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Heavy Metals in Oysters from a Subtropical Coastal Lagoon Associated with an Agricultural Drainage Basin

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Agricultural pollution is generally associated with the Altata-Ensenada del Pabellón lagoon system, a subtropical complex located on the northwest coast of Mexico and bordered by a vast zone of intensive agriculture, mostly of vegetables and sugar cane. Considerable concern has been expressed by agencies such as the Secretary of Urban Development and Ecology SEDUE (Sinaloa Delegation, Mexico) that environmental pollution may be severe in localized areas close to the agricultural and sugar industry discharges. Phosphorus levels in sediments from the Ensenada del Pabellón area are higher than the remaining portions of the lagoon system (Páez-Osuna et al. 1991a), but no studies have been conducted on heavy metal levels despite the importance of molluscs which are collected in the lagoon complex for human consumption.

Páez-Osuna and Marmolejo-Rivas (1990a) recently showed that the levels of lead, chromium, nickel and cobalt in the oyster Crassostrea corteziensis were correlated with those in the particulate fraction of the lagoonal water. These results, the geographical distribution (Keen 1971), long life, abundance, reasonable size and easy sampling provide evidence that C. corteziensis may be effective as a bioindicator of contamination in the coastal lagoons of the Pacific Latin America region.

The present study reports on the annual (1988-1991) trends in concentrations of Cd, Cr, Cu, Fe, Mn, Ni, and Zn in the soft tissue of the oysters C. corteziensis and C. palmula from seven stations of the Altata-Ensenada del Pabellón lagoon system.

MATERIALS AND METHODS

No single sessile bivalve species occurs throughout the Altata-Ensenada del Pabellón lagoon system in sufficient abundance to be used as a unique

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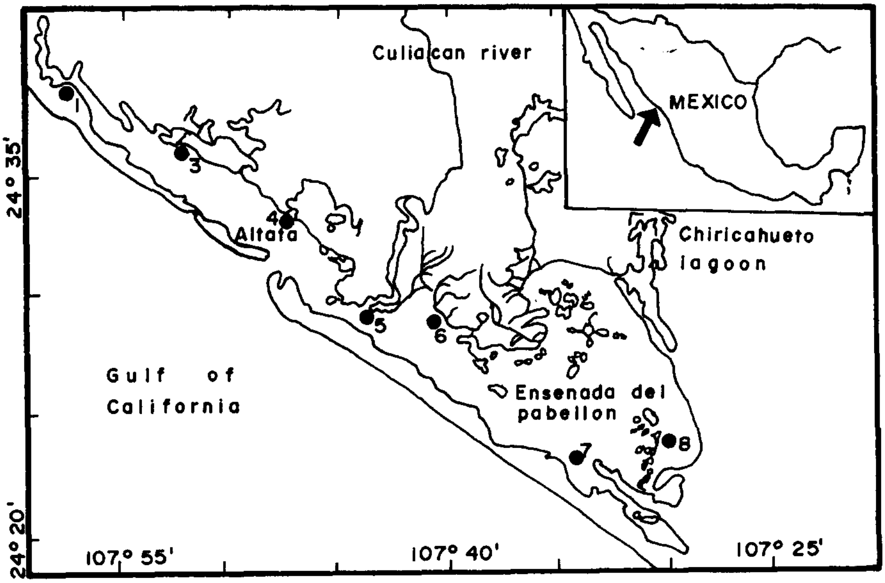

Figure 1. Sampling sites in the Altata-Ensenada del Pabellón lagoon system of Northwest México (●).

bioindicator of contamination. However, the oysters are more widely distributed and C. corteziensis predominates in the Ensenada del Pabellón area where the fluctuations of salinity is variable (2.5 - 33.5 parts per thousand) (Peraza-Vizcarra 1973) and C. palmula is found principally in the Altata portion where marine conditions prevail. C. palmula was collected at stations 1, 3, 4 and 5 and C. corteziensis at stations 5, 6, 7 and 8 (Fig. 1). These stations were chosen to provide examples of the range of hydrodynamic and hydrologic conditions that exist in the lagoon complex. Stations 1 and 3 are located (apparently) in a poorly flushed lagoon section. Station 4 appears to be subject to strong flushing by tidal currents originating at the principal mouth of the lagoon. Station 5 is subject to regular riverine influence and minor flushing by tidal currents. The remaining stations are less regularly influenced by direct river discharges, although station 8 is affected by the intermittent discharge of agricultural runoff.

