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The Society holds regular meetings the fourth Wednesday in each of the following months: August, September, October, January, February, March, April, and May. In November, the meeting is held the third Wednesday. An annual auction is held in place of the March or April Meeting

Meetings are held at Southside Place Club House, 3743 Garnet, Houston, Texas. Meetings begin at 8:00 p. m.

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The Texas Conchologist accepts contributions for publication from amateurs, students, and professionals, subject to approval by the Editors. Manuscripts should be typed and double spaced, and should be in the hands of the Editors the first day of the month preceding publication dates. Photos accompanying articles are welcomed.

Recent Harold W. Harry Memorial Award Winners

The Houston Conchology Society, Inc. continues to present awards to students doing graduate research in malacology, at both private and public Texas institutions. In this issue of **Texas Conchologist** we present papers offered by three recent winners. The application forms for 2000 will be mailed to interested institutions in the fall of 1999.

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In response to the Editors' request, we present some background information from the winners.

1999 Winner Christine Ritter

Mary Christine Ritter was born in Austin, Texas on July 7, 1966, the daughter of Mary Catherine Johnson Ritter and Timothy Henderson Ritter. She has two younger siblings, John Timothy Ritter and Catherine Ann Ritter. After completing Stephen F. Austin High School, she went to Trinity University, San Antonio, Texas. While at Trinity she attended summer school at the University of Texas, and the Bermuda Biological Station. She also attended field based courses offered by Boston University and Northeastern University. After graduating from Trinity with a Bachelor of Arts degree in Biology, May, 1988, she attended Texas A. & M. University where she received a Masters of Science in Wildlife and Fisheries Sciences in May, 1991. During the following years she worked for the Texas General Land Office and Congressman Greg Laughlin. In June, 1994, she entered the Graduate School of the University of Texas at Austin to pursue a Ph.D. in Marine Science. Her advisor is Dr. Paul A. Montagna. She hopes to defend her dissertation this summer and graduate in August. There are several options for her to choose from for the future. She hopes to continue research to develop her scientific understanding of estuarine succession and her policy background.

Permanent Address: 404 Mercer, Port Aransas, Texas 78373.

1999 Winner David Wayne Hicks

David Hicks will be completing his Ph.D. in August, 1999 at the University of Texas at Arlington, Texas. His advisor is Dr. Robert F. McMahon. He has accepted the position of Assistant Professor of Marine Biology at Lamar University in Beaumont, Texas. He will teach and will be directing their marine laboratory facility on Pleasure Island which has not been in use for some time.

Hicks received his B.S. in Marine Biology at the Texas A & M University at Galveston, Texas in 1989. He was awarded his M.S. in Biology at Texas A. & M. University at Corpus Christi, Texas in 1993, with Dr. J. W. Tunnell, Jr. as his thesis supervisor. He has had a varied professional experience as research assistant, graduate teaching assistant and is presently associate professor at Colin County Community College at Plano, Texas.

His list of publication is varied and large. In the last few years he has several papers published with others on the brown mussel, *Perna perna.* He has received support from the Texas A. & M. University Sea Grant College Program.

Current Research Activities:
"My dissertation research details the resistance adaptations of nonindigenous *Perna perna* to the major physio-chemical parameters likely to influence its capacity to colonize estuarine and coastal waters of North America. The physio-chemical parameters being examined include upper thermal limit (acute and chronic), lower thermal limit (chronic and freeze resistant), salinity tolerance, desiccation resistance, and tolerance of anoxia/hypoxia. Regulation of respiratory responses in each of the aforementioned physiology stressor experiments are also being examined. Aside from detailing the basic physiology of *P. perna*, the results of my research can be utilized in developing habitat risk assessment for predicting the spread of this species and to estimate efficacy of physiological treatments for use as nonchemical control strategies for mussel fouling in raw water systems," writes Hicks.

With his wife Kim and daughter Savannah, David will move to Beaumont, sometime in August.

