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A SURVEY OF THE TRACE-METAL CONTENT OF *Corbicula fluminea* AND ASSOCIATED SEDIMENTS IN THE TIDAL POTOMAC RIVER

by

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ABSTRACT

Concentrations of selected trace metals cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), lead (Pb), zinc (Zn) were determined in *Corbicula fluminea* tissue and associated sediments from the tidal Potomac River. The relationship between sediment and tissue values was examined as well as the trace-metal-to-age and trace-metal-to-dry-tissue weight relationships of *Corbicula*.

The conclusions derived from this study indicate that metal-to-age and metal-to-dry-weight trends in *Corbicula* can differ considerably from organisms collected in sand or to those collected in mud. Also, differences in metal-to-age and metal-to-dry-weight occur depending upon from what part of the river *Corbicula* was collected. Some sections are greatly influenced by effluent, others are more distant from effluent sources. There was no correlation between tissue trace-metal values and sediment values, which may reflect the hydrodynamics of a major river such as the Potomac rather than a physiological partitioning of the sediment trace metals.

INTRODUCTION

The Asiatic clam of North America, *Corbicula fluminea*, has generated interest in recent years because of its ability to quickly establish itself in freshwater systems and to do so in such abundance as to cause negative economic results in certain freshwater-oriented industries (e.g., *Corbicula* clog intake and discharge pipes in electrical power plants). Indigenous clam populations and other riverine or limnetic communities have also been negatively affected. Conversely, because of *Corbicula's* abundance, it may have positive applications in aquaculture or as environmental monitors.

The objectives of this study were to determine concentrations of selected trace metals (Cd, Cr, Cu, Fe, Mn, Pb, Zn) in *Corbicula fluminea* and in associated sediments from the tidal Potomac River. The relationship between sediment and tissue values was examined as well as the trace-metal relationship to age and to dry-tissue weight.

METHODS

Ten transects were sampled from April 23 to July 1, 1980. Nine transects were located in the tidal Potomac River and one was located in the tidal Anacostia River (Fig. 1). In most instances, each sampling transect was represented by a Maryland (Md), channel (ch), and a Virginia (Va) component. Distances are given in river miles (nautical miles distant from the mouth of the Potomac River) and are followed by an abbreviation showing the river sampling site, e.g., 92Md. An attempt was made to collect a minimum of 10 clams per transect (minimum of 3 per site) representing the various age groups. A total of 110 *Corbicula* was collected ranging in size from 7 mm to 39 mm. For this study, the shell length of *Corbicula* is transposed with age, because the two are correlated in *Corbicula*. However, shell length is not translated into a specific age class in this study; that is beyond the scope of this presentation.

Once the clams were retrieved, they were left in the aerated containers for 24 hours to allow purging of digestive tracts and gills. Subsequently the clams were shucked to obtain wet and dry weights, and transferred to class A volumetric flasks for digestion in concentrated nitric acid. The

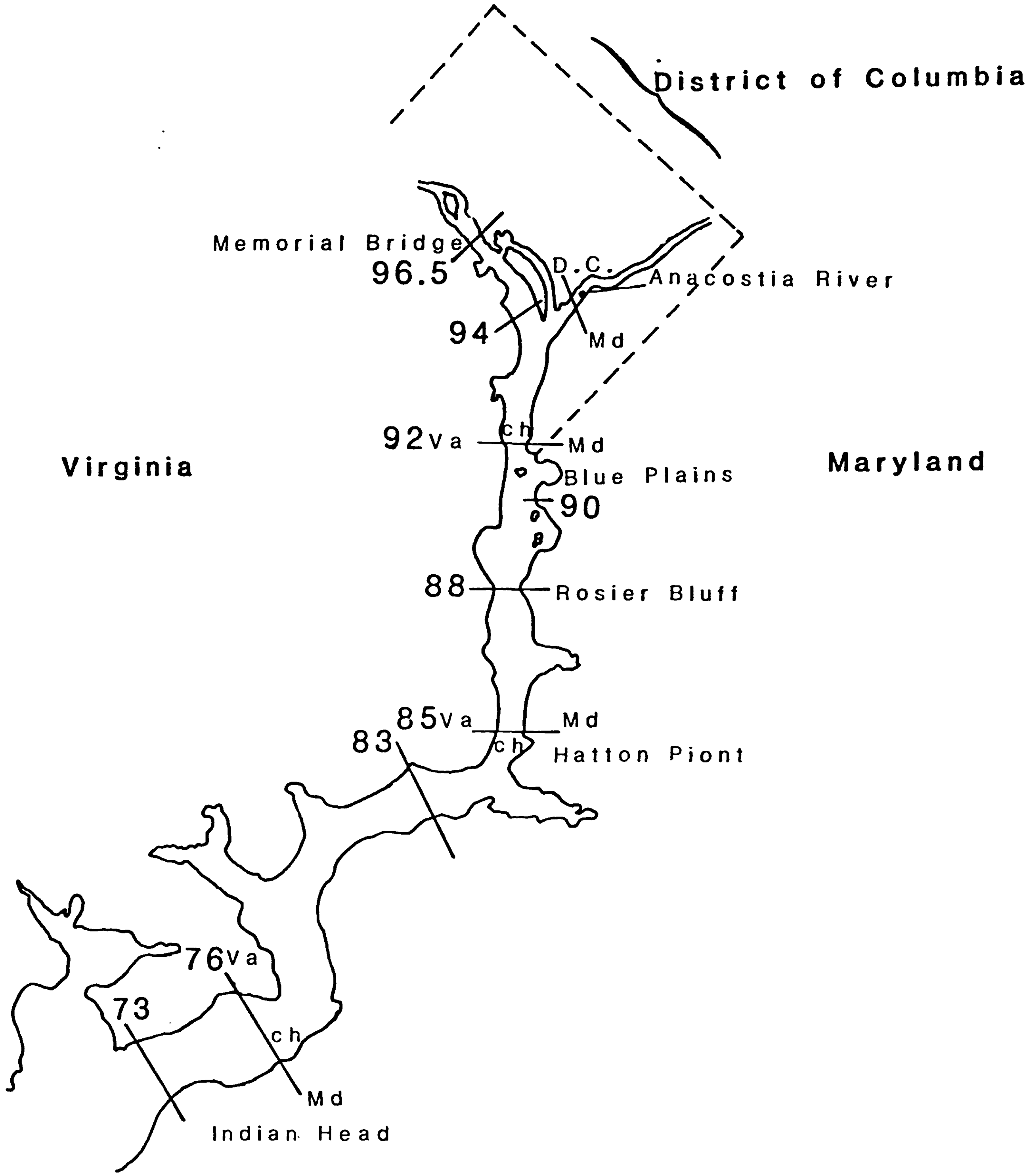

Figure 1.

Tidal-Potomac River sampling transects

Va, Virginia; ch, channel; Md, Maryland

numbers represent nautical miles distant from mouth of Potomac and transect numbers final volume in the flasks represented a 60-80 percent nitric acid solution and subsamples of this final volume were used for dilutions (when necessary) for analysis of Cd, Cr, Cu, Fe, Mn, Pb, and Zn by atomic absorption spectrophotometry. Cu, Fe, Mn, and Zn were analyzed on a Perkin-Elmer 4000 flame spectrophotometer and Cd, Cr, and Pb were analyzed on a Perkin-Elmer 360 flameless spectrophotometer. The atomic absorption procedure was checked for accuracy and reproducibility by analyzing oyster tissue standards from the U.S. National Bureau of Standards. The results are shown in Table 1. Signal depression occurred in the analytical instrumentation for some elements, notably Cr (Table 1), because of the strong acid medium required for tissue dissolution.

Table 1. National Bureau of Standards (NBS) oyster tissue metal values compared to values obtained for this study.

NBS values (ppm)		This study (ppm)	
Cd	3.5 ± 0.4	Cd	3.8 ± 0.6
Cr	.69 ± 0.27	Cr	.49 ± 0.24
Cu	63.0 ± 3.5	Cu	59.18 ± 1.73
Fe	195 ±34	Fe	177 ±13.5
Mn	17.5 ± 1.2	Mn	16.23 ± 0.79
Pb	0.48 ± 0.4	Pb	0.49 ± 0.04
Zn	852 ±14	Zn	844 ±11

Sediment samples were also acid leached with concentrated nitric acid and analyzed for the same trace metals as the tissue samples. Sediment texture was determined by a Coulter TA-II fine-particle analyzer for the mud fraction and a rapid-sand analyzer was used to determine sand fraction values. An induction furnace was used to determine carbon concentrations.

