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CONCENTRATIONS OF CADMIUM COPPER, LEAD, NICKEL AND ZINC IN WALLEYE, DRUM, YELLOW PERCH AND GIZZARD SHAD FROM WESTERN LAKE ERIE WITH RESPECT TO AGE AND TROPHIC LEVEL

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PREFACE

The following document is based on a thesis prepared by Robert W. Foster for a Master of Science Degree in the Department of Biology, Bowling Green State University. Research conducted for this report was part of a project coordinated by the Center for Lake Erie Area Research and was sponsored by the U.S. Environmental Protection Agency, Contract No. 68-01-5881. Drs. Lester J. Walters, Jr. and Rex Lowe served as faculty co-advisors; Dr. Karl Schurr served as a member of the reading and examination committee.

On behalf of the Center for Lake Erie Area Research, I am pleased that we are able to reproduce copies of this research report and make them available to other scientists.

Charles E. Herdendorf
Director

ABSTRACT

Four species of fish were collected at the same time and from the same location in the western basin of Lake Erie near Monroe, Michigan. Concentrations of cadmium, copper, nickel, lead and zinc were measured in nine different tissues (scales, stomach, flesh, muscle, kidney, spleen, heart, liver, and gills) to study the effects of species, age, and trophic level on metals concentrations. Whole water samples, planktonic and benthic organisms were also analyzed for comparison.

Metal concentrations were analyzed by an atomic absorption spectrophotometer on acid-digested samples. Results were examined for trophic level and age-tissue differences by an analysis of variance and a multivariate analysis of variance respectively.

Significant differences (at the .05 level) were found between tissues for all metals tested. Significant differences were also found for species (Cd, Ni, Zn), age groups (Cd, Cu, Ni), species age interactions (Cd, Cu, Pb), age-tissue interactions (Cd, Pb, Zn) and for species-tissue interactions (Cd, Zn).

No relationships were found between the concentrations of metals and the trophic level of the fish or between concentrations in the fish and the food consumed. Overall, metal concentrations were found to decrease with age in both

species giving results similar to those found in mammalian studies of this kind. Metals were found to accumulate mainly in the kidney, scales, heart and gills of the fish and least in the muscle tissue.

ACKNOWLEDGEMENTS

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And last but certainly not least I express my love and appreciation to Melissa Foster for her love, understanding

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INTRODUCTION

Western Lake Erie has been the subject of many investigations dealing with heavy metals because of the heavy industrialization around the basin and particularly the Detroit and Maumee Rivers, which are the largest sources of discharge into the basin. Studies on metals in the sediments (Walters, et al., 1974; Stith, 1973; Kovacik and Walters, 1973) and the role of sediments in taking up and holding metals (Wilson, 1978) shows the sediment in the lake to be an important "sink" for heavy metals via adsorption onto sediment particles. Likewise, adsorption of metals takes place on phytoplankton, detritus and other particulates suspended in the water column. Benthic organisms have been shown to concentrate metals from the sediments (Thommes, et al., 1972; Thomas, 1975) and because of this concentration of heavy metals at the base of the food chain, attention has been focused in recent years on the possible accumulation of the metals in fish higher up in the food chain of the lake.

Lucas et al. (1970) analyzed whole fish and fish livers for cadmium, copper and zinc and found levels of copper and zinc varied little between species and lakes and that levels of cadmium varied both between species and between lakes. In another study, Lovett et al. (1972) analyzed decapitated and eviscerated fish for cadmium and found levels to be only rarely species dependent. In addition, this study found no relationship between concentrations of cadmium and the size, sex or food ingested. Hutchinson, et al. (1977), in a study of nickel and copper in an aquatic ecosystem, found a species specificity in levels of both metals in fish but found no relationship between metal concentrations and the trophic level of the organism. This study utilized levels of metals in the muscle, liver, kidney and gills in order to draw these conclusions.

The present study is based on the hypothesis that the discrepancies between the studies of Hutchinson, et al. (1977), Lovett et al. (1972), and Lucas et al. (1970) are a result of the poor indicating qualities of the muscle alone and that analysis of the internal organs of the fish in addition to the muscle would provide a more accurate picture of relationships between species, size (or age) groups and the trophic levels in a natural population. In addition, attention was directed towards comparisons between the results of this study on fish and the results of previous studies dealing with the characteristics of heavy metal accumulation in mammals. A review of the literature concerning the metabolism of heavy metals in mammals can be found in Jugo (1977).

Walleye (Stizostedion vitreum vitreum), drum (Aplodinotus grunniens), yellow perch (Perca flavescens), and gizzard shad (Dorosoma cepedianum) were chosen for study because of their radically different feeding habits and co-habitation in the Western Basin. The walleye is known as a top carnivore in the Western Basin (Priegal, 1969) and would therefore occupy the highest trophic level of the fish in this study. Perch and drum are also carnivores but feed mainly on zooplankters when young and benthic crustaceans and molluscs when mature (Hubbs and Lagler, 1958; Turner, 1920; Keast, 1977). Shad have been found to be filter-feeders on phytoplankton (and thus herbivorous) and therefore occupy the lowest trophic position of the species in question (Baker, 1971; Velasquez, 1939).

Copper, nickel, lead, zinc and cadmium were chosen because of their high degree of toxicity and presence in relatively high concentrations in fish, plankton and benthos in a preliminary study by Wilson (1978).

MATERIALS AND METHODS

Description of Study Area

The western basin of Lake Erie comprises only five percent of the total volume of the lake yet receives 90% of all inflowing water. This high influx of water coupled with the overall shallowness and flat morphometry causes drastic effects on the limnological conditions of the lake, especially those related to temperature, turbidity, water level and nutrient cycling (Chandler and Weeks, 1945). In addition, the basin receives extensive nutrient and silt loading from the Detroit, Maumee and Sandusky Rivers which, along with high temperatures, calmness and high light intensity, result in stimulation of algal blooms leading to high productivity. The high levels of sediment influx, estimated to be approximately 4.4 million metric tons to the basin each year (Kemp, 1975, 1977), have been considered to be beneficial in trapping and burying heavy metal pollutants. However, the sediment may be mixed as a result of bioturbation, gas movement or water turbulance (Lee, 1970), and a number of chemical reactions may cause the mobilization of certain metals (Lu and Chen, 1977).

Stizostedion vitreum vitreum, *Aplodinotus grunniens*, *Perca flavescens* and *Dorosoma cepedianum* feed extensively throughout the Western Basin (Priegal, 1969; Bodola, 1966; Hubbs, 1958; Jobes, 1952). Reports from local fishermen indicate that most schooling of these species occurs along drop-offs running parallel to and within two to three miles of the shore.

The sampling station (Fig. 1) for the fish used in this study is located approximately one and one half miles offshore from the mouth of the River Raisin near Monroe, Michigan (lattitude 41°52'N., longitude 83°19'W.). Water depth at the station varied along the length of the collection net (16 m) from 5 to 6 meters. At the time of collection in October the water temperature ranged from 13°C at the surface to 11°C one foot from the bottom. The pH of the surface waters at this time was 8.18. Bottom sediments were generally fine-grained and dark in color.

Water, sediment, benthos and plankton samples were taken from a second station approximately two and one half miles from the first (latitude 41°55'00"N., Longitude 83°12' 30"W.). Water depth at this station was 8.0 meters with bottom sediments similar to that of the previous station.

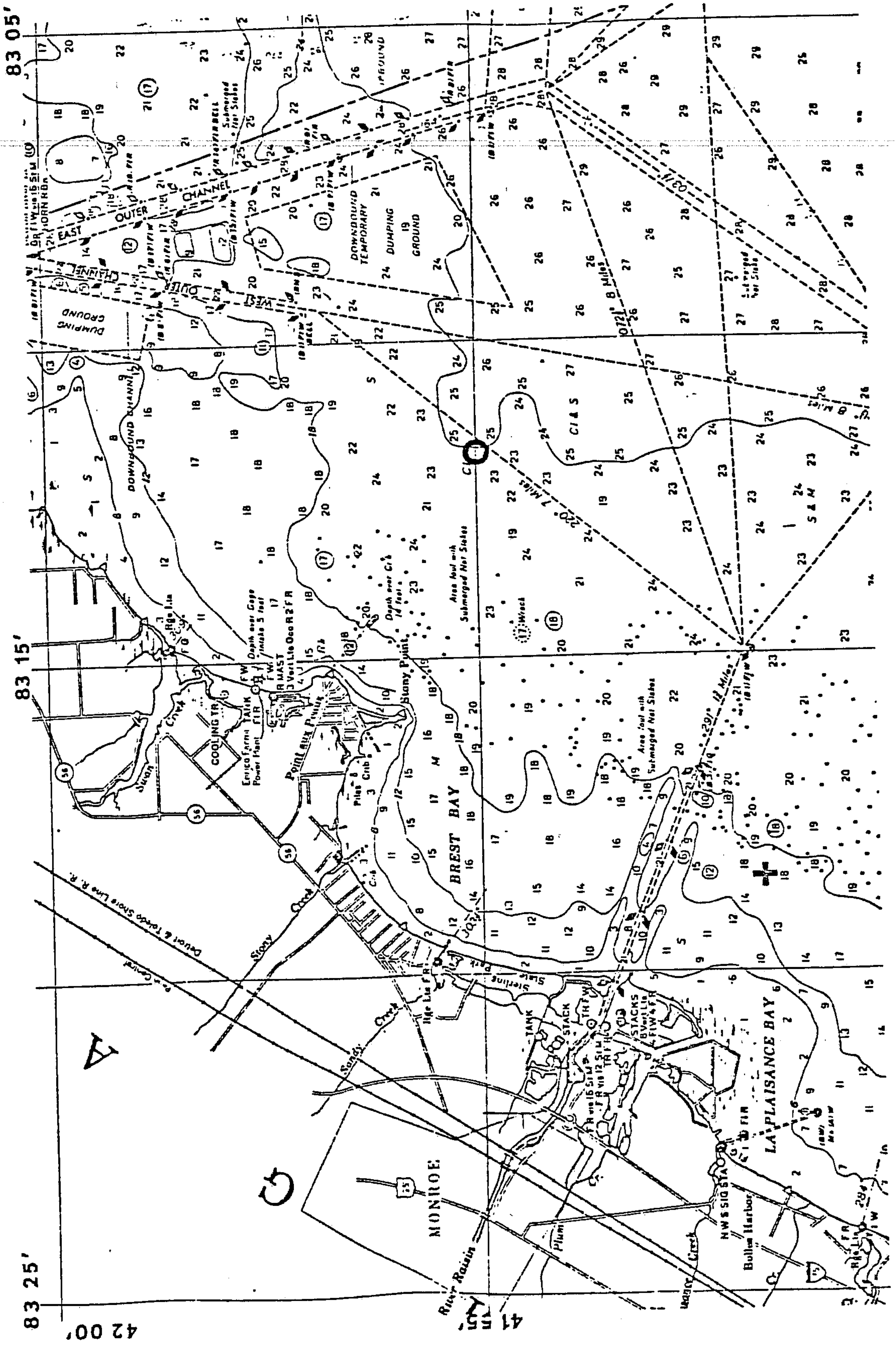
Sampling Procedure

All fish used in the study were collected on October 22, 1978 using a research monofilament gill net with three mesh sizes of 10cm, 5cm, and 2.5cm. Fish were tagged and put on ice immediately after removal from the net. All fish were then frozen until dissection (three weeks maximum).