1998 Winner Daniel E. Webb

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Dan Webb grew up near Crosby, Texas. He completed his Master's Degree at San Angelo University, with Dr. Ned Strength his advisor. He has enjoyed teaching science at Paint Rock this last year and has signed a contract to teach there the 1999-2000 school year. He plans to continue his research at San Angelo State as that university is close to Paint Rock.

Webb has published several papers on varied research interests and received many honors and grants to support his unique study involving mollusks. His wife also teaches at Paint Rock.

All your winners have expressed appreciation for the Harry awards and mentioned them in publications.

Estaurine Macrobenthic Community Succession: The influence of hypoxia, salinity fluctuations, sediment resuspension and disturbance frequency

Christine Ritter
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Succession theory describes community changes over time in the absence of disturbance. The theory was initially developed for terrestrial systems where the progress of succession was characterized by increasing community diversity, abundance, and biomass, and by changing species composition from species capable of rapid population growth (opportunists) to larger, more rare and slow growing species (Clements 1918; Cooper 1939). The application of succession theory to estuarine ecosystems is comparatively new (Pearson and Rosenberg 1976; Rhoads *et al.* 1978; Dauer 1993) and is problematic due to the great amount of environmental heterogeneity (e.g., salinity, oxygen, temperature) that affect organisms present.

Macrobenthic succession models focus on defining the characteristics of early succession versus climax (e.g., late succession) communities. A key characteristic of early succession communities is dominance by opportunistic species (e.g., the bivalve *Mulinia lateralis*; Dauer 1993). Other characteristics include lower biomass and diversity compared with that of a climax community (Dauer 1993). Larger infauna (e.g., Ophiuroida, Enteropneusta), often associated with climax communities, may facilitate oxygenation of deeper sediments by bioturbation (Flint and Kalke 1986). The oxygenation of deeper sediments allows infauna (e.g., bivalves) to become more deeply distributed, enhancing colonization by still other infaunal species (Flint and Kalke 1986), facilitating an increase in diversity and promoting the progression of succession.

The benthic estuarine environments of south Texas bays appear to be in a state of perpetual early succession (Montagna *et al,* 1998). Benthic communities in this area are characterized by low diversity and opportunistic species. There are three possible explanations for this observation. First, present sampling methods may not adequately sample larger deep dwelling species typically characteristic of late succession communities. Second, benthic communities of south Texas may be in a state of constant disturbance due to sediment resuspension (natural and anthropogenic), broad salinity variations,

and seasonal hypoxia (low oxygen). Third, estuarine succession models developed for application in other areas may not be suitable for south Texas estuaries due to physical (e.g., depth, tides) and climatological (e.g., rainfall, wind speed) differences.

To determine why Texas estuarine benthic communities appear to be in a state of constant disturbance, I conducted three experiments. The climax community study determined the adequacy of the present sampling effort and characterized a late succession estuarine community for Corpus Christi Bay. The hypoxia study determined the effect of hypoxia on benthic communities, proposed models describing how community characteristics respond to declining oxygen levels, and examined the present definition of hypoxia. The flow-resuspension experiment determined the effect of three flow/turbidity regimes on natural bottom and colonization of trays filled with defaunated sediment. In addition, the macrobenthic effects of frequency of physical disturbance and flooding were determined in the context of flow/turbidity disturbance. Based on these investigations, a theoretical model is being developed to describe the roles of disturbance frequency and intensity in the temporal context of estuarine benthic succession

Summary of Findings Pertinent to Mollusks

Climax Community Study

Macrobenthic communities of station C and E in Corpus Christi Bay (Figure 1) were markedly different with station E having much higher diversity, abundance and biomass than station C. This trend is reflected in the mollusk fauna of these stations (Table. 1). No gastropods, and very few bivalves (<1% annual abundance and biomass), were found at station C, probably because of the fine sediment and possible high sediment deposition and resuspension. Mollusks at station E comprised 2.3% total community abundance and 3.2% of biomass.

