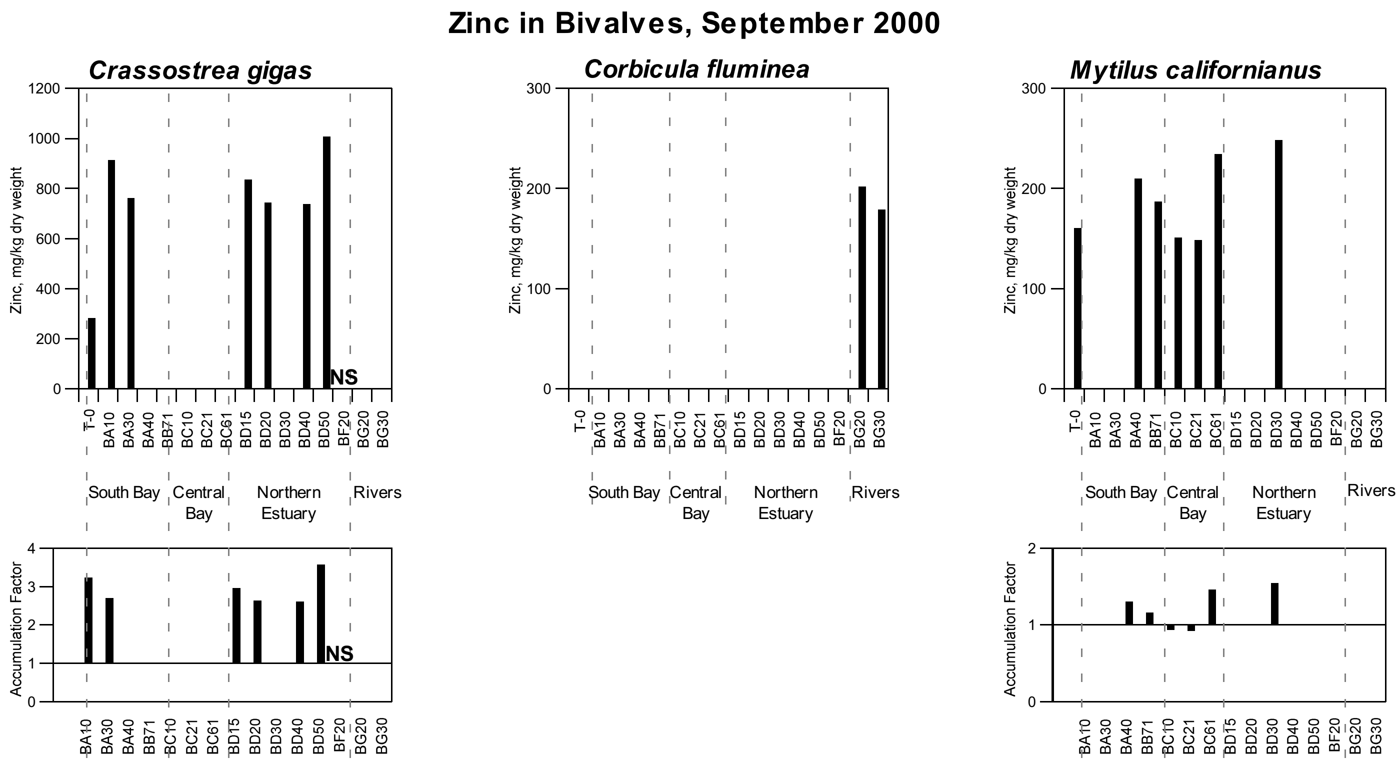


Figure 4.8. Zinc concentrations in parts per million dry weight (ppm) in two transplanted and one native bivalve species at 15 RMP stations during the dry-season sampling period. NS = not sampled. Note different y-axis scales. T-0 (time zero) is the initial concentration before deployment in the Estuary. Accumulation factors ranged from 0.93 (depuration) to 3.57. Median concentrations were highest in *C. gigas,* intermediate in *M. californianus*, and lowest in *C. fluminea*. The highest measured concentration was in *C. gigas*, at Napa River (BD50).

Source Data:
See Data
Table 19

Sum of PAHs in Bivalves, September 2000

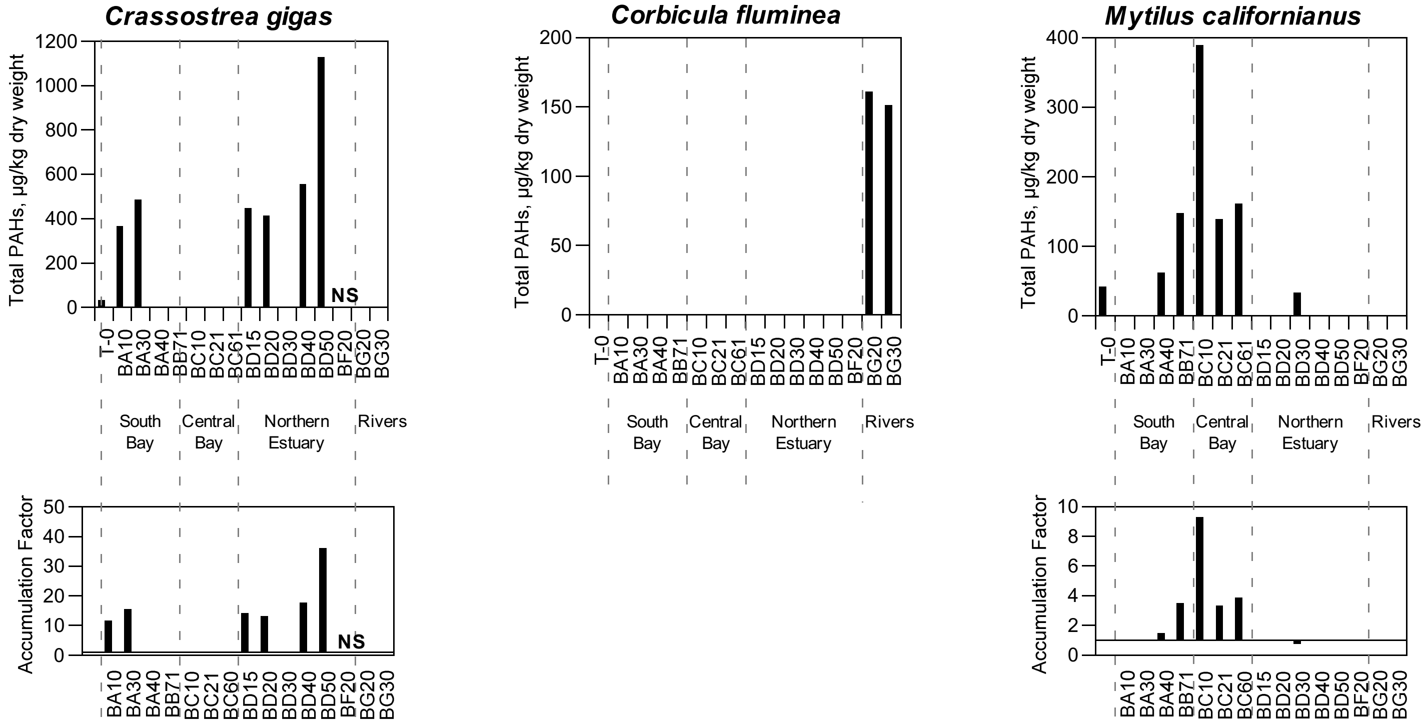


Figure 4.9. Sum of PAH concentrations in parts per billion dry weight (ppb) in two transplanted and one native bivalve species at 15 RMP stations during the dry-season sampling period. NS = not sampled. T-0 (time zero) is the initial concentration before deployment in the Estuary. Note different y-axis scales. Accumulation factors ranged from 0.79 (depuration) to 36.06. Median concentrations were highest in *C. gigas,* intermediate in *C. fluminea*, and lowest in *M. californianus*. The highest measured concentration was in *C. gigas*, at Napa River (BD50).