Samples of oysters were collected from mangrove roots before their spawning period in March-April (Stuardo and Martínez 1975) during 1988 (stations 1,3,4,6,7 and 8), 1989 (only station 1), 1990 (all stations) and 1991 (stations 1,3,4,5,7 and 8). The samples were rinsed with sea water and transported in pre-cleaned polyethylene containers (Moody and Lindstrom 1977). Each site was sampled during low tide and oysters were returned to the laboratory within 24 hr of collection. They were promptly cleaned in distilled water and were not depurated, so the soft tissue included the digestive gland and sediment particles. While choosing oysters for the preparation of composite samples used for determination of trace metals (25 individuals), emphasis was placed on organisms of nearly equal length (4.0-6.2 cm for C. corteziensis and 3.9-5.3 cm for C. palmula); in this way we hoped to limit as far as possible differences attributable to size and age. All oysters were measured and removed from their shells. Each composite sample of soft tissue was dried by heating (95° C) for 48 hr. Pulverization and homogenization were achieved by grinding in a teflon mortar. Samples and blanks for analysis were prepared by digesting triplicate samples of dry material with concentrated and distilled nitric acid using the multiple standard addition method. The digests were slowly evaporated to dryness (100° C) and the remainder dissolved in 1 M nitric acid. Samples were placed in acid-washed polyethylene bottles (Moody and Lindstrom 1977) and analyzed by flame atomic absorption spectroscopy using a Shimadzu AA-630. All metal concentrations refer to μg metal per gram dry weight. The accuracy and precision of the method employed was established by means of a reference material mussel homogenate MA-M-2/TM (IAEA 1985) as indicated previously in Páez-Osuna et al. (1991b).

RESULTS AND DISCUSSION

The results of the metals analysis are summarized in Figs. 2a and 2b. A total of twenty composite samples were analyzed, eleven of C. palmula and nine of C. corteziensis. In the case of chromium, levels were undetected in eleven samples (Fig. 2a). The detection limit for this element was 0.30 μg/g. There were two characteristics of the metal concentrations in oysters from Altata-Ensenada del Pabellón lagoon: (i) 1990 samples appeared to have significantly ($P<0.05$ by Students' t-test) higher levels of cadmium, copper, iron and zinc than either 1988 or 1991 (except for stations 1 and 3); and (ii) In 1990 station 5 had higher concentrations of copper, iron, manganese and zinc than the other stations.

The relatively high values in 1990 samples from stations 5, 6, 7 and 8 was similar to results obtained with mussels (Páez-Osuna et al. submitted) at stations 7, 8 and other sites of the lagoon complex which suggest that these levels may have been related to discharges from agricultural facilities and runoff in the region. Prior to sampling in April 1990, extreme rain resulted in considerable runoff from the drainage basin. This event probably influenced increased metals levels observed in oysters.

At station 5, which is located near the mouth of the Culiacán River (Fig. 1), C. palmula was collected during 1990 only, and C. corteziensis in 1991. Consequently, the notable differences in metal levels between the different years could have been influenced by the distinctive ability of the organisms to bioaccumulate these elements. Unfortunately, both species were not sampled simultaneously to explain this situation. In the Navachiste lagoon, also in the northwest coast of Mexico, C. corteziensis and C. palmula had