Hypoxia Study

Mollusks were found at only two stations, neither of which were subjected to the seasonal Corpus Christi Bay, Texas low oxygen (hypoxic) event.

Flow-Resuspension Experiment

Mulinia lateralis was found infrequently in undisturbed sediment of normal and reduced flow treatments indicating the possible inability of

this bivalve to tolerate high water velocities of the increased flow treatment. Although *M. lateralis* is an opportunistic species (Table 1), it did not recruit to defaunated sediment trays during the experiment indicating that the ability of this species to respond opportunistically may depend on environmental conditions. Because of the infrequency of *M. lateralis* at the study site, neither of these hypotheses have been tested yet.

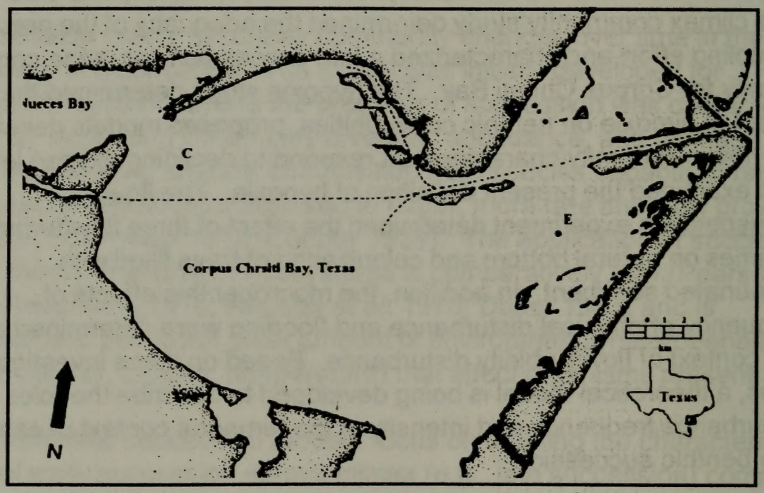

Figure 1: Map of Corpus Christi Bay, TX denoting station C and E (adapted from Martin and Montagna 1995).

Table 1: Average Mollusc abundance and biomass at stations C and E by species and identified with class, feeding guild and life history. Class: G=Gastropoda, B=Bivalvia. Guilds: C=carnivore/omnivore, I=Interface Feeder, D=Deep Deposit Feeder, E=Ectoparasite, and F=Filter Feeder. Life Histories: E=Equilibrium Species, O=Opportunistic Species. References: [1] Dauer (1993), [2] Weisberg et al. (1997), [3] Ranasinghe et al. (1994).

Species Name	Class	Feeding Guild	Life History	Station C		Station E	
				n m^{-2}	g m^{-2}	n m^{-2}	g m^{-2}
Crepidula sp.	G	I				70.91	0.0021
Polinices duplicatus	G	C				70.91	0.0090
Nassarius acutus	G	C				6.45	0.0026
Pyrgiscus sp.	G	E				25.79	0.0032
Nuculana acuta	B	D	O[2]	6.45	0.0629	6.45	0.0001
Anadara transversa	B	I[3]	E1			6.45	0.0004
Aligena texasiana	B	I				221.33	0.0826
Mysella planulata	B	I				6.45	0.0002
Mulinia lateralis	B	I	O[2]			47.27	0.0071
Ensis minor	B	I	E[2]			23.64	0.7821
Tellina sp.	B	I	E[2]	23.64	0.0047		
Mercenaria campechiensis	B	I[3]	E[1]			6.45	0.0760
Corbula contracta	B	I				23.64	0.0643
Lyonsia hyalina floridana	B	I				6.45	0.0007
Periploma cf. orbiculare	B	I				260.00	0.0560

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The Effects of Environmental Factors on the Production and Strength of Byssal Threads in the Nonindigenous Marine Mussel, *Perna perna*