The fish were aged by the scale method (Wallin, 1957) and keyed to species using the key by Trautman (1899). This

Figure 1.

Fish sampling location (at cross) approximately one and one-half miles south west of Monroe, Michigan. Water, sediment, benthos and plankton sampling location (at circle) approximately two miles east of Stony Point. Map taken from U.S. Department of Commerce, NOAA--National Ocean Survey, Lake Survey Center (1972).


83 05'
83 15'
83 25'
42 00'
41 55'
DUMPING GROUND
DOWNBOUND CHANNEL
EAST OUTER CHANNEL
DOWNBOUND TEMPORARY DUMPING GROUND
Enrico Fermi Power Plant
COOLING TR
Swan Creek
Point Aux Peaux
Stony Point
BREST BAY
Stony Creek
Detroit & Toledo Shore Line R.R.
Penn Central
Sandy Creek
Sterling State Park
TANK
STACK
STACKS
LA PLAISANCE BAY
MONROE
River Raisin
Plum Cr
NWS SIG STA
Bolles Harbor
Area foul with Submerged Net Stakes
8 Miles
12 Miles
7 Miles
A
G

method of aging has been deemed valid for both Perca and Dorosoma which were the only species used in the age analysis (Jobes, 1952; Bodola, 1966). Fish actually used in age analysis were randomly selected from three age groups in each species (four fish per age group per species). For Perca, age group I consisted of fish aged 1-2 years. Age group II was comprised of fish aged 3-4 years and age group III was comprised of fish aged 6-7 years. Dorosoma age group I consisted of fish 1 year old and less, age group II included fish aged 3-5 years and age group III included fish aged 7-8 years.

Benthic organisms were collected by ponar and washed through a Nalgene LPE/Polyester seive with lake water. The organisms were separated from the sediment by a flotation process in a solution of sucrose and water with a specific gravity of 1.12 grams per liter (Lind, 1974). The floating organisms were washed three times with lake water to remove any sugar and were refrigerated in polyethylene bottles.

Plankton were collected by a vertical draw net with a 0.75 meter opening and a 64 micron nylon mesh. Concentrated plankton was refrigerated in polyethylene bottles until digestion.

Sample Preparation

Parts of the fish to be analyzed were removed using teflon instruments and a glass tray. Fish parts were placed into 32 or 72 ml snap cap glass bottles depending on size, weighed wet, and were digested in a water bath on a hot plate using 5 ml H_2SO_4 and 2 ml HNO_3 in the 32 ml bottles or 20 ml H_2SO_4 and 8 ml HNO_3 in the 72 ml bottles. Samples were diluted to 15 ml and 50 ml in the 32 ml and 72 ml bottles respectively using distilled-deionized water. Because some residue remained in many of the sample bottles after digestion filtration was necessary. All samples were filtered using Whatman GF/A glass fiber paper washed with a 1:1 nitric acid solution. Corrections for the dilution of samples during filtration were made by adding a known amount of lithium (not previously found in the samples) before filtration and then analyzing the samples for lithium after filtration. Several blanks were run along with the samples and values obtained from the blank analysis were subtracted from the sample values, although blank values were very low for all metals tested.

With the exception of scales, flesh and muscle, all tissues (organs) were removed in as much a whole state as possible. Enough scales, flesh and muscle was removed to obtain sample weights of between one and three grams. The nomenclature is self-explanatory for all tissues with the exception of "stomach." This term includes both the stomach of *Perca*, *Stizostedion* and *Aplodinotus* and the gizzard of *Dorosoma*. In addition, both organs were digested as removed and no attempt was made to remove the contents.

Plankton and benthos samples were digested by the procedure outlined in Perkin-Elmer (1976, p. BC-13) as modified by Wilson (1978) and listed here in Appendix I.

Metals Analyses

All analyses were performed using a Perkin-Elmer model 603 atomic absorption spectrophotometer. Lithium and zinc were run with a 3-slot Boling-type burner head using an air-acetylene flame. Lithium was determined using the flame emission mode. Copper, nickel, cadmium and lead were run with an HGA-2100 graphite furnace attachment because of lower concentrations of these metals. Samples run using the graphite furnace were diluted 1:6 with distilled-deionized water to insure the complete atomization of the sample. Samples with known concentrations were run repeatedly throughout each analysis as a quality control.

Statistical Analyses

Nine separate analyses of variance were run for the nine body parts taken from all four species to test for significant trends between species. The subprogram ONEWAY of the SPSS statistical package (Nie, Hull, Jenkens, Steinbrenner and Bent, 1975) was used which included an aposteriori test for significance at the 0.05 level (SCHEFFE).

Two separate multivariate analyses of variance (SAS statistical package; Barr, Goodnight, Sall, Helwig, 1976) were run on the data collected for *Perca* and *Dorosoma* to test

RESULTS

The results of this study are given as non-transformed means for the analysis of variance run on all fish species (Appendix II) and for the multivariate analysis of variance run on <u>Perca</u> and <u>Dorosoma</u> (Appendix III). The raw data used for these analyses of variance are given in Appendices IV, V, and VI respectively. A summary of the analysis of variance results from transformed means is given in Table I and the results of the multivariate analysis of variance on transformed data are given in Table II, listed as probability values greater than F. In all cases an alpha (α) of 0.05 was used to determine significance.

The summary of the analysis of variance results for differences in concentrations among all four species (Table I) shows no consistent trends in concentration values for any one species. By tissue there seems to be a tendency towards higher concentrations of metals in the stomach of <u>Aplodinotus</u> (in this case cadmium, lead and zinc), but no other such trends are evident.

The analysis of the data collected from <u>Perca</u> and <u>Dorosoma</u> over all tissues showed significant differences in concentrations between the two species for nickel, zinc and cadmium (Table III). <u>Perca</u> contained higher overall concentrations of nickel and zinc than <u>Dorosoma</u> but was lower in lead. This analysis differs from the previous one on all four species in that all tissues are averaged.

for significant concentration trends by age, species, species by age, tissue, age by tissue species by tissue and species by age by tissue. Subject (species by age) was used as an error term for the age, species, and species by age analysis. The spleen was dropped from this analysis because of an inability to collect this tissue from age group I *Dorosoma*. Thus this analysis involved a 2*3*8 factoral design for each of the five metals analyzed. Scheffé's test of Multiple Comparisons was used as an aposteriori test here also to distinguish between metal concentrations in tissues and age groups. This test was done by hand using the formula given in Scheffé, 1959. A square root transformation was necessary for all statistical analyses because of an increase in the standard deviation of sample means with increases in the metal concentrations in the samples.

TABLE I

Summary of results of analysis of variance testing trophic level significance.

TABLE I

Metal	Species			
	Drum	Walleye	Shad	Perch
Ni		> perch in scales	> walleye in stomach	> walleye
Zn	> walleye and perch in stomach			> all in kidney
Cd	> all in stomach		> walleye in gills	
Pb	> walleye in stomach			
Cu	NO SIGNIFICANT DIFFERENCES			

TABLE II

Summary of results of multivariate analysis of variance. Values are given as probabilities F. An alpha of 0.05 was used to test for significance.

TABLE II

Source	Probability Value > F				
	Cd	Cu	Ni	Pb	Zn
Age	0.000	0.013	0.015	0.078	0.831
Species	0.013	0.210	0.036	0.734	0.008
Spec*Age	0.000	0.012	0.650	0.010	0.256
Tissue	0.000	0.000	0.000	0.000	0.000
Age*Tissue	0.000	0.058	0.274	0.000	0.053
Spec*Tissue	0.012	0.483	0.681	0.535	0.000
Spec*Age*Tissue	0.000	0.003	0.668	0.006	0.194

TABLE III

Results of multivariate analysis of variance testing age and species. A solid line connecting values indicates no significant difference using Scheffé's test of Multiple Comparisons. Values given are mean concentrations in parts per million (ppm).

TABLE III

OVERALL SPECIES RESULTS

	Concentration ug/g	
Metal	Perca	Dorosoma
Cd*	0.66	1.40
Cu	11.42	13.23
Ni*	3.68	2.42
Pb	0.30	0.44
Zn*	27.88	17.95

*significance difference

OVERALL AGE RESULTS

	Concentration ug/g		
Metal	Age Group I	Age Group II	Age Group III
Cd	2.21	0.67	0.22
Cu	16.64	14.50	5.84
Ni	4.62	2.15	2.37
Pb	0.51	0.37	0.23
Zn	25.47	22.69	20.58

Differences between age groups were found for copper, nickel and cadmium. In each case the concentration of these metals decreased as age increased; however, only cadmium shows a significant difference in concentration between age groups I and II (Table III). An age-species interaction was found to be significant for cadmium, copper and lead (Table IV). Dorosoma exhibited higher concentrations of all three metals than Perca in age group I and Perca showed a higher concentration of copper in age group II. In addition, the data show two significant increases in concentration from age group I to age group II in the cases of copper and lead in Perca.

Differences in metal concentration between tissues sampled over all species and age groups were significant for all metals at the 0.05 level (Table V). Cadmium was found to accumulate most in the kidneys with the heart, scales and flesh following in order. The gills and liver showed no significant difference at a relatively low concentration as did the stomach and muscle which contained the lowest concentrations. Copper concentrations were also highest in the kidneys and heart but in this case the liver concentration was not significantly different from that of the flesh. Muscle concentration ranked low in copper also. Nickel concentrations were highest in the scales and kidney; heart and liver concentrations were significantly lower. In this case all tissue concentrations other than that of the scales were

TABLE IV

Results of multivariate analysis of variance on species-age interaction. A box enclosing two values indicates the values are significantly different. A solid line between values also indicates a significant difference using Scheffé's test of Multiple Comparisons. Values are given as mean concentrations in parts per million (ppm). Results are given only for those metals showing significant differences.

TABLE IV
SPECIES - AGE INTERACTION

Metal	Species	Mean Concentration (ug/g) Age Group I	Age Group II	Age Group III
Cd	*Perca*	0.979	0.722	0.284
	Dorosoma	3.431	0.621	0.151
Cu	*Perca*	7.682	21.100	0.505
	Dorosoma	25.602	7.906	6.181
Pb	*Perca*	0.244	0.354	0.305
	Dorosoma	0.779	0.386	0.159

TABLE V

Results of multivariate analysis of variance on tissue interactions. A solid line connecting values indicates no significant difference using Scheffé's test of Multiple Comparisons. Values are given as mean concentrations in parts per million (ppm).