Source Data:
See Data
Table 20

Sum of PCBs in Bivalves, September 2000

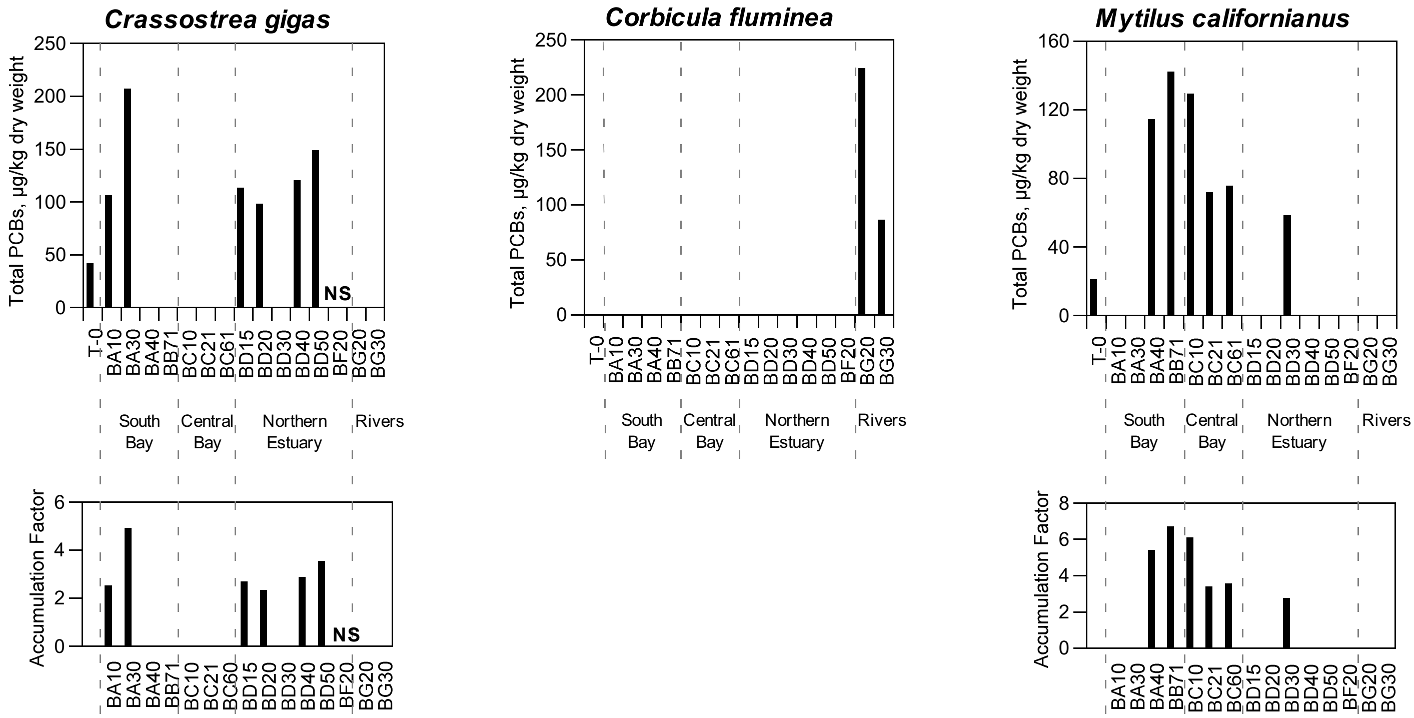


Figure 4.10. Sum of PCB concentrations in parts per billion dry weight (ppb) in two transplanted and one native bivalve species at 15 RMP stations during the dry-season sampling period. NS = not sampled. Note different y-axis scales. Accumulation factors ranged from 2.34 to 6.73. Median concentrations were highest in *C. fluminea,* intermediate in *C. gigas*, and lowest in *M. californianus*. The highest measured concentration was in *C. fluminea*, at Sacramento River (BG20).

Source Data:
See Data
Table 21

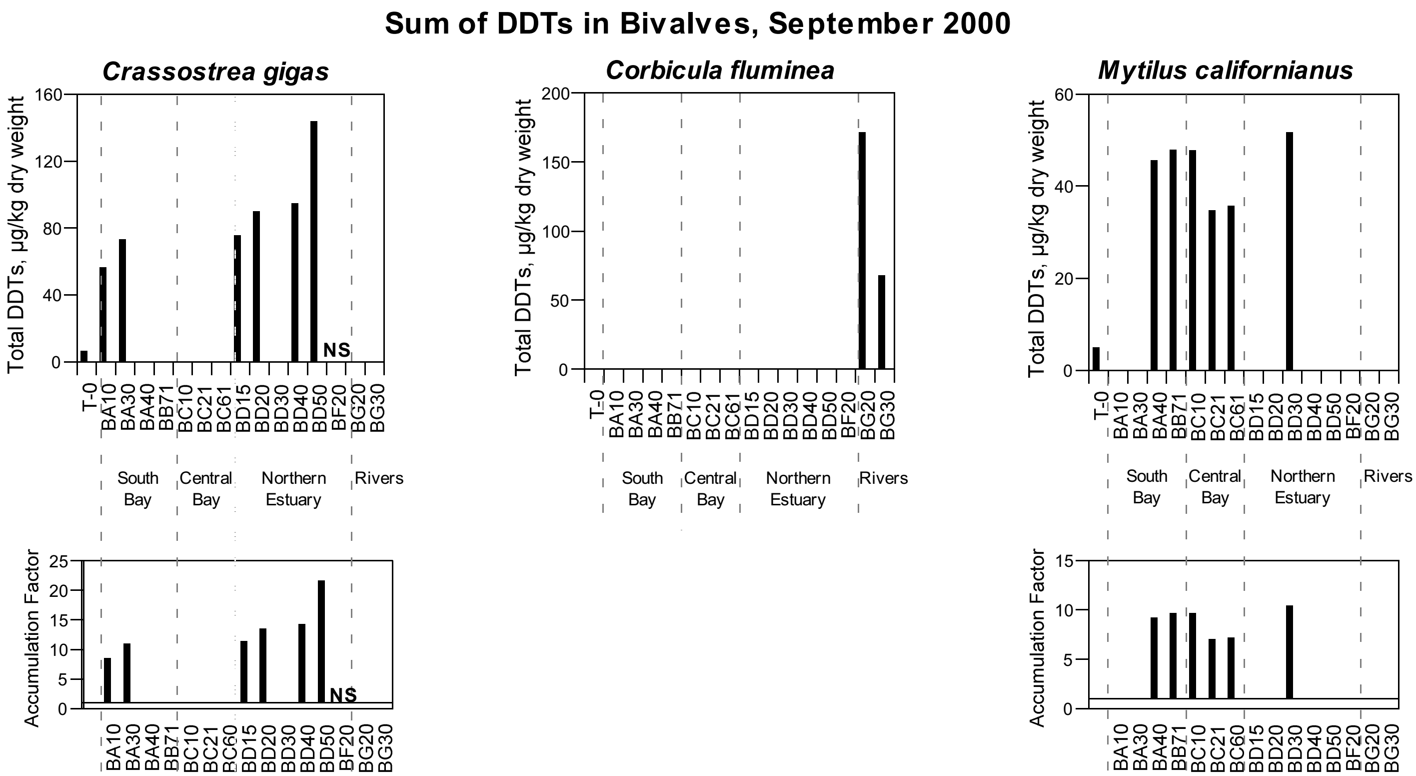


Figure 4.11. Sum of DDT concentrations in parts per billion dry weight (ppb) in two transplanted and one native bivalve species at 15 RMP stations during the dry-season sampling period. NS = not sampled. Note different y-axis scales. Accumulation factors ranged from 7.06 to 21.65. Median concentrations were highest in *C. fluminea*, intermediate in *C. gigas*, and lowest in *M. californianus*. The highest measured concentration was in *C. fluminea*, at Sacramento River (BG20).

Source Data:
See Data
Table 22

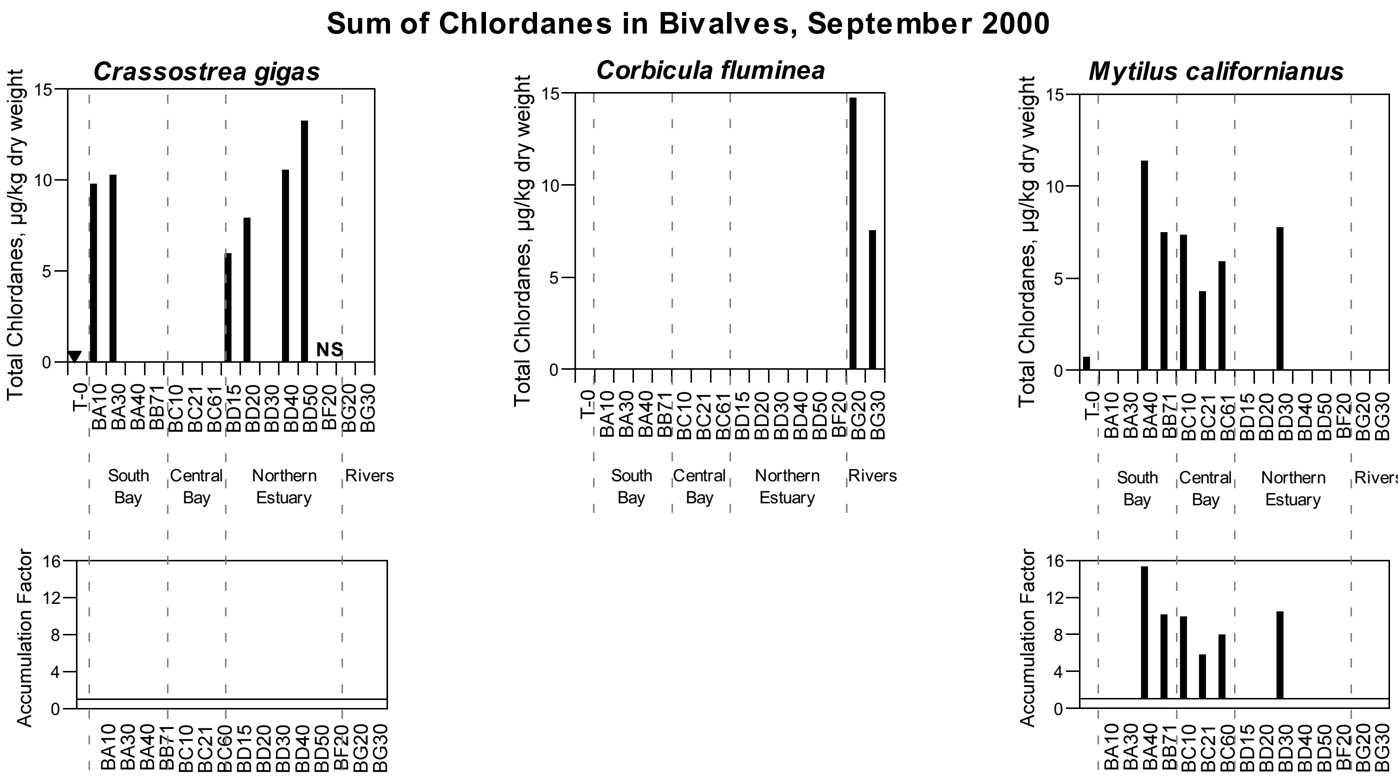


Figure 4.12. Sum of chlordane concentrations in parts per billion dry weight (ppb) in two transplanted and one native bivalve species at 15 RMP stations during the wet- and dry-season sampling period. ▼= not detected, NS = not sampled. Accumulation factors ranged from 5.80 to 15.36. Median concentrations were highest in *C. fluminea*, intermediate in *C. gigas*, and lowest in *M. californianus*. The highest measured concentration was in *C. fluminea* at Sacramento River (BG20).