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Invasive marine mussels, *Perna perna,* were first detected on the jetties at Port Aransas, Texas in February of 1990. *P. perna* populations are now found on other isolated hardshores along 1,700 km of coast from Freeport, Texas, to southern Veracruz, Mexico. Aside from threats to native biota, this aggressive new member of the fouling community has the potential to dramatically increase the maintenance costs of offshore navigation aids and other marine structures as well as raw water systems; particularly those of coastal power generating stations. *P. perna* is a known biofouler of raw water using facilities. Heavy infestations of *P. perna* resulting in serious flow blockage of cooling water systems has caused frequent power station outages in its native range. Despite the expense involved in the mechanical removal of mussels from fouled surfaces, little has been done to determine which factors affect the production of byssus threads or what forces are required to dislodge them. Thus, the study of environmental variables affecting byssal attachment is essential to the prevention of mussel fouling, since the disruption of a mussel's ability to produce byssal threads offers a means of control.

Marine mytilids and freshwater dreissenids (zebra mussels) are two of the few groups of bivalves that neotenously retain byssal attachment beyond the juvenile stage. Retention of byssal threads by the adult is fundamental to the success of these two groups as colonizers of hard substrata and as macrofoulers of man-made raw-water structures and systems. Secure attachment to the substratum in the face of substantial hydrodynamic forces (>IO m/sec) is achieved by a byssus composed of numerous collagenous threads secreted by the mussels foot. The entire structure is linked to the byssus retractor muscles by the root. The stem which extends from the root supports each of the byssal threads.

This research proposes to investigate the biology and mechanical properties of byssal thread production in *P. perna.* The effects of high temperature, low salinity, and low oxygen tensions on the production and strength of byssal threads will be examined. Application of

thermal, hypoosmotic, and oxygen stress are potentially highly economical, environmentally acceptable, nonchemical tools for inhibiting and or eliminating mussel fouling. Prior to each experiment, 20 mussels will be randomly assigned to acclimation groups of varying temperatures, salinity, or oxygen tension. Following the acclimation periods, all byssal threads will be severed at the byssal gape with a razor blade. Mussels then will be allowed to byssally reattach and thereafter, the cumulative number of threads produced will be recorded over the course of 21 days. Tensile strength and strain of byssal threads of five randomly selected threads from each individual will be determined using a Chatillon-DFGS2 digital force gauge at an extension rate of< IO mm/min. Both thread thickness and mussel size will be considered in thread strength determinations. To evaluate the susceptibility of different structures to mussel fouling, whole mussel attachment strength to various substrates including steel, concrete, and plastic will be tested, on both field and laboratory animals.

Studies of the mechanism of byssal attachment in bivalve molluscs have focused almost exclusively with the blue mussel, *Mytilus edulis,* with nothing known about the biology and mechanical properties of byssal threads in *Perna perna.* Preliminary tests indicate that the threads of *Perna perna* are as much as four times the strength values reported for *Mytilus spp.*

A Comparison of Arsenic and Lead Concentrations in the freshwater bivalves *Corbicula fluminea* (Corbiculidae) and *Quadrula apiculata* (Unionidae) from the Concho River, Texas using Energy Dispersive X-ray Fluorescence.

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Abstract

Asian clams *(Corbicula fluminea)* and southern mapleleaf clam *(Quadrula apiculala)* were collected from a mussel sanctuary on the Concho River approximately one kilometer west of Paint Rock, Concho County, Texas. Gill tissue from seventeen individuals of each species was analyzed for concentrations of arsenic (As) and lead (Pb) using energy dispersive x-ray fluorescence spectroscopy (EDXRF). Gill tissue from *Corbicula fluminea* contained significantly greater levels of As and Pb than did gill tissue from *Quadrula apiculata.*

INTRODUCTION

Asian clams, *Corbicula fluminea,* have often been used to determine whether elemental pollutants are present and bioavailable in aquatic systems. They are able to concentrate many elements to several orders of magnitude greater than the concentrations of those same elements in the environment. The southern mapleleaf, *Quadrula apiculata,* has never been used as a bioindicator of elemental pollutants. The fact that it does not occur in all U.S. surface waters and is more difficult to identify than *Corbicula fluminea* may have caused others to dismiss it as a potential bioindicator. This study was undertaken to compare the relative abilities of these two bivalve species to concentrate As and Pb because both species are two of the most common bivalve species in Texas and both occur in large numbers in the Concho River. Additionally, this study confirms the presence of As and Pb in the Concho River in a chemical form that can be incorporated into tissue.