TABLE V

OVERALL TISSUE RESULTS

Metal	Mean Concentration (ug/g)							
Cd	Kidney 2.589	Heart 2.010	Scales 1.391	Flesh 0.875	Gills 0.415	Liver 0.408	Stomach 0.291	Muscle 0.274
Cu	Kidney 33.943	Heart 16.767	Liver 11.657	Scales 11.219	Tills 9.877	Flesh 5.862	Stomach 6.396	Muscle 2.917
Ni	Scales 6.442	Flesh 3.471	Gills 2.955	Stomach 2.829	Muscle 2.577	Kidney 2.334	Heart 2.111	Liver 1.655
Pb	Kidney 0.663	Scales 0.641	Heart 0.387	Gills 0.548	Flesh 0.293	Liver 0.188	Stomach 0.167	Muscle 0.081
Zn	Scales 57.458	Kidney 38.009	Gills 18.069	Liver 18.272	Stomach 16.062	Flesh 15.011	Heart 10.928	Muscle 9.480

not significantly different. Lead concentrations were similar to those of cadmium in distribution with the kidney, scales, heart and gills highest in order and muscle concentrations very low. Zinc concentrations were highest in the scales but most other tissues showed no significant concentration differences.

Proportions of metal concentrations between tissues were found to remain the same between Dorosoma and Perca with the exceptions of cadmium and zinc (Table VI). In cadmium, the difference between the two species is seen in the actual number of significant differences. Although the order of tissue concentrations from highest to lowest is similar, more tissues are significantly different in Dorosoma. Zinc concentrations however exhibit a major difference in the kidneys between the two species. Kidney concentrations are significantly higher than other tissues in Perca (although not significantly higher in the scales) but rank very low in Dorosoma.

Significant differences were also found between the proportions of cadmium, lead and zinc between tissues among the three age groups (Table VII). For each metal the between-tissue variation is only seen from age group I to II. These results may not present a clear picture of the true variation however, as the sample sizes in this and the age-species-tissue interaction are very small.

Results of the analyses of plankton and benthos

(Table VIII) show concentrations to be higher for all metals in the benthos than in the plankton and water samples. Plankton in turn was in all cases higher than the water samples.

TABLE VI

Results of multivariate analysis of variance on species-tissue interaction. A solid line connecting two values indicates no significant difference using Scheffé's test of Multiple Comparisons. Values are given as mean concentrations in parts per million (ppm). Results are given only for those metals showing significant differences.

TABLE VI

SPECIES-TISSUE INTERACTION

Metal		Tissue/Concentration (ug/g)							
Cd	Perca	Kidney 1.543	Heart 1.549	Scales 0.641	Flesh 0.349	Stomach 0.379	Gills 0.275	Liver 0.247	Muscle 0.312
	Dorosoma	Kidney 3.635	Heart 2.470	Scales 2.141	Flesh 1.401	Gills 0.554	Liver 0.569	Muscle 0.237	Stomach 0.202
Zn	Perca	Kidney 69.261	Scales 62.262	Flesh 19.588	Gills 17.727	Liver 15.879	Stomach 13.994	Heart 12.578	Muscle 11.711
	Dorosoma	Scales 52.654	Gills 18.411	Liver 20.665	Stomach 18.130	Flesh 10.434	Heart 9.278	Muscle 7.250	Kidney 6.756

TABLE VII

Results of multivariate analysis of variance on age-tissue interaction. A solid line connecting two values indicates no significant difference using Scheffé's test of Multiple Comparisons. Values are given as mean concentrations in parts per million (ppm). Results are given only for those metals showing significant differences.

TABLE VII

AGE-TISSUE INTERACTION

Metal	Age Group	Tissue/Mean Concentration (ug/g)							
Cd	I	Kidney 5.825	Heart 4.768	Scales 2.914	Flesh 1.568	Liver 0.855	Gills 0.583	Muscle 0.667	Stomach 0.461
	II	Kidney 1.426	Scales 1.010	Heart 0.983	Flesh 0.824	Gills 0.583	Liver 0.264	Stomach 0.251	Muscle 0.086
	III	Kidney 0.516	Heart 0.277	Flesh 0.233	Scales 0.248	Gills 0.533	Stomach 0.160	Liver 0.106	Muscle 0.070

TABLE VII (continued)

Metal	Age Group	Tissue/Mean Concentration (ug/g)							
Pb	I	Scales 1.243	Kidney 1.026	Heart 0.807	Flesh 0.417	Liver 0.198	Gills 0.138	Stomach 0.136	Muscle 0.125
	II	Gills 1.394	Scales 0.488	Kidney 0.325	Flesh 0.246	Liver 0.159	Stomach 0.135	Heart 0.154	Muscle 0.059
	III	Kidney 0.637	Stomach 0.234	Flesh 0.216	Liver 0.206	Scales 0.191	Heart 0.198	Gills 0.122	Muscle 0.058

TABLE VII (continued)

Metal	Age Group	Tissue/Mean Concentration (ug/g)						
Zn	I	Scales	Kidney	Flesh	Gills	Stomach	Liver	Muscle	Heart
		83.379	38.884	17.264	15.832	13.515	11.591	14.947	8.338
	II	Scales	Kidney	Gills	Liver	Heart	Flesh	Stomach	Muscle
		49.550	51.135	22.790	15.241	12.825	12.778	11.066	6.131
	III	Scales	Liver	Stomach	Kidney	Gills	Flesh	Heart	Muscle
		39.445	27.983	23.605	24.007	15.585	14.992	11.621	7.362

TABLE VIII

Metal concentration in possible sources of heavy metals in Lake Erie fish. Values are given in parts per million (ppm).

TABLE VIII

HEAVY METALS IN LAKE ERIE FISH

	Metal Concentration (ppm)				
Source	Cd	Cu	Ni	Pb	Zn
Water*	0.002	0.400	0.010	0.007	0.310
Plankton	0.045	0.560	0.180	0.040	5.400
Benthos	0.080	2.050	2.000	0.650	12.000

*dissolved metals

DISCUSSION

Comparisons of the results of this study to those of previous studies on metals concentrations in *Perca valvescens* and *Dorosoma cepedianum* in natural populations (Lucas et al., 1970; Lovett et al., 1972; Pakkala et al., 1972; Uthe and Bligh, 1971) show a very close similarity in most cases although these studies generally used decapitated and eviscerated fish. Concentrations of metals found in muscle tissue of fish used in this study were used for the above comparison. The only direct comparison made between average liver concentrations for cadmium, copper and zinc by Lucas et al. (1970) and liver concentrations in this study is very close for values of cadmium and copper and reasonably close for values of zinc (<10%).

The data obtained seem to back up the conclusions of Hutchinson et al. (1977) that there is a species dependency of metal uptake (over all tissues for nickel, zinc and cadmium in this study) but there is no relationship between metal content and the trophic level of the organism. If this were so, *Stizostedion* would be expected to have the highest overall concentrations as a top carnivore and *Dorosoma* the lowest overall concentrations as an herbivore. However, in this study no trends of this sort are evident for any particular metal or tissue. Metal concentrations in *Stizostedion* were if anything lower than those of the other species tested this study with those found in previous studies on mammals (Jugo, 1977) shows many similarities. The overall decrease in metal concentrations between the juvenile and adult fish seen here has been shown in both rats and humans and is considered to be a result of a higher rate of absorption (Shields et al., 1939; Kostial et al., 1971; Alexander et al., 1972, 1974) and a lower rate of excretion in the juveniles (Kostial et al., 1973; Jugo, 1973; Alexander et al., 1972, 1974). Age-related differences in the body distribution of heavy metals has also been found in mammals for lead (Momcilovic and Kostial, 1974), cadmium (Gunn and Gould, 1957), inorganic mercury (Jugo, 1975b) and for other metals. The general trend seems to be a higher retention of metals in the brain of the immature organism and a lower retention in the kidneys compared to adults. The data from this study shows no significant differences between kidney concentrations from juvenile to adult. Other tissue concentration differences do occur between age groups as seen in cadmium, lead and zinc (Table VII) but the data show differences in the numbers of tissues significantly differing from each other between age groups rather than differences in the order of tissues ranked high to low. It is doubtful whether generalizations could (or should) be made about these differences without a larger sample size. This caution should also be exercised when examining the results of the species-tissue interaction in which cadmium and lead showed significant differences. In these two cases it is probably most appropriate to recognize only that differences do occur and that the metals showing these significant differences may not be acting in the same manner.

with the single exception of nickel concentrations in the scales (Table I).

Age group analyses of the levels of metals in both Perca and Dorosoma decreased from the juvenile to adult age groups (Table IV) for all metals that showed significance (copper, cadmium and lead). However, in Perca copper and lead concentrations increased from age group I to II and then decreased to a level below that of the juvenile fish. Although this increase in concentration in the age group II perch may be attributed to their physiological condition in a still immature state (Jugo, 1975), other factors such as differences in habitat or feeding habits may also be causes. Habitat differences are assumed negligible because all the fish were caught at the same time and at the same location. Changes in the feeding habits of Perca may be a contributing factor to the increase as Perca flavescens has been found to have three fairly distinct feeding stages in its life history (Turner, 1920; Keast, 1977): young perch (year class 0) feed exclusively on copepods, cladocerans and other pellagic forms; middle aged fish (year class II) switch to insect larvae and other mostly benthic forms, and older fish (year class V and on) feed mainly on fish, crayfish and small snails. The important change here, from year class 0 to year class II, involves a tremendous increase in the concentration of metals per gram of food material, at least in the broad categories "plankton" and "benthos" used in this study

(Table VIII). The age groups used for Perca in this study correspond closely but not exactly to those listed above. Only a detailed study of stomach contents and analysis of these foods from the area of fish collection can resolve the question entirely. An interesting point is that analysis of the stomachs in this study do not reflect the dramatic change in metal uptake predicted. Only lead of the three metals significant for age exhibits a significant increase in stomach concentration from age group I to II.

Physiological changes during the development of Dorosoma seem to have completely obscured an apparent increase in metals consumption in the diet with age. Young Dorosoma have been found to selectively feed on zooplankters, then abruptly change to a diet of phytoplankton and gradually widen the variety of food sizes consumed as they age and their gill rakers become more developed (Cramer and Marzolf, 1970; Bodola, 1966; Tiffany, 1920; Velasquez, 1939). Their final diet as an adult consists of everything from filamentous algae to microscopic algal forms, sand and detritus. This would be expected to represent an increase in the amount of metals per gram of food ingested from the data collected here. Physiological changes during development that may account for this inverse relationship include such things as a faster rate of digestion in the young fish and maturation of the excretory system (Jugo, 1975).

Comparison of the trends found in metal accumulation in

CONCLUSIONS

The water and sediment conditions now present in Lake Erie's western basin cause fish to accumulate heavy metals well in excess of concentrations found in the water but below that of the food they consume. Most metal accumulation is species-dependent in nature and overall concentrations do not correspond to the trophic level of the fish. In addition, each metal in this study accumulated in selective tissues of the fish which in some cases were found to vary between species and/or between age groups.

Generally, fish show an overall decrease in metal concentration from juvenile to adult. This trend has also been found in mammals and is believed due to physiological changes in the organism as it matures. It seems likely that similar factors are involved in fish. However, a rise in metals concentrations in middle-aged perch corresponding to a major change in feeding habits suggests the possibility that feeding habits may in some cases override the physiological changes from juvenile to adult; perhaps in cases of very high metal concentrations.

