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DISTRIBUTION OF SELECTED METALS IN BOTTOM SEDIMENTS, WATER, CLAMS, TUBIFICID ANNELIDS, AND FISHES OF THE MIDDLE ILLINOIS RIVER

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TABLE OF CONTENTS

ABSTRACT

Distribution of Selected Metals in Bottom Sediments, Water, Clams, Tubificid Annelids, and Fishes of the Middle Illinois River

This study was designed to assess the potential application for further research of metal contamination in a large mid-western river that is utilized by industries and certain cities as a source of potable water as well as for sewage disposal. Analyses were made for thirteen metals in bottom sediments, twelve in water, and ten in tubificid worms, clams, and fishes. The study revealed that the ten metals, for which analyses were made in biota, do not concentrate along successive trophic levels as is the case with pesticides. Organisms such as clams and worms that inhabit the mud or mud-water interface where metal concentrations were observed to be the highest, exhibited the highest metal concentrations. At higher trophic levels, however, concentrations were lower, with fishes that are primarily carnivorous in nature exhibiting the lowest concentrations. The problem of metal contamination in aquatic systems is just now being recognized as a potential hazard to human health while the degree to which aquatic biota are affected remains speculative. This study, basically a pilot study, outlines procedures by which similar studies can be made and provides data that others may use in assessing the degree of metal contamination in multiple use rivers.

Mathis, B. J., and Cummings, T. F.
Distribution of Selected Metals in Bottom Sediments, Water, Clams, Tubificid Annelids, and Fishes of the Middle Illinois River.
Water Pollution*/ Heavy Metals*/ Biota*/ Illinois River/ Copper/ Nickel/ Iron/ Calcium/ Lead/ Chromium/ Potassium/ Magnesium/ Lithium/ Sodium/ Zinc/ Cobalt/ Cadmium/ Atomic Absorption spectrophotometry/ Benthos*/ Aquatic Environment*/ Limnology/ Food Chain*/ Lotic Environment

OBJECTIVES AND SCOPE

The objective of this investigation was to determine the effect of selected metals in reducing the biotic diversity of the Illinois River.

The objective was to be accomplished by:

1) determining concentrations of selected metals in mud, water, and biota of the Illinois River.
2) comparing concentrations of metals found in the Illinois River mud and biota with concentrations in mud and biota of streams located near Peoria, Illinois not receiving sewage and industrial wastes.
3) collecting selected species of fishes and benthic macroinvertebrates from unpolluted streams and exposing them to various concentrations of Illinois River water in order to determine what effect metals in Illinois River water have on species that do not inhabit the river.

As the project developed, it became evident that all three aspects of the objective could not be fully implemented due to limitations of manpower and time. As can be seen in the remainder of the report, the concentrations of selected metals in water and bottom sediments of the Illinois River as well as three non-industrial use streams were determined quite intensively. The concentrations of these metals in Illinois River water were also monitored for a full year. Metal concentrations in selected biota from the Illinois River were also determined.

Distribution of Selected Metals in Bottom Sediments, Water, Clams, Tubificid Annelids, and Fishes of the Middle Illinois River

INTRODUCTION

It has been known for some time that metals affect aquatic organisms to various degrees. Fishes seem to be the most studied group and the literature is replete with the results of studies that have been made on numerous species (Doudoroff and Katz, 1958). Most metals are deleterious to aquatic organisms at varying concentrations depending on pH, temperature, hardness, etc. However, little is known about the long term effects of certain heavy metals that are present in sub-lethal concentrations on aquatic organisms.

An early observation on the effects of metals on fishes was made by Ellis (1937) who reported that the salts of heavy metals combine readily with mucus secreted by fishes. Mucus precipitated at the gill surface apparently affects the uptake of oxygen and blood circulation. Now there is some evidence to support the idea that severe internal physiological stresses are induced by exposure to metals. Hiltibran (1970) reported that cadmium and zinc severely limited oxygen metabolism of blue gill liver mitochondria.

The biota of major streams, lakes, and rivers have changed drastically since man began using them to carry away sewage and industrial wastes. No doubt, one of the major factors responsible for reducing biotic diversity in such systems has been the depletion of oxygen due to heavy organic enrichment. On the other hand, the role played by metals entering streams, lakes, and rivers in reducing biotic diversity is largely unknown, although there is some suspicion that this role is much greater than it was originally thought to be.

Many industrial wastes contain metals or salts of metals and these have been accumulating in the sediments of streams, lakes, and rivers for years. These metals may act either synergistically or antagonistically upon the aquatic biota, and in some cases may cause a decrease in biotic diversity.

The Illinois River has been receiving sewage and industrial wastes for years and the drastic decline in biotic diversity has been well documented (Mills, Starrett, and Bellrose, 1966).

In the present study, an atomic absorption spectrophotometer was utilized to determine the concentrations of copper, nickel, lead, chromium, magnesium, lithium, zinc, cobalt, cadmium, and iron in tubificids, clams, and fishes taken from the Illinois River. In addition, concentrations of calcium, potassium, and sodium were determined in water and sediments from the Illinois River and three non-industrial use streams. Analyses were not made for iron in water.

DESCRIPTION OF STUDY AREA

Five stations along a nine mile stretch of the Illinois River near Peoria were selected for study (Figure 1). Station locations are indicated by miles upstream from the confluence of the Illinois River with the Mississippi River. The upper station was located at the lower end of what is known as Upper Peoria Lake while the lower station was located below the cities of Peoria and East Peoria. The three non-industrial use streams selected for study are tributaries of the Illinois River (Figure 2).

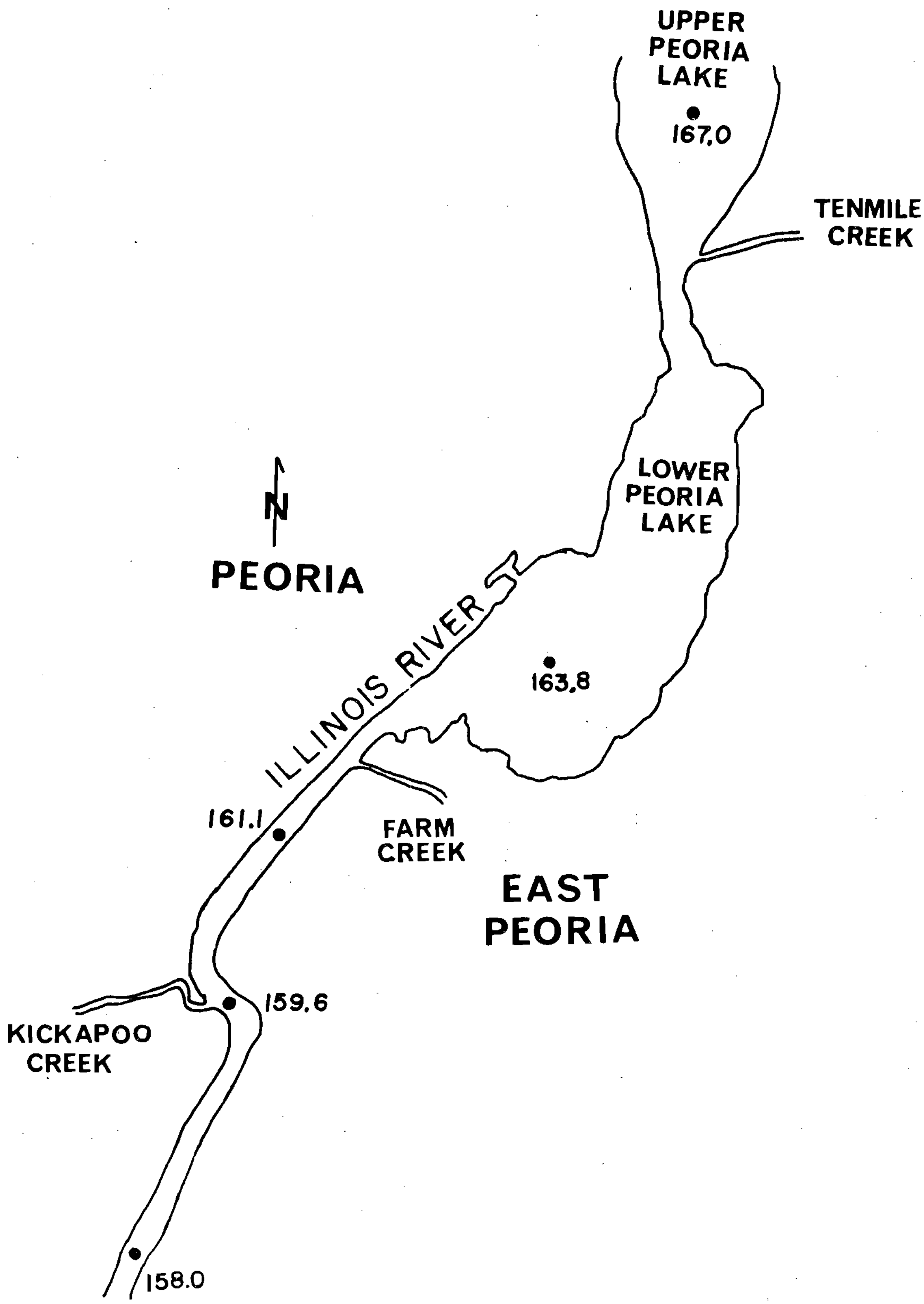


Figure 1. Map of the Illinois River near Peoria. Station locations are indicated by miles upstream from the confluence of the Illinois River with the Mississippi River.

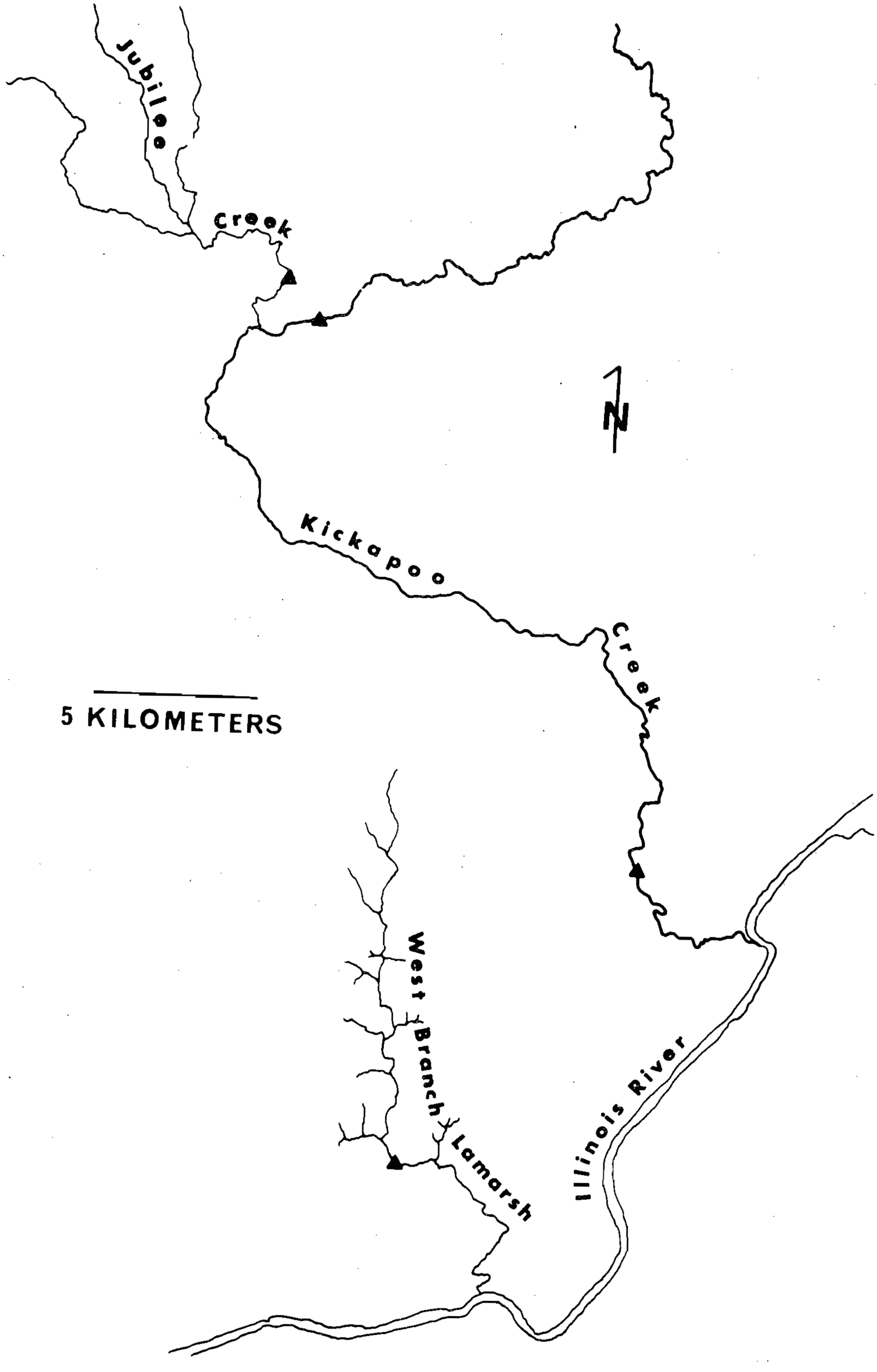


Figure 2. Map showing sampling locations on three non-industrial use streams near Peoria. Stations = (▲)

FIELD PROCEDURES

Weekly water samples were taken from the middle of the river and near each shore at each station during the summer of 1969. Daily water samples only were taken from a sixth station located approximately mid-way between Stations 161.1 and 163.8 for a period of four months at the beginning of the study and, subsequently, on a weekly basis.

Bottom sediments and tubificids were also collected from the middle of the river and near each shore at each station. Bottom sediments were brought to the surface by means of a Peterson dredge and the tubificids extracted by sieving the sediment through standard soil sieves. Grab samples of bottom sediments were also taken at this time.

Fishes were collected by electrofishing methods. Most were collected near the western shore at Station 163.8 while a few *Dorosoma cepedianum* (shad) and *Cyprinus carpio* (carp) were collected near Station 159.6. Clams were obtained from commercial organizations fishing the river.

LABORATORY PROCEDURES

Organisms

Tubificids were preserved in 70% isopropyl alcohol after removal from bottom sediments. At the time analyses for metals were made, the worms were removed from the solution, placed on blotting paper to remove excess water and then weighed. Fishes were fileted, sponged, and cut into samples of approximately thirty grams for analysis. Internal organs of fishes were not analyzed. Clam tissue was removed from the shell, sponged and then weighed.

Samples of tissue to be analyzed were placed in 50 ml beakers. Ten mls of a mixed acid solution (5 volumes of concentrated nitric acid and one volume of concentrated perchloric acid) made from ACS reagent grade acids were then added to the sample. The sample was heated at low heat under a hood. Evaporated acid was replaced by adding 10 ml aliquots until the tissue had been completely dissolved. The solution was evaporated until the volume had been reduced to 3-5 mls. The remaining mixture was transferred to a 25 ml volumetric flask and diluted to 25 mls with distilled deionized water. This solution was analyzed by a Perkin-Elmer Model 290-B atomic absorption spectrophotometer and the metal concentration in the tissue determined as follows:

$$\text{ppm of metal in the solution} \times \frac{25 \text{ mls}}{\text{grams of sample}} = \text{ppm of metal in sample material}$$

It was assumed that the density of the solution was one g/ml.

Bottom sediments were prepared for analysis in approximately the same manner as the organisms. Approximately ten grams of bottom sediments were placed in a 50 ml beaker and dried to constant weight at 100 C. To this sample 10 mls of the mixed acid solution of perchloric and nitric acid were added. After heating at low heat for approximately sixteen hours, the solution was allowed to settle. The supernatant liquid was drawn off and placed in another 50 ml beaker. On two more occasions, 10 mls of the acid solution were added to the sample and the supernatant liquid subsequently removed. Then 10 mls of water were added to extract the remaining acid from the sediment. The combined acid and water solutions were again treated with mixed acid and heated until the solution turned faint yellow or clear. The remaining solution was evaporated to 3-5 mls, diluted to 25 mls with distilled deionized water, and then subjected to analysis by the atomic absorption spectrophotometer. A record of the total quantity of acid used during the process was kept, and the concentration of metal impurities subtracted from the final reading.

Water

Water samples were brought to the laboratory from the field and filtered through a highly retentive filter (Sargent No. 501) in order to remove such impurties as plankton and clay praticles. The concentrations of sodium, magnesium, calcium, potassium, zinc, and lithium were determined by aspirating directly into the atomic absorption spectrophotometer. Cobalt, copper, cadmium, chromium, nickel, and lead, however, were present in such low concentrations that they had to be concentrated as follows. Three mls of 1% ammonium pyrrolidinecarbodithioate in water and 3 mls of 3% 8-hydroxyquinoline in methyl isobutyl ketone (MIBK) were added to one liter of filtered water. After stirring for 2-5 minutes 50 mls of MIBK were added, this mixture was stirred for 3-5 minutes, and the pH adjusted to between 7.7 and 8.0 with aqueous NH_3 and H_3PO_4. The MIBK solution, containing the metals in solution, was removed and aspirated into the atomic absorption spectrophotometer.

Extractions of known concentrations of metals were carried out by the above procedure in order to prepare standards. An MIBK blank saturated with water was aspirated into the atomic absorption spectrophotometer at all times to give a constant base line on the recorder.

RESULTS AND DISCUSSION

Sediments

Sediments from the Illinois River and three non-industrial use streams located in Peoria County were analyzed for thirteen different metals during the study (Tables 1 and 2). At this point in time it is difficult to say what constitutes normal metal concentrations of heavy metals in sediments of major rivers. Concentrations of metals in sediments of three non-industrial use streams were, however, significantly different (Table 3). With the

TABLE 1
Variation in Concentrations of Metals Extracted
From Sediments of the Illinois River+

Station	Metal	Cu ppm	Ni ppm	Fe ppm	Ca ppm	Pb ppm	Cr ppm	K ppm	Mg ppm	Li ppm	Na ppm	Zn ppm	Co ppm	Cd ppm
	Mean	28	45	14,600	24,800	39	31	520	13,300	5.3	90	127	8.0	4.1
167.0	C.I.*	±15	±21	±5,400	±5,400	±22	±15	±220	±2,800	±2.2	±30	±61	±2.8	±2.2
	Range	1 82	3 124	1,100 30,200	7,400 45,200	3 140	2 87	30 1,190	3,800 22,700	0.5 11.9	20 189	6 315	1.1 17.6	0.2 12.1
	Mean	27	46	16,700	51,900	40	29	730	16,700	5.8	106	135	8.3	3.7
163.8	C.I.	±16	±25	±6,800	±22,200	±20	±18	±480	±3,800	±3.2	±45	±78	±3.5	±2.3
	Range	3 70	5 121	1,900 32,100	20,400 145,000	7 129	2 82	30 2,080	7,000 29,600	0.5 16.3	32 249	15 339	1.5 16.8	0.3 10.4
	Mean	16	12	7,100	30,100	28	7	230	15,100	1.7	50	73	3.4	1.1
161.1	C.I.	±10	±4	±2,400	±9,000	±12	±4	±200	±2,900	±1.0	±11	±43	±1.0	±0.5
	Range	1 63	4 26	2,500 17,800	12,700 64,100	8 96	2 25	10 1,100	7,000 26,400	0.3 5.9	29 85	8 287	1.4 7.4	0.3 2.9
	Mean	11	16	9,600	16,900	15	10	280	15,300	2.6	47	41	4.7	0.8
159.6	C.I.	±4	±3	±2,300	±2,800	±3	±3	±120	±9,900	±0.9	±8	±8	±0.8	±0.2
	Range	3 38	9 30	3,800 22,300	6,800 23,400	9 31	3 28	50 800	6,900 96,800	0.8 8.1	27 84	22 68	2.7 9.0	0.4 1.5
	Mean	15	19	12,800	13,800	21	9	350	8,800	3.7	53	42	6.1	0.7
158.0	C.I.	±6	±5	±2,800	±2,600	±6	±3	±150	±1,400	±1.3	±13	±10	±1.6	±0.2
	Range	3 53	8 44	6,100 27,600	5,300 20,800	9 52	2 17	40 880	4,000 13,300	0.9 10.8	21 110	23 81	2.2 14.6	0.2 1.5

+ Analyses based on the following number of samples per station:
16- 167.0; 13- 163.8; 14- 161.1; 18- 159.6; 15- 158.0

*C.I. = Confidence Interval (Mean ± t.95 x Standard error of the mean).

TABLE 2
Variation in Concentrations of Metals Extracted
From Sediments of Three Non-Industrial Use Streams+

Station	Metal	Cu ppm	Ni ppm	Fe ppm	Ca ppm	Pb ppm	Cr ppm	K ppm	Mg ppm	Li ppm	Na ppm	Zn ppm	Co ppm	Cd ppm
Lamarsh Creek	Mean	6.3	15.4	15,600	2,500	14.8	5.4	206	2,100	3.6	62	29	6.4	0.30
	C.I.*	±1.2	±2.0	±1,800	±700	±1.7	±1.1	±77	±540	±1.3	±32	±3	±0.6	±0.06
	Range	5.1 7.4	13.3 17.7	13,400 17,400	1,900 3,500	12.9 16.5	4.0 6.2	154 312	1,400 2,500	2.3 4.9	29 99	27 33	5.5 7.2	0.23 0.35
Jubilee Creek	Mean	10.5	21.5	18,900	6,000	17.5	6.9	324	4,500	5.2	40	34	7.9	0.37
	C.I.	±0.8	±0.7	±1,900	±2,200	±2.0	±0.5	±52	±1,400	±0.6	±9	±3	±0.7	±0.09
	Range	10.0 11.2	21.0 22.2	17,000 20,400	4,400 8,200	16.4 19.7	6.5 7.2	291 373	3,800 6,100	4.7 5.7	33 48	32 36	7.2 8.4	0.31 0.44
Upper Kickapoo Creek	Mean	7.2	14.9	12,500	18,800	15.7	5.9	240	12,400	3.7	47	26	6.0	0.35
	C.I.	±2.8	±4.3	±4,400	±5,100	±2.6	±1.9	±132	±3,200	±1.6	±4	±7	±1.5	±0.07
	Range	3.5 9.6	10.0 18.4	8,200 16,600	12,600 24,900	13.6 19.2	3.4 7.4	85 356	9,900 16,500	2.0 5.2	43 51	18 34	4.4 7.3	0.28 0.42
Lower Kickapoo Creek	Mean	7.4	14.4	11,700	24,000	20.9	5.2	192	14,100	3.0	60	31	5.4	0.43
	C.I.	±2.5	±3.7	±2,000	±16,200	±5.2	±1.6	±95	±3,000	±1.2	±18	±10	±1.2	±0.12
	Range	4.1 9.8	10.6 17.5	8,400 14,400	10,600 48,400	16.0 27.1	3.5 6.6	85 291	7,900 23,400	1.7 4.2	45 85	21 41	4.1 6.3	0.27 0.53

+ Analyses based on 4 samples from Jubilee Creek and 5 from the others.

* C.I. = Confidence Interval (Mean ± t.95 x standard error of the mean).

TABLE 3

Means of Metal Concentrations in Bottom Sediments
of the Illinois River and Three Non-Industrial Use Streams*

Metal ppm	Illinois River+	Three Non-Industrial Use Streams++
Cu	19.1	7.7
Ni	27	16
Fe	12,000	14,500
Ca	26,400	13,200
Pb	28	17
Cr	17	6
K	414	236
Mg	13,800	8,500
Li	3.8	3.8
Na	67	53
Zn	81	30
Co	6.0	6.4
Cd	2.0	0.4

*All metals were significantly different at the 95% level.
+Results for each metal based on 76 samples except for Cd which was based on 73.
++Results for each metal based on 19 samples.

exception of iron and lithium, mean concentration for each metal was higher in sediments of the Illinois River.

Water

Water from the Illinois River and three non-industrial use streams was analyzed for twelve metals (Table 4 and Figures 3-6). Concentrations of extractable metals, with the exception of sodium, were considerably lower in water than in sediments. The greatest difference in concentrations between sediments and water was exhibited by copper, nickel, lead, chromium, lithium, zinc, cobalt, and cadmium.

Concentrations of metals in the water of three non-industrial use streams were determined on only one occasion (Table 5). Calcium was more highly concentrated in water of the non-industrial use streams while lead was present in considerably lower concentrations. With the exception of chromium and lead, concentrations of other metals in the water of non-industrial use streams generally fell within the range of concentrations found in water of the Illinois River.

Clams

Three species of clams were analyzed for the presence of ten metals during the study (Figures 7, 8, and 9). Specimens were taken from the Illinois River between Stations 167.0 and 161.1. All three species exhibited concentrations of metals exceeding concentrations observed in water. With the exception of magnesium, lithium, and iron, concentrations of metals in clams and bottom sediments were of the same order of magnitude. Mean concentration of zinc in *Amblema plicata* exceeded the mean concentrations in bottom sediments observed at the three down stream stations. Mean concentrations of zinc and chromium in

TABLE 4

Variation in Concentrations of Metals in Illinois River Water by Station During Summer, 1969

Station	Metal	Cu ppb	Ni ppb	Ca ppm	Pb ppb	Cr. ppb	K ppm	Mg ppm	Li ppb	Na ppm	Zn ppb	Co ppb	Cd ppb
	Mean	1.2	2.8	19	2.0	20	4.0	26	10	27	50	3.0	0.5
167.0	C.I.*	±0.3	±0.4	±2	±0.3	±8.0	±0.4	±1	±2	±2	±37	±0.4	±0.2
	Range	0.6 4.7	1.0 5.0	11 26	1.0 5.0	10 33	2.0 9.0	21 35	3 21	20 37	3 610	1.0 6.0	0.2 1.9
	Mean	1.1	2.9	19	2.1	23	3.9	26	10	27	25	3.1	0.6
163.8	C.I.	±0.3	±0.4	1.0	±0.3	±7	±0.2	±1	±2.0	±2	±9	±0.5	±0.2
	Range	0.5 5.2	1.0 5.0	11 26	1.0 4.0	14 33	2.0 5.0	21 32	1 22	20 37	1 110	1.0 5.0	0.2 2.0
	Mean	1.2	2.9	20	2.6	21	4.1	27	11	27	29	2.8	0.6
161.1	C.I.	±0.2	±0.3	±2	±1.2	±8.0	±0.3	±1	±2	±2	±14	±0.4	±0.2
	Range	0.4 3.6	1.0 5.0	12 26	1.0 18.0	12 33	3.0 6.0	21 34	1 25	21 36	3 230	1.0 5.0	0.1 2.0
	Mean	1.1	3.0	19	1.9	22	3.9	27	11	30	27	3.1	0.7
159.6	C.I.	±0.2	±0.3	±2	±0.3	±11	±0.2	±1	±1	±1	±7	±0.5	±0.2
	Range	0.5 3.1	1.0 6.0	12 26	1.0 5.0	7 38	2.0 5.0	21 32	3 19	21 37	7 140	1.0 6.0	0.1 2.0
	Mean	1.0	2.7	19	2.1	21	4.0	27	10	28	28	3.0	0.6
158.0	C.I.	±0.2	±0.3	±2	±0.5	±10.0	±0.3	±1	±1.0	±2	±16	±0.4	±0.2
	Range	0.1 4.2	1.0 5.0	12 26	1.0 8.0	5 33	2.0 8.0	21 32	3 18	21 37	3 300	1.0 5.0	0.2 1.8
		30+	26+	38+	28+	6+	36+	36+	38+	36+	34+	26+	26+

*C.I. = Confidence Interval (Mean ± t.95 X Standard error of mean).

\+ = Number of samples analyzed per station

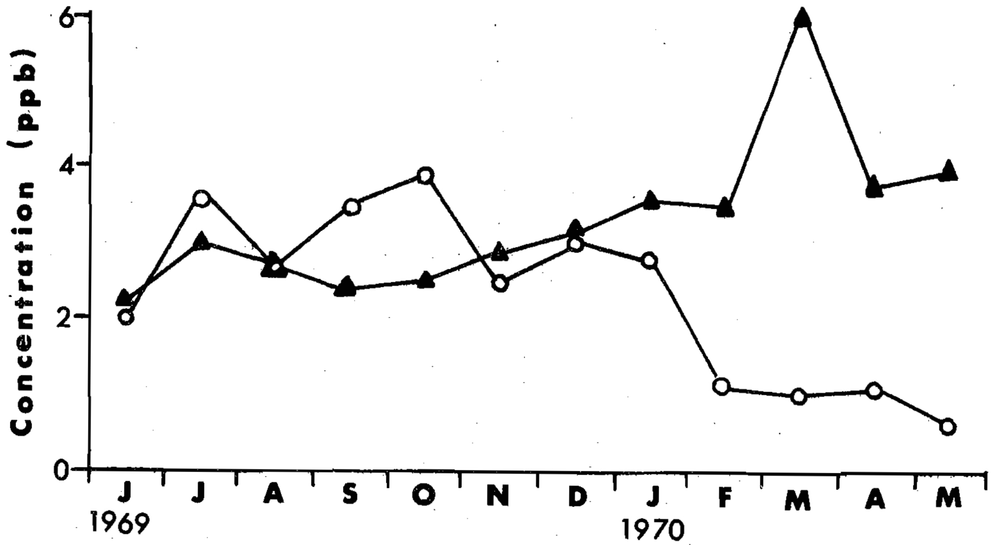


Figure 3. Mean monthly variation in concentrations of cobalt (—○—) and nickel (—▲—) in Illinois River water.

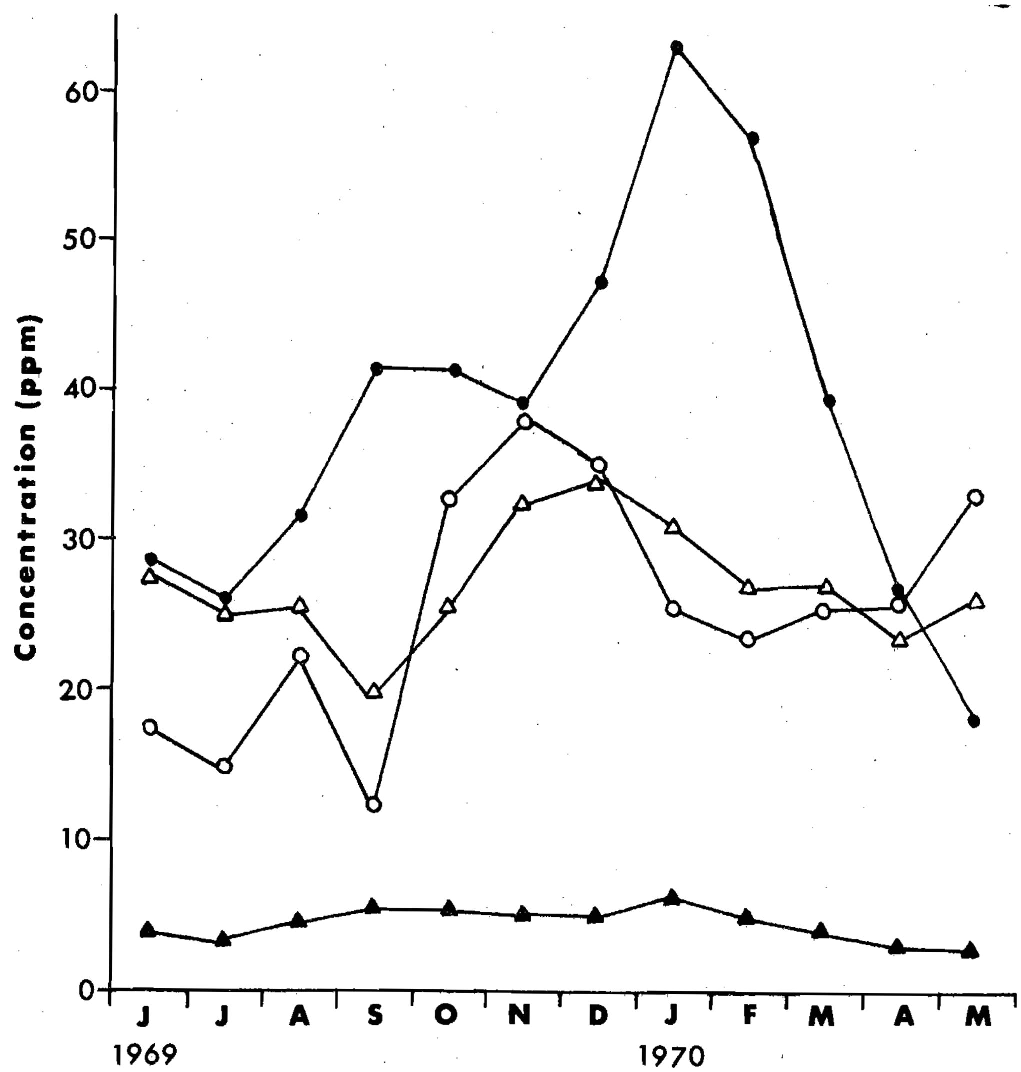


Figure 4. Mean monthly variation in concentrations of calcium (—○—), sodium (—●—), magnesium (—△—), and potassium (—▲—) in Illinois River water.

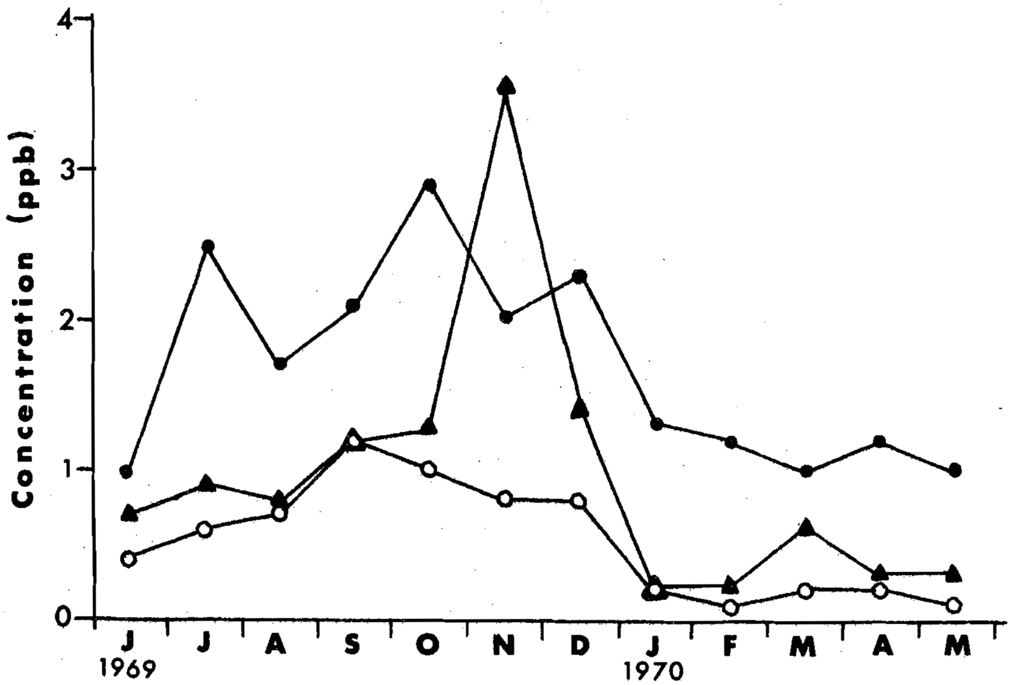


Figure 5. Mean monthly variation in concentrations of cadmium (—○—), lead (—●—), and copper (—▲—) in Illinois River water.

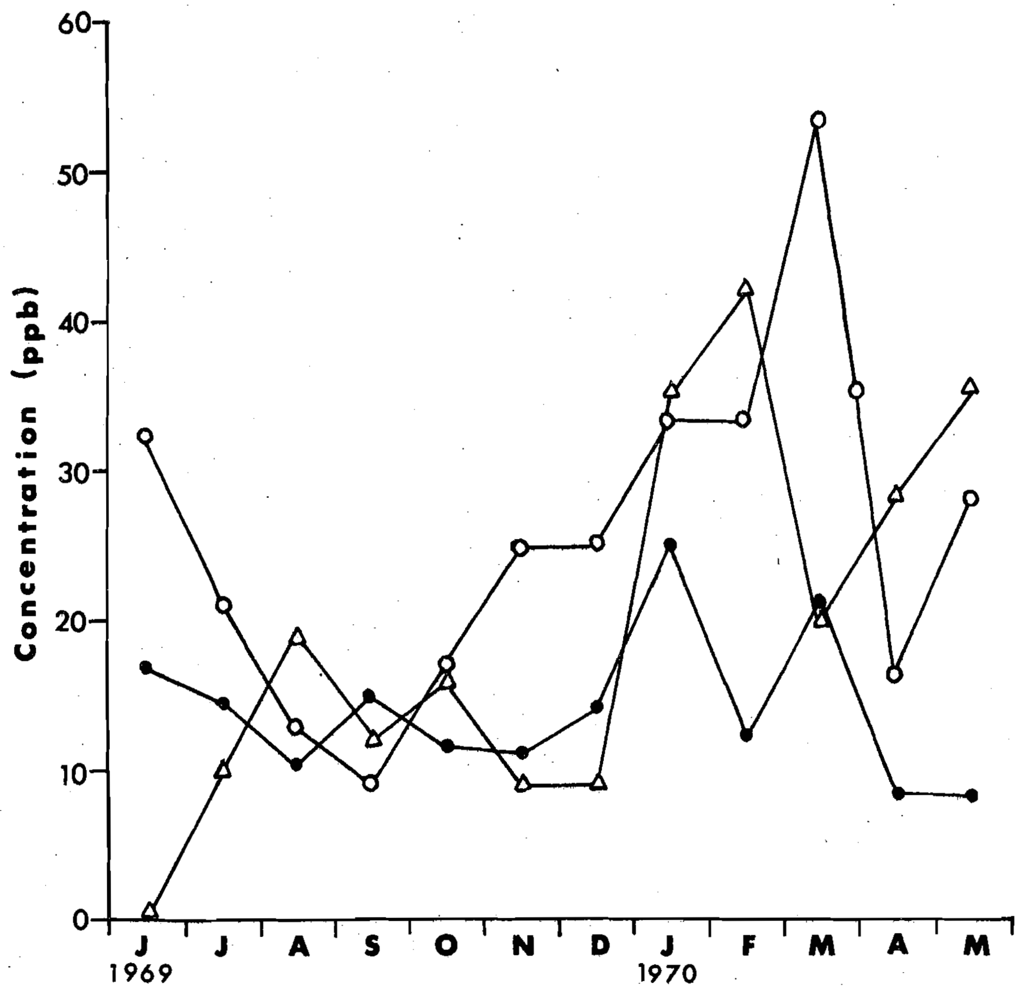


Figure 6. Mean monthly variation in concentrations of lithium (—●—), zinc (—○—), and chromium (—△—).

TABLE 5

Concentrations of Metals In Water of Three Non-Industrial Use Streams on June 10, 1970

Station	ppb ppm	Ni ppb	Ca ppm	Pb ppb	Cr ppb	K ppm	Mg ppm	Li ppb	Na ppm	Zn ppb	Co ppb	Cd ppb
LaMarsh Creek	0.1	1.0	41	0.4	4.7	3.6	34	13	42	23	0.7	0.1
Jubilee Creek	0.2	1.0	38	0.5	2.0	2.6	33	9	10	19	0.8	0.1
Upper Kickapoo Creek	0.2	1.0	39	0.1	2.3	1.6	33	8	9	25	1.2	0.2
Lower Kickapoo Creek	0.2	2.2	37	0.2	2.0	2.8	29	14	14	26	0.7	0.1

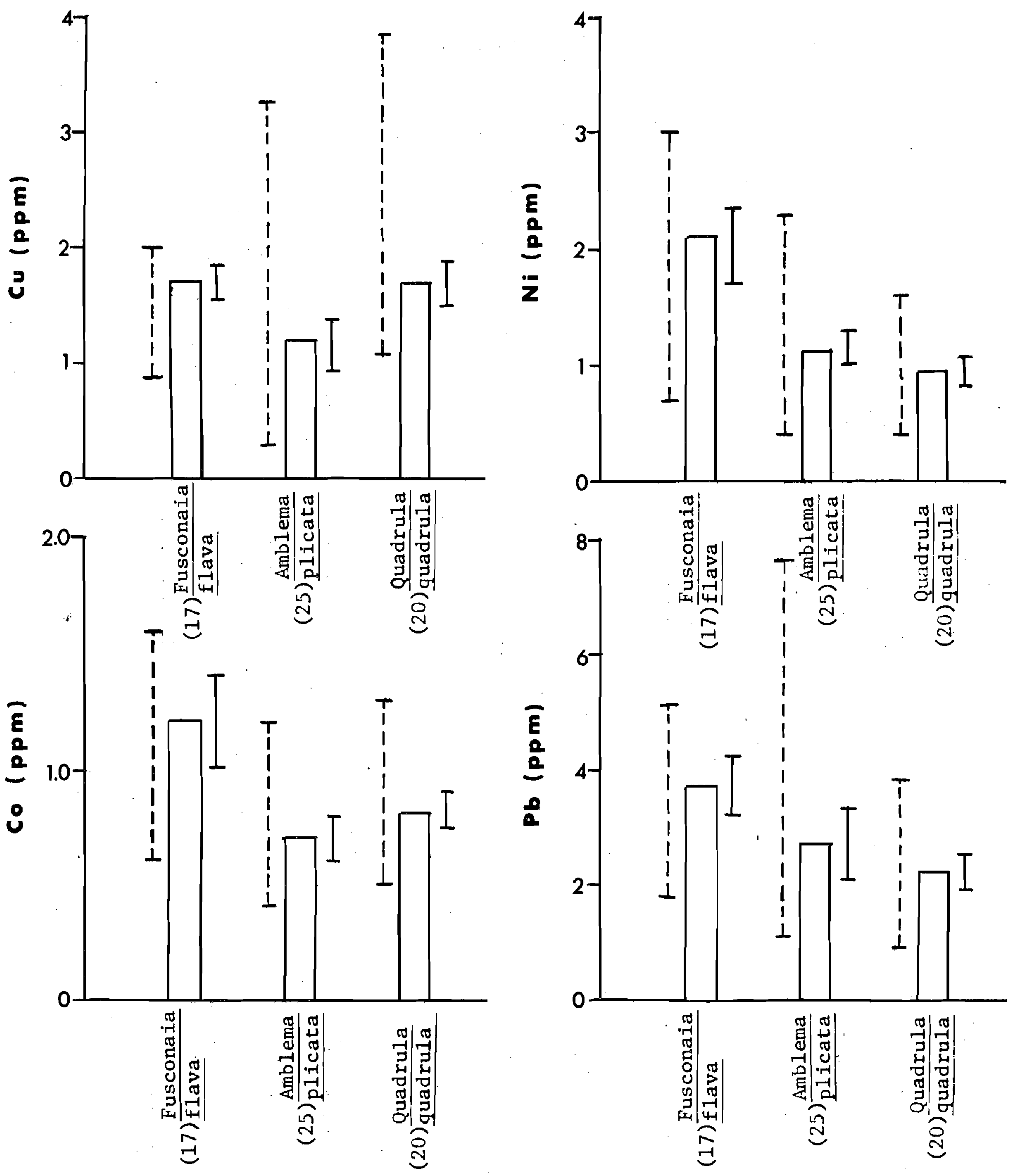


Figure 7. Mean concentrations of copper, nickel, cobalt, and lead in three species of Illinois River clams. Numbers in parentheses indicate number of samples. (---) = range (——) = confidence interval at the 95 percent level.

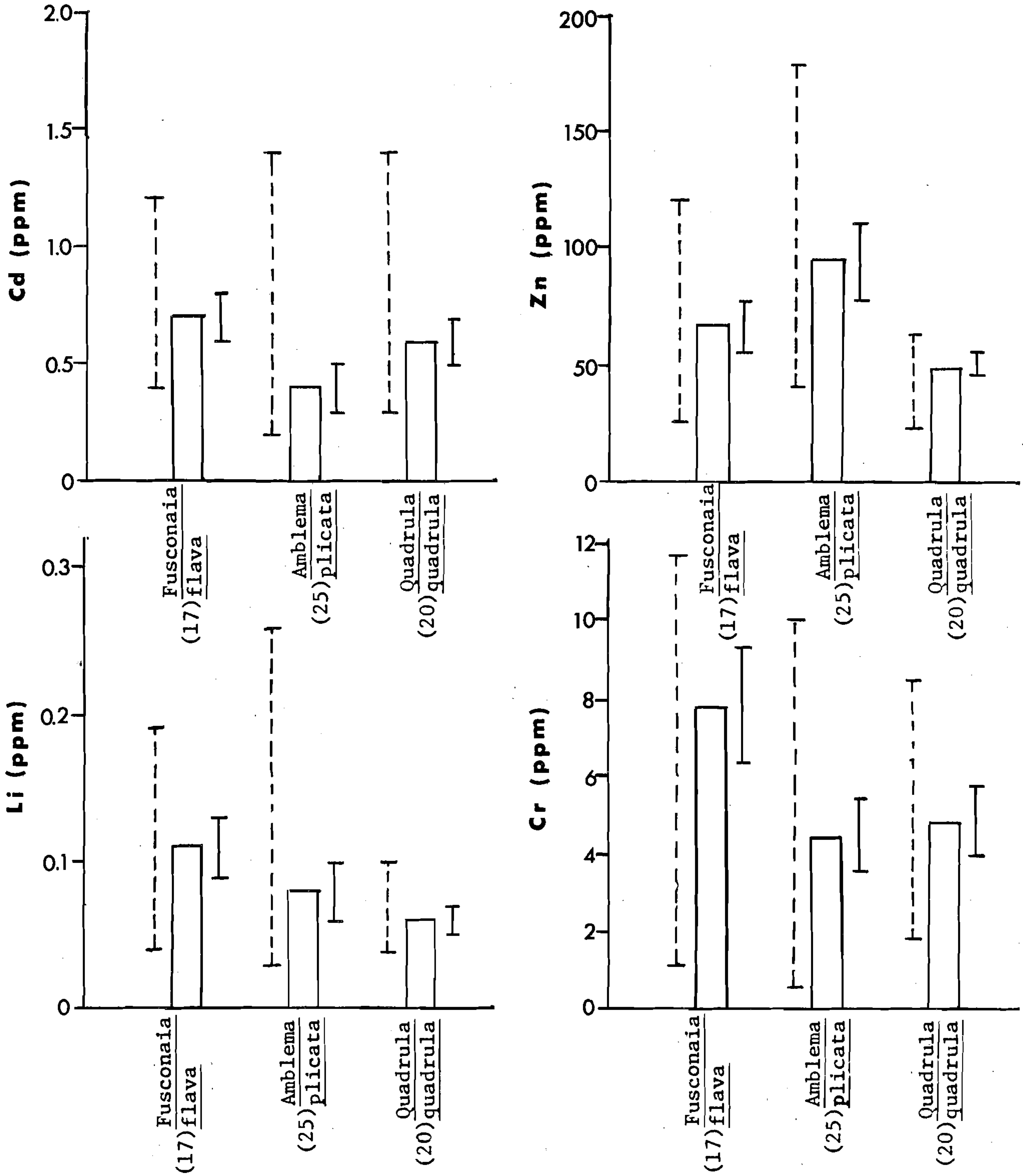


Figure 8. Mean concentrations of cadmium, zinc, lithium and chromium in three species of Illinois River clams. Numbers in parentheses indicate number of samples. (----) = range, (——) = confidence interval at the 95 percent level.

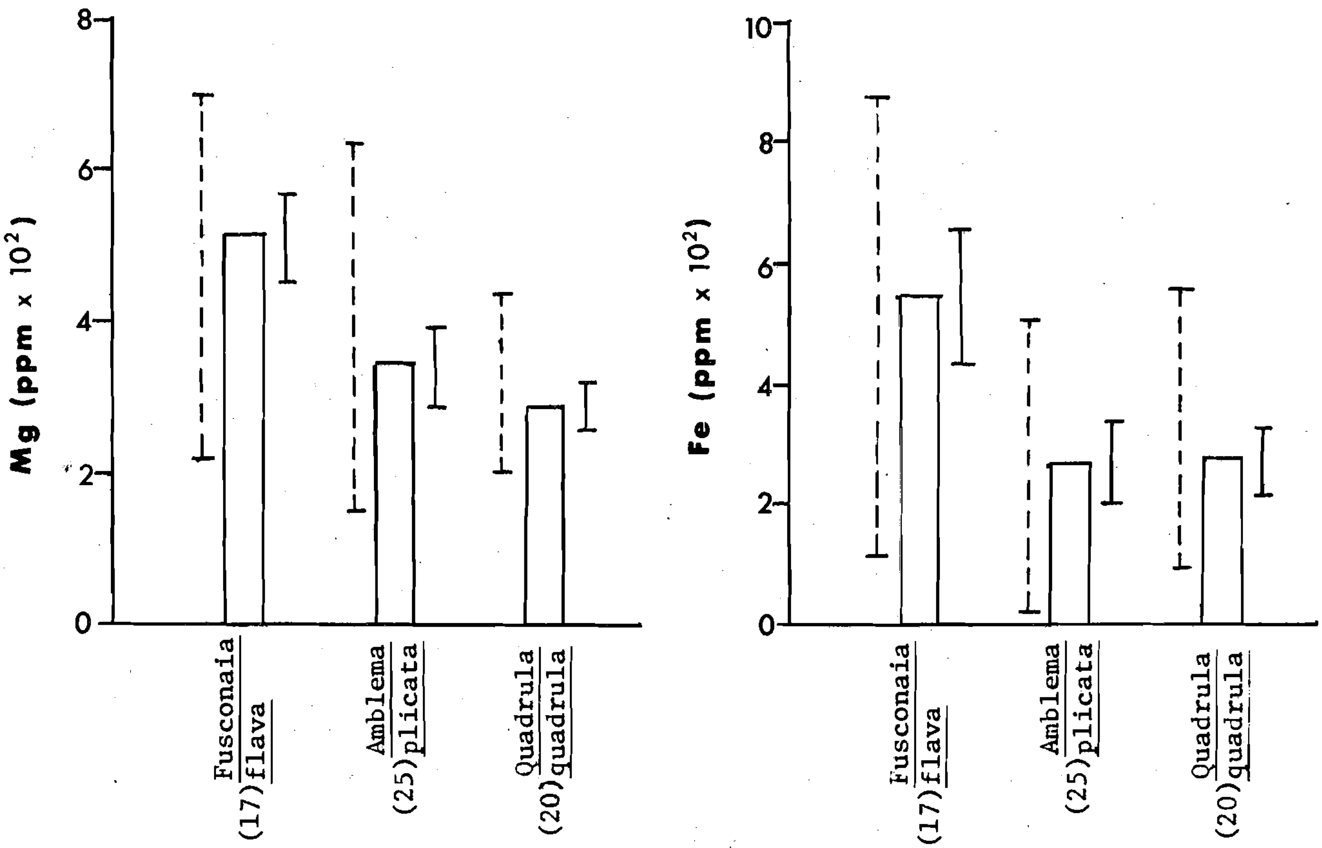


Figure 9. Mean concentrations of magnesium and iron in three species of Illinois River clams. Numbers in parentheses indicate number of samples. (----) = range, (——) = confidence interval at the 95 percent level.

clams were similar to concentrations in sediments of the three downstream stations.

All three species of clams exhibited overlapping ranges of concentration for each metal. The ranges of concentrations calculated at the 95 percent confidence interval did not always overlap, however. Whether these variations are due to the differences in the location of each species in the river bed, their physiology, or their niches is unknown at this time.

While a detailed study on the abundance of clams was not undertaken, the three species analyzed for metals in this study are present in numbers large enough to support several companies collecting them for comercial use. By contrast, a tiny fingernail clam, Sphaerium transversum, which was once an important source of food for other organisms and which was once present in large numbers in the Illinois River and its bottom land lakes has virtually disappeared since 1954 (Mills, Starrett and Bellrose, 1966).

Tubificids

Tubificid worms, Limodrilus hoffmeisteri and Tubifex tubifex were collected from the Illinois River and analyzed for ten different metals (Figures 10 and 11). L. hoffmeisteri and T. tubifex, two of the more common species associated with a polluted environment, show similar responses to various test solutions (Whitley 1968).

Worms were not present in equal abundance at the five sampling stations. Most were collected from Stations 167.0, 163.8, and 159.6 where find grained sediments offered optimal conditions for their survival.

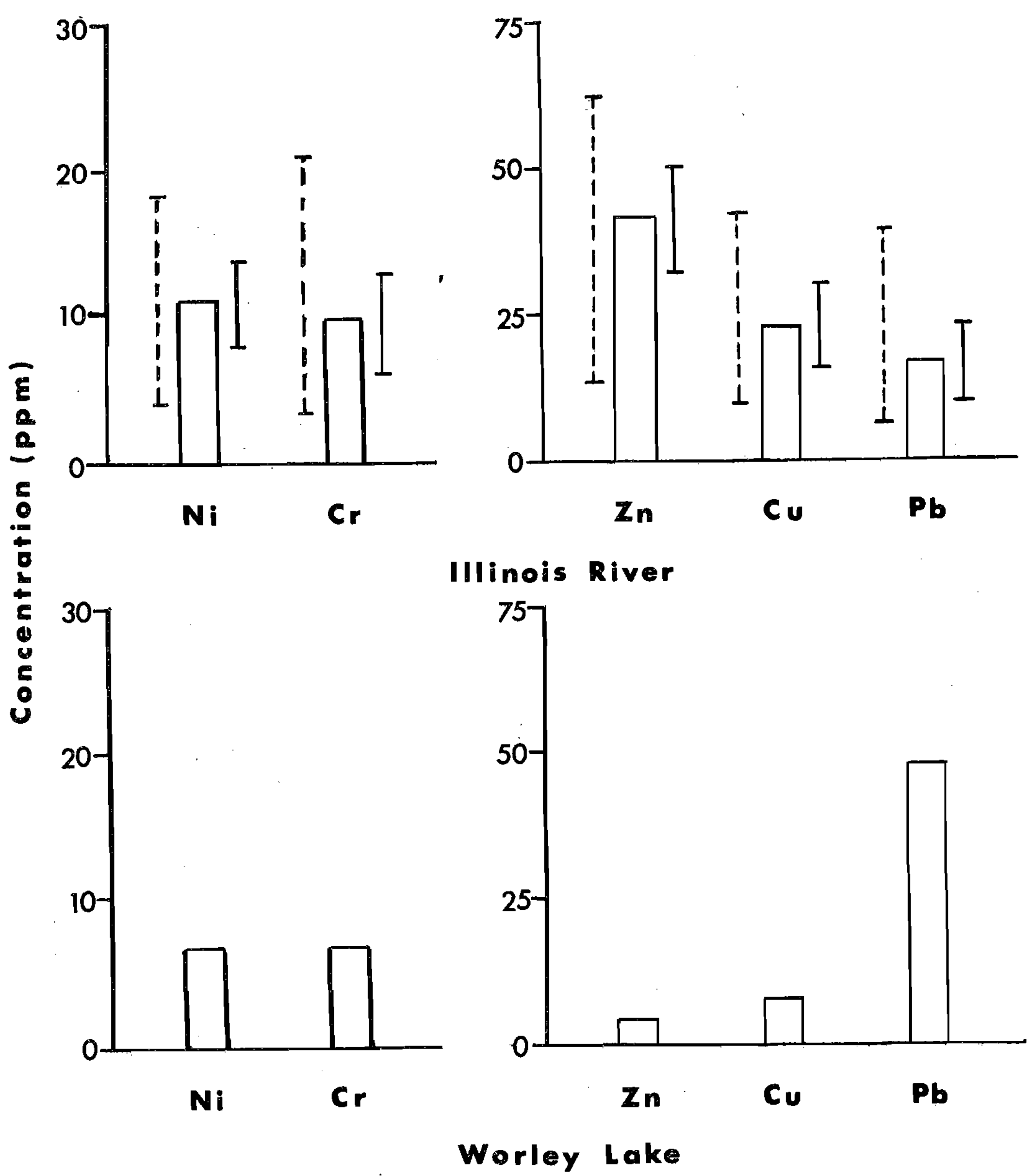


Figure 10. Mean concentrations of nickel, chromium, zinc, copper and lead in tubificid annelids of the Illinois River (11 samples) and Worley Lake (2 samples). (----) = range, (——) = confidence interval at the 95 percent level.

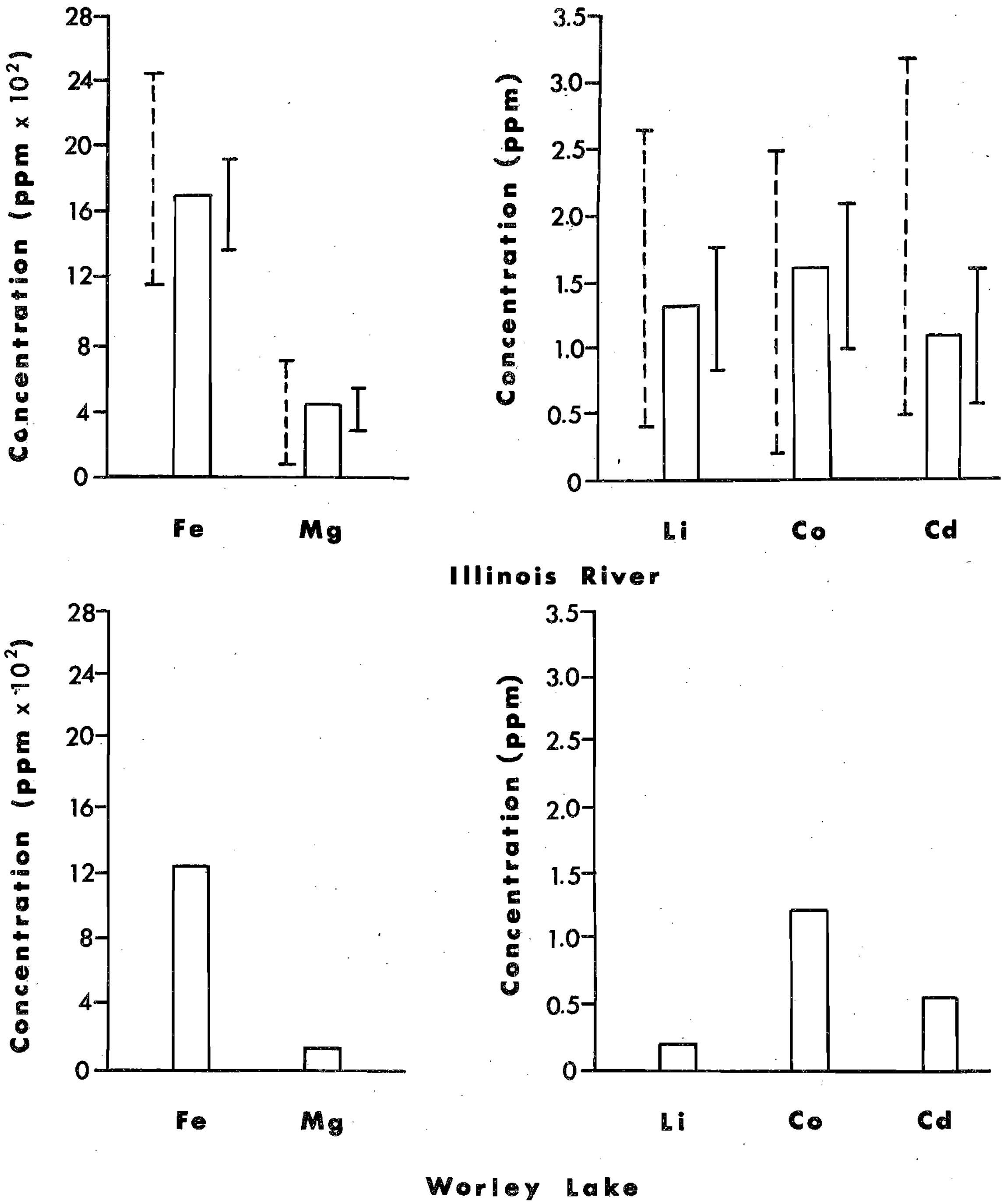


Figure 11. Mean concentrations of iron, magnesium, lithium, cobalt and cadmium in tubificid annelids of the Illinois River (11 samples) and Worley Lake (2 samples). (----) = range, (——) = confidence interval at the 95 percent level.

Samples of tubificids collected from each station were lumped together for analysis inasmuch as the total weight of worms at any one station was rather small. The total number collected was then divided into eleven samples for analysis. It should be borne in mind that the digestive tracts of the worms contained bottom sediments at the time analyses were made and thus contributed a source of variation.

Two samples of tubificid worms collected from Worley Lake in 1966 were also analyzed for metals. Worley Lake, a shallow flood plain lake of the Illinois River, is located approximately five miles downstream from the city of Peoria. The lake is inundated several times each year by overflow from the Illinois River.

Concentrations of eight of the ten metals in Illinois River tubificids were quite similar to concentrations in bottom sediments. Magnesium and iron, however, were present in considerably lower concentrations in tubificids. Mean concentrations of metals in Illinois River tubificids, with the exception of lead, exceeded mean concentrations in Worley Lake tubificids.

Tubificid worms have been shown by Whitley (1968) to be quite tolerant to lead and zinc. Zinc in tubificids from Worley Lake was quite low but some samples from the Illinois River exhibited concentrations exceeding Whitley's established tolerance limit.

Fishes

Ten species of fishes taken from the Illinois River were analyzed for ten different metals during the study (Figures 12-21). Concentrations of the ten metals in fish flesh were considerably less than concentrations encountered in bottom sediments. Conversely, the ten metals were present in lower concentration in water than in fish.

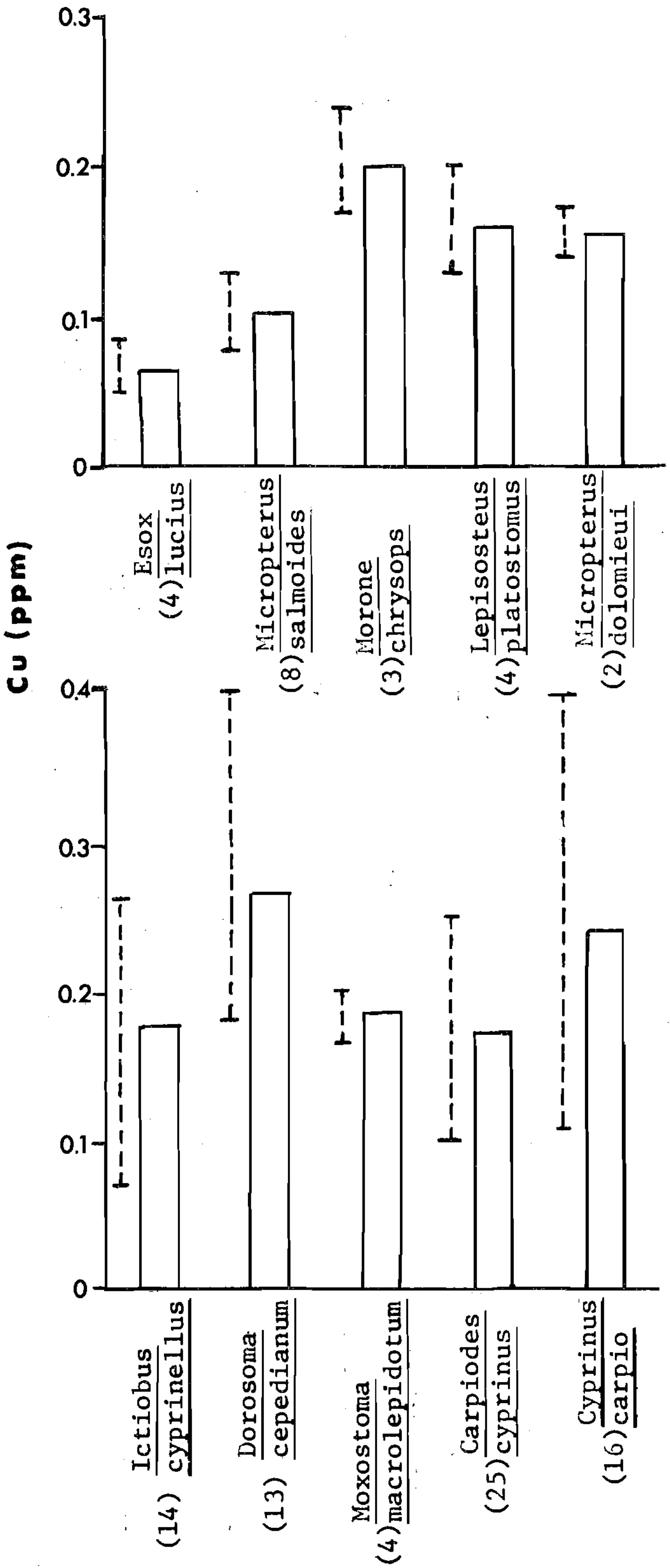


Figure 12. Mean concentration of copper in Illinois River fishes. Numbers in parantheses indicate number of samples. (----) = range.

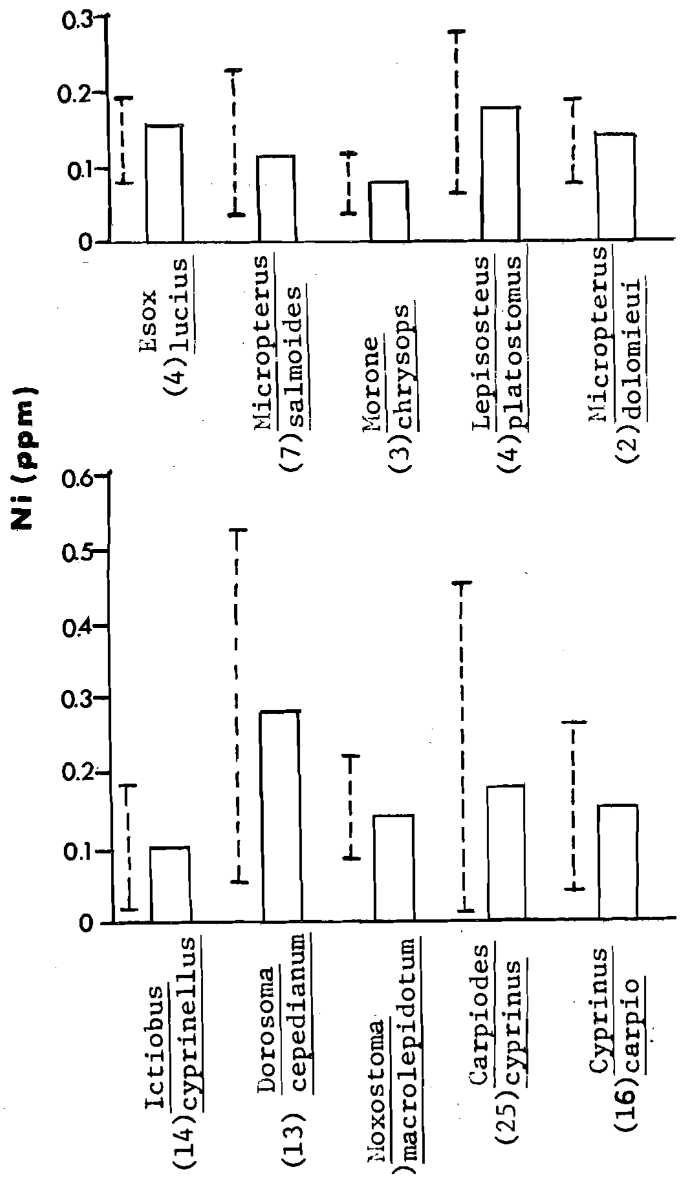


Figure 13. Mean concentration of nickel in Illinois River fishes. Numbers in parentheses indicate number of samples. (----) = range.

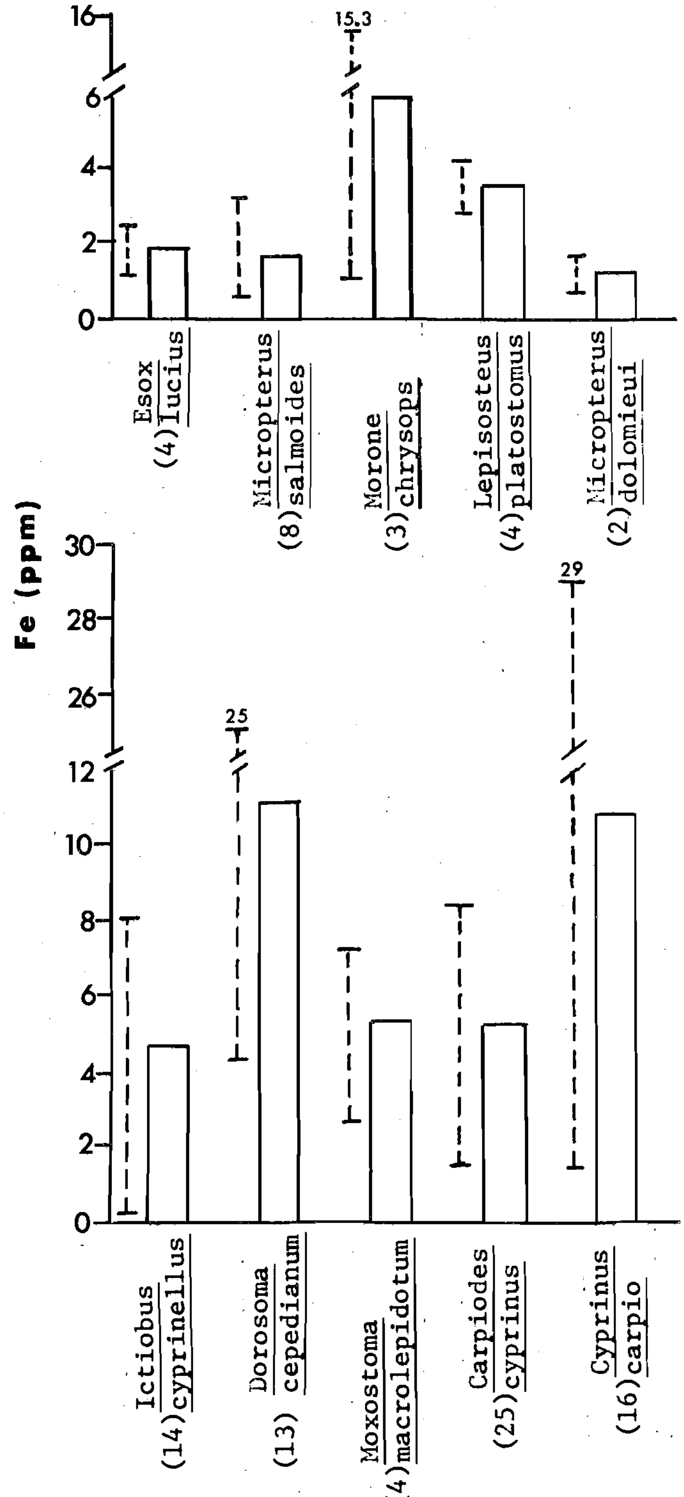


Figure 14. Mean concentration of iron in Illinois River fishes. Numbers in parentheses indicate number of samples. (----) = range.

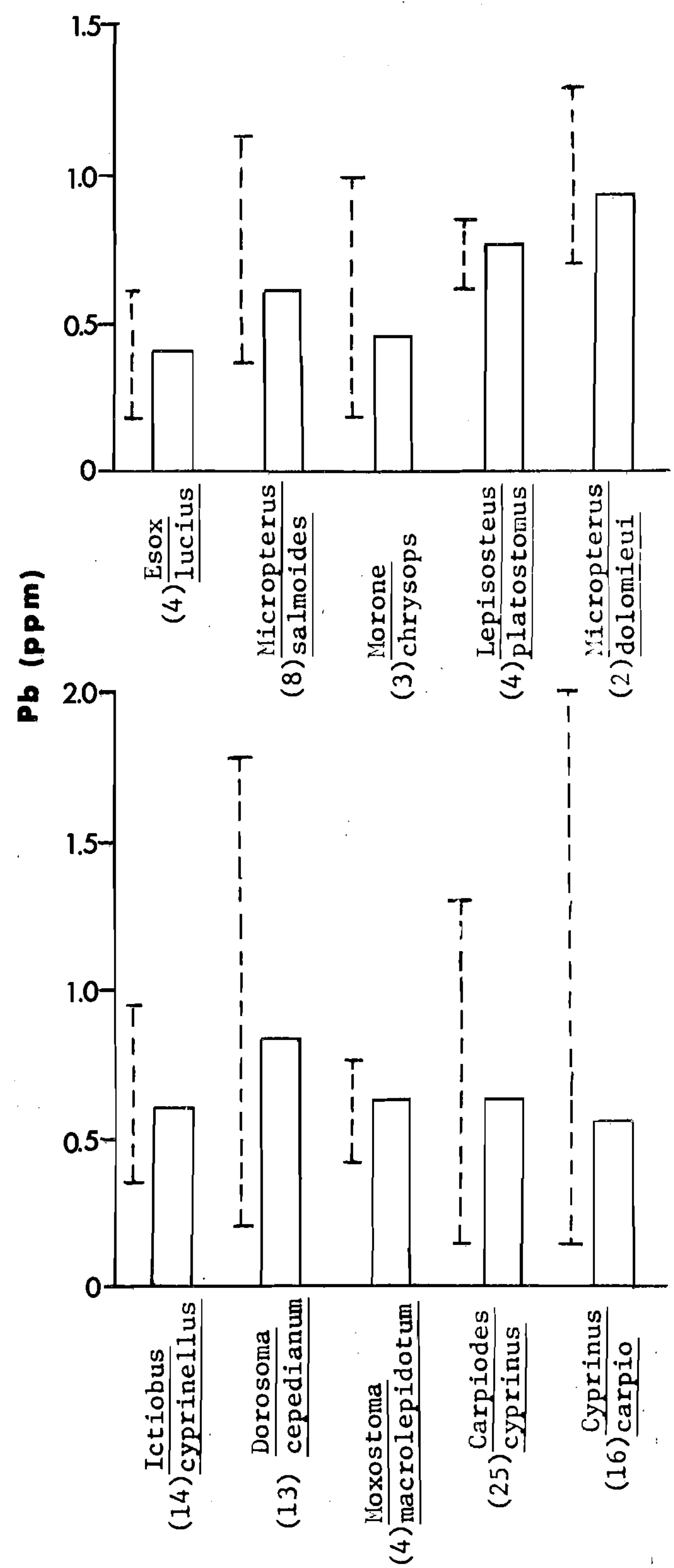


Figure 15. Mean concentration of lead in Illinois River fishes. Number in parentheses indicate number of samples. (⊢‒‒⊣) = range.

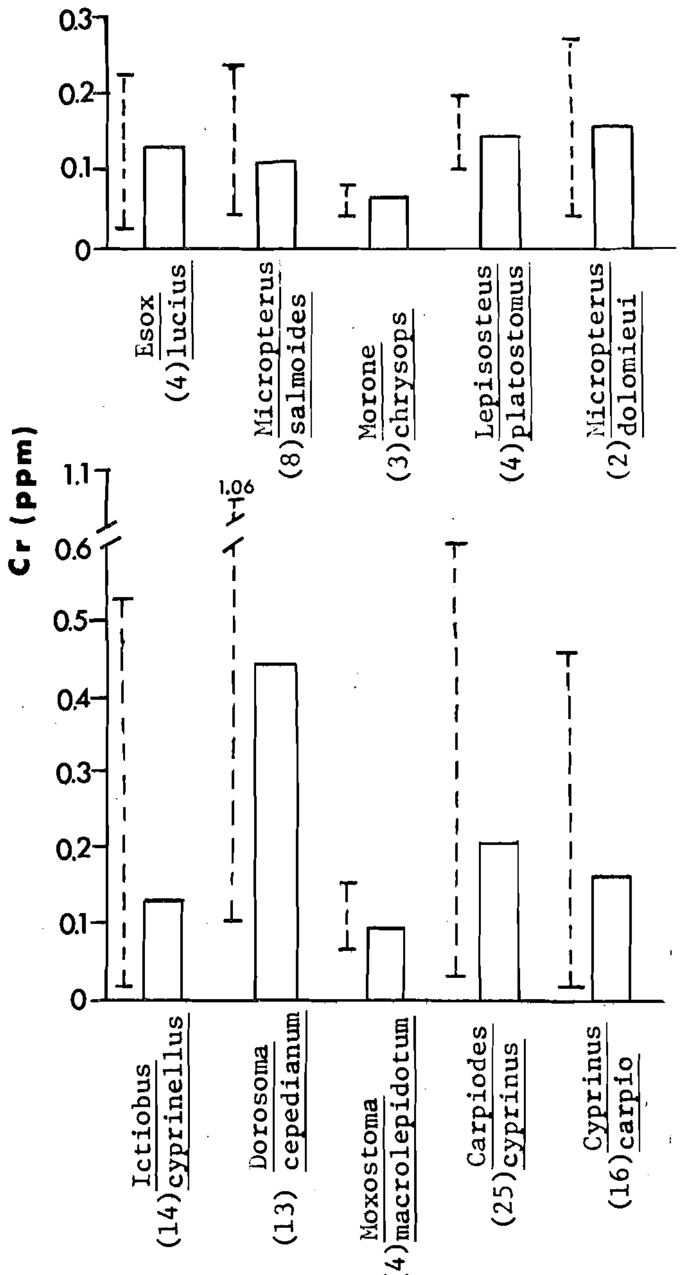


Figure 16. Mean concentration of chromium in Illinois River fishes. Numbers in parentheses indicate number of samples. (----) = range.

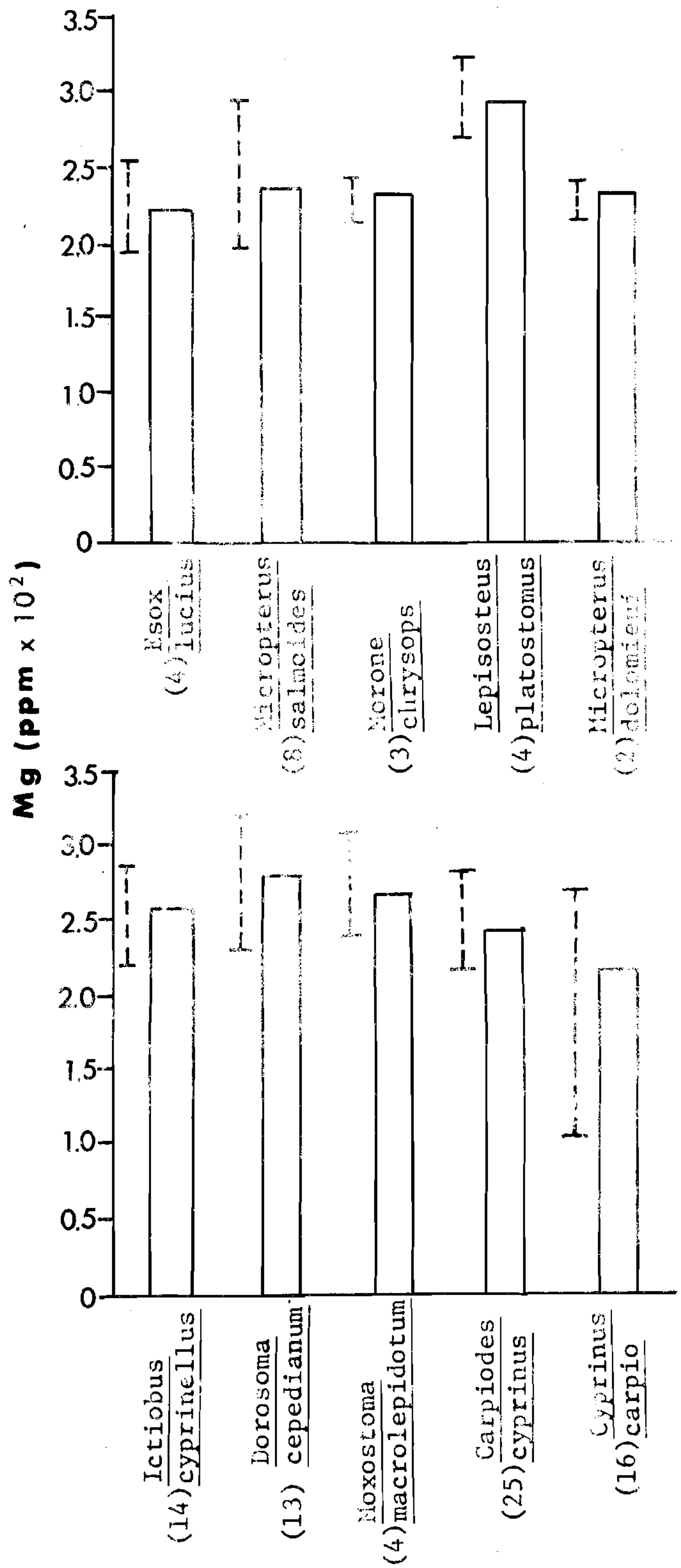


Figure 17. Mean concentration of magnesium in Illinois River fishes. Numbers in parentheses indicate number of samples. (----) = range.

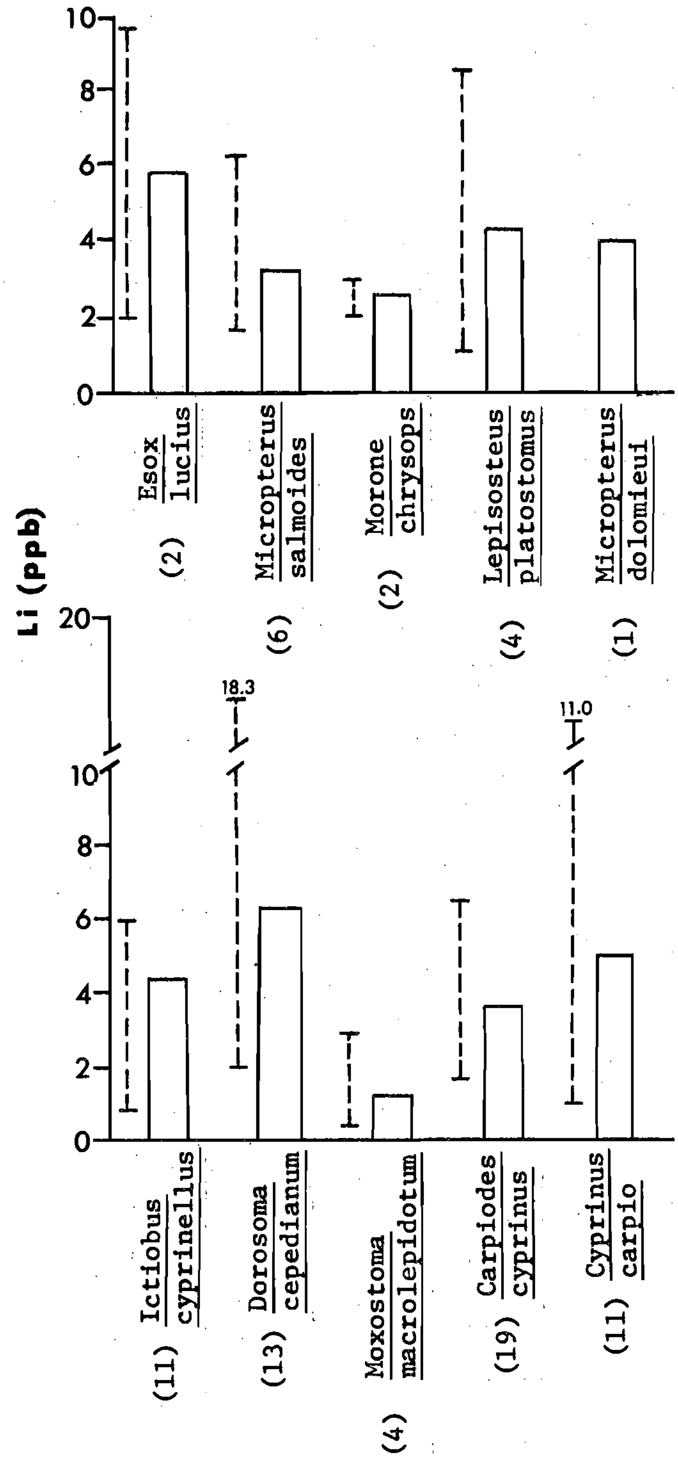


Figure 18. Mean concentration of lithium in Illinois River fishes. Numbers in parentheses indicate number of samples. (----) = range.

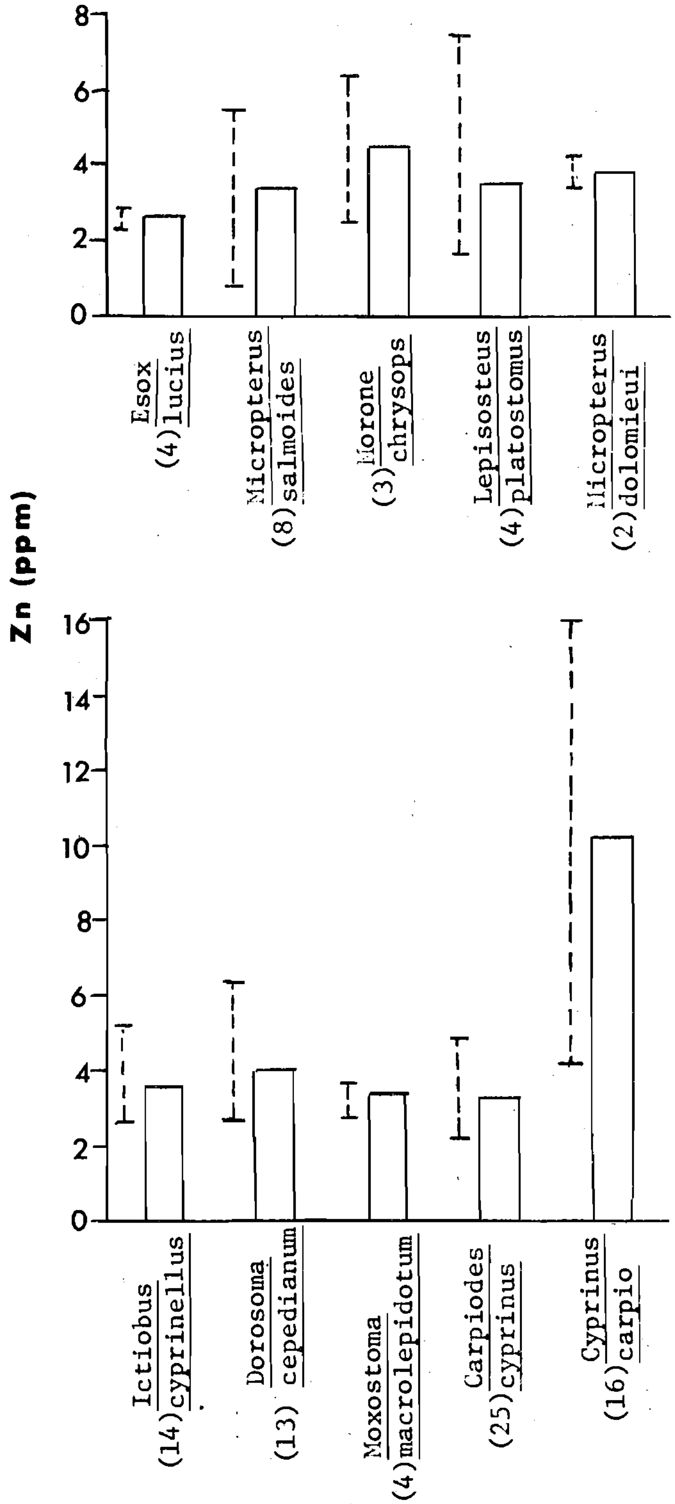


Figure 19. Mean concentration of zinc in Illinois River fishes. Numbers in parentheses indicate number of samples. (----) = range.

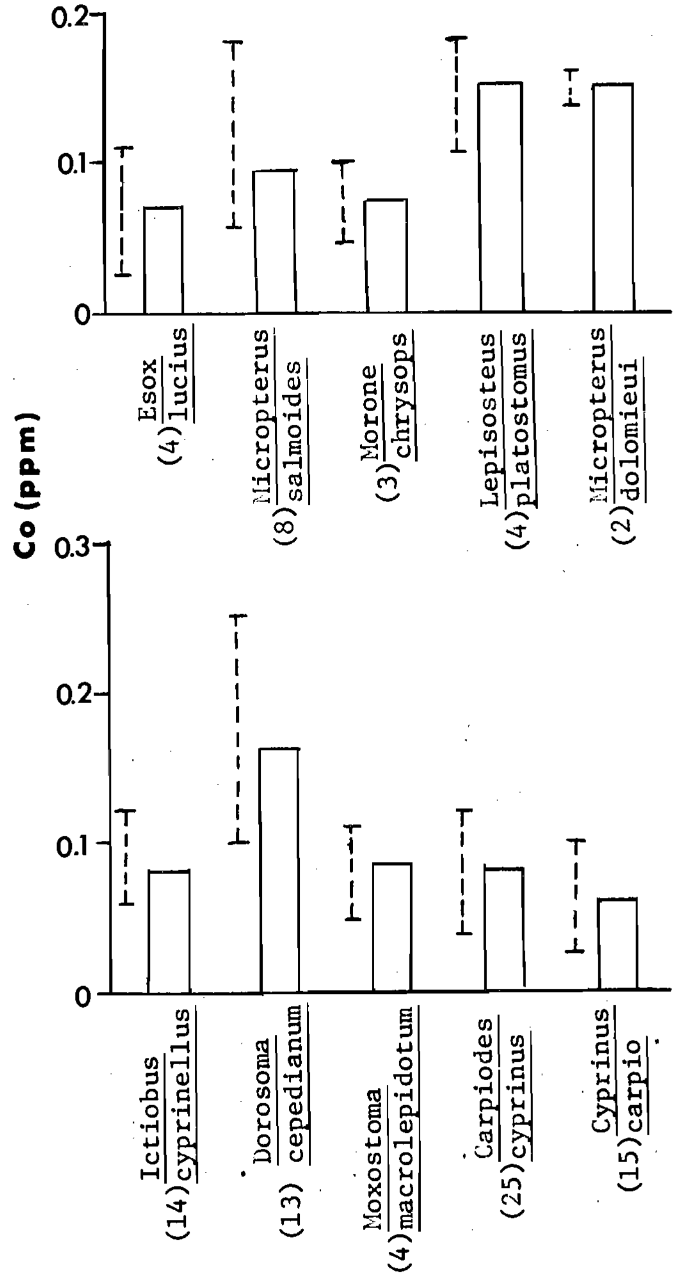


Figure 20. Mean concentration of cobalt in Illinois River fishes. Numbers in parentheses indicate number of samples. (----) = range.

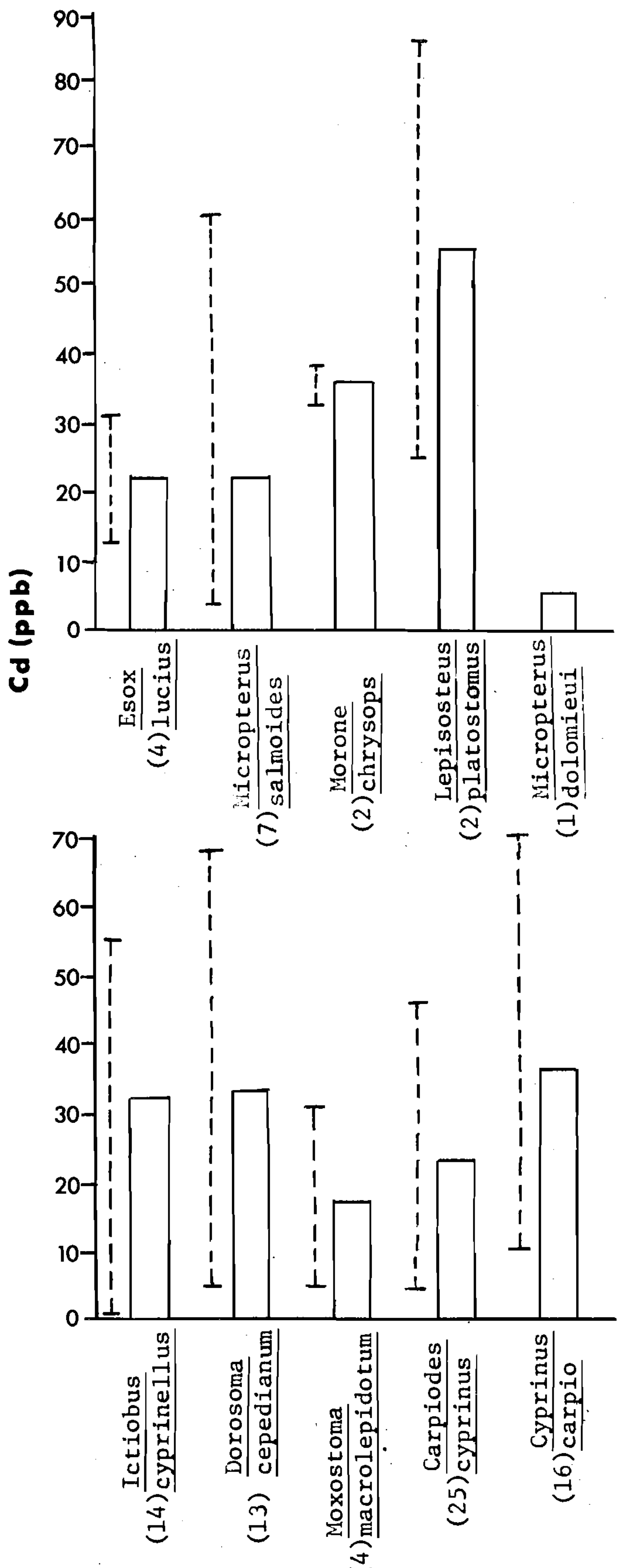


Figure 21. Mean concentration of cadmium in Illinois River fishes. Numbers in parentheses indicate number of samples. (----) = range.

Species of fishes in Figures 12 through 21 have been grouped primarily according to their feeding habits. Those in the upper half of the graphs are primarily carnivorous in nature while those in the lower half are primarily non-carnivorous. It is recognized, however, that some overlap between the two groups may occur on occasion. When carnivorous and non-carnivorous groups are compared statistically, it can be shown that there are no significant differences at the 95 percent level between lead, magnesium, cobalt, lithium, and cadmium (Table 6). There are significant differences, however, at the 95 percent level for the other five metals but in each case, the non-carnivorous fishes exhibited higher mean concentrations.

The bottom dwelling tubificids and clams more closely reflected the concentrations of metals found in bottom sediments than did the fishes. A concentration gradient ranging from highest levels in worms, intermediate levels in clams, and lowest levels in fishes was observed for copper, nickel, iron, lead, chromium, lithium, cobalt, and cadmium (Figures 22-25). Zinc, however, exhibited a partial reversal of this trend (Figure 25). It was present in highest concentrations in clams, at intermediate levels in worms, and at lowest levels in fishes. Magnesium was present in about equal concentrations in all three groups of organisms.

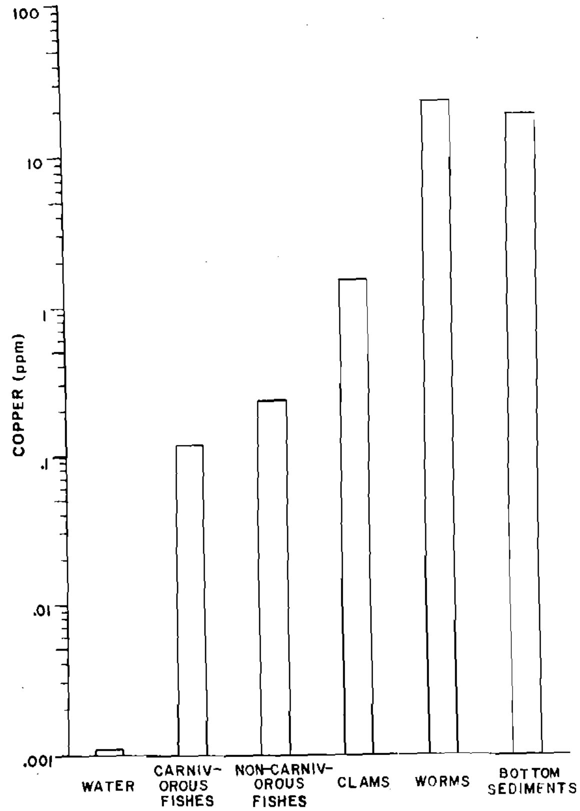
TABLE 6

Means of Metal Concentrations in Carnivorous and Non-Carnivorous Species of Fishes from the Illinois River

Metal (ppm)	Number of Samples Analyzed	Carnivorous Fishes	Number of Samples Analyzed	Non-Carnivorous Fishes	Results of Analysis of Variance
Cu	22	0.13	72	0.21	*
Ni	21	0.12	71	0.17	*
Fe	22	2.50	72	7.36	*
Pb	22	0.57	72	0.64	**
Cr	22	0.12	72	0.22	*
Mg	22	240	72	245	**
Li	15	0.004	58	0.004	**
Zn	22	3.49	72	5.02	*
Co	22	0.10	71	0.10	**
Cd	17	0.02	64	0.03	**

* Indicates significant difference at the 95 percent level.

**Indicates no significant difference at the 95 percent level.



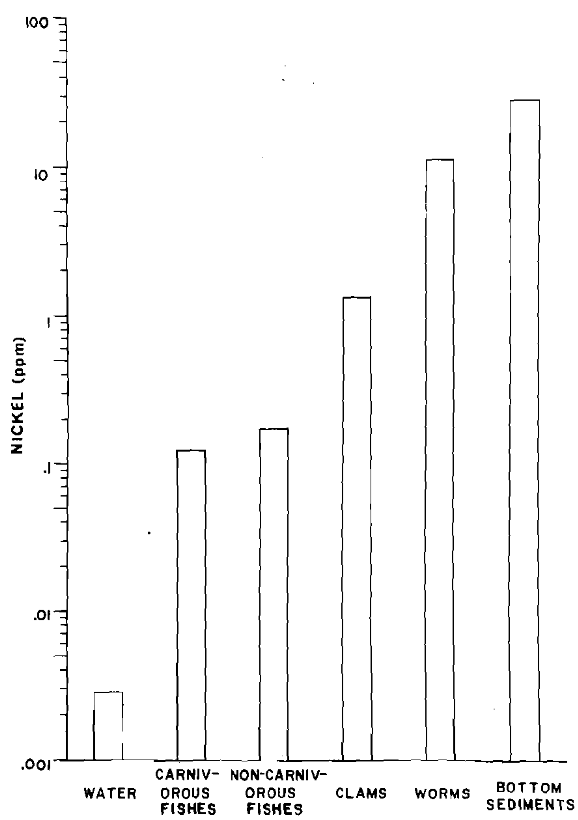
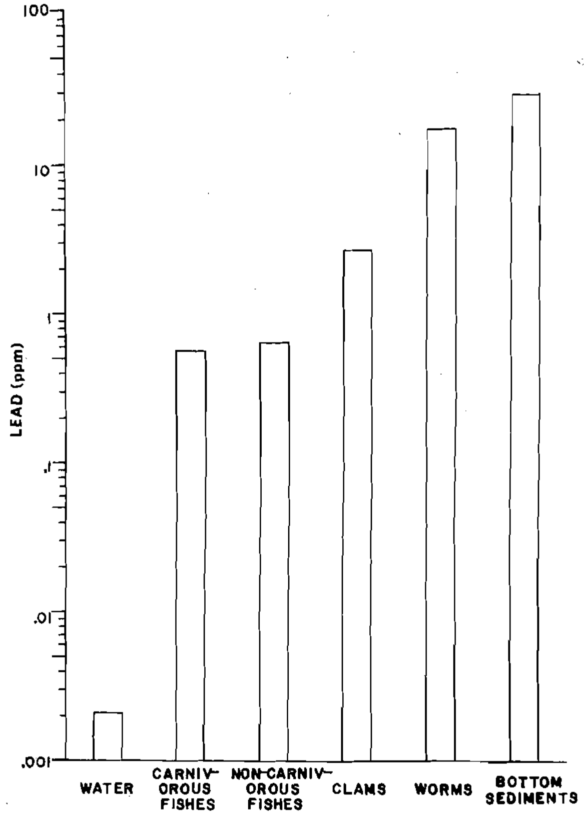


Figure 22. Mean concentrations of copper and nickel in water, biota and sediments of the Illinois River.



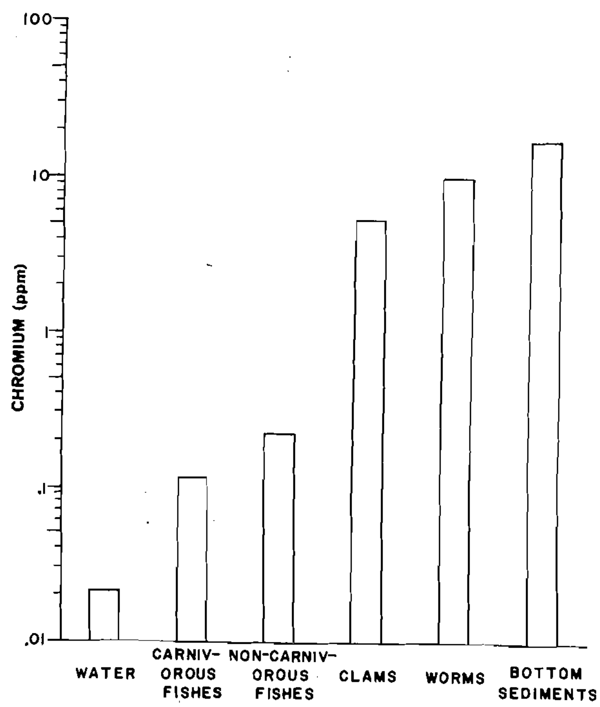
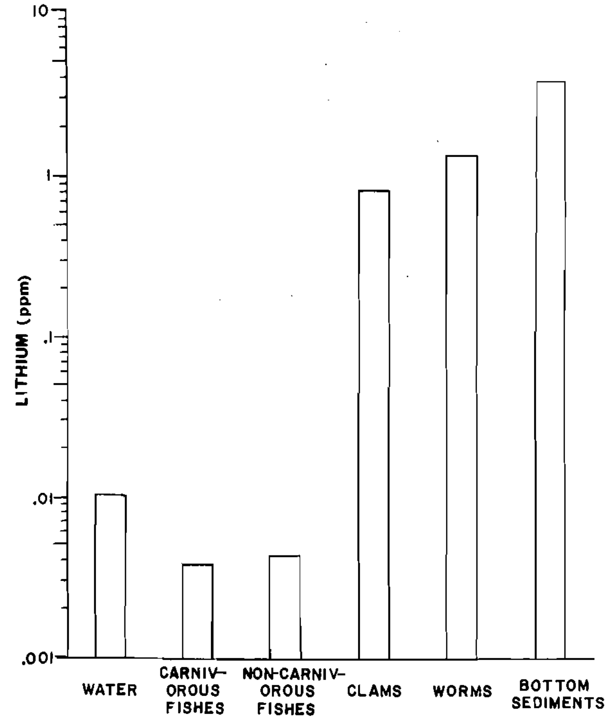


Figure 23. Mean concentrations of lead and chromium in water, biota and sediments of the Illinois River.



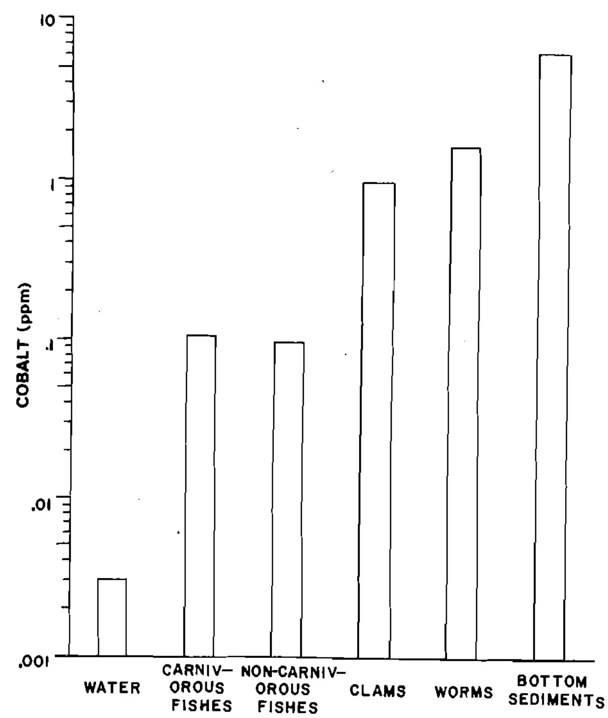


Figure 24. Mean concentrations of lithium and cobalt in water, biota and sediments of the Illinois River.

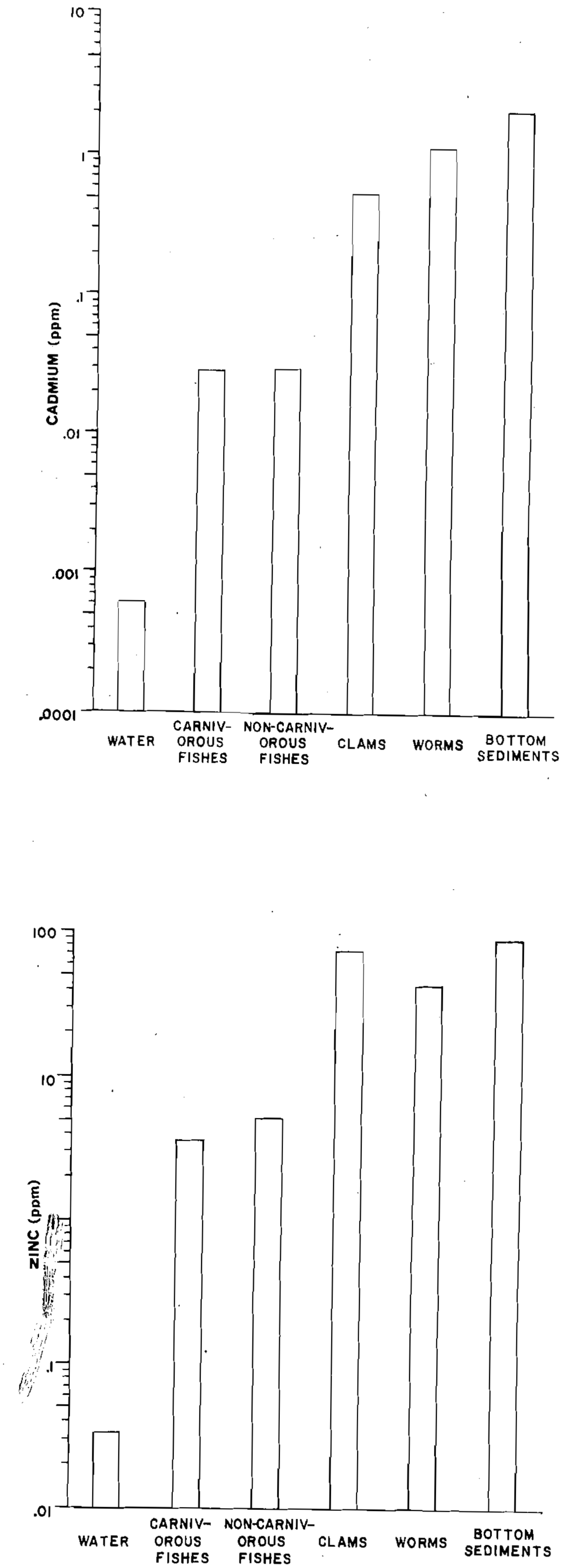


Figure 25. Mean concentrations of cadmium and zinc in water, biota and sediments of the Illinois River.

Distribution of Selected Metals in Bottom Sediments, Water, Clams, Tubificid Annelids, and Fishes of the Middle Illinois River

Summary

Analyses were made for thirteen metals in bottom sediments, twelve in water, and ten in tubificid worms, clams, and fishes. Significant differences in concentrations of metals in bottom sediments of the Illinois River and three non-industrial use streams were observed. Analyses for twelve metals in Illinois River water and three non-industrial use streams revealed concentrations, except for lead, copper, and cobalt, to be similar. These three metals were more highly concentrated in Illinois River water.

Bottom dwelling tubificid worms and clams more closely reflected the concentrations of metals found in bottom sediments than did fishes. Fishes that are primarily non-carnivorous in nature exhibited significantly different concentrations of copper, nickel, iron, chromium, and zinc when compared to carnivorous fishes.

Thus it appears that the ten metals for which analyses were made in biota do not concentrate along successive trophic levels as is the case with pesticides. Organisms such as clams and worms that inhabit the mud or mud-water interface exhibited the highest metal concentrations. At higher trophic levels, however, concentrations were lower, with fishes that are primarily carnivorous in nature exhibiting the lowest concentrations.

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POTENTIAL APPLICATION TO WATER RESOURCES PROBLEMS

This study was designed to assess the extent of metal contamination in a large mid-western river that is utilized by industries and certain cities as a source of potable water as well as for sewage disposal. The problem of metal contamination in aquatic systems is just now being recognized as a potential hazard to human health while the degree to which aquatic biota are affected remains speculative. This study, basically a pilot study, outlines procedures by which similar studies can be made and provides data that others may use in assessing the degree of metal contamination in multiple use rivers.

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