Energy dispersive x-ray fluorescence was used because it is accurate and relatively easy to use with samples in organic matrices. Moreover, the concentration of many elements can be determined from a single spectrum, thereby reducing sample-handling time.

xDetection and/or quantification of elemental pollutants often present several problems. Little information is available concerning the presence of elements in any but the most polluted of industrialized surface water (Heit *et al.*, 1980), and qualitative studies by most methods are expensive and time consuming (Webb & Dawkins, 1998). Additionally, many contaminants occur in such low quantities in surface waters and their substrates that they must be concentrated by appropriate methods in order to be detected and quantified by instrumental methods of analysis (Buhrke *et al.*, 1998). The fact that bioaccumulation occurs in this group of organisms alleviates the need to perform time consuming and, possibly, expensive concentration procedures in the laboratory.

METHODS AND MATERIALS

Sample Collection Site

The collection site was a 10 m x 10 m area in the Concho River approximately one km west of Paint Rock, Concho County, Texas. The United States Geological Survey (USGS) has had a water sampling and field testing station (USGS Site 08136500) one kilometer east of the sample collection site since 1967. The Texas Natural Resource Conservation Committee (TNRCC) considers the sample collection site to be a part of Section 1421 of the Colorado River drainage system. The TNRCC considers the water to be safe for contact recreation with the following average annual physical and chemical parameters: sulfate, 425 mg/L; chloride, 775 mg/L; total dissolved solids, 1600 mg/L; dissolved oxygen, 5.0 mg/L; pH range, 6.5-9.0; temperature, 32° C (Lower Colorado River Authority et al., 1996).

The mussel fauna at the site contains many individuals from at least seven species. One reason mussel populations are relatively healthy and stable here is that the shorelines of the Concho River are heavily vegetated for more than two km upstream of the site. This vegetation prevents excessive siltation due to runoff. In addition to the species in this study, the site is inhabited by paper pondshell, *Anodonta imbecillis;* giant floater, *Anodonta grandis;* bleufer, *Potamilus purpuratus;* fragile papershell, *Leptodea fragilis;* and the largest known population of the endangered and protected Texas pimpleback, *Quadrula petrina.* The population density of *Corbicula fluminea* at the site is > than 2200 individuals/m^2 (Howells et al., 1996) . The

Quadrula apiculata population has not been quantitatively described by Texas Parks and Wildlife but it is large. A semi-quantitative, timed search has produced as many as 77 individuals per hour in a recent survey.

Sample Collection

Thirty five *Corbicula fluminea* and 30 *Quadrula apiculata* were collected by wading in water approximately 0.5 m deep. Live animals were placed on ice overnight then frozen at -65° C until processed for analysis. The weights of the animals that were used for EDXRF are recorded on Table 1. It is not necessary to know the weight of a sample to calculate elemental concentrations with EDXRF, but the animals were weighed for several reasons. Dare & Edwards (1975) found that tissue weight and composition was seasonally variable in *Mytilus edulis*. Although the age of a bivalve is difficult to assess (Neves & Moyer, 1988), weight is generally relative to age for a given population. This study used only adult bivalves of similar age in each species so that contact time with contaminants would be the same.