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APPENDIX I

PROCEDURE FOR DIGESTION OF WATER, PLANKTON AND BENTHOS SAMPLES FOR TOTAL METALS ANALYSIS

1. Pre-rinse all glassware before using with 1:1 nitric acid followed by filtered water.*
2. For a water sample, add 6 ml ultrapure nitric acid to 100 ml sample and evaporate to near dryness.
3. Add 6 ml ultrapure nitric acid. For plankton and benthos samples add 6 ml ultrapure nitric to dried and weighed sample.
4. Cover with a pre-rinsed watch glass.
5. Digest approximately 30 minutes or until dryness is reached.
6. Allow to cool.
7. Add 5 ml 1:1 nitric acid rinsing the watch glass and sides of beaker.
8. Warm the beaker to aid in dissolution of the cake.
9. Allow to cool.
10. Filter through a pre-rinsed glass fiber filter paper (Whatman GF/A) into a 125 ml flask.
11. Rinse filter column with filtered water (small volume) and transfer quantitatively to a 50 ml volume tricflask.
12. Bring up to volume with filtered water.

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*Filtered water refers to water put through a Millipore charcoal-resin system. The resistivity of such water is approximately 18 megaohms.

APPENDIX II

NON-TRANSFORMED MEAN CONCENTRATIONS USED IN THE ANALYSIS OF VARIANCE TESTING TROPHIC LEVEL SIGNIFICANCE

Scales

	Species			
	Drum	Walleye	Shad	Perch
Metal	N=6	N=12	N=12	N=12
Cd	1.24	1.96	2.32	0.64
Cu	56.08	12.19	12.06	10.38
Ni*	8.84	6.01	4.04	1.44
Pb	1.24	1.96	2.14	0.64
Zn	52.46	44.37	52.56	62.26

Stomach

	N=6	N=9	N=12	N=12
Cd*	3.55	0.42	0.39	0.34
Cu	8.20	2.31	14.45	2.72
Ni*	5.01	0.31	6.82	2.22
Pb*	0.87	0.05	0.54	0.17
Zn*	73.35	29.59	17.25	14.40

*denotes significant differences

APPENDIX II (continued)

	Species			
	Drum	Walleye	Shad	Perch
Metal	N=6	N=12	N=12	N=12
Flesh				
Cd	0.98	1.20	1.34	0.35
Cu	31.05	19.10	7.52	3.03
Ni	3.01	4.00	2.03	3.94
Pb	0.31	0.15	0.36	0.21
Zn	22.74	23.72	14.13	19.65
Muscle				
	N=6	N=12	N=12	N=12
Cd	0.13	0.19	0.22	0.32
Cu	7.70	2.37	5.22	1.91
Ni	1.25	0.57	2.81	2.71
Pb	0.06	0.05	0.06	0.10
Zn	7.84	4.11	9.18	12.44
Kidney				
	N=6	N=7	N=12	N=12
Cd	1.40	0.34	3.21	1.54
Cu	6.26	1.77	20.56	44.25
Ni	1.13	1.77	2.00	2.39
Pb	0.64	0.16	0.63	0.69
Zn*	18.57	13.90	12.22	69.26

APPENDIX II (continued)

	Species			
	Drum	Walleye	Shad	Perch
Metal	N=6	N=11	N=12	N=11
		Spleen		
Cd	11.22	3.27	1.23	10.02
Cu	79.10	6.39	6.38	32.80
Ni	80.34	2.14	3.87	34.80
Pb	1.58	0.17	0.38	0.54
Zn	169.68	19.40	20.19	70.75
		Liver		
	N=5	N=11	N=12	N=12
Cd	1.82	5.73	2.03	2.40
Cu	56.15	5.41	14.72	19.35
Ni	5.66	2.01	1.66	6.14
Pb	0.78	0.17	0.63	0.33
Zn	45.78	15.24	13.34	29.91
		Heart		
	N=6	N=12	N=12	N=12
Cd	0.41	0.51	0.58	0.30
Cu	46.26	3.17	12.89	5.26
Ni*	4.23	0.67	1.69	2.93
Pb	0.77	0.25	0.31	0.21
Zn	24.86	23.06	36.48	18.87

APPENDIX II (continued)

	Species			
Metal	Drum N=1	Walleye N=7	Shad N=12	Perch N=12
	Gills			
Cd*	0.00	0.11	0.55	0.28
Cu	0.45	0.85	13.46	6.29
Ni	0.44	1.17	2.22	3.69
Pb	0.03	0.08	0.84	0.26
Zn	8.96	10.17	18.41	17.73

APPENDIX III

MANOVA

GENERAL LINEAR MODELS PROCEDURE

MEANS (ug/g)

SPEC	N	CU	NI	ZN	CD	PB
PERCA	96	11.4292470	3.67600479	27.8750627	0.66199187	0.30095375
DOROSOMA	96	13.2301491	2.41733010	17.9473979	1.40119542	0.44133552

AGE	N	CU	NI	ZN	CD	PB
1	64	16.6425206	4.62510844	25.4688067	2.20509016	0.51157375
2	64	14.5031934	2.14864701	22.6094737	0.67214625	0.37001047
3	64	5.8433720	2.36636609	20.5754105	0.21754453	0.23184969

LOC	N	CU	NI	ZN	CD	PB
SCALES	24	11.2186012	6.44226292	57.4580679	1.39089125	0.64111458
STOMACH	24	6.3961012	2.32963417	16.0622433	0.29077292	0.16664917
FLESH	24	5.8618771	3.47093542	15.0109350	0.87503167	0.24292792
MUSCLE	24	2.9172571	2.57682042	9.4804767	0.27436833	0.08697375
KIDNEY	24	33.9434117	2.33386125	38.0069258	2.58893333	0.66502708
HEART	24	16.7666333	2.11096333	10.9280687	2.00962458	0.38668708
LIVER	24	11.6566325	1.05498792	18.2720021	0.40637083	0.16772917
GILLS	24	9.8766700	2.95519417	18.0691229	0.41475625	0.54804833

SPEC	AGE	N	CU	NI	ZN	CD	PB
PERCA	1	32	7.6821069	5.60466250	31.5111581	0.97959031	0.24435094
PERCA	2	32	21.1002253	2.91747281	31.1660697	0.72239094	0.35377156
PERCA	3	32	5.5054087	2.50611906	20.9471603	0.28399437	0.30473875
DOROSOMA	1	32	25.6029503	3.64555437	19.4264553	3.43059000	0.77879656
DOROSOMA	2	32	7.9061616	1.37982281	14.2120778	0.62190156	0.38624937
DOROSOMA	3	32	6.1813353	2.22661312	20.2036606	0.15109469	0.15896062

APPENDIX III(cont'd)

MANOVA

GENERAL LINEAR MODELS PROCEDURE

MEANS (µg/g)

SPEC	LOC	N	CU	NI	ZN	CD	PB
PERCA	SCALES	12	12.0576733	8.84512083	62.2624583	0.64111667	0.52530750
PERCA	STOMACH	12	2.8470475	2.31139083	13.9940642	0.37924750	0.18202750
PERCA	FLESH	12	3.1309850	4.16286917	19.5603017	0.34920417	0.22182667
PERCA	MUSCLE	12	1.9199092	2.84064500	11.7100650	0.31168417	0.10042500
PERCA	KIDNEY	12	44.2506392	2.39829583	69.2615117	1.54322667	0.68691583
PERCA	HEART	12	15.9077025	3.01829917	12.5779767	1.54913250	0.21529500
PERCA	LIVER	12	5.0155258	2.14545583	15.0707767	0.24714633	0.20776917
PERCA	GILLS	12	6.2950933	3.60660167	17.7267467	0.27517500	0.25926333
DOROSOMA	SCALES	12	10.3795292	4.03940500	52.6536775	2.14066583	0.75692167
DOROSOMA	STOMACH	12	9.9443550	3.34537750	10.1304225	0.20229833	0.15447083
DOROSOMA	FLESH	12	8.5047692	2.77900167	10.4335603	1.40085917	0.36402917
DOROSOMA	MUSCLE	12	3.9146050	2.31299583	7.2500875	0.23705250	0.05352250
DOROSOMA	KIDNEY	12	23.6361842	2.26942667	6.7565400	3.63464000	0.63913833
DOROSOMA	HEART	12	17.6259642	1.20362750	9.2781608	2.47011667	0.55007917
DOROSOMA	LIVER	12	18.2963392	1.16452000	20.6652275	0.56959333	0.16760917
DOROSOMA	GILLS	12	13.4574467	2.22378667	18.4114992	0.55433750	0.03683333

AGE	LOC	N	CU	NI	ZN	CD	PB
1	SCALES	8	9.5928675	9.38295625	83.3786787	2.91403750	1.24375875
1	STOMACH	8	3.9686475	2.55451875	13.5148925	0.46104000	0.13633875
1	FLESH	8	9.4152000	4.68241250	17.2636187	1.56791000	0.41662125
1	MUSCLE	8	3.9519875	5.37830475	14.9473175	0.66668750	0.12546250
1	KIDNEY	8	27.6994337	5.14459750	38.8845412	5.82451625	1.02618625
1	HEART	8	33.0530150	4.03731375	8.3376500	4.76840250	0.60753750
1	LIVER	8	25.9607837	1.28331875	11.5913037	0.85520250	0.19827625
1	GILLS	8	18.4980937	4.53736125	15.8324512	0.58292500	0.13840875
2	SCALES	8	20.0793987	5.70598125	49.5504400	1.01030875	0.48791625
2	STOMACH	8	2.7963212	1.88872500	11.0663762	0.25110250	0.13537250
2	FLESH	8	6.2662975	2.30265250	12.7765487	0.82372875	0.24576750
2	MUSCLE	8	1.5039550	0.69603625	6.1312187	0.08613625	0.05941500
2	KIDNEY	8	63.1080462	1.12564500	51.1350137	1.42597125	0.32501000
2	HEART	8	8.2206112	0.99049075	12.0251587	0.98342375	0.15423500
2	LIVER	8	6.9350962	1.65335000	15.2412975	0.26357500	0.15864875

APPENDIX III(cont'd)

MANOVA

GENERAL LINEAR MODELS PROCEDURE

MEANS (ug/g)

AGE	LOC	N	CU	NI	ZN	CD	PB
2	GILLS	8	7.1158212	2.62349375	22.7897362	0.53292375	1.39371875
3	SCALES	8	3.9835375	4.23785125	39.4450850	0.24832750	0.19166075
3	STOMACH	8	12.4231350	4.04265875	23.6054612	0.16017625	0.23423625
3	FLESH	8	1.9041337	3.42774125	14.9926375	0.23345625	0.21639500
3	MUSCLE	8	3.2950287	1.65323625	7.3628937	0.07028125	0.05804375
3	KIDNEY	8	10.0227550	0.73134125	24.0072225	0.51631250	0.63788500
3	HEART	8	8.2260737	1.30507750	11.6213975	0.27704750	0.19828875
3	LIVER	8	2.0746175	2.02829500	27.9834050	0.10633500	0.20626250
3	GILLS	8	4.0160950	1.50472750	15.5851812	0.12842000	0.11201750