RESULTS

Sediment

To give a better overview of the distribution pattern for sediment trace metals, sediment trace-metal values (Tables 2 & 3, Figs. 2, 3, 4, & 5) represent all samples taken, including those sites where no *Corbicula* was found. When sediment trace-metal values were compared to *Corbicula* tissue values, only sediments that contained *Corbicula* were considered. Most sampling sites were characterized by mud sediments. However, sites 73Md, 76Md, 83Md, 85ch, 88Md, 88ch, and 96.5 (no *Corbicula* present at river mile 96.5) were sand dominated. Overall, sediment texture data and sediment trace-metal data are shown in Tables 2 and 3. As expected, the highest average trace-metal values were in the mud fractions rather than in sands (Table 3).

There is a general overt trend for Cd, Cu, Cr, and Pb to decrease in concentration down river; Fe, Mn, and Zn are erratic by comparison, but still diminish in average value down river (Table 2, Fig. 6). As a result of this erraticism, the averages of these elements for each transect are given (Fig. 6) rather than for each site as in Figs. 2, 3, 4, & 5.

Corbicula

Corbicula tissue trace-metal values and sediment trace-metal values correlated very poorly to one another. In comparing overall tissue values to shell length or to dry-tissue weight, correlations were poor. Clams were divided into those found in sand and in mud, and further segregated into those obtained from river miles 73 to 88 and those from river miles 90 to 96.5 inclusive (Figs. 7, 8, 9, & 10). This was done for two reasons. The first was to compare trace-metal trends in *Corbicula* according to the sediment texture in which they were found; secondly, to compare trace metal trends in Corbicula found in two parts of the Potomac River based on average sediment trace-metal values (Tables 4 & 5). River miles 90-96.5 had higher concentration averages for sediment trace metals than river miles 73-88 because of their proximity to effluent sources (Tables 2 & 3, Figs. 2, 3, 4, 5 & 6).

Figures 7 & 8 show the relationship between the various trace-metal concentrations and shell lengths (age) for Corbicula found in sand or mud in each of the two river segments. An r (correlation coefficient) value for all trends is given in each graph.

For river miles 73-88, sand sediment Cd demonstrates a good negative (inverse) correlation (-.71) indicating a decrease in Cd concentration with increasing age (Fig. 7). Cr and Mn show no correlation to shell length, while Cu has a weak positive correlation of .65. Fe has a poor correlation to shell length (.35), but still demonstrates a general trend to increase in concentration with increasing age. Pb and Zn appear to be very erratic. Zn, however, indicates a rough trend toward its increased accumulation with increasing age.

Similar trends are observed or enhanced in the mud sediment of river miles 73-88 (Fig. 7). Cd has an unusual trend that may be curvilinear; this trend may imply that increased concentration occurs with increasing age beginning at a particular age or shell length. Cr is erratic as it was in sand. Cu shows a positive, though weak, correlation of .51 between its increasing metal concentration and increasing shell length. Pb is apparently indiscriminately taken up while Zn demonstrates a good positive trend (.66).

The trace-metal values to shell length of Corbicula in mud for river miles 90-96.5 (Fig. 8) show a distinct departure in trends from Corbicula

Table 2. Comparison of average trace-metal values (ppm) of all sampling sites for river mile sections 73-88 and 90-96.5.

	73-88	90-96.5	% increase over 73-88
Cd	.45	1.21	63
Cr	33.25	54.56	39
Cu	17.42	35.30	51
Fe	28,336.69	33,888.56	16
Mn	601.25	895.42	33
Pb	21.67	60.67	64
Zn	150.59	251.42	40

Table 3. Comparison of average trace metal values (ppm) and textural data for each sediment type in each river section (96.5ch omitted since only sand representative for 90-96.5.

	73-88 sand	76-88 mud	90-96.5 mud
Cd	0.266	0.616	1.214
Cr	24.23	40.98	54.56
Cu	12.19	21.91	35.30
Fe	24,313.33	31,785.29	33,888.56
Mn	479.80	705.34	895.42
Pb	16.52	26.09	60.67
Zn	98.99	194.81	251.42
%sand	74.18	18.89	18.09
%mud	25.82	81.11	81.91
average phi size	3.02	6.10	6.48
sand/mud ratio	3.34	0.28	0.24
average % of organic C	2.38	2.40	3.04