Tissue Preparation: EDXRF

Seventeen individuals of each species were prepared for x-ray analysis. All tissue was prepared according to Webb and Dawkins (1998). Triplicate samples from a single gill were prepared by using a micropipette to transfer five μL of macerated gill material to each of three Formvar (Ladd Research Industries, Inc., Burlington, Vermont) films. The films were prepared by making a weight/weight solution of 2% Formvar in 1,2-dichloroethane.(Webb and Dawkins,1998). The samples dried at indoor ambient temperature before being irradiated. Samples were routinely placed in the instrument's sample chamber within 90 minutes of being prepared. This precaution minimized the chance that airborne contaminants might corrupt or otherwise affect the organic matrix and subsequent size of the Compton scatter peak.

Instrumentation and Experimental Procedure: EDXRF

Both elements were analyzed with a Philips Electronics Instruments PV9550HP energy dispersive x-ray fluorescence spectrometer coupled to an EDAX PV9800 analyzer system. Continuous spectrum, primary, x-rays were generated at a Rh target and filtered with a thin-foil Rh filter. Samples were irradiated for 1000 live seconds with 35 kV x-rays with an x-ray tube current of 30 mA. Net intensities of

fluorescent x-rays, I_e, which vary in direct proportion to the mass of a given element in a sample, were obtained by subtracting the background radiation and integrating the K_α peak for As, and the L_α and L_β peaks for Pb. The intensity of the Compton scatter peak, I_{cs}, which varied in proportion to the mass of the total sample, was integrated in a window of 19.80 keV to 20.40 keV according to Webb and Dawkins (1998). The net intensity of fluorescent x-rays to the intensity of the integrated portion of the Compton scatter peak (I_e/I_{cs} ratio) was then used to determine the concentrations of the elements under study. The fluorescent x-rays produced by the sample were detected with a lithium drifted silicon detector and digitized by the EDAX PV9800.

Determination of the concentrations of Pb and As present obstacles that must be overcome when using EDXRF. To begin, Pb is larger than Rh so primary x-rays from a Rh target are not energetic enough to elicit K_α, or K_β peaks from Pb. Consequently, the less desirable L lines must be used to quantify Pb. Additionally, the Pb L_α peak is centered at 10. 549 keV and the As $K_\alpha$peak is centered at 10. 532 keV. Their spectral lines interfere with each other when both elements are present.

The relationship of I_e/I_{cs} to concentration is linear for both Pb and As to a concentration of 150 ppm. The following method was used to determine the concentrations of Pb and As in tissue when both elements were present in a sample at concentrations of less than 150 ppm. Multiple samples of standard reference material bovine albumin (U.S. Department of Commerce, National Bureau of Standards, Gaithersburg, MD) were analyzed. Blank values for each element are generated by analyzing the matrix without adding any standards. The blank values are subtracted from the I_e/I_{cs} ratios. It is assumed hereafter that, when discussing I_e/I_{cs}, blank values have already been subtracted and the I_e/I_{cs} reported is the corrected value. Next albumin samples were spiked with 50.00 ppm Pb and the mean I_e/I_{cs}, ratio for the L_α peak was discovered to be 1.5210. The I_e/I_{cs} ratio for the As K_α peak is 3.244 when Pb is not present and the As concentration is 50.00 ppm. When 50.00 ppm Pb and 50.00 ppm As are present in the same tissue sample the resulting I_e/I_{cs} ratio for the Pb L_β peak is 1.168.

For simplicity, let the I_e/I_{cs} ratio for the Pb L_β peak equal x and I_e/I_{cs} ratio for the Pb L_α plus As $K_\alpha$peak equal y. Also, let (Pb) equal the concentration of Pb in a sample in ppm and (As) equal the concentra-

tion of As in a sample in ppm. Let C_1, C_2, C_3 be constants and the following equations can be used to describe the concentrations of Pb and As in tissue:

$x = C_1(Pb)$ equation 1
$y = C_2(Pb) + C_3(As)$ equation 2
These equations are true when:
$C_1 = x/(Pb) = 1.168/50.00 = 0.02336,$ equation 3
$C_2 = Y\text{-}C_3(As)/(Pb)=1.521\text{-}0/50.00=0.03042$ equation 4
$C_3= Y\text{-}C_2(Pb)/As=3.244\text{-}0/50.00=0.06488$ equation 5