SPEC	AGE	LOC	N	CU	NI	ZN	CD	PB
<u>PERCA</u>	1	SCALES	4	4.392432	12.0839750	84.8039400	0.66716250	0.53589250
	1	STOMACH	4	2.900722	2.2771025	14.5238800	0.63970250	0.10990750
	1	FLESH	4	6.722960	6.6034800	20.4400000	0.29620500	0.10631000
	1	MUSCLE	4	4.728407	6.8670550	24.2985000	0.80358000	0.10858500
	1	KIDNEY	4	5.384715	4.7215175	69.9620625	1.92630750	0.57339000
	1	HEART	4	27.582327	5.4122550	12.6516525	2.83701000	0.22925250
	1	LIVER	4	7.435845	1.4346175	11.6339275	0.40016250	0.12758500
	1	GILLS	4	2.309445	5.4372975	13.7753025	0.26659250	0.08400500
<u>PERCA</u>	2	SCALES	4	29.034507	7.3710950	55.7892700	0.85595250	0.77443000
	2	STOMACH	4	2.524600	3.2487100	8.9359900	0.39819000	0.21387500
	2	FLESH	4	0.687442	2.8230925	20.2682875	0.45373750	0.30535250
	2	MUSCLE	4	0.571155	0.7702475	6.8715175	0.07049750	0.05232750
	2	KIDNEY	4	111.578350	2.0605075	99.5853225	2.09404250	0.50387500
	2	HEART	4	7.925785	1.5368825	17.0582325	1.34567250	0.24534250
	2	LIVER	4	5.225587	2.5664625	21.1090900	0.10917750	0.23983500
	2	GILLS	4	11.252575	2.9619850	19.7172475	0.37165750	0.49463500
<u>PERCA</u>	3	SCALES	4	2.746080	7.0802925	46.1941650	0.40023500	0.26560000
	3	STOMACH	4	3.118220	1.4083600	18.5223225	0.09965000	0.22470000
	3	FLESH	4	2.006552	3.0612350	18.0566175	0.29767000	0.25381750
	3	MUSCLE	4	0.460165	0.8846325	3.9625000	0.06097500	0.08436250
	3	KIDNEY	4	15.780852	0.4120625	38.2365500	0.60933000	0.48348250
	3	HEART	4	12.213195	2.1057600	8.0240450	0.46471500	0.17179000

APPENDIX III (cont'd)

MANOVA

GENERAL LINEAR MODELS PROCEDURE

MEANS (ug/g)

SPEC	AGE	LOC	N	CU	NI	ZN	CD	PB
	3	LIVER	4	2.384545	2.4352875	14.8933125	0.15210500	0.25598750
	3	GILLS	4	5.325660	2.6605225	19.6076900	0.10707500	0.19827000
DOROSOMA	1	SCALES	4	14.793302	6.6919375	81.9534175	5.16041250	1.95162500
	1	STOMACH	4	5.036972	2.8319350	12.5059050	0.28237750	0.16277000
	1	FLESH	4	12.107440	2.7613450	14.0872375	2.83961500	0.72693250
	1	MUSCLE	4	3.175567	3.0897225	5.5961350	0.52979500	0.06234000
	1	KIDNEY	4	50.414152	5.5676775	7.8070200	9.72272500	1.47998250
	1	HEART	4	40.123702	2.6623725	4.0236475	6.69979500	1.38692250
	1	LIVER	4	44.485722	1.1320200	11.5486800	1.31024250	0.26996750
	1	GILLS	4	34.686742	3.6374250	17.8696000	0.89925750	0.19193250
DOROSOMA	2	SCALES	4	11.124290	4.0408675	43.3116100	1.16466500	0.20140250
	2	STOMACH	4	3.068042	0.5287400	13.1967625	0.10401500	0.05687000
	2	FLESH	4	11.845152	1.7814125	5.2848100	1.19372000	0.16418250
	2	MUSCLE	4	2.436755	0.6274250	5.3909200	0.10177500	0.06650250
	2	KIDNEY	4	14.637742	0.1907825	2.6647050	0.75790000	0.14614500
	2	HEART	4	8.513637	0.4441150	8.5920050	0.62117500	0.06262750
	2	LIVER	4	8.644605	0.7402375	9.3735050	0.33797250	0.07746250
	2	GILLS	4	2.979067	2.6850025	25.8622250	0.69399000	2.29290250
DOROSOMA	3	SCALES	4	5.220995	1.3954100	32.6960050	0.09642000	0.11773750
	3	STOMACH	4	21.728050	6.6769575	28.6886000	0.22050250	0.24377250
	3	FLESH	4	1.801715	3.7942475	11.9206575	0.16924250	0.17897250
	3	MUSCLE	4	6.131492	2.4218400	10.7632075	0.07958750	0.03172500
	3	KIDNEY	4	5.856657	1.0498200	9.7778950	0.42329500	0.29228750
	3	HEART	4	4.240552	0.5043950	15.2187500	0.08938000	0.22478750
	3	LIVER	4	1.764690	1.6213025	41.0734975	0.06056500	0.15663750
	3	GILLS	4	2.706530	0.3489325	11.4826725	0.06976500	0.02576500

APPENDIX IV. DATA FROM FISH USED IN MULTIVARIATE ANALYSIS OF VARIANCE

SPECIES: 1=PERCH, 2=SHAD

TISSUE: 1=SCALES, 2=STOMACH, 3=FLESH, 4=MUSCLE,
5=HEART, 7=KIDNEY, 8=LIVER, 9=GILLS

TAG	SPE-CIE	TIS-SUE	AGE	AGE GRP.	CU PPM	NI PPM	ZN PPM	CD PPM	PB PPM
T-172	1	1	1	1	7.67	37.04	195.85	1.430	0.896
T-172	1	2	1	1	5.41	6.04	15.54	0.676	0.116
T-172	1	3	1	1	7.04	13.53	43.59	0.435	0.068
T-172	1	4	1	1	0.78	2.61	8.25	0.093	0.029
T-172	1	5	1	1	5.62	6.37	72.60	3.380	1.907
T-172	1	7	1	1	10.65	19.25	8.38	4.123	0.227
T-172	1	8	1	1	22.40	1.56	11.51	0.133	0.171
T-172	1	9	1	1	3.79	6.11	11.51	0.082	0.064
T-167	1	1	1	1	4.41	4.52	50.12	0.593	0.648
T-167	1	2	1	1	3.86	1.55	28.92	0.420	0.083
T-167	1	3	1	1	1.68	2.33	13.00	0.037	0.113
T-167	1	4	1	1	13.20	6.58	73.37	2.898	0.567
T-167	1	5	1	1	9.48	11.83	111.33	1.555	0.107
T-167	1	7	1	1	93.29	0.85	11.53	1.326	0.028
T-167	1	8	1	1	3.47	2.85	16.36	0.305	0.080
T-167	1	9	1	1	2.29	2.43	17.50	0.560	0.065
T-170	1	1	1	1	2.13	3.05	41.15	0.123	0.195
T-170	1	2	1	1	0.80	0.39	7.28	1.047	0.147
T-170	1	3	1	1	13.57	6.10	9.31	0.486	0.114
T-170	1	4	1	1	4.51	17.77	11.82	0.190	0.153
T-170	1	5	1	1	2.70	0.51	57.07	0.659	0.129
T-170	1	7	1	1	1.90	1.18	15.42	2.708	0.212
T-170	1	8	1	1	2.99	0.93	16.11	0.423	0.161
T-170	1	9	1	1	2.76	10.71	14.33	0.399	0.159
T-174	1	1	1	1	3.37	3.72	52.10	0.523	0.404
T-174	1	2	1	1	1.53	1.13	6.35	0.415	0.093
T-174	1	3	1	1	4.60	4.46	15.87	0.227	0.130
T-174	1	4	1	1	0.42	0.51	3.75	0.033	0.004
T-174	1	5	1	1	3.75	0.18	38.85	2.101	0.151
T-174	1	7	1	1	4.49	0.38	15.28	3.191	0.445
T-174	1	8	1	1	0.89	0.40	2.56	0.738	0.098
T-174	1	9	1	1	0.40	2.50	11.75	0.025	0.052
T-176	1	1	3	2	2.26	9.40	53.12	1.872	1.269
T-176	1	2	3	2	3.25	1.69	0.06	0.878	0.202
T-176	1	3	3	2	1.26	2.94	20.81	0.984	0.073
T-176	1	4	3	2	0.10	0.27	5.38	0.005	0.016
T-176	1	5	3	2	199.49	1.76	261.18	3.022	0.323

APPENDIX IV. (CONTINUED)

TAG	SPE-CIE	TIS-SUE	AGE	AGE GRP.	CU PPM	NI PPM	ZN PPM	CD PPM	PB PPM
T-176	1	7	3	2	14.37	2.79	49.22	3.091	0.356
T-176	1	8	3	2	6.71	1.19	38.67	0.138	0.201
T-176	1	9	3	2	14.32	2.27	21.37	0.425	0.115
T-156	1	1	3	2	109.16	5.86	75.81	1.194	0.538
T-156	1	2	3	2	0.87	8.86	16.60	0.327	0.304
T-156	1	3	3	2	0.51	3.49	23.38	0.281	0.065
T-156	1	4	3	2	0.24	0.61	4.86	0.050	0.025
T-156	1	5	3	2	17.37	4.00	61.30	3.339	0.240
T-156	1	7	3	2	2.75	0.22	6.89	1.678	0.012
T-156	1	8	3	2	1.37	2.90	16.53	0.272	0.118
T-156	1	9	3	2	5.30	5.12	24.34	0.397	0.241
T-034	1	1	3	2	0.87	11.16	60.44	0.251	0.772
T-034	1	2	3	2	0.21	1.21	7.35	0.201	0.146
T-034	1	3	3	2	0.50	2.91	20.76	0.309	0.227
T-034	1	4	3	2	1.04	0.99	7.99	0.127	0.078
T-034	1	5	3	2	41.70	1.96	33.28	0.906	0.446
T-034	1	7	3	2	1.88	1.59	5.43	0.220	0.235
T-034	1	8	3	2	1.46	2.31	20.39	0.104	0.231
T-034	1	9	3	2	22.78	2.42	18.37	0.289	1.522
T-025	1	1	3	2	3.85	3.06	33.78	0.106	0.519
T-025	1	2	3	2	5.76	1.24	11.72	0.187	0.203
T-025	1	3	3	2	0.49	1.96	16.12	0.242	0.856
T-025	1	4	3	2	0.91	1.22	9.25	0.101	0.090
T-025	1	5	3	2	187.76	0.52	42.58	1.109	1.006
T-025	1	7	3	2	12.71	1.55	6.69	0.394	0.380
T-025	1	8	3	2	11.36	3.86	8.85	0.243	0.410
T-025	1	9	3	2	2.62	2.03	14.79	0.377	0.101
T-178	1	1	6	3	5.53	17.87	36.37	0.164	0.057
T-178	1	2	6	3	8.90	1.06	16.88	0.053	0.103
T-178	1	3	6	3	1.80	1.29	20.48	0.406	0.025
T-178	1	4	6	3	0.15	1.11	3.21	0.017	0.011
T-178	1	5	6	3	8.70	1.11	38.31	0.181	0.369
T-178	1	7	6	3	7.03	1.10	8.58	0.127	0.048
T-178	1	8	6	3	1.07	1.51	12.78	0.030	0.190
T-178	1	9	6	3	11.46	1.01	17.06	0.151	0.055
T-037	1	1	6	3	1.59	2.95	63.31	0.381	0.500
T-037	1	2	6	3	1.39	2.64	13.90	0.183	0.420
T-037	1	3	6	3	0.99	2.23	12.94	0.153	0.234
T-037	1	4	6	3	0.42	1.33	8.12	0.141	0.281
T-037	1	5	6	3	32.06	0.20	40.35	1.334	2.483
T-037	1	7	6	3	1.43	4.62	6.75	0.769	0.424
T-037	1	8	6	3	2.48	2.40	15.18	0.314	0.538
T-037	1	9	6	3	1.24	3.68	21.81	0.175	0.474
T-020	1	1	6	3	2.61	5.89	48.68	0.388	0.356
T-020	1	2	6	3	1.18	1.36	12.73	0.127	0.277
T-020	1	3	6	3	2.42	5.54	21.19	0.342	0.591