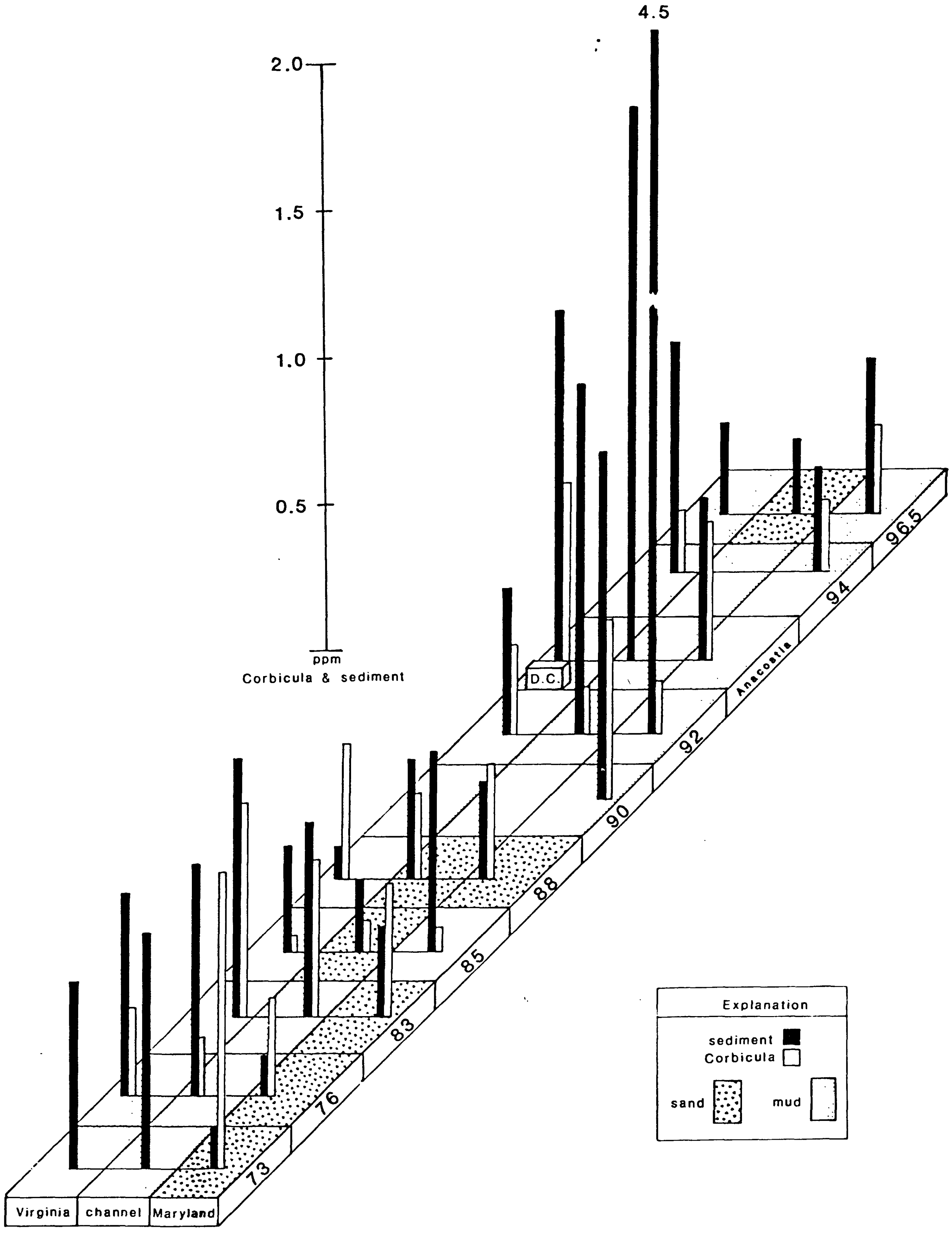

Figure 2. Cd values (ppm) for **Corbicula** and sediment

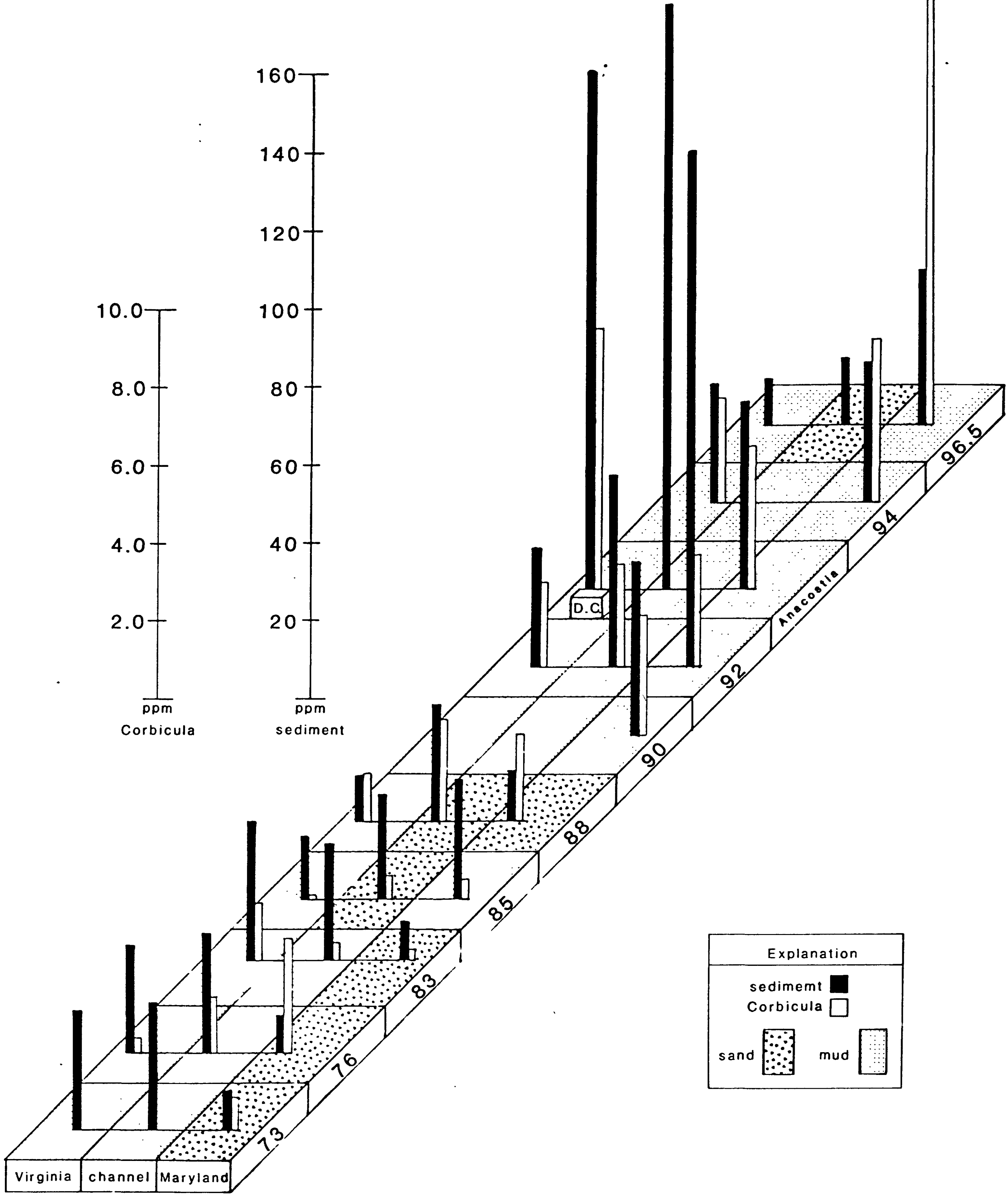

Figure 3. Pb values (ppm) for **Corbicula** and sediment

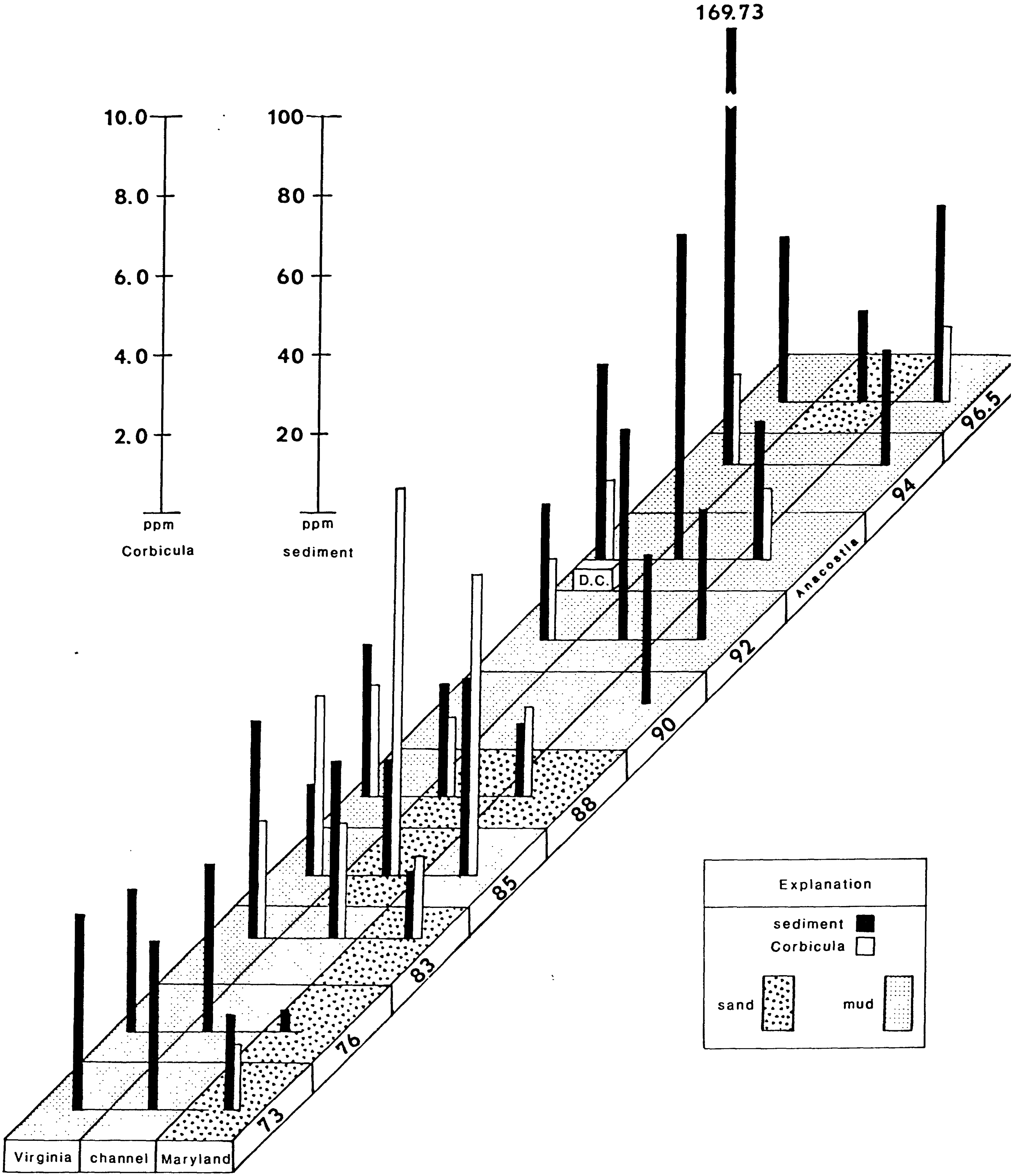

Figure 4. Cr values (ppm) for Corbicula and sediment