Source Data:
See Data
Table 22

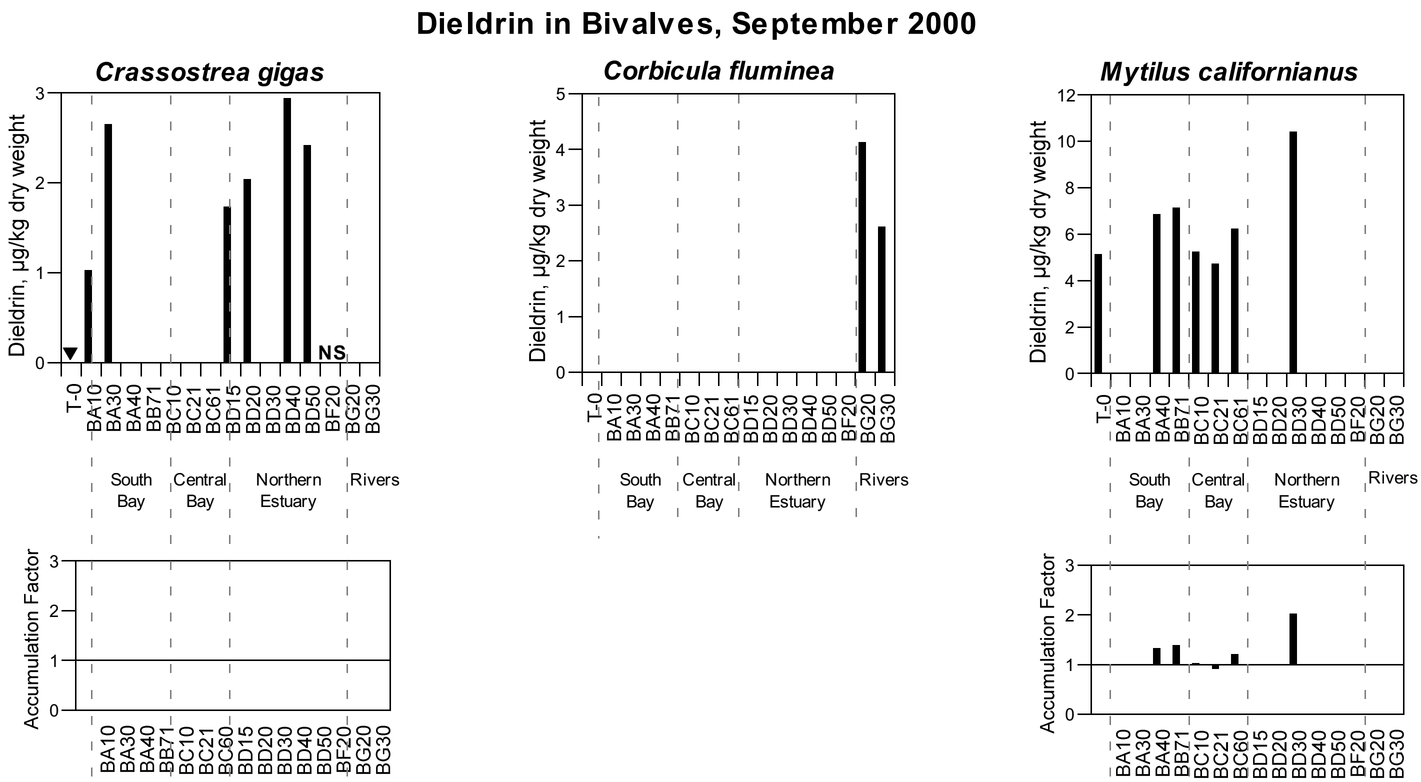
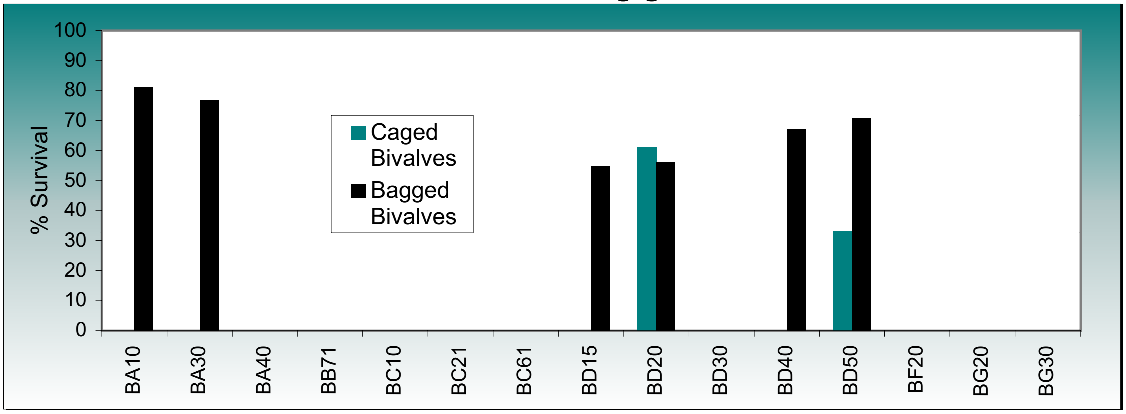


Figure 4.13. Dieldrin concentrations in parts per billion dry weight (ppb) in two transplanted and one native bivalve species at 15 RMP stations during the dry-season sampling period. ▼= not detected, NS = not sampled. Note different y-axis scales. Accumulation factors ranged from 0.92 (depuration) to 2.02. Median concentrations were highest in *M. californianus*, intermediate in *C. fluminea*, and lowest in *C. gigas*. The highest measured concentration was in *M. californianus* at Pinole Point (BD30).

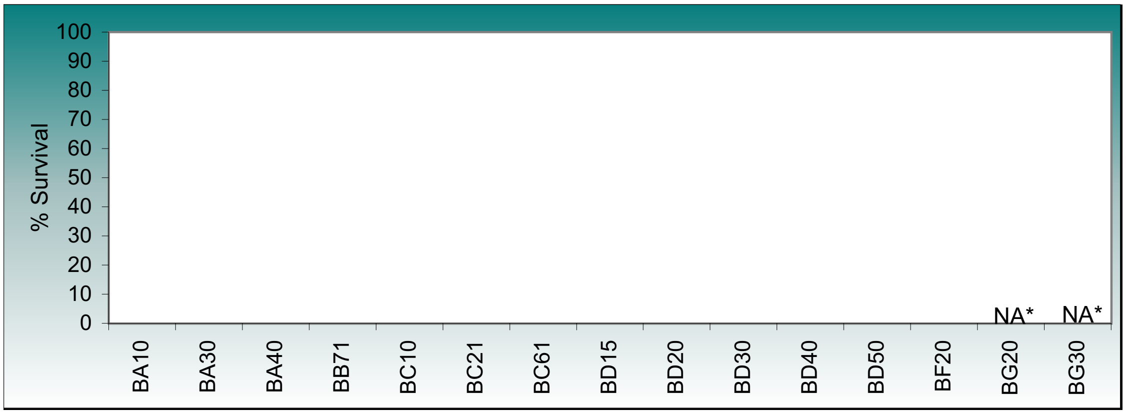
Source Data:
See Data
Table 22

Bivalve Survival (2000)

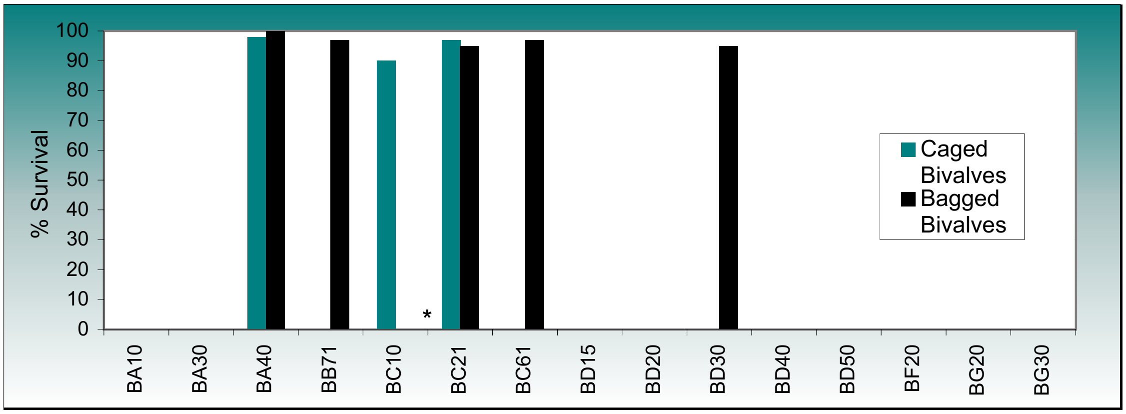
Crassostrea gigas



Corbicula fluminea



***Mytilus* spp.**



Figures 4.14. Percent survival of transplanted bivalves following exposure to Estuary conditions during the dry season (September) of 2000.
* indicates 0% survival and NA* = not available, resident bivalves used.