Substituting C_1 from equation 3 into equation 1 and substituting C_2 and C_3 from equations four and five respectively into equation 2, one has machine formulas that can be employed to determine the concentrations of As and Pb in tissue samples:

$x = 0.02336(Pb)$ equation 6
$y = 0.03042(Pb) + 0.06488(AS)$ equation 7

The value of x was determined by integrating the Pb L_β peak in a window of 12.40 keV to 12.05 keV and the value of y was determined by integrating the additive Pb L_α, As K_α peak in a window of 10.30 keV to 10.81 keV.

RESULTS

Concentrations (ppm dry weight) from each of the three EDXRF spectra/animal were averaged and recorded as a single concentration measurement (Tables 2 and 3). Concentrations of each element, from each animal, were then averaged and recorded (Table 4).

T-tests were employed to determine if the difference in the concentration of each element was significant between *Corbicula fluminea and Quadrula apiculata.* SYSTAT 5.2.1 (Statistical Products and Service Solutions Inc., Chicago, IL) was used to determine t-test scores. A separate variance tscore and a pooled variance t-score were calculated for the means of each species. An F-score was calulated to test the variance of the concentration of each element in each species. Though pooled variance t-tests are very robust to differences in variance (Zar 1996), the separate variance t-test was referred to when the differences in variance were significant. At an alpha value of 0.05, there was a significant difference in the variances of the mean concentrations of As and Pb (Table 4). T-tests confirm that *Corbicula*

fluminea gills contain significantly greater concentrations of As and Pb than do the gills of *Quadrula apiculata.* Consequently, Corbicula *fluminea* is a better bioindicator of these elements than *Quadrula apiculata.*

DISCUSSION

The primary focus of this study was to determine which of two common bivalve species, *Corbicula fluminea and Quadrula apiculata,* would make a better bioindicator of arsenic and lead. This was determined solely on their relative abilities to concentrate those elements. The study was also undertaken to determine the presence, or absence, and bioavailability of As and Pb in the Concho River.

FUTURE RESEARCH

An earlier study of *Corbicula* sp. collected from the same site on the Concho River found the genus to have significantly higher concentrations of Br, Cu, Ni, P, Se, and Zn than the background concentrations of those elements in the river sediment (Webb &]Dawkins, 1998). This study concludes that *Corbicula fluminea* concentrates As and Pb more readily than *Quaclrula apiculata* and would make a better bioindicator of those two elements. A follow-up study would determine if it would be feasible to use *Corbicula fluminea* as an indicator of those metals or whether it would be better to use the sediment instead. Such a study would possibly help determine the ultimate source of the As as well; *Corbicula fluminea only* have a three year lifespan and arsenic acid, a cotton defoliant and the assumed source of As in the bivalve, has been banned for more than five years. It is unlikely that As will be found in the Concho River sediment unless it is coming from another source because the K_{a3} of arsenic acid is 6 x IO-$^{-10}$and all of the As used as a cotton defoliant should be in an ionic form (most as $HAsO_3^{2-}$) at a pH of 8. A study of the sediment would reveal whether the As at the study site is a recent phenomena or possibly incorporated into the sediment in a manner that is unknown at this time.

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LITERATURE CITED

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Table 1. Whole animal weight of *Q. apiculata* (QA) and *C. fluminea* (C) analyzed with EDXRF.

Sample Number	Weight (g) (shell & tissue)	Sample Number	Weight (g) (shell & tissue)
QA1	113.0	C1	22.8
QA2	116.1	C2	20.5
QA3	90.3	C3	25.8
QA4	126.3	C4	23.8
QA5	108.9	C5	21.5
QA6	141.4	C6	19.6
QA7	96.8	C7	24.6
QA8	121.8	C8	24.8
QA9	188.1	C9	19.9
QA10	139.4	C10	25.5
QA11	174.1	C11	30.1
QA12	120.8	C12	23.6
QA13	156.2	C13	21.8
QA14	102.1	C14	20.6
QA15	132.6	C15	24.3
QA16	127.0	C16	23.6
QA17	98.2	C17	33.7
Average Weight & SD (g)	126.7 ± 27.0	Average Weight & SD (g)	23.9 ± 3.6

Table 2. Mean Concentration of As in 17 *C. fluminea* and 17 *Q. apiculata*.