APPENDIX IV. (CONTINUED)

TAG	SPE-CIE	TIS-SUE	AGE	AGE GRP.	CU PPM	NI PPM	ZN PPM	CD PPM	PB PPM
T-020	1	4	6	3	0.10	0.54	0.93	0.014	0.022
T-020	1	5	6	3	1.47	0.26	41.47	0.411	0.542
T-020	1	7	6	3	16.39	1.72	9.41	0.694	0.152
T-020	1	8	6	3	4.43	4.98	18.77	0.216	0.232
T-020	1	9	6	3	1.02	1.18	15.04	0.244	0.077
T-014	1	1	6	3	1.25	1.61	36.41	0.667	0.150
T-014	1	2	6	3	1.00	0.57	30.58	0.037	0.098
T-014	1	3	6	3	2.82	3.18	17.62	0.290	0.165
T-014	1	4	6	3	1.17	0.56	3.60	0.072	0.024
T-014	1	5	6	3	20.94	0.09	32.82	0.511	0.540
T-014	1	7	6	3	24.01	0.97	7.36	0.269	0.063
T-014	1	8	6	3	1.56	0.85	12.83	0.049	0.063
T-014	1	9	6	3	7.58	4.77	24.84	0.179	0.187
B-24	2	1	0	1	5.65	4.67	38.51	5.265	0.367
B-24	2	2	0	1	6.37	0.16	3.98	0.056	0.010
B-24	2	3	0	1	3.42	4.91	9.93	2.903	0.449
B-24	2	4	0	1	1.10	1.13	3.59	0.431	0.057
B-24	2	5	0	1	89.17	10.17	1.68	8.231	1.614
B-24	2	7	0	1	89.33	0.76	4.25	4.701	1.355
B-24	2	8	0	1	121.33	0.32	6.14	2.412	0.465
B-24	2	9	0	1	79.60	7.00	14.91	0.955	0.343
B-25	2	1	0	1	9.62	12.54	191.72	10.390	4.776
B-25	2	2	0	1	4.93	3.77	21.08	0.452	0.334
B-25	2	3	0	1	4.83	2.56	9.14	5.415	1.751
B-25	2	4	0	1	1.15	12.34	4.37	0.781	0.035
B-25	2	5	0	1	77.49	1.95	11.07	9.189	1.779
B-25	2	7	0	1	11.48	6.97	1.59	10.655	1.907
B-25	2	8	0	1	12.26	0.23	14.00	1.054	0.298
B-25	2	9	0	1	48.58	1.89	14.75	0.893	0.183
B-4	2	1	0	1	14.66	5.71	88.83	2.892	1.758
B-4	2	2	0	1	3.47	2.79	15.55	0.373	0.188
B-4	2	3	0	1	6.22	1.40	24.58	1.238	0.494
B-4	2	4	0	1	0.94	0.32	10.75	0.537	0.120
B-4	2	5	0	1	12.17	0.96	8.81	14.253	1.027
B-4	2	7	0	1	8.13	0.64	5.43	5.645	1.095
B-4	2	8	0	1	40.66	0.23	9.29	1.290	0.232
B-4	2	9	0	1	6.90	2.27	12.76	0.657	0.060
B-5	2	1	0	1	29.25	3.81	8.76	2.096	0.906
B-5	2	2	0	1	5.37	4.60	9.42	0.249	0.119
B-5	2	3	0	1	33.95	2.18	12.70	1.803	0.215
B-5	2	4	0	1	9.51	1.77	3.67	0.369	0.037
B-5	2	5	0	1	22.82	9.20	9.67	7.218	1.496
B-5	2	7	0	1	51.56	2.28	4.83	5.798	1.191
B-5	2	8	0	1	3.70	3.75	16.76	0.485	0.081
B-5	2	9	0	1	3.68	3.39	29.14	1.092	0.182
T-048	2	1	3	2	0.95	9.34	43.71	0.782	0.362

APPENDIX IV. (CONTINUED)

TAG	SPE-CIE	TIS-SUE	AGE	AGE GRP.	CU PPM	NI PPM	ZN PPM	CD PPM	PB PPM
T-048	2	2	3	2	3.37	0.52	13.56	0.138	0.075
T-048	2	3	3	2	3.00	1.66	0.21	1.194	0.042
T-048	2	4	3	2	1.64	0.99	0.55	0.091	0.045
T-048	2	5	3	2	7.36	0.15	0.21	1.149	0.099
T-048	2	7	3	2	3.92	0.12	8.03	0.326	0.083
T-048	2	8	3	2	7.04	0.53	7.95	0.309	0.051
T-048	2	9	3	2	1.32	0.20	7.78	0.391	0.661
T-046	2	1	4	2	1.23	3.21	31.39	0.272	0.172
T-046	2	2	4	2	1.97	0.64	13.95	0.018	0.066
T-046	2	3	4	2	1.98	1.64	3.32	0.202	0.157
T-046	2	4	4	2	0.79	0.58	8.15	0.045	0.140
T-046	2	5	4	2	34.00	0.10	2.23	0.298	0.316
T-046	2	7	4	2	4.81	0.09	9.23	0.278	0.010
T-046	2	8	4	2	10.42	0.59	9.46	0.139	0.153
T-046	2	9	4	2	0.92	3.91	27.45	0.986	0.175
T-049	2	1	4	2	4.00	0.81	49.78	1.056	0.083
T-049	2	2	4	2	4.28	0.68	12.88	0.144	0.045
T-049	2	3	4	2	3.99	1.15	0.55	3.237	0.018
T-049	2	4	4	2	6.94	0.23	6.55	0.212	0.036
T-049	2	5	4	2	16.43	0.45	4.80	1.260	0.126
T-049	2	7	4	2	11.86	0.34	9.11	0.709	0.058
T-049	2	8	4	2	12.59	0.09	9.00	0.446	0.054
T-049	2	9	4	2	6.38	1.11	20.41	0.504	0.125
T-047	2	1	5	2	38.32	2.80	48.36	2.549	0.188
T-047	2	2	5	2	2.66	0.27	12.39	0.117	0.041
T-047	2	3	5	2	38.41	2.68	17.05	0.153	0.528
T-047	2	4	5	2	0.38	0.66	6.31	0.058	0.045
T-047	2	5	5	2	0.76	0.06	3.51	0.325	0.053
T-047	2	7	5	2	13.46	1.23	7.99	1.172	0.099
T-047	2	8	5	2	4.53	1.75	11.09	0.458	0.053
T-047	2	9	5	2	3.29	5.51	47.81	0.895	8.211
T-045	2	1	8	3	2.74	1.43	15.53	0.046	0.050
T-045	2	2	8	3	1.61	1.33	13.68	0.055	0.029
T-045	2	3	8	3	0.43	7.53	11.89	0.081	0.063
T-045	2	4	8	3	1.84	0.56	4.96	0.043	0.014
T-045	2	5	8	3	0.31	0.19	8.67	0.081	0.074
T-045	2	7	8	3	2.37	1.09	16.47	0.123	0.126
T-045	2	8	8	3	0.84	0.54	11.05	0.028	0.030
T-045	2	9	8	3	0.64	0.15	10.83	0.034	0.021
T-044	2	1	7	3	0.21	0.88	21.32	0.082	0.089
T-044	2	2	7	3	1.16	0.44	16.61	0.049	0.061
T-044	2	3	7	3	3.32	3.89	21.46	0.310	0.432
T-044	2	4	7	3	0.94	0.17	3.00	0.008	0.019
T-044	2	5	7	3	16.94	2.16	15.90	0.067	0.207
T-044	2	7	7	3	1.82	0.41	11.71	0.073	0.071
T-044	2	8	7	3	2.92	3.95	19.45	0.133	0.353

APPENDIX IV. (CONTINUED)

TAG	SPE-CIE	TIS-SUE	AGE	AGE GRP.	CU PPM	NI PPM	ZN PPM	CD PPM	PB PPM
T-044	2	9	7	3	1.19	0.65	9.24	0.154	0.014
T-162	2	1	8	3	1.09	1.12	23.42	0.186	0.234
T-162	2	2	8	3	2.93	0.21	17.55	0.035	0.113
T-162	2	3	8	3	2.82	3.25	7.80	0.174	0.070
T-162	2	4	8	3	0.87	0.24	2.73	0.207	0.019
T-162	2	5	8	3	3.63	1.59	10.58	0.274	0.136
T-162	2	7	8	3	0.74	0.30	8.65	0.036	0.047
T-162	2	8	8	3	2.45	1.32	37.42	0.059	0.034
T-162	2	9	8	3	3.04	0.38	5.38	0.040	0.045
01	2	1	8	3	16.84	2.15	70.52	0.072	0.098
01	2	2	8	3	81.21	24.73	66.91	0.743	0.772
01	2	3	8	3	0.63	0.51	6.56	0.112	0.151
01	2	4	8	3	20.88	8.72	32.35	0.060	0.075
01	2	5	8	3	2.54	0.26	3.96	1.272	0.753
01	2	7	8	3	12.02	0.22	24.05	0.125	0.655
01	2	8	8	3	0.85	0.68	96.37	0.023	0.210
01	2	9	8	3	5.95	0.22	20.47	0.051	0.023