Source Data:
See Data
Table 18

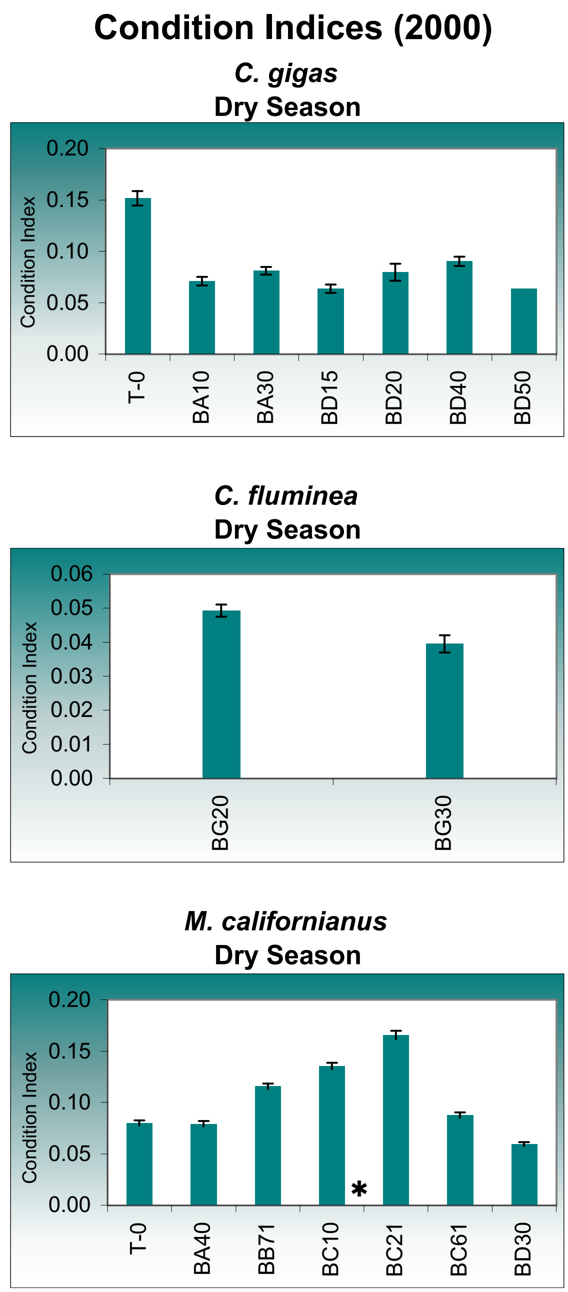


Figure 4.15. Condition indices of three species of bivalve at their original "reference" locations, prior to deployment (T-0), and at the end of their exposure to San Francisco Estuary waters (various locations) during the dry seasons of 2000.
✱ = 0 % survival for bagged bivalves due to heavy predation; CI was calculated from caged bivalves at the same site. A *Corbicula* reference site for the dry season was not available, since clams could no longer be found at "clean" sites. Consequently, resident specimens were collected from a population in the Sacramento River (BG20) and San Joaquin River (BG30); the Grizzly Bay (BF20) site was discontinued. Bars indicate range of values.

Source Data:
See Data
Table 18

Cadmium, mg/kg, dry weight

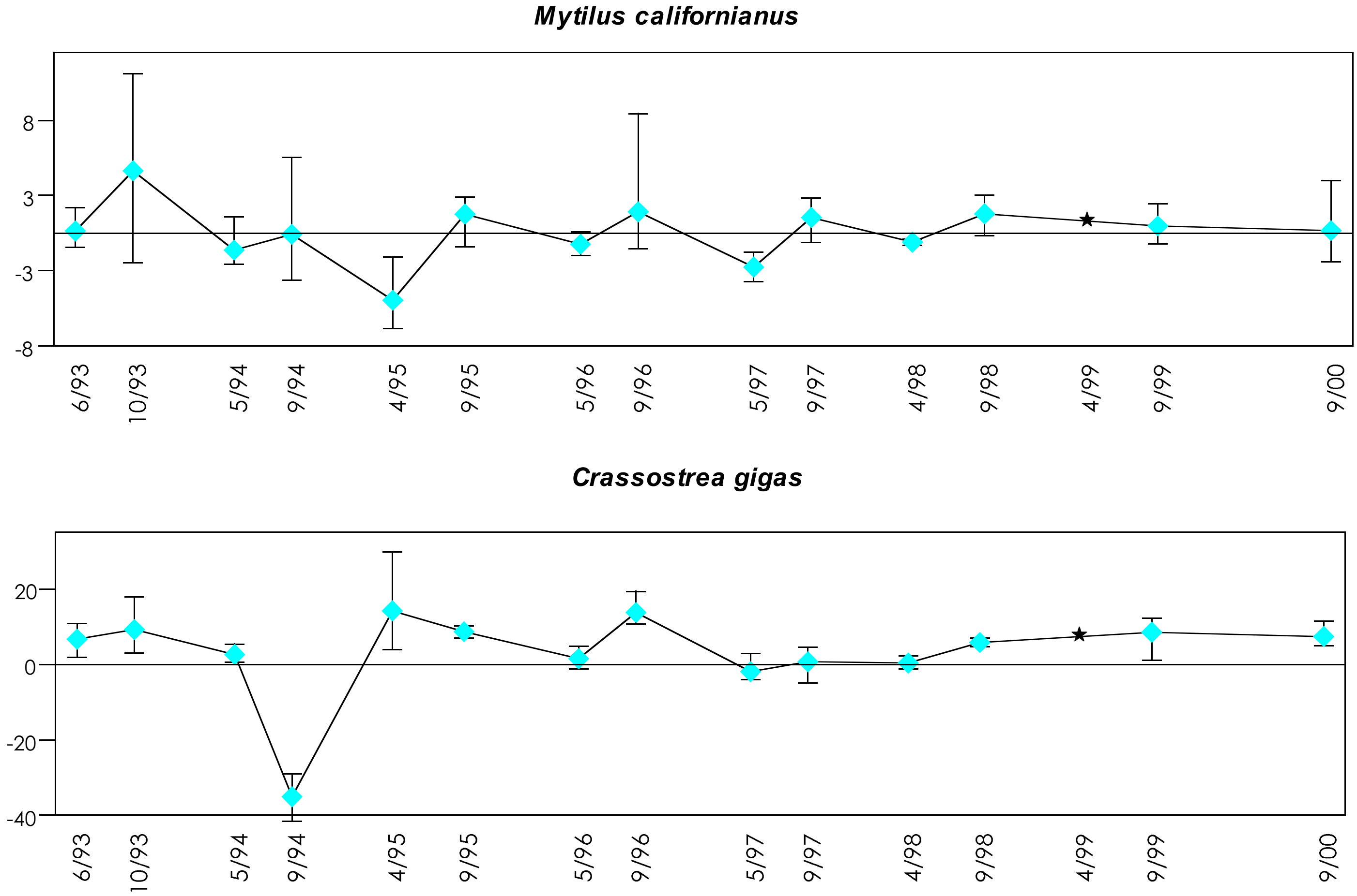


Figure 4.16. Cadmium accumulation or depuration in parts per million dry weight (ppm) in two transplanted bivalve species for 14 sampling periods from 1993–2000. Initial (T-0) concentrations are subtracted from tissue concentrations after retrieval to give concentrations accumulated or depurated (negative value) during deployment in the Estuary. Bars indicate the range of values of all stations where species were deployed. Note different y-axis scales. ★ means no analyzed data available.

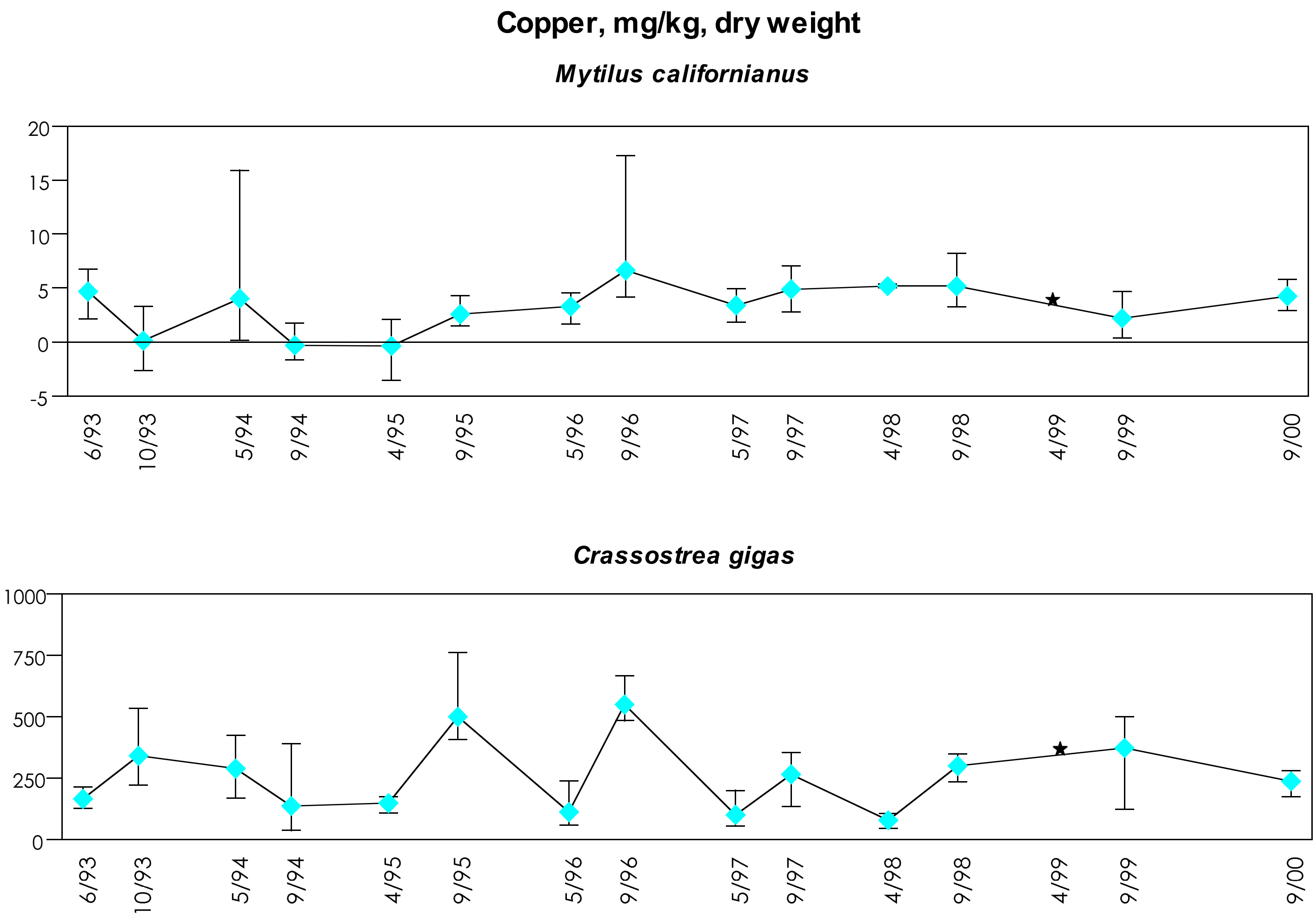


Figure 4.17. Copper accumulation or depuration in parts per million dry weight (ppm) in two transplanted bivalve species for 14 sampling periods from 1993–2000. Initial (T-0) concentrations are subtracted from tissue concentrations after retrieval to give concentrations accumulated or depurated (negative value) during deployment in the Estuary. Bars indicate the range of values of all stations where species were deployed. Note different y-axis scales. ★ means no analyzed data available.