C. fluminea		*Q. apiculata*	
ID Number	Concentration & SD (ppm dry weight)	ID Number	Concentration & SD(ppm dry weight)
C1	20.71 ± 3.99	QA1	7.29 ± 2.17
C2	11.68 ± 3.89	QA2	1.78 ± 1.56
C3	15.02 ± 3.67	QA3	5.26 ± 2.62
C4	12.11 ± 3.08	QA4	4.24 ± 1.52
C5	17.16 ± 3.20	QA5	2.05 ± 1.95
C6	20.45 ± 3.30	QA6	2.85 ± 3.50
C7	16.74 ± 4.77	QA7	6.61 ± 2.53
C8	14.29 ± 1.27	QA8	4.90 ± 0.74
C9	18.12 ± 1.73	QA8	4.45 ± 2.41
C10	14.62 ± 2.14	QA9	3.84 ± 2.87
C11	24.69 ± 2.15	QA10	2.34 ± 2.11
C12	11.19 ± 1.66	QA11	3.14 ± 0.48
C13	20.29 ± 0.52	QA12	6.71 ± 1.47
C14	14.83 ± 3.20	QA13	2.44 ± 2.67
C15	16.61 ± 2.75	QA14	2.48 ± 2.99
C16	13.50 ± 3.05	QA15	5.43 ± 3.98
C17	18.35 ± 5.44	QA16	6.08 ± 3.53

Table 3. Mean Concentration of Pb in 17 *C. fluminea* and 17 *Q. apiculata*.

C. fluminea		*Q. apiculata*	
ID Number	Concentration & SD (ppm dry weight)	ID Number	Concentration & SD (ppm dry weight)
C1	42.30 ± 2.25	QA1	19.76 ± 2.61
C2	38.65 ± 5.76	QA2	22.23 ± 3.28
C3	29.38 ± 7.18	QA3	23.55 ± 5.26
C4	27.68 ± 6.56	QA4	25.39 ± 3.58
C5	29.92 ± 3.49	QA5	24.01 ± 6.94
C6	29.27 ± 3.94	QA6	23.59 ± 1.64
C7	37.65 ± 11.31	QA7	21.91 ± 4.43
C8	40.75 ± 3.42	QA8	23.49 ± 2.94
C9	30.88 ± 1.82	QA9	30.80 ± 3.82
C10	33.25 ± 6.52	QA10	23.26 ± 1.52
C11	33.34 ± 3.51	QA11	23.99 ± 4.97
C12	37.89 ± 3.71	QA12	26.19 ± 1.30
C13	23.23 ± 0.95	QA13	26.81 ± 2.64
C14	36.28 ± 5.20	QA14	22.58 ± 8.10
C15	39.19 ± 5.96	QA15	23.78 ± 4.99
C16	45.20 ± 4.69	QA16	27.39 ± 5.99
C17	34.41 ± 5.05	QA17	21.59 ± 2.08

Table 4. Concentrations of As and Pb in *C. fluminea* and *Q. apiculata*. Also included are t-scores and F-scores.

Element	Concentration (ppm dry weight)		t-scores		F-scores	
	C. fluminea	*Q. apiculata*	Separate variance	Pooled variance	Calculated	F crit.
As	16.49 ± 3.66	4.22 ± 1.79	12.40 DF=23.3 Prob=0.00	12.40 DF=32 Prob=0.00	4.17	2.76
Pb	34.66 ± 5.82	24.14 ± 2.58	6.82 DF=22.1 Prob=0.00	6.82 DF=32 Prob=0.00	5.08	2.76

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