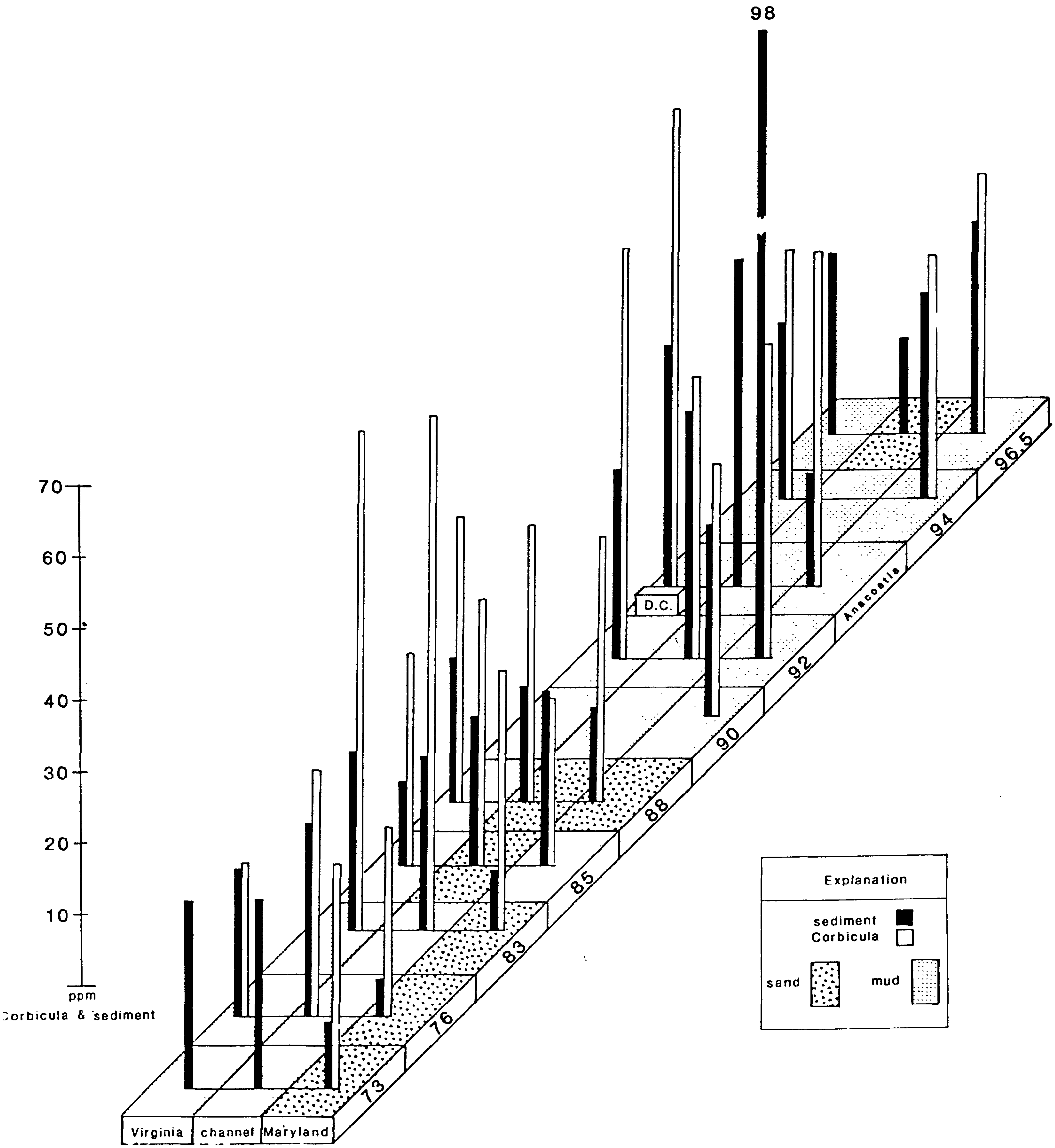

Figure 5. Cu values (ppm) for Corbicula and sediment

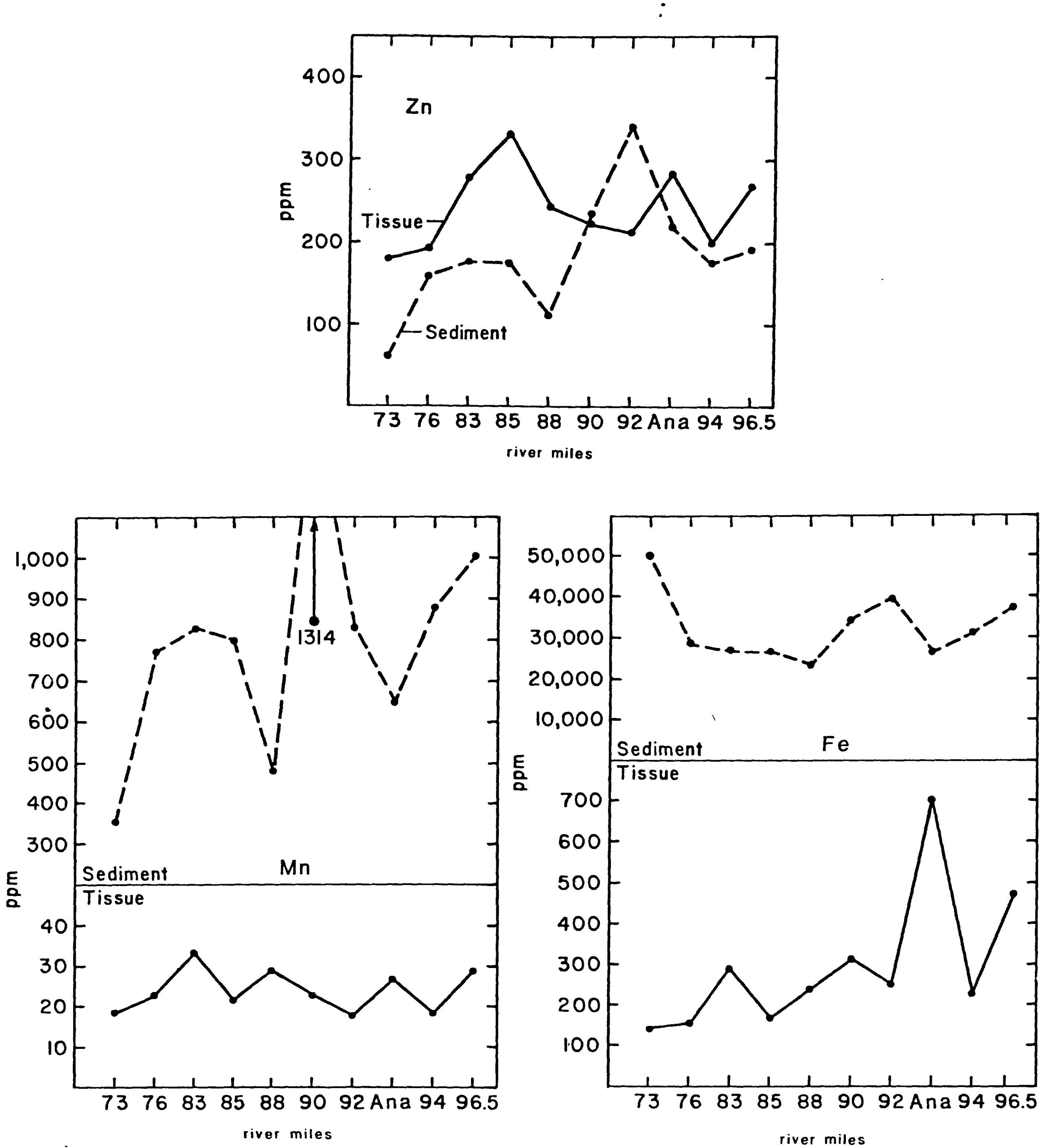

Figure 6. Average trace-metal values for Zn, Mn, and Fe in *Corbicula* and associated sediment for each transect