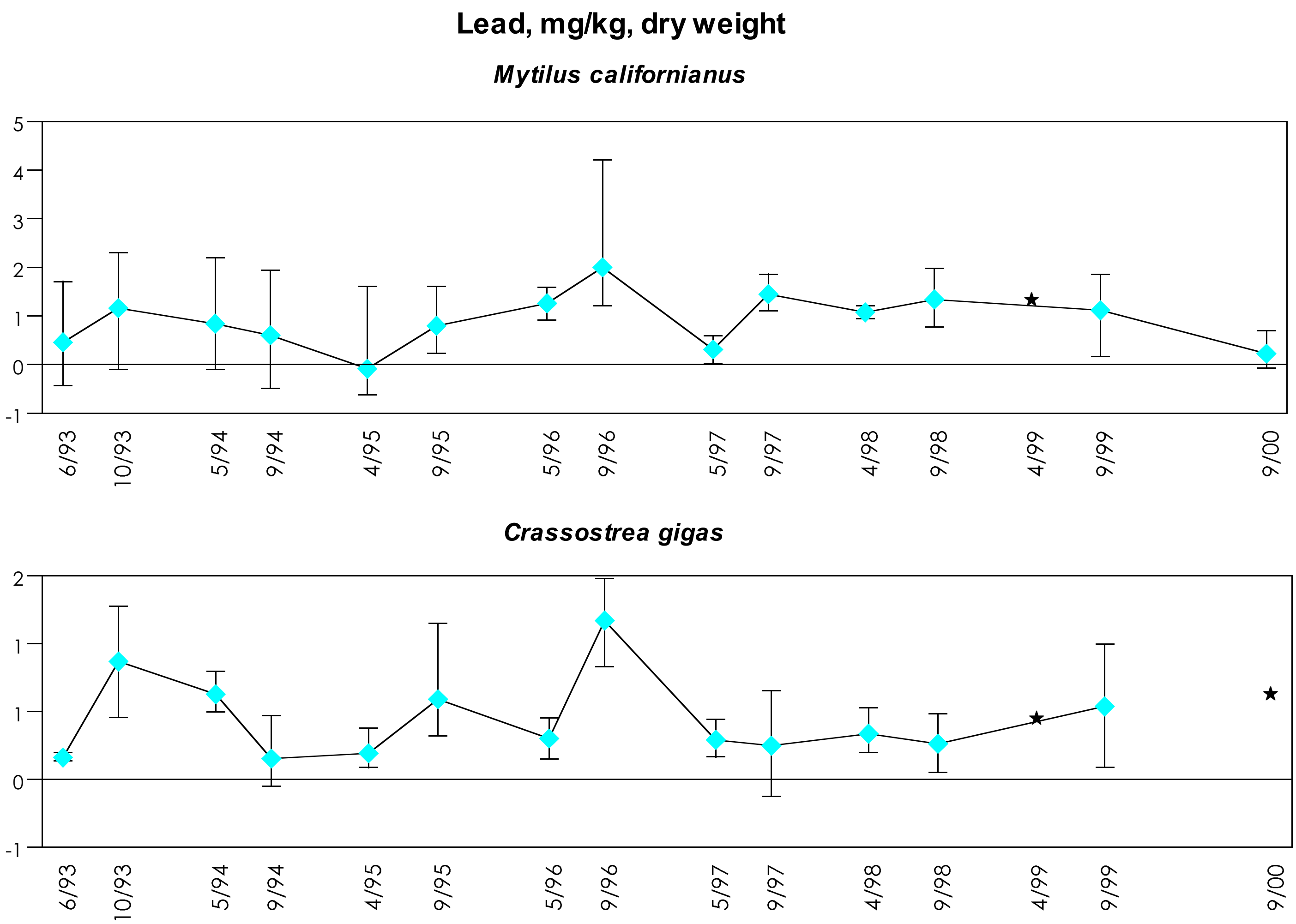


Figure 4.18. Lead accumulation or depuration in parts per million dry weight (ppm) in two transplanted bivalve species for 14 sampling periods from 1993–2000. Initial (T-0) concentrations are subtracted from tissue concentrations after retrieval to give concentrations accumulated or depurated (negative value) during deployment in the Estuary. Bars indicate the range of values of all stations where species were deployed. Note different y-axis scales. ★ means no analyzed data available.

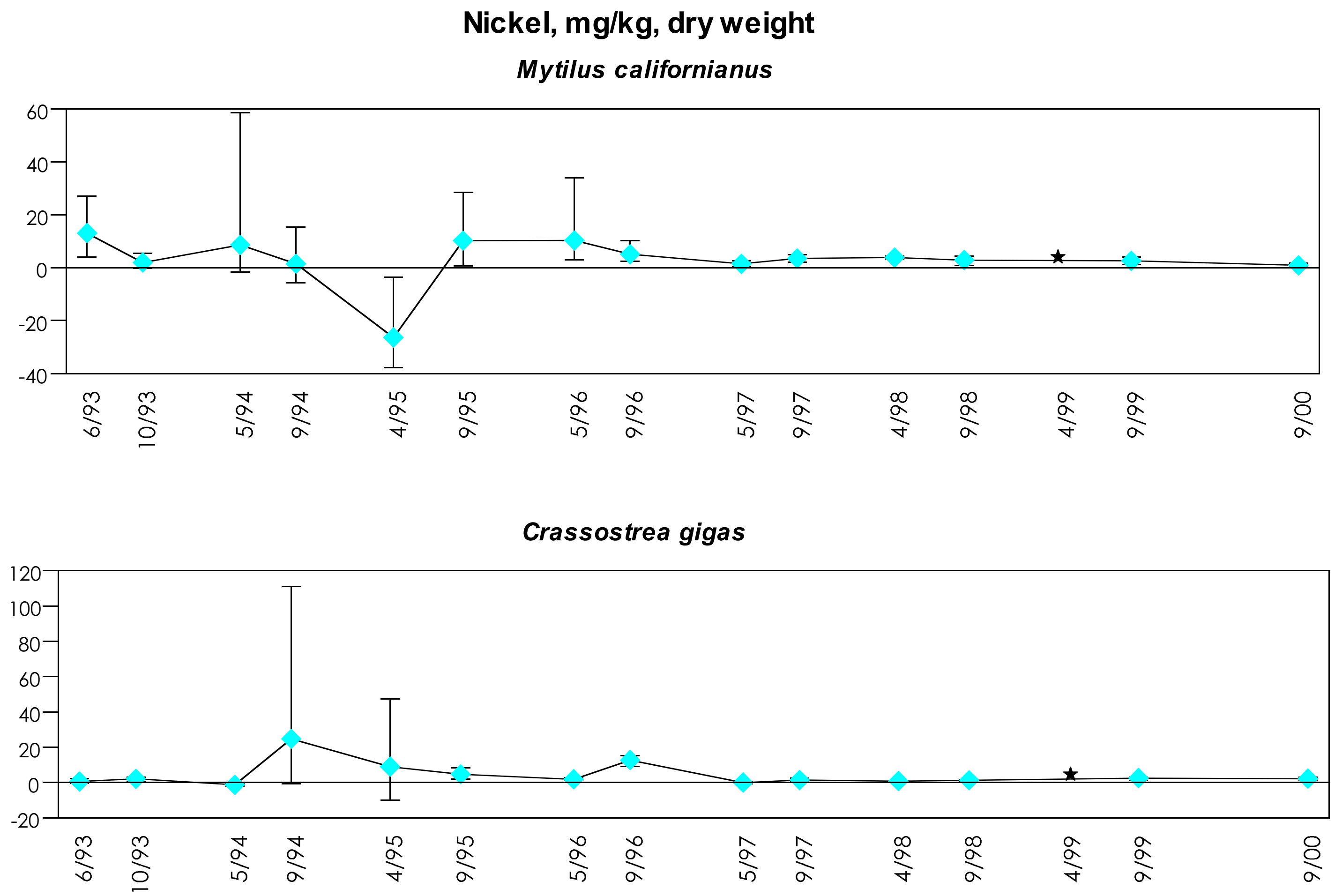


Figure 4.19. Nickel accumulation or depuration in parts per million dry weight (ppm) in two transplanted bivalve species for 14 sampling periods from 1993–2000. Initial (T-0) concentrations are subtracted from tissue concentrations after retrieval to give concentrations accumulated or depurated (negative value) during deployment in the Estuary. Bars indicate the range of values of all stations where species were deployed. Note different y-axis scales. ★ means no analyzed data available.