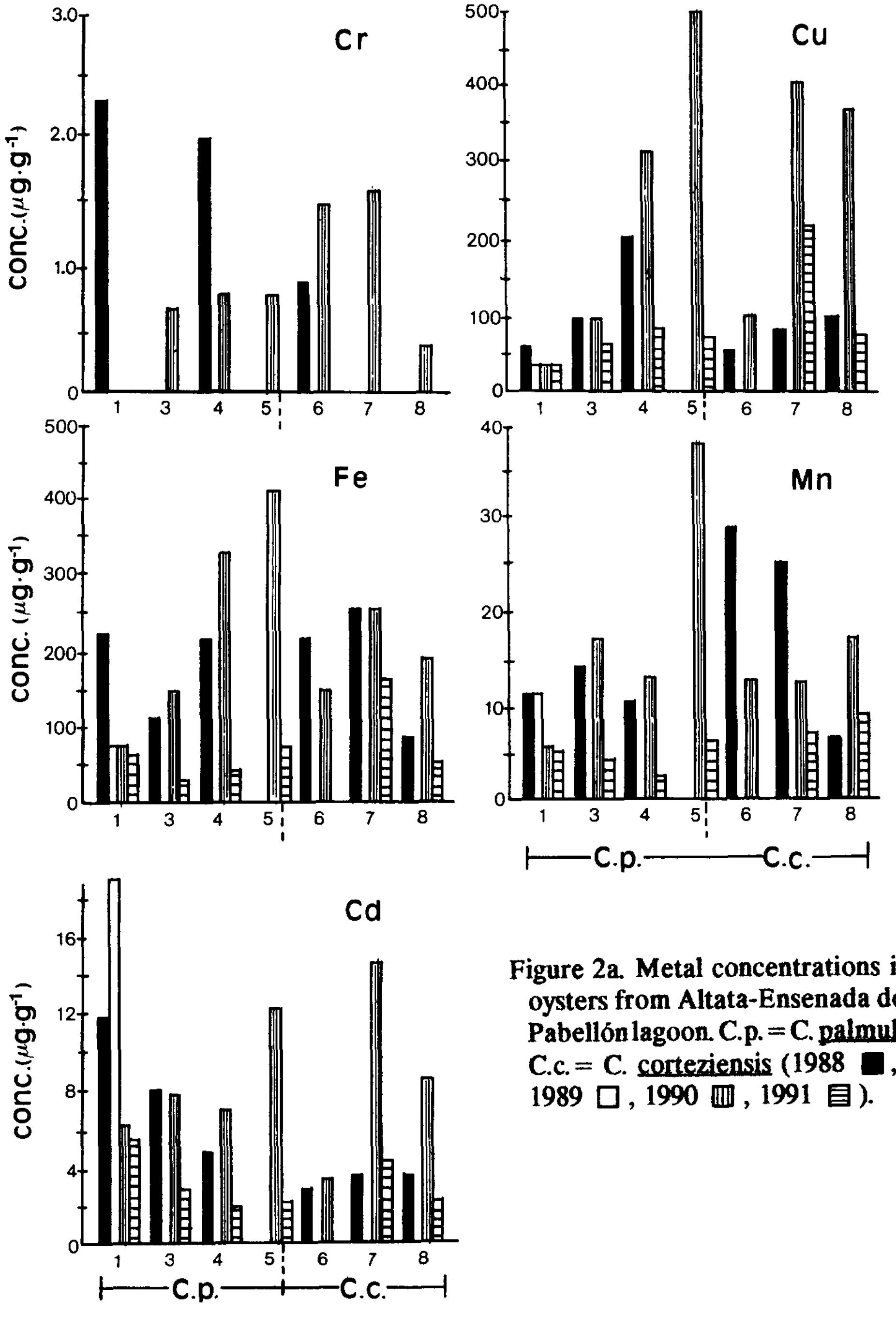

Figure 2a. Metal concentrations in oysters from Altata-Ensenada del Pabellón lagoon. C.p. = C. palmula C.c. = C. corteziensis (1988 ■, 1989 □, 1990 ▥, 1991 ▤).

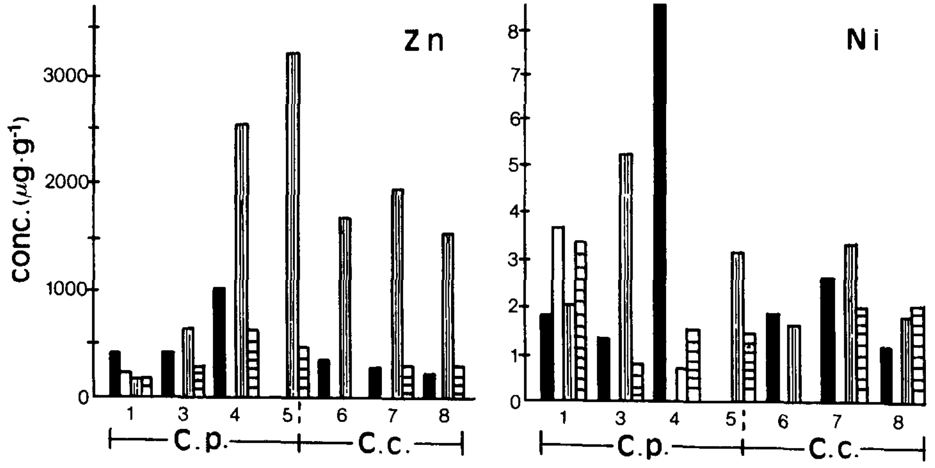

Figure 2b. Metal concentrations in oysters from Altata-Ensenada del Pabellón lagoon. C.p. = C. palmula, C.c. = C. corteziensis (1988 ■, 1989 □, 1990 ▥, 1991 ▤).

similar concentrations of cadmium, cobalt, chromium, manganese and nickel, but the specimens of C. palmula contained 37, 50 and 42 % more copper, lead and zinc, respectively, than C. corteziensis from the same station. This last species, in comparison with C. palmula, had 32 % more iron. These observations suggest that the comparison of some elements must be made considering such differences in the accumulation between the two species of oysters.

Numerous studies of