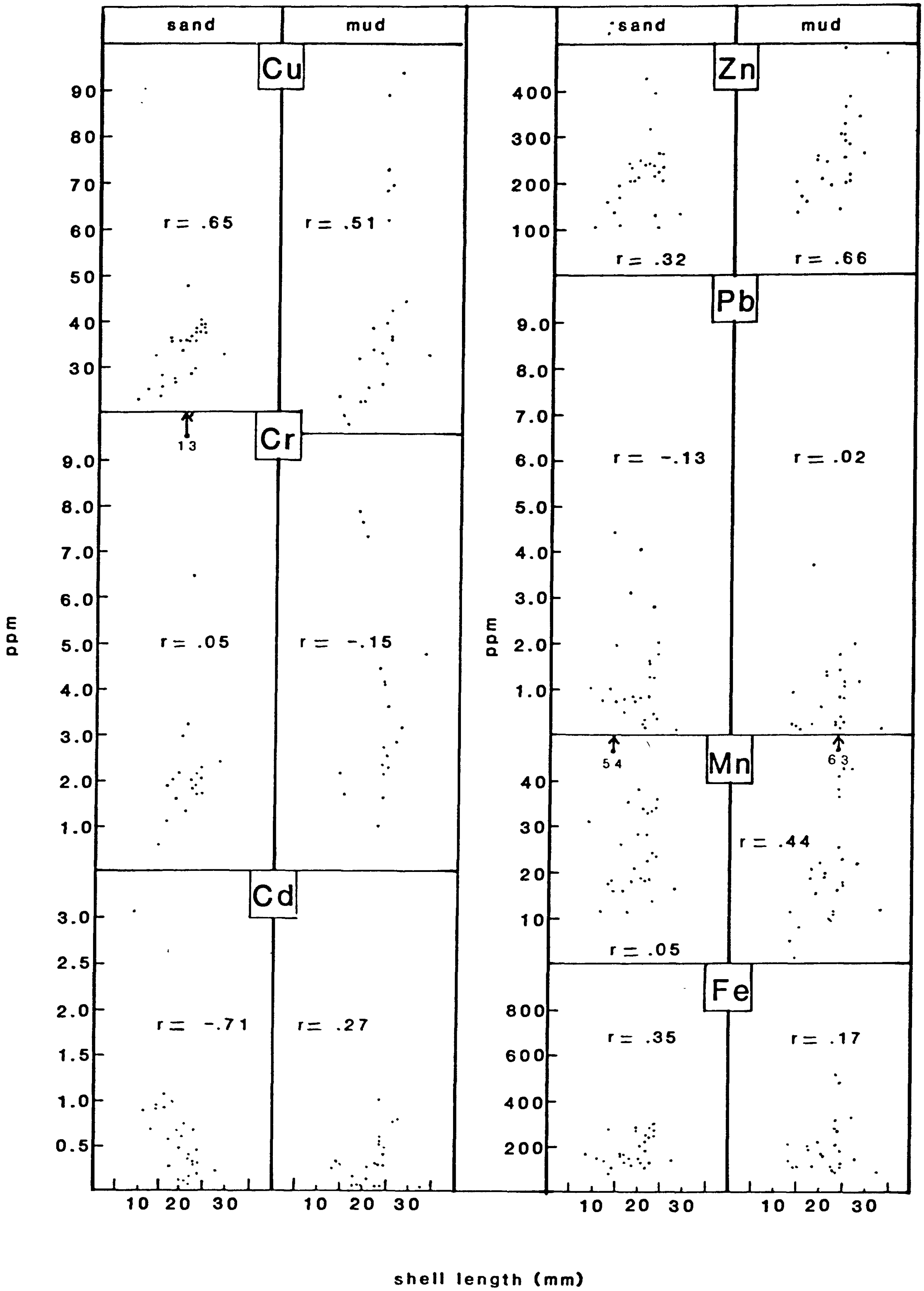

Figure 7. Tissue trace-metal values versus shell length of Corbicula (river miles 73-88)

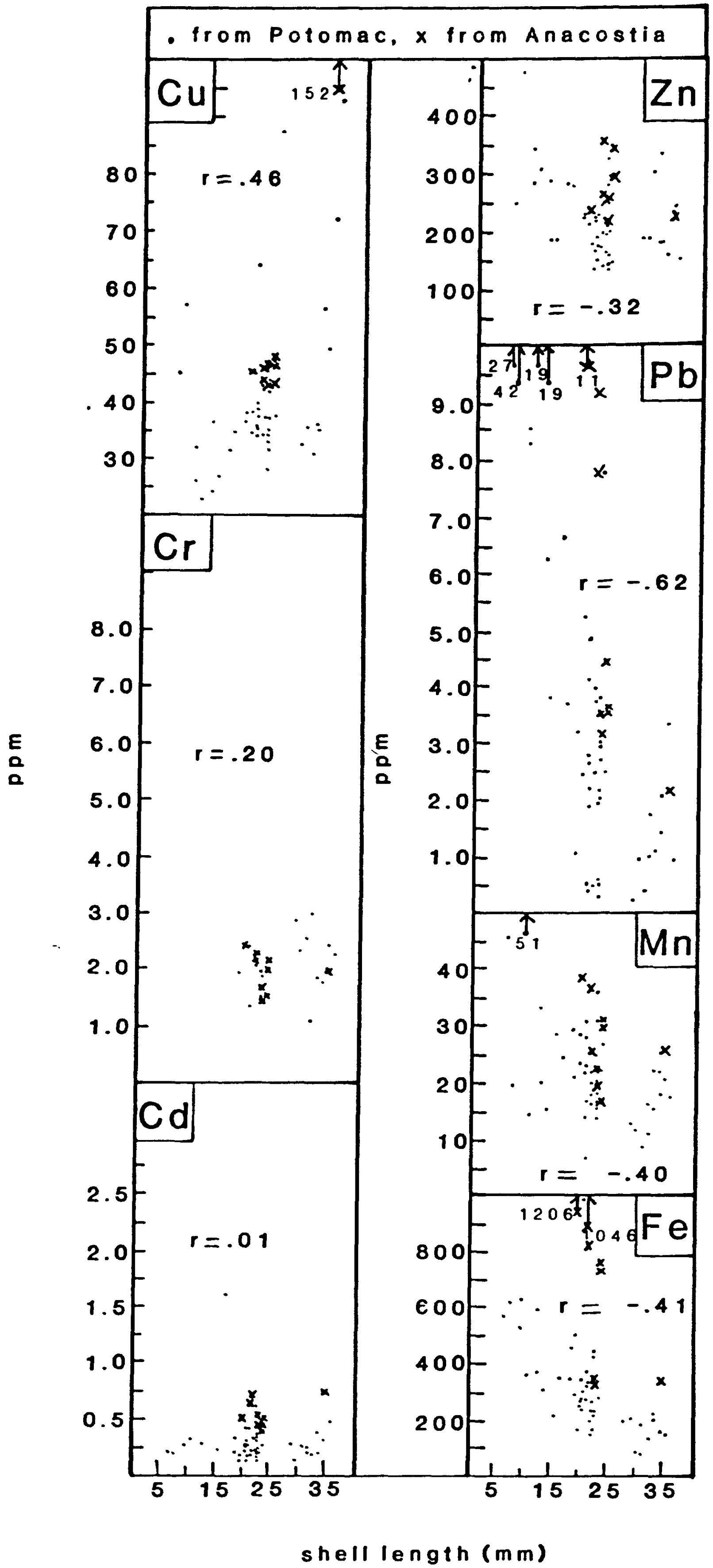

Figure 8. Tissue trace-metal values versus shell length of **Corbicula** (river miles 90-96.5,mud only)

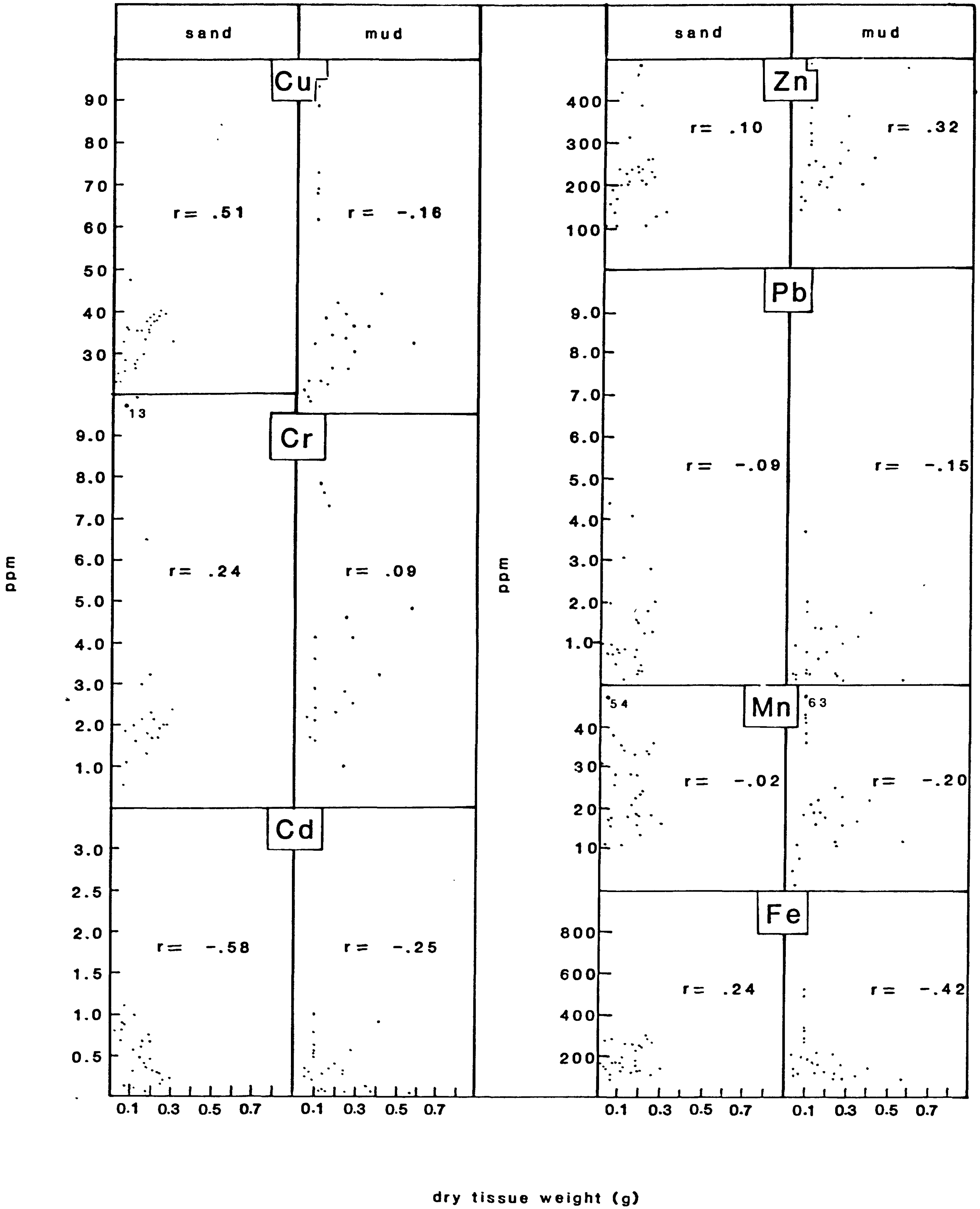

Figure 9. Tissue trace-metal values versus dry tissue weight of *Corbicula* (river miles 73-88)

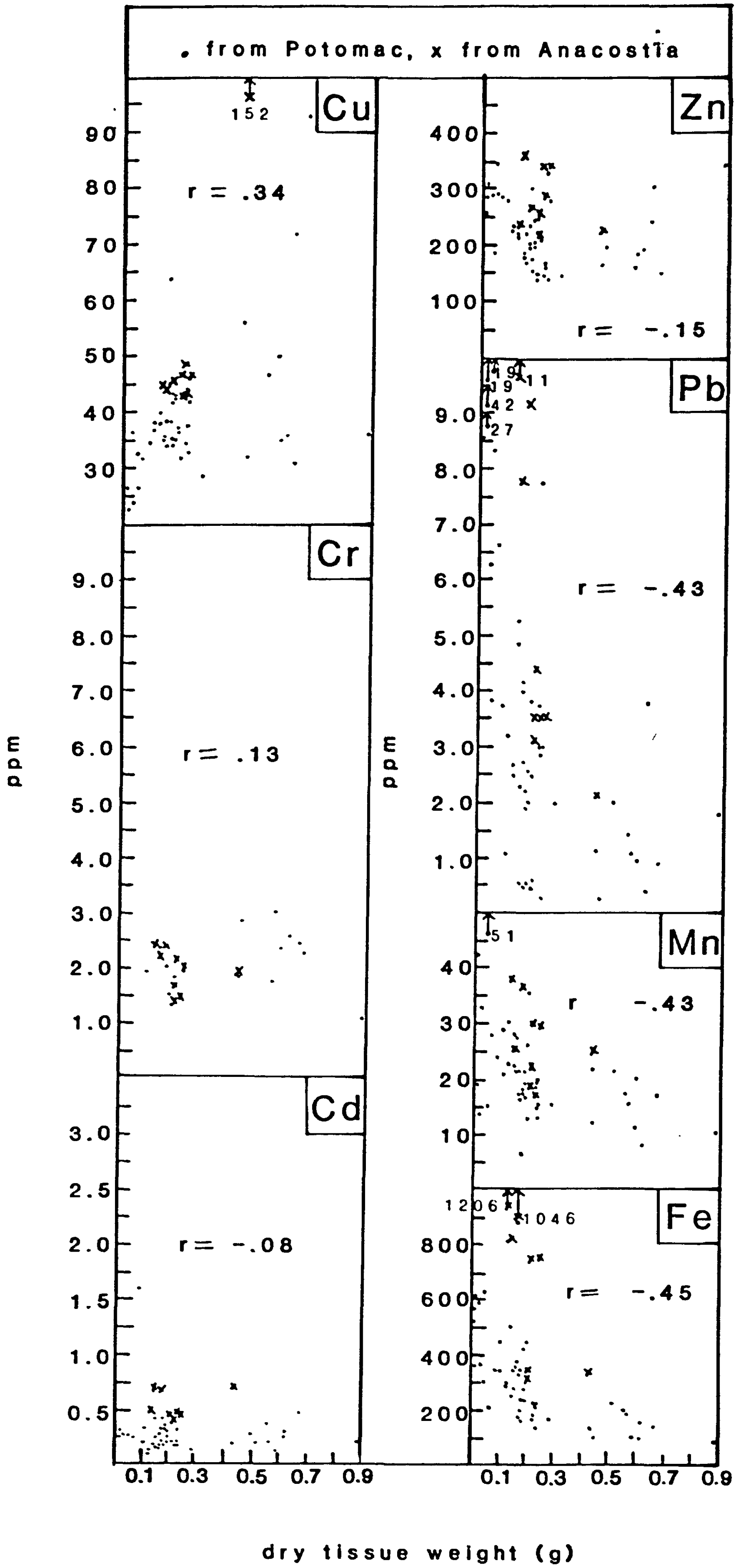

Figure 10. Tissue trace-metal values versus dry tissue weight of Corbicula (river miles 90-96.5,mud only)

collected from river miles 73-88, except for Cd. Of particular note for this group of Corbicula is the appearance of a second population of Corbicula. Specifically, there is a population from about 28 mm to 37 mm that mirrors the trends of the younger population (6-25 mm) on the left of each graph. This results in misleading r values at times, consequently they are not emphasized. There were too few representatives of this second group to consider them for separate statistical analysis. Therefore, in viewing overall trends of the trace metals, this second group is considered with the whole sampled population.

Cd best demonstrates the existence of the two Corbicula populations. There is a propensity to increase Cd values with increasing shell length at a certain point in their lives as was implicated in Corbicula collected in mud for river miles 73-88. For the younger group, accumulation seems to begin around 20 mm, and for the older group, around 33 mm. Before this tendency to accumulate Cd, an upper limit seems to be maintained. Cr shows no relationship to shell length for each group. Overall, there is a weak positive trend to accumulate Cr with increasing age. Cu shows a poor, but generally, positive trend with increasing shell length. Fe has a distinct inverse correlation with shell length and is a departure from river miles 73-88 sand and mud trends for Fe. The r value for Fe in this instance is low because of five Corbicula from the Anacostia River with high concentrations. Mn also demonstrates a poor but general tendency to decrease in concentration with increasing shell length, and Zn too displays an erratic inverse correlation to shell length.

If this second population, above 28 mm (Fig. 8), is considered separately from those on the left (less than 28 mm), there appears to be a reversal of trends for some elements (e.g., Pb and Mn). Again, there were not enough data points to make definitive statistical conclusions in these cases. Observations concerning this second group are presented in the Discussion section of this report.

Figures 9 & 10 show the trends of tissue trace-metal values compared to dry tissue weight. These are arranged in the same manner as Figures 7 & 8 described above.

Beginning with Corbicula found in sand (river miles 73-88), Cd shows a good negative correlation to the tissue weight (the three low values to the left are from one site, 85ch) (Fig. 9). Cr shows a weak but general tendency to accumulate with increasing tissue weight (the three highest values are from 85ch). Cu shows a positive trend toward accumulation with increasing body weight. Fe shows a very weak positive correlation with increasing tissue weight, while Mn and Pb have no correlation. The Zn trend is curvilinear and therefore, has a poor r value of .10; Zn probably accumulates with increasing tissue weight for the three high values are from 85ch and the three low points on the right seem equally unrepresentative of the main sequence (these three are from two other sites).

The Corbicula in mud sediment from river miles 73-88 demonstrates some erratic relationships between the trace-metal concentration and dry-tissue weight. As shown in Figure 9, at the 0.1 g mark for Corbicula found in mud, there is a consistent 6-point vertical component for all elements that, at times, deviates from the main sequence for each trace metal to tissue-weight relationship. These are Corbicula from river mile 83. This group does not always represent the majority of Corbicula collected in their relationships to trace metal uptake or to their weight versus shell length (Fig. 11). As such, they too can give erroneously weak r values when comparing metal concentrations to dry weight. Again, for the sake of consistency, they are included in all calculations.

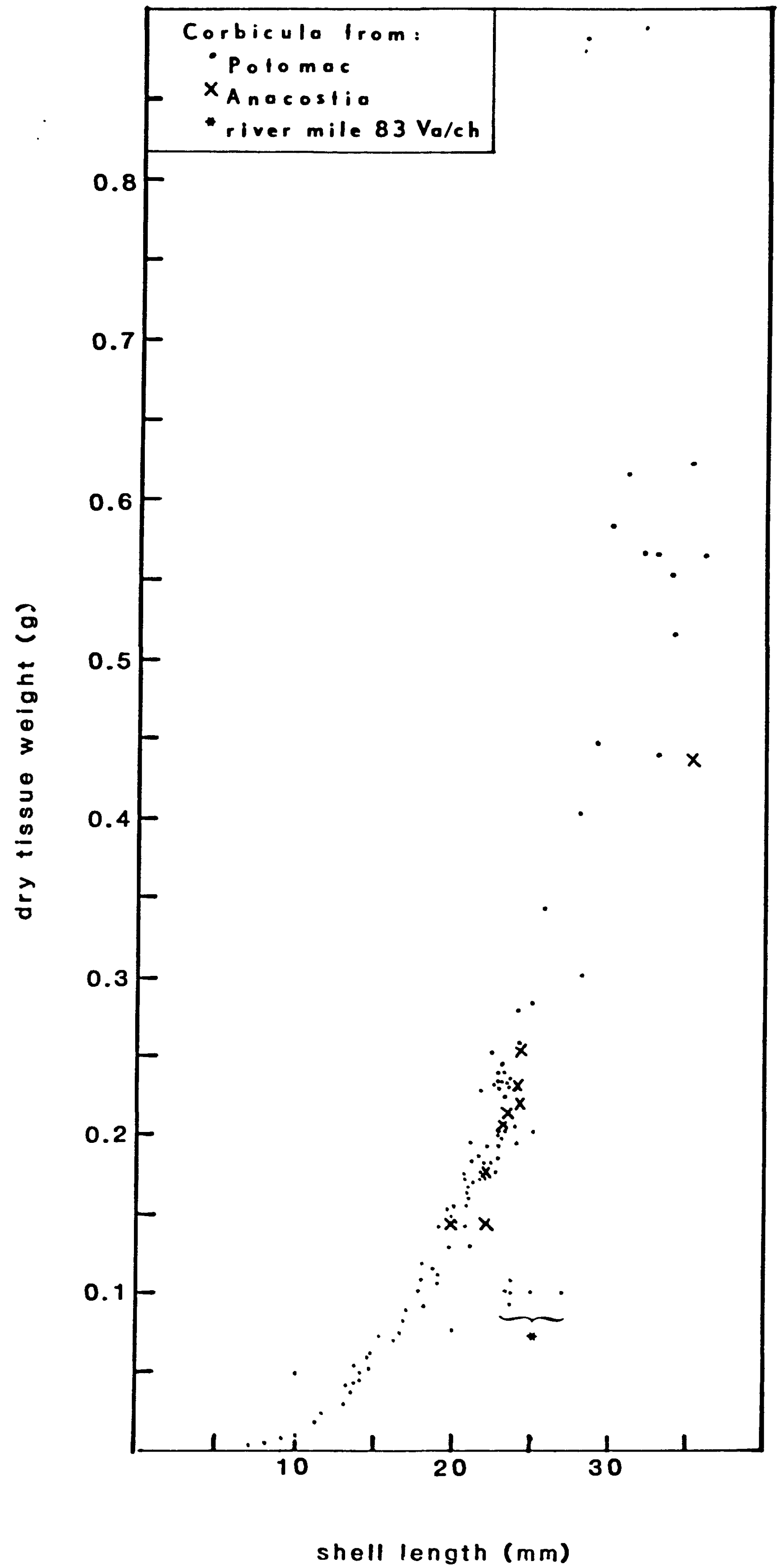

Figure 11. Shell length versus dry tissue weight for all collected **Corbicula**

Cd demonstrates three separate lines or trends; the vertical trend is represented by Corbicula from river mile 83, the horizontal one is Corbicula from river mile 85, and the diagonal trend is the remaining Corbicula which probably represents the typical trend. Exclusive of Corbicula from river miles 83 and 85, Cr and Cu increase with increasing tissue weight. Fe shows a fair inverse correlation to tissue weight; a correlation that would be numerically improved without the vertical component at 0.1 g. Mn shows no discernible relationship to tissue weight. Pb shows an amazingly similar trend to Cd; the trends or lines in Pb involve the same Corbicula from the same sites as in Cd. Zn demonstrates an increase with increasing tissue weight (again, exclusive of specimens from 83 at 0.1 g).

For river miles 90-96.5, the tissue metal concentrations to dry-tissue weight of Corbicula found in mud (Fig. 10) also demonstrates the existence of two populations, as previously mentioned. Cd and Cr show no apparent relationship to tissue weight, but the heavier group to the right has a higher average metal concentration than the group on the left, implying a possible overall positive correlation. Cu, overall, becomes very erratic beyond 0.4 g; up to this weight, a positive correlation exists, though scattered. Fe, Mn, and Pb show very similar patterns or relations to tissue weight, each being an inverse relation to weight. Zn demonstrates virtually no trending.

DISCUSSION

Sediment

At least two general surveys have been made of the sediment trace-metal content of the upper Potomac River (Pheiffer, 1972, Martin and others, 1981). Their values, in and near areas covered in this study, are similar. The largest difference occurs in comparing Cd results of this study to

Pheiffer's; our values are approximately twice those of Pheiffer's and the Mn trends are reversed. Pheiffer demonstrated that there is a great seasonal variability in the concentrations of trace metals for a major river like the Potomac; Troup and Bricker (1975) observed the same phenomena for Susquehanna River sediments. They noted that trace-metal concentrations in rivers vary greatly as a function of discharge rate, suspended load (sediment), and the time of year. Consequently, the availability of trace metals to organisms will also vary. Trace-metal concentrations vary greatly between different rivers (Troup and Bricker 1975) and within the length of the river itself (Forstner and Wittman 1981), there may be large gradients in trace-metal concentrations if the river receives urban and industrial effluent, as the Potomac does. In and around the Washington, D.C. metropolitan area, there are numerous outfalls into the Potomac; the two prominent effluent sources are the Blue Planes sewage treatment plant at river mile 92 on the Virginia side and the Potomac Electric and Power Company (PEPCO) thermal effluent at river mile 92.5 on the Maryland side. These particular outfalls are apparently sources of large quantities of various trace metals (Pheiffer 1972). Cd, Cu, Pb, and Zn were highest for the Potomac sediments near these two sources in this study (river mile 92, Figs. 2, 3, 4, 5, & 6).

From river mile 88 at Rosier Bluff to river mile 73 at Indian Head, effluent discharges into the Potomac are considerably reduced as reflected in the average sediment trace-metal content (Table 2). Fe and Mn show great variability and are probably reflective of the organic detritus, phytoplankton, and regional geochemistry. Cr values were fairly consistent except at river mile 94, Virginia side. At this site, the Cr value for sediment is almost three times higher than for any other portion of the Potomac sampled; there are no outfalls in this area. There are at least two possible explanations for this high Cr content. The first is that this area is adjacent to an old discontinued spoil area; a second and purely speculative source may be the Washington International Airport which is directly in front of this sampling site. Runoff from the runways after rain or snow storms may be a source of Cr because commercial jet fuels utilize Cr additives as antioxidants (Valkovic, 1978) and to a limited extent, to enhance electrical conductivity of the fuel (Boldt and Hall, 1977). It can also appear as a wear metal in used oils. The elevated Cr value in the Anacostia River (82.07 ppm) probably comes from an outfall in the area. The Anacostia, being a small river, does not have the volume or velocity of water to adequately flush out some of the metals that have been accumulating over the years, especially in its channel.

As is expected, sand sediments contained fewer concentrations of trace metals than mud sediments (Table 2). This is another variable in the availability and toxicity of trace metals (Pesch, 1979) to a predominantly infaunal organism such as Corbicula.

Corbicula

As noted earlier, trace-metal analyses of Corbicula are few; their shells were analyzed for Pb (Clarke and others, 1979) and their accumulation rates and behavioral reactions examined under various conditions (Rodgers and others, 1979, 1980). Rodgers and others analyzed the sediment trace metals associated with Corbicula, but made no definitive statement concerning the relationship between Corbicula metal values and sediment metal values. In this study, the correlation of sediment trace-metal values to tissue values was poor (Figs. 2, 3, 4, 5, & 6). Studies of freshwater clams (Mathis and Cummings, 1973; Mathis and others, 1979; Mattice, 1979) show a correlation between clam and sediment metal values.

These studies, however, were made in streams, ponds, or a small river where the amount of suspended material, volume of water, and water velocity are considerably reduced compared to those of a major river such as the Potomac. Therefore, by increasing the role of a river's hydrodynamic properties, the sediment trace metal to organism trace-metal relationship will probably become more obscure.

Unlike the average sediment values for the metals from river miles 90-96.5 that exceeded all the average values of those from river miles 73-88, peak values for Corbicula were mixed between the two river sections. That is, Cd and Cr were highest for river miles 73-88; Cu, Fe, and Pb were highest for river miles 90-96.5, and Mn and Zn were almost identical in Corbicula from either river segment. The number of variables that may affect the trace metal uptake of an organism can be legion (Vernberg and Vernberg, 1974; Perkins, 1974; Cossa and others, 1979; Forstner and Wittmann 1981; Harrison and Martin, 1982). Of particular note for this study regarding variables is that the average length for those Corbicula found from river miles 73-88 and 90-96.5 are quite close (20.7 mm and 22.3 mm respectively), placing them in virtually the same age class. However, their average dry tissue weights differ by more than 50 percent (Table 4). The group from river miles 90-96.5 is heavier and has a lower percentage of water loss than those from river miles 73-88. These differences may reflect the general health and condition of Corbicula in each section of the river as well as differences between each river section. The reason Corbicula would be heavier and have less water loss (implying healthier) in the more contaminated upper portion of the Potomac River is highly speculative. The influx of thermal effluent (Mattice, 1979; Rodgers, and others, 1979) and sewage may provide a better growth medium than farther down river where these influences are much diminished or diluted. The increase of certain trace metals under these conditions may be beneficial. Some metals that were thought to have no metabolic significance have been proven otherwise, e.g., Cr (Mertz, 1981).

Figure 11 shows the typically good relationship of dry weight to shell length for Corbicula. Some Corbicula fall noticeably outside the main sequence of the relationship; specifically, all the Corbicula from river mile 83 channel and Virginia segments (Fig 6). The implication is that something in this vicinity has caused this group to depart from the normal weight-to-length relationship. Whatever factor caused their departure from the mean also manifests itself in their trace-metal uptake causing them to accumulate higher amounts of metals than other Corbicula of the same weight and age class. Water temperature may have been a factor because these particular Corbicula were collected at 15°C while the rest were collected at elevated water temperatures. The effects of temperature, however, may be nominal in this case. Corbicula collected at the same time on the Maryland side show no deviation nor do those collected in 17°C water at river mile 73.

Concentration maxima of the metals are similar for Corbicula whether found in mud or sand. Major exceptions are Corbicula found in the Anacostia River and the elements Fe and Pb (Tables 4 & 5, Figs. 2, 3, 4, 5 & 6). Of particular importance and significance is that the pattern of uptake seems to vary with sediment type (sand or mud) and river segment. Describing mechanisms of cause and effect in the metal uptake trends are beyond the scope of this study. The trends, however, lend themselves to some interpretation concerning the general implications of trace-metal content to Corbicula's age, weight, and associated substrate.

The Cd trend in Corbicula found in sand is distinctly inverse to age for this study (Fig. 7). However, the trend is practically reversed for

Table 4. Comparison of average trace-metal values (ppm) and physical data for *Corbicula* from their respective river segments.

	73-88	90-96.5
Cd	0.484	0.325
Cr	3.33	2.03
Cu	37.23	42.68
Fe	196.04	361.95
Mn	23.81	22.11
Pb	1.13	4.90
Zn	240.31	234.13
average length	20.7 mm	22.3 mm
average dry tissue weight	0.160 g	0.238 g
% water loss	87.06	83.86

Table 5. Comparison of average trace-metal values (ppm) and physical data for *Corbicula* tissue from each sediment type and respective river segment.

	73-88 sand	76-88 mud	90-96.5 mud
Cd	0.61	0.34	0.33
Cr	3.07	3.62	2.03
Cu	33.53	41.38	42.68
Fe	189.46	203.41	361.95
Mn	24.98	22.49	22.11
Pb	1.32	0.90	4.90
Zn	215.25	267.35	234.13
average length	19.36 mm	22.1 mm	22.3 mm
average dry tissue weight	0.144 g	0.179 g	0.238 g
% water loss	85.95	88.29	83.86

Corbicula found in mud where it appears curvilinear and positively correlated to age (shell length). A possible explanation may simply be that the sand bottom is indicative of a faster moving water column which would cause less exposure time to Cd in the water column and afford better flushing of accumulated Cd in both organism and sediment. The relationship between dry tissue weight and Cd concentration in Corbicula found in sand (Fig. 9) is similar to the one for shell length (Fig. 7). Those found in mud have an erratic tissue-weight to concentration relationship.

As noted in the results, river miles 73-88 have erratic Cd patterns because of two specific groups--clams from river miles 83 and 85. Clams from river miles 90-96.5 had no correlation with Cd to dry tissue weight. Weak to good trends are shown for Cr, Cu, Fe, and Zn while no correlation is shown for Mn and Pb. The consistent similarity between weight-to-metal and age-to-metal concentration plots of Corbicula found in sand is not manifested in Corbicula found in mud. Being in or associated with a mud substrate seems to cause changes in tissue-to-metal and age-to-metal relationships.

The shell length to tissue-metal relationships for Corbicula found in mud for river miles 90-96.5 (Fig. 8) show two distinct differences compared to those Corbicula found in mud for river miles 73-88. First, some correlations are reversed; Fe, Mn, Pb, and perhaps Zn and Cr while trends are essentially the same for Cd and Cu. The second important difference is the appearance of what seems to be a second group of Corbicula in the river miles 90-96.5 section; this is best demonstrated for Cd. This second group appears from 28 mm on, and the representatives of this group are not confined to any one sampling site. They may represent a different year class or a group that grew faster as a result of more optimal conditions (Rodgers and others, 1979). Corbicula populations can become very dense.

Location of an individual clam in this densely packed population could govern its accessibility to nutrients and pollutants. Additionally, the concentrations of trace metals in sediments can affect the burrowing behavior of infaunal organisms (McGreer, 1979; Stirling, 1975; Pesch, 1979; Stephenson and Taylor, 1975; Akberali, 1981). In these cases, as sediment metals increased in concentration, burrowing activity decreased. The burrowing behavior of larger Macoma was affected more than smaller individuals (McGreer 1979). Avoidance of burrowing into contaminated sediment might cause a predominantly infaunal species, such as Corbicula, to become predominantly epifaunal as an avoidance response. This could also affect population density and establishment of pioneering populations.

In the Australian freshwater mussel, Velesunio ambiguus, Fe, Mn, and Zn concentrations increased with increasing age; in comparing concentration levels to body weight, the trend was reversed (Jones and Walker 1972). Ayling (1974) showed that in Pacific oysters, Crassostrea gigas, the concentrations of Cd and Cu, and probably Zn and Pb, increased with age. As figures 7, 8, 9 & 10 of this study demonstrate, Corbicula can fit all these trends, depending upon the sediment texture or river segment from which it was collected. An unusual trend was shown for the freshwater mussel, Quadrula quadrula, where Cu concentrations decreased with increasing age (Foster and Bates, 1978).

Corbicula has a propensity for accumulating and tolerating trace metals (Rodgers and others, 1979, 1980). If the excess metals are stored in such a manner as to prevent their metabolic incorporation, then the clam could tolerate seemingly high tissue-metal values. Such storage of metals is possible for many bivalve species as the result of binding to granular cells or proteins (Jones and Walker, 1979; Bryan, 1971). Hobden (1970) stated that the gills of freshwater mussels are rich in Fe; Corbicula, not being a mussel, had total Fe concentrations that were not unusually high implying that significant concentrations of Fe probably did not occur in the gills. In fact, the overall Fe content in Corbicula is rather low compared to their associated sediment and other studies. Heit and others (1980) analyzed the freshwater molluscs Lampsilus, Eliptio, and Anodonta for trace metals; the results showed no correlation between metal content and dry-tissue weights. Consequently, these may be a poor choice for consideration as environmental monitors compared to Corbicula, even though they too are present in the Potomac River.

CONCLUSIONS

Considering the broad-based nature of this study, many seemingly weak correlations previously mentioned may be significant, for if any discernible trends can survive such broad-based sampling with all the inherent variables built in, then the trends may be considered significant or at least noteworthy.

1. Metal-to-age and metal-to-dry weight trends in Corbicula can differ considerably for the same metal depending if the organism was collected in sand or mud.

2. Differences in metal uptake patterns also occur depending upon what part of the river Corbicula is collected, i.e., that section which is greatly influenced by effluent or that section which is more distant from effluent sources.

3. There was no correlation between tissue trace-metal values and sediment values, which may be reflective of the influence of the hydrodynamics of a major river such as the Potomac rather than a physiological partitioning of the sediment trace metals.

4. Sampling a single mollusc species from differing sediment textures may lead to conflicting or confusing results, especially if that species is being used as a monitor. Therefore, if Corbicula were to be used as an instream monitor of pollutants in general, and metals specifically, then the clams should be suspended in a cage at their various stations to preclude or minimize possible effects or influences by sediments.

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