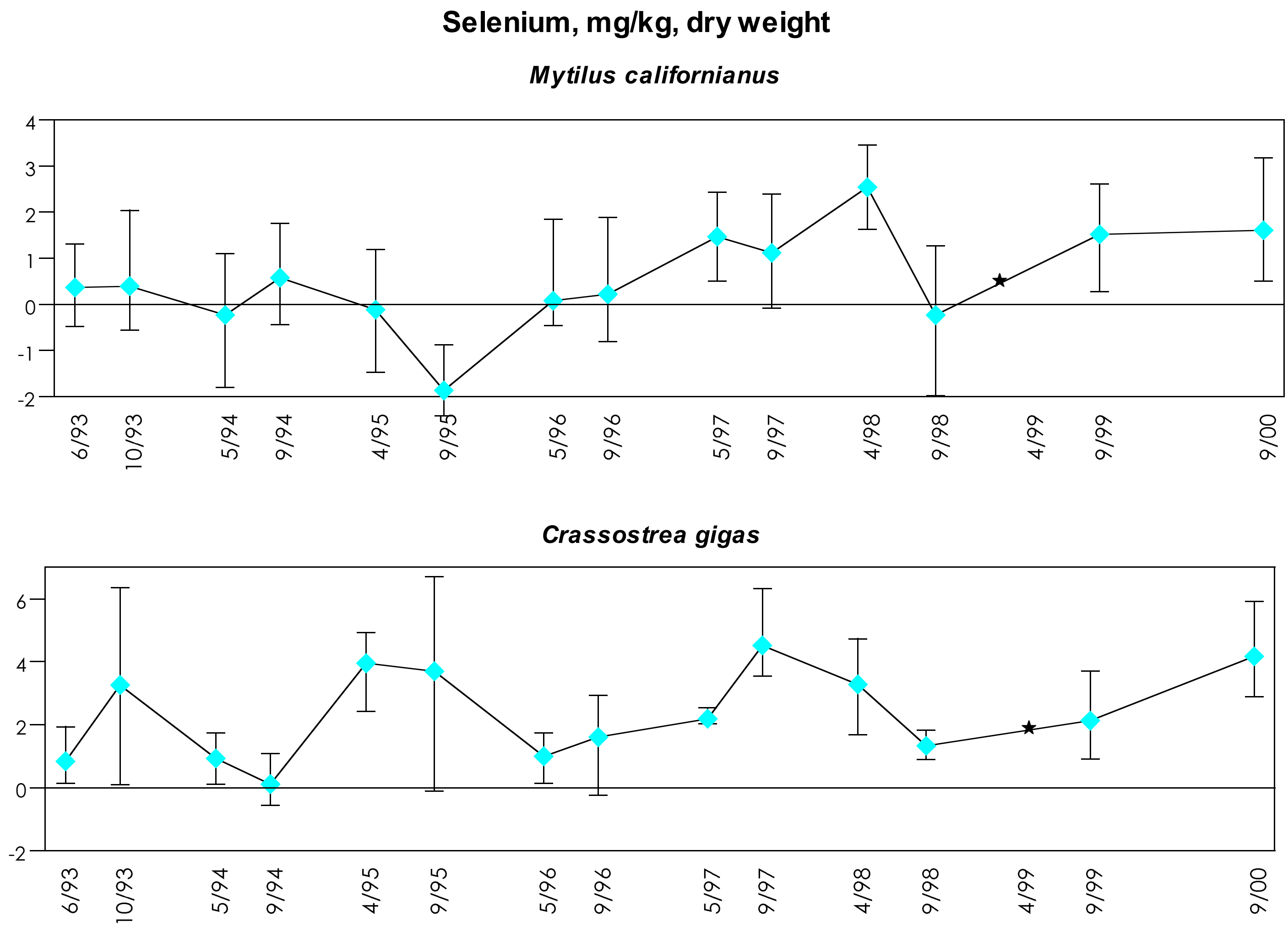


Figure 4.20. Selenium accumulation or depuration in parts per million dry weight (ppm) in two transplanted bivalve species for 14 sampling periods from 1993–2000. Initial (T-0) concentrations are subtracted from tissue concentrations after retrieval to give concentrations accumulated or depurated (negative value) during deployment in the Estuary. Bars indicate the range of values of all stations where species were deployed. Note different y-axis scales. ★ means no analyzed data available.

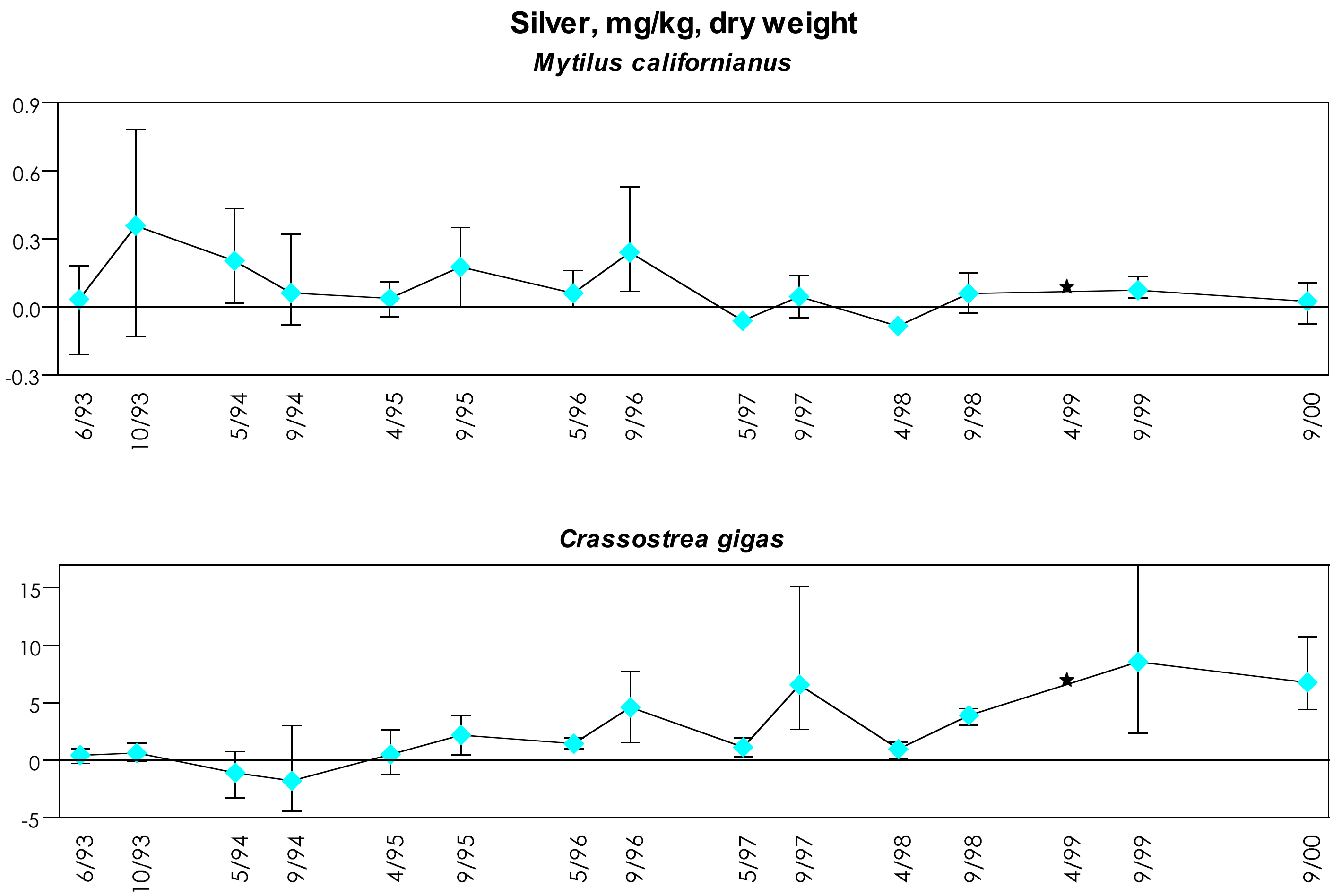


Figure 4.21. Silver accumulation or depuration in parts per million dry weight (ppm) in two transplanted bivalve species for 14 sampling periods from 1993–2000. Initial (T-0) concentrations are subtracted from tissue concentrations after retrieval to give concentrations accumulated or depurated (negative value) during deployment in the Estuary. Bars indicate the range of values of all stations where species were deployed. Note different y-axis scales. ★ means no analyzed data available.