APPENDIX V. DATA FROM FISH USED IN ANALYSIS OF VARIANCE

SPECIES: 1=PERCH, 2=SHAD, 3=WALLEYE, 4=DRUM

TISSUE: 1=SCALES, 2=STOMACH, 3=FLESH, 4=MUSCLE, 5=HEART, 6=SPLEEN, 7=KIDNEY, 8=LIVER, 9=GILLS

TAG	SPE-CIE	TIS-SUE	AGE	AGE GRP.	CU PPM	NI PPM	ZN PPM	CD PPM	PB PPM
T-172	1	1	1	1	7.67	37.04	195.85	1.430	0.896
T-172	1	2	1	1	5.41	6.04	15.54	0.676	0.116
T-172	1	3	1	1	7.04	13.53	43.59	0.435	0.068
T-172	1	4	1	1	0.78	2.61	8.25	0.093	0.029
T-172	1	5	1	1	5.62	6.37	72.60	3.380	1.907
T-172	1	6	1	1	137.39	24.45	118.80	73.542	1.448
T-172	1	7	1	1	10.65	19.25	8.38	4.123	0.227
T-172	1	8	1	1	22.40	1.56	11.51	0.133	0.171
T-172	1	9	1	1	3.79	6.11	11.51	0.082	0.064
T-167	1	1	1	1	4.41	4.52	50.12	0.593	0.648
T-167	1	2	1	1	3.86	1.55	28.92	0.420	0.093
T-167	1	3	1	1	1.68	2.33	13.00	0.037	0.113
T-167	1	4	1	1	13.20	6.58	73.37	2.898	0.567
T-167	1	5	1	1	9.48	11.83	111.33	1.555	0.107
T-167	1	6	1	1	12.30	5.05	7.02	1.872	0.021
T-167	1	7	1	1	93.29	0.85	11.53	1.326	0.028
T-167	1	8	1	1	3.47	2.85	16.36	0.306	0.080
T-167	1	9	1	1	2.29	2.43	17.50	0.560	0.065
T-170	1	1	1	1	2.13	3.05	41.15	0.123	0.195
T-170	1	2	1	1	0.30	0.39	7.28	1.047	0.147
T-170	1	3	1	1	13.57	6.10	9.31	0.486	0.114
T-170	1	4	1	1	4.51	17.77	11.82	0.190	0.153
T-170	1	5	1	1	2.70	0.51	57.07	0.669	0.129
T-170	1	6	1	1	12.14	10.70	33.65	8.290	1.594
T-170	1	7	1	1	1.90	1.18	15.42	2.708	0.212
T-170	1	8	1	1	2.99	0.93	16.11	0.423	0.161
T-170	1	9	1	1	2.76	10.71	14.33	0.399	0.159
T-174	1	1	1	1	3.37	3.72	52.10	0.523	0.404
T-174	1	2	1	1	1.53	1.13	6.35	0.415	0.093
T-174	1	3	1	1	4.60	4.46	15.87	0.227	0.130
T-174	1	4	1	1	0.42	0.51	3.75	0.033	0.004
T-174	1	5	1	1	3.75	0.18	38.85	2.101	0.151
T-174	1	6	1	1	33.51	2.34	30.33	9.163	0.654
T-174	1	7	1	1	4.49	0.38	15.28	3.191	0.445
T-174	1	8	1	1	0.89	0.40	2.56	0.738	0.098
T-174	1	9	1	1	0.40	2.50	11.75	0.025	0.052

APPENDIX V. (CONTINUED)

TAG	SPECIE	TISSUE	AGE	AGE GRP.	CU PPM	NI PPM	ZN PPM	CD PPM	PB PPM
T-176	1	1	3	2	2.26	9.40	53.12	1.872	1.269
T-176	1	2	3	2	3.25	1.69	0.06	0.878	0.202
T-176	1	3	3	2	1.26	2.94	20.81	0.984	0.073
T-176	1	4	3	2	0.10	0.27	5.38	0.005	0.016
T-176	1	5	3	2	199.49	1.76	261.18	3.022	0.323
T-176	1	6	3	2	2.78	0.83	10.43	2.943	0.122
T-176	1	7	3	2	14.37	2.79	49.22	3.091	0.356
T-176	1	8	3	2	6.71	1.19	38.67	0.138	0.201
T-176	1	9	3	2	14.32	2.27	21.37	0.425	0.115
T-156	1	1	3	2	109.16	5.86	75.81	1.194	0.538
T-156	1	2	3	2	0.87	8.86	16.60	0.327	0.304
T-156	1	3	3	2	0.51	3.49	23.38	0.281	0.065
T-156	1	4	3	2	0.24	0.61	4.86	0.050	0.025
T-156	1	5	3	2	17.37	4.00	61.30	3.339	0.240
T-156	1	6	3	2	47.43	3.02	0.74	0.898	0.523
T-156	1	7	3	2	2.75	0.22	6.89	1.678	0.012
T-156	1	8	3	2	1.37	2.90	16.53	0.272	0.118
T-156	1	9	3	2	5.30	5.12	24.34	0.397	0.241
T-034	1	1	3	2	0.87	11.16	60.44	0.251	0.772
T-034	1	2	3	2	0.21	1.21	7.35	0.201	0.146
T-034	1	3	3	2	0.50	2.91	20.76	0.309	0.227
T-034	1	4	3	2	1.04	0.99	7.99	0.127	0.078
T-034	1	5	3	2	41.70	1.96	33.28	0.906	0.446
T-034	1	7	3	2	1.88	1.59	5.43	0.220	0.235
T-034	1	8	3	2	1.46	2.31	20.39	0.104	0.231
T-034	1	9	3	2	22.78	2.42	18.37	0.289	1.522
T-025	1	1	3	2	3.85	3.06	33.78	0.106	0.519
T-025	1	2	3	2	5.76	1.24	11.72	0.187	0.203
T-025	1	3	3	2	0.49	1.96	16.12	0.242	0.856
T-025	1	4	3	2	0.91	1.22	9.25	0.101	0.090
T-025	1	5	3	2	187.76	0.52	42.58	1.109	1.006
T-025	1	6	3	2	90.34	3.97	22.16	0.483	0.482
T-025	1	7	3	2	12.71	1.55	6.69	0.394	0.380
T-025	1	8	3	2	11.36	3.86	8.85	0.243	0.410
T-025	1	9	3	2	2.62	2.03	14.79	0.377	0.101
T-178	1	1	6	3	5.53	17.87	36.37	0.164	0.057
T-178	1	2	6	3	8.90	1.06	16.88	0.053	0.103
T-178	1	3	6	3	1.80	1.29	20.48	0.406	0.025
T-178	1	4	6	3	0.15	1.11	3.21	0.017	0.011
T-178	1	5	6	3	8.70	1.11	38.31	0.181	0.369
T-178	1	6	6	3	10.12	0.78	11.55	0.157	0.078
T-178	1	7	6	3	7.03	1.10	8.58	0.127	0.048
T-178	1	8	6	3	1.07	1.51	12.78	0.030	0.190
T-178	1	9	6	3	11.46	1.01	17.06	0.151	0.055
T-037	1	1	6	3	1.59	2.95	63.31	0.381	0.500
T-037	1	2	6	3	1.39	2.64	13.90	0.183	0.420

APPENDIX V. (CONTINUED)

TAG	SPE-CIE	TIS-SUE	AGE	AGE GRP.	CU PPM	NI PPM	ZN PPM	CD PPM	PB PPM
T-037	1	3	6	3	0.99	2.23	12.94	0.153	0.234
T-037	1	4	6	3	0.42	1.33	8.12	0.141	0.281
T-037	1	5	6	3	32.06	0.20	40.35	1.334	2.483
T-037	1	6	6	3	7.43	226.76	6.11	0.341	0.377
T-037	1	7	6	3	1.43	4.62	6.75	0.769	0.424
T-037	1	8	6	3	2.48	2.40	15.18	0.314	0.538
T-037	1	9	6	3	1.24	3.68	21.81	0.175	0.474
T-020	1	1	6	3	2.61	5.89	48.68	0.388	0.356
T-020	1	2	6	3	1.18	1.36	12.73	0.127	0.277
T-020	1	3	6	3	2.42	5.54	21.19	0.342	0.591
T-020	1	4	6	3	0.10	0.54	0.93	0.014	0.022
T-020	1	5	6	3	1.47	0.26	41.47	0.411	0.542
T-020	1	6	6	3	1.11	2.41	19.56	0.513	0.290
T-020	1	7	6	3	16.39	1.72	9.41	0.694	0.152
T-020	1	8	6	3	4.43	4.98	18.77	0.216	0.232
T-020	1	9	6	3	1.02	1.18	15.04	0.244	0.077
T-014	1	1	6	3	1.25	1.61	36.41	0.667	0.150
T-014	1	2	6	3	1.00	0.57	30.58	0.037	0.098
T-014	1	3	6	3	2.92	3.18	17.62	0.290	0.165
T-014	1	4	6	3	1.17	0.56	3.60	0.072	0.024
T-014	1	5	6	3	20.94	0.09	32.82	0.511	0.540
T-014	1	6	6	3	6.04	0.48	14.32	0.056	0.157
T-014	1	7	6	3	24.01	0.97	7.36	0.269	0.063
T-014	1	8	6	3	1.56	0.85	12.83	0.049	0.063
T-014	1	9	6	3	7.58	4.77	24.84	0.179	0.187
B-24	2	1	0	1	5.65	4.67	38.51	5.265	0.367
B-24	2	2	0	1	6.37	0.16	3.98	0.056	0.010
B-24	2	3	0	1	3.42	4.91	9.93	2.903	0.449
B-24	2	4	0	1	1.10	1.13	3.59	0.431	0.057
B-24	2	5	0	1	89.17	10.17	1.68	8.231	1.614
B-24	2	7	0	1	89.33	0.76	4.25	4.701	1.355
B-24	2	8	0	1	121.33	0.32	6.14	2.412	0.465
B-24	2	9	0	1	79.60	7.00	14.91	0.955	0.343
B-25	2	1	0	1	9.62	12.54	191.72	10.390	4.776
B-25	2	2	0	1	4.93	3.77	21.08	0.452	0.334
B-25	2	3	0	1	4.83	2.56	9.14	5.415	1.751
B-25	2	4	0	1	1.15	12.34	4.37	0.781	0.035
B-25	2	5	0	1	77.49	1.95	11.07	9.189	1.779
B-25	2	7	0	1	11.48	6.97	1.59	10.655	1.907
B-25	2	8	0	1	12.26	0.23	14.00	1.054	0.298
B-25	2	9	0	1	48.58	1.89	14.75	0.893	0.183
B-4	2	1	0	1	14.66	5.71	88.83	2.892	1.758
B-4	2	2	0	1	3.47	2.79	15.55	0.373	0.188
B-4	2	3	0	1	6.22	1.40	24.58	1.238	0.494
B-4	2	4	0	1	0.94	0.32	10.75	0.537	0.120
B-4	2	5	0	1	12.17	0.96	8.81	14.253	1.027

APPENDIX V. (CONTINUED)