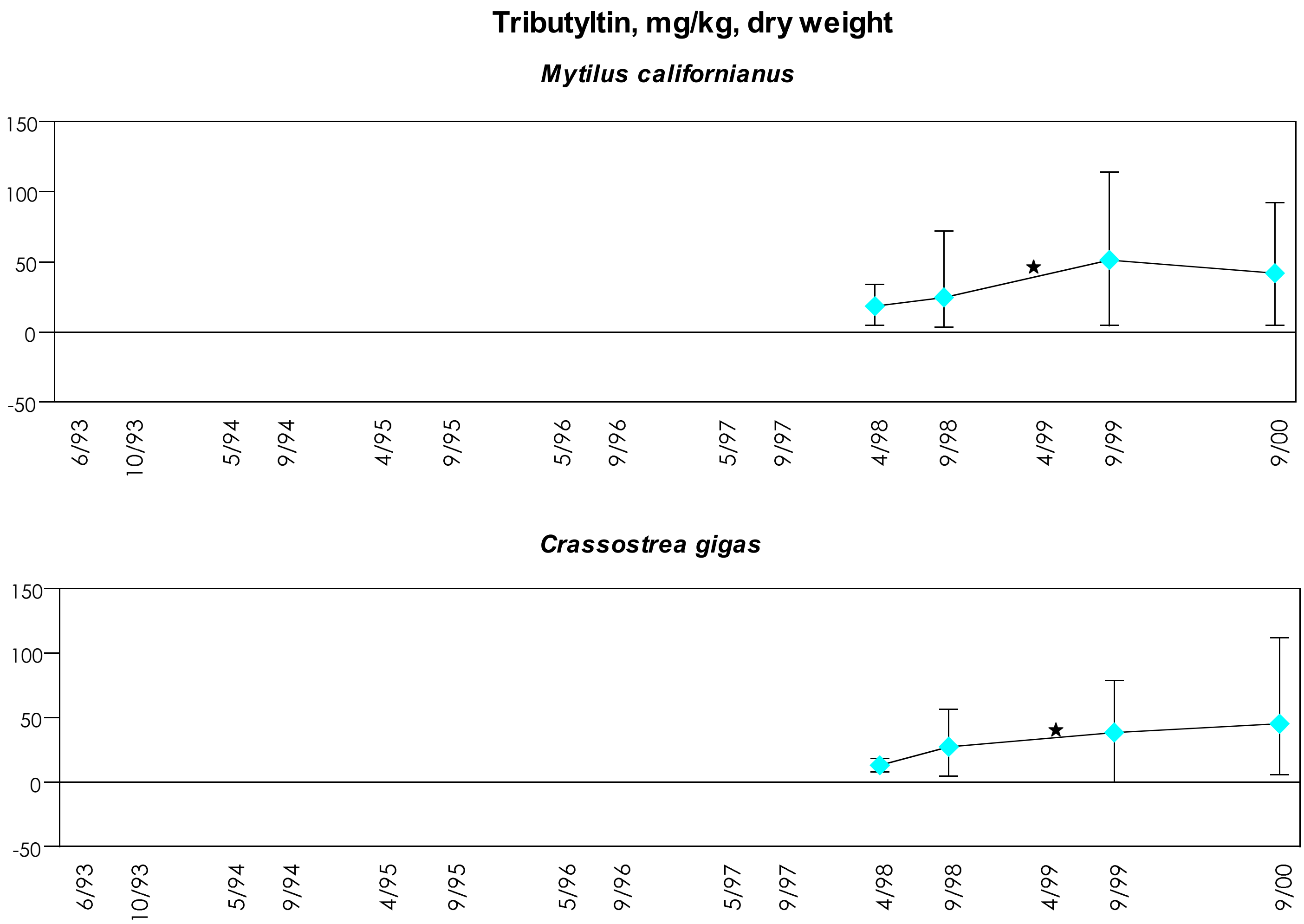


Figure 4.22. Tributyltin accumulation or depuration in parts per million dry weight (ppm) in two transplanted bivalve species for 4 sampling periods from 1998–2000. Initial (T-0) concentrations are subtracted from tissue concentrations after retrieval to give concentrations accumulated or depurated (negative value) during deployment in the Estuary. Bars indicate the range of values of all stations where species were deployed. Note different y-axis scales. ★ means no analyzed data available.

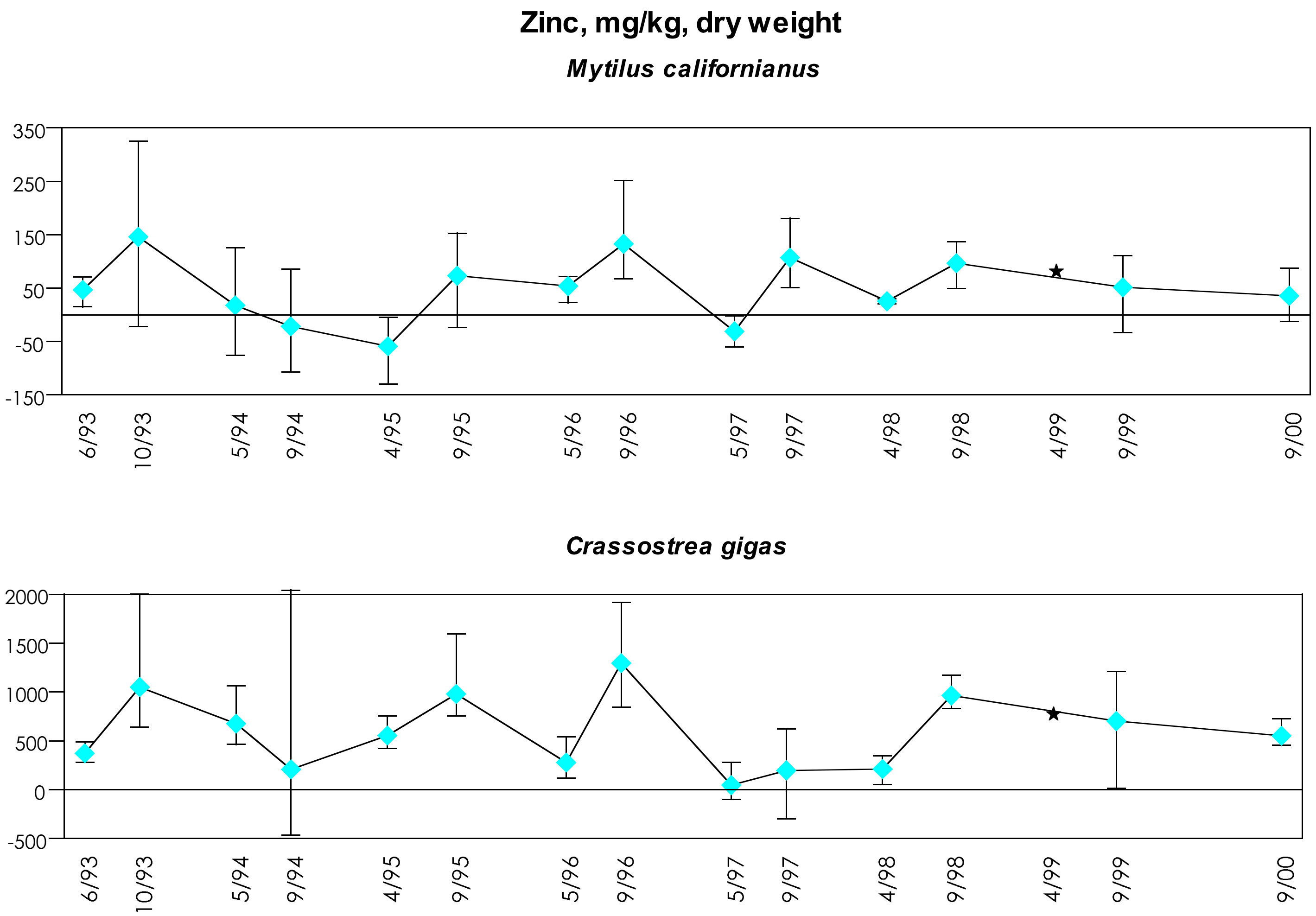


Figure 4.23. Zinc accumulation or depuration in parts per million dry weight (ppm) in two transplanted bivalve species for 14 sampling periods from 1993–2000. Initial (T-0) concentrations are subtracted from tissue concentrations after retrieval to give concentrations accumulated or depurated (negative value) during deployment in the Estuary. Bars indicate the range of values of all stations where species were deployed. Note different y-axis scales. ★ means no analyzed data available.

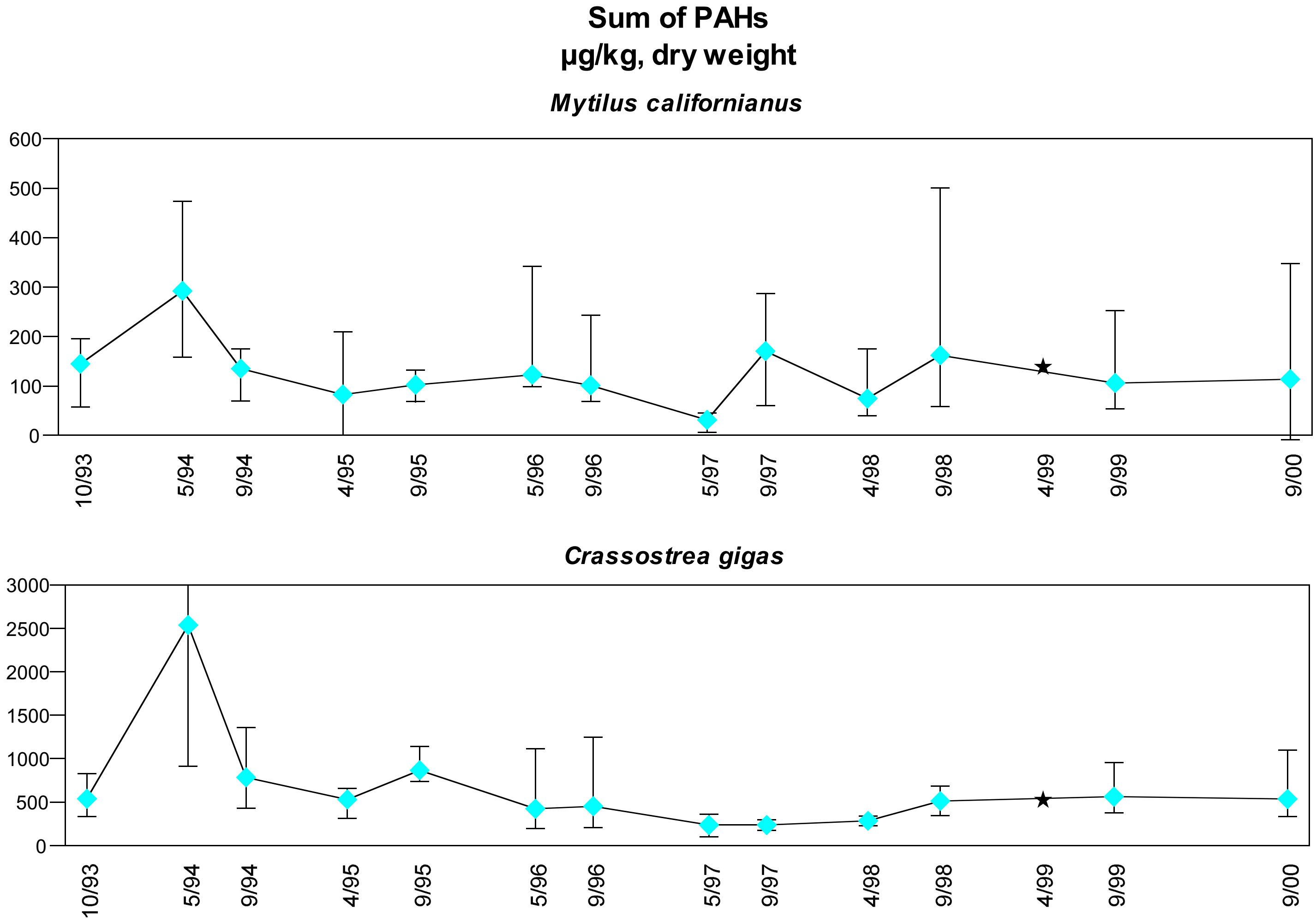


Figure 4.24. PAH accumulation or depuration in parts per billion dry weight (ppb) in two species of transplanted bivalves for 14 sampling periods from 1993–2000 (mean of all stations). Accumulation or depuration was calculated by subtracting initial tissue (T-0) concentrations from concentrations after deployment. Bars indicate range of values within a sampling period.
★ means no analyzed data available.

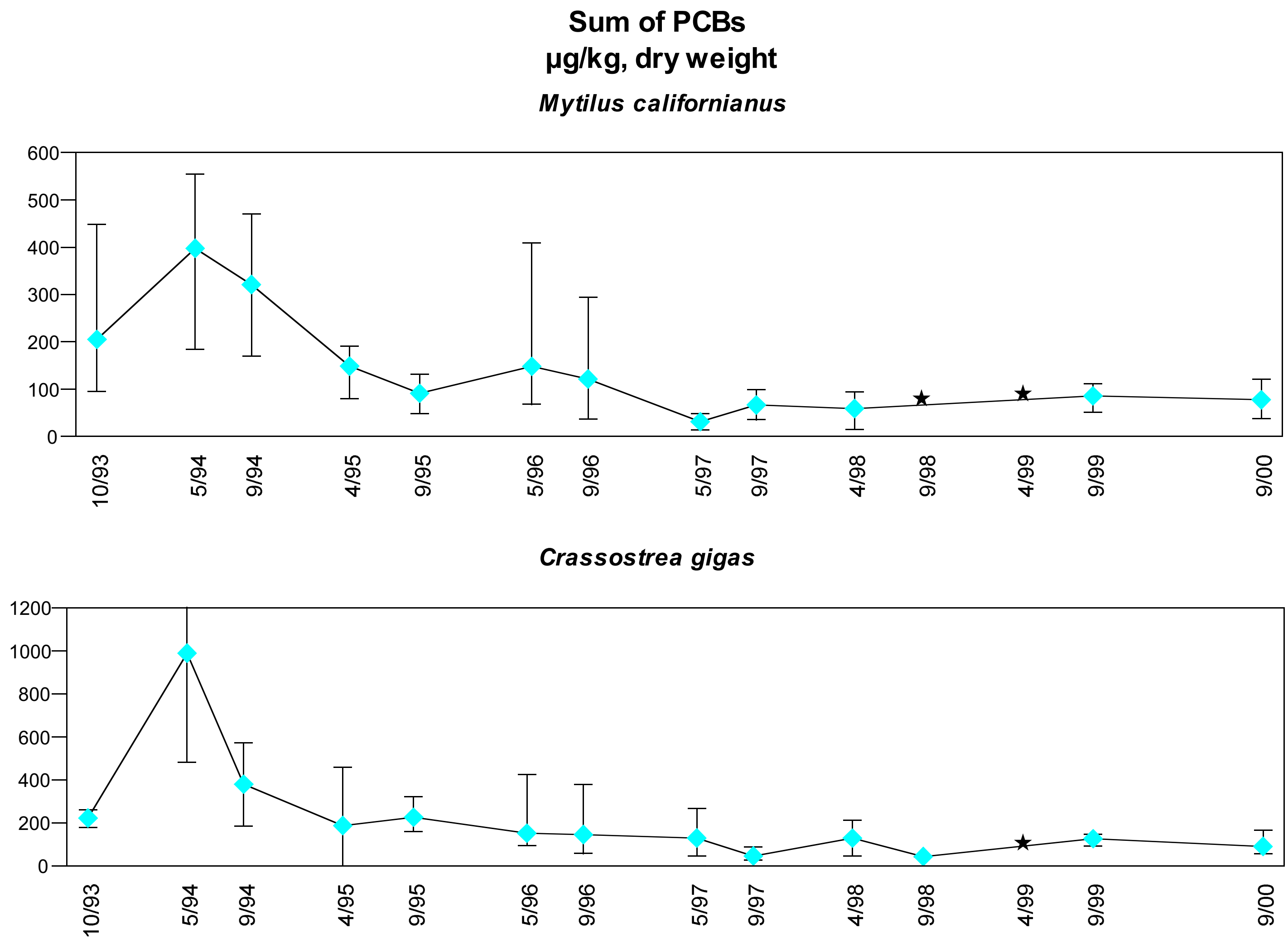


Figure 4.25. PCB accumulation or depuration in parts per billion dry weight (ppb) in two species of transplanted bivalves for 14 sampling periods from 1993–2000 (mean of all stations). Accumulation or depuration was calculated by subtracting initial tissue (T-0) concentrations from concentrations after deployment. Bars indicate range of values within a sampling period.
★ means no analyzed data available.

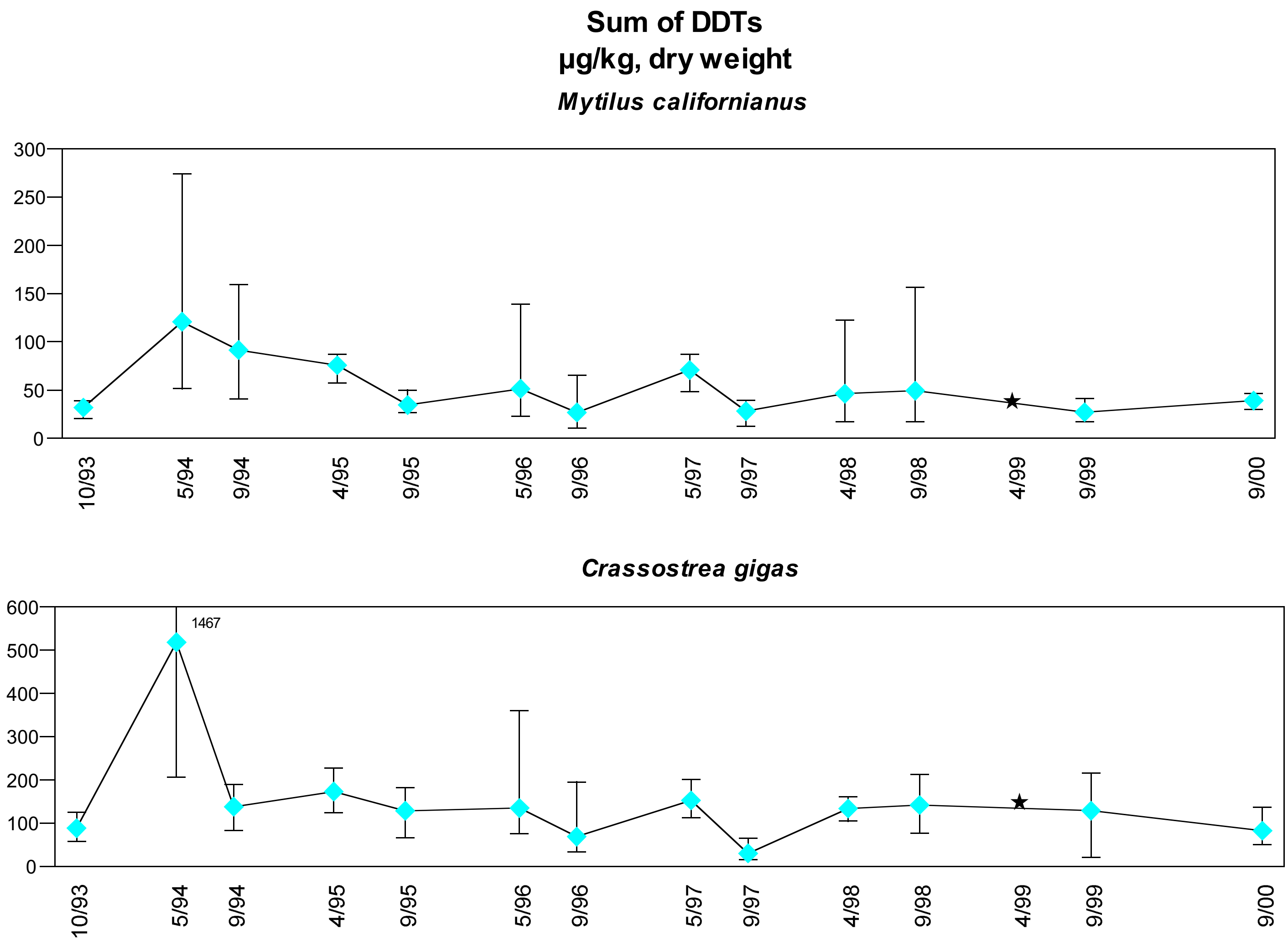


Figure 4.26. DDT accumulation or depuration in parts per billion dry weight (ppb) in two species of transplanted bivalves for 14 sampling periods from 1993–2000 (mean of all stations). Accumulation or depuration was calculated by subtracting initial tissue (T-0) concentrations from concentrations after deployment. Bars indicate range of values within a sampling period.
★ means no analyzed data available.