TAG	SPECIE	TISSUE	AGE	AGE GRP.	CU PPM	NI PPM	ZN PPM	CD PPM	PB PPM
B-4	2	7	0	1	8.13	0.64	5.43	5.645	1.095
B-4	2	8	0	1	40.66	0.23	9.29	1.290	0.232
B-4	2	9	0	1	6.90	2.27	12.76	0.657	0.060
B-5	2	1	0	1	29.25	3.81	8.76	2.096	0.906
B-5	2	2	0	1	5.37	4.60	9.42	0.249	0.119
B-5	2	3	0	1	33.95	2.18	12.70	1.803	0.215
B-5	2	4	0	1	9.51	1.77	3.67	0.369	0.037
B-5	2	5	0	1	22.82	9.20	9.67	7.218	1.496
B-5	2	7	0	1	51.56	2.28	4.83	5.798	1.191
B-5	2	8	0	1	3.70	3.75	16.76	0.485	0.081
B-5	2	9	0	1	3.68	3.39	29.14	1.092	0.182
T-048	2	1	3	2	0.95	9.34	43.71	0.782	0.362
T-048	2	2	3	2	3.37	0.52	13.56	0.138	0.075
T-048	2	3	3	2	3.00	1.66	0.21	1.184	0.042
T-048	2	4	3	2	1.64	0.99	0.55	0.091	0.045
T-048	2	5	3	2	7.36	0.15	0.21	1.149	0.090
T-048	2	6	3	2	0.16	0.01	0.02	0.112	0.001
T-048	2	7	3	2	3.92	0.12	8.03	0.326	0.083
T-048	2	8	3	2	7.04	0.53	7.95	0.309	0.051
T-048	2	9	3	2	1.32	0.20	7.78	0.391	0.661
T-046	2	1	4	2	1.23	3.21	31.39	0.272	0.172
T-046	2	2	4	2	1.97	0.64	13.95	0.018	0.066
T-046	2	3	4	2	1.98	1.64	3.32	0.202	0.157
T-046	2	4	4	2	0.79	0.58	8.15	0.045	0.140
T-046	2	5	4	2	34.00	0.10	2.23	0.298	0.316
T-046	2	7	4	2	4.81	0.09	9.23	0.278	0.010
T-046	2	8	4	2	10.42	0.59	9.46	0.139	0.153
T-046	2	9	4	2	0.92	3.91	27.45	0.986	0.175
T-049	2	1	4	2	4.00	0.81	49.78	1.056	0.083
T-049	2	2	4	2	4.28	0.68	12.88	0.144	0.045
T-049	2	3	4	2	3.99	1.15	0.55	3.237	0.018
T-049	2	4	4	2	6.94	0.28	6.55	0.212	0.036
T-049	2	5	4	2	16.43	0.45	4.80	1.260	0.126
T-049	2	7	4	2	11.86	0.34	9.11	0.709	0.058
T-049	2	8	4	2	12.59	0.09	9.00	0.446	0.054
T-049	2	9	4	2	6.38	1.11	20.41	0.504	0.125
T-047	2	1	5	2	38.32	2.80	48.36	2.549	0.188
T-047	2	2	5	2	2.66	0.27	12.39	0.117	0.041
T-047	2	3	5	2	38.41	2.68	17.05	0.153	0.528
T-047	2	4	5	2	0.38	0.66	6.31	0.058	0.045
T-047	2	5	5	2	0.76	0.06	3.51	0.325	0.053
T-047	2	7	5	2	13.46	1.23	7.99	1.172	0.099
T-047	2	8	5	2	4.53	1.75	11.09	0.458	0.053
T-047	2	9	5	2	3.29	5.51	47.81	0.895	8.211
T-045	2	1	8	3	2.74	1.43	15.53	0.046	0.050
T-045	2	2	8	3	1.61	1.33	13.68	0.055	0.029

APPENDIX V. (CONTINUED)

TAG	SPE-CIE	TIS-SUE	AGE	AGE GRP.	CU PPM	NI PPM	ZN PPM	CD PPM	PB PPM
T-045	2	3	8	3	0.43	7.53	11.89	0.081	0.063
T-045	2	4	8	3	1.84	0.56	4.96	0.043	0.014
T-045	2	5	8	3	0.31	0.19	8.67	0.081	0.074
T-045	2	6	8	3	2.30	1.58	17.23	0.040	0.163
T-045	2	7	8	3	2.37	1.09	16.47	0.123	0.126
T-045	2	8	8	3	0.84	0.54	11.05	0.028	0.030
T-045	2	9	8	3	0.64	0.15	10.83	0.034	0.021
T-044	2	1	7	3	0.21	0.88	21.32	0.082	0.089
T-044	2	2	7	3	1.16	0.44	16.61	0.049	0.061
T-044	2	3	7	3	3.32	3.89	21.46	0.310	0.432
T-044	2	4	7	3	0.94	0.17	3.00	0.008	0.019
T-044	2	5	7	3	16.94	2.16	15.90	0.067	0.207
T-044	2	7	7	3	1.82	0.41	11.71	0.073	0.071
T-044	2	8	7	3	2.92	3.95	19.45	0.133	0.353
T-044	2	9	7	3	1.19	0.65	9.24	0.154	0.014
T-162	2	1	8	3	1.09	1.12	23.42	0.186	0.234
T-162	2	2	8	3	2.93	0.21	17.55	0.035	0.113
T-162	2	3	8	3	2.82	3.25	7.80	0.174	0.070
T-162	2	4	8	3	0.87	0.24	2.73	0.207	0.019
T-162	2	5	8	3	3.63	1.59	10.58	0.274	0.136
T-162	2	7	8	3	0.74	0.30	8.65	0.036	0.047
T-162	2	8	8	3	2.45	1.32	37.42	0.059	0.034
T-162	2	9	8	3	3.04	0.38	5.38	0.040	0.045
01	2	1	8	3	16.84	2.15	70.52	0.072	0.098
01	2	2	8	3	81.21	24.73	66.91	0.743	0.772
01	2	3	8	3	0.63	0.51	6.56	0.112	0.151
01	2	4	8	3	20.88	8.72	32.35	0.060	0.075
01	2	5	8	3	2.54	0.26	3.96	1.272	0.753
01	2	7	8	3	12.02	0.22	24.05	0.125	0.655
01	2	8	8	3	0.85	0.68	96.37	0.023	0.210
01	2	9	8	3	5.95	0.22	20.47	0.051	0.023
T-159	3	1	4	0	1.57	1.58	14.20	0.099	0.031
T-159	3	2	4	0	1.83	0.46	11.34	0.107	0.037
T-159	3	3	4	0	2.71	9.66	25.36	0.554	0.131
T-159	3	4	4	0	0.26	0.93	2.74	0.026	0.030
T-159	3	5	4	0	2.41	4.16	16.07	0.067	0.245
T-159	3	6	4	0	2.18	3.02	14.75	0.841	0.109
T-159	3	7	4	0	4.43	2.29	16.43	0.521	0.126
T-159	3	8	4	0	1.42	0.28	6.44	0.071	0.041
T-159	3	9	4	0	1.05	1.84	8.96	0.221	0.073
T-158	3	1	4	0	0.76	1.64	13.31	0.014	0.046
T-158	3	3	4	1	2.83	2.14	19.42	0.266	0.161
T-158	3	4	4	0	0.18	1.11	2.50	0.044	0.031
T-159	3	5	4	0	2.18	1.99	7.54	0.362	0.283
T-158	3	6	4	0	3.45	3.63	15.69	0.406	0.332
T-158	3	7	4	0	2.30	0.13	10.83	0.473	0.036

APPENDIX V. (CONTINUED)

TAG	SPE-CIE	TIS-SUE	AGE	AGE GRP.	CU PPM	NI PPM	ZN PPM	CD PPM	PB PPM
T-158	3	8	4	0	0.43	0.10	4.07	0.078	0.021
T-158	3	9	4	0	0.53	2.08	9.10	0.261	0.066
T-160	3	1	3	0	0.21	0.38	15.73	0.383	0.041
T-160	3	2	3	0	1.30	0.55	7.50	0.433	0.049
T-160	3	3	3	0	1.30	3.73	14.11	0.154	0.114
T-160	3	4	3	0	0.14	1.30	2.30	0.153	0.013
T-160	3	5	3	0	1.33	1.68	14.83	0.992	0.153
T-160	3	6	3	0	4.13	4.98	19.79	0.206	0.360
T-160	3	7	3	0	3.11	2.70	14.54	0.691	0.060
T-160	3	8	3	0	0.47	0.33	10.12	0.003	0.089
T-160	3	9	3	0	2.69	1.62	10.53	0.065	0.265
T-157	3	1	5	0	0.25	1.00	15.08	0.042	0.008
T-157	3	2	5	0	0.14	0.21	7.35	0.008	0.017
T-157	3	3	5	0	0.33	0.81	13.41	0.124	0.039
T-157	3	4	5	0	0.02	0.13	1.85	0.0	0.007
T-157	3	5	5	0	1.27	0.87	13.70	0.197	0.068
T-157	3	6	5	0	1.66	3.20	13.35	0.438	0.026
T-157	3	7	5	0	1.48	2.33	19.02	0.180	0.076
T-157	3	8	5	0	0.53	0.06	9.17	0.033	0.068
T-157	3	9	5	0	0.28	0.67	10.85	0.086	0.033
T-009	3	1	7	0	0.49	0.50	22.11	0.051	0.030
T-009	3	2	7	0	0.82	0.39	15.19	0.027	0.024
T-009	3	3	7	0	1.13	0.83	12.53	0.225	0.057
T-009	3	4	7	0	0.04	0.43	2.32	0.032	0.005
T-009	3	5	7	0	2.03	0.55	13.67	0.196	0.075
T-009	3	6	7	0	1.73	3.44	11.06	0.014	0.005
T-009	3	7	7	0	1.58	0.58	7.99	0.093	0.099
T-009	3	8	7	0	0.72	0.14	9.16	0.003	0.053
T-009	3	9	7	0	0.67	0.52	9.47	0.040	0.059
T-011	3	1	7	0	2.89	0.51	21.27	0.074	0.044
T-011	3	2	7	0	2.82	0.08	31.39	0.011	0.038
T-011	3	3	7	0	2.75	0.82	17.73	0.001	0.087
T-011	3	4	7	0	0.12	0.02	2.59	0.013	0.021
T-011	3	5	7	0	2.00	0.51	14.46	0.154	0.084
T-011	3	6	7	0	4.89	0.61	18.21	0.182	0.104
T-011	3	7	7	0	1.64	5.26	10.40	0.163	0.081
T-011	3	8	7	0	1.27	0.18	10.49	0.009	0.047
T-011	3	9	7	0	0.44	0.97	10.97	0.052	0.057
T-010	3	1	6	0	3.27	0.54	21.72	0.155	0.089
T-010	3	2	6	0	0.13	0.22	8.99	0.017	0.019
T-010	3	3	6	0	0.73	0.62	14.74	0.087	0.045
T-010	3	4	6	0	0.04	0.19	2.14	0.024	0.013
T-010	3	5	6	0	1.21	2.66	17.04	0.413	0.188
T-010	3	6	6	0	2.17	3.30	36.97	0.617	0.193
T-010	3	7	6	0	2.23	0.33	6.71	0.398	0.002
T-010	3	8	6	0	0.39	0.15	7.22	0.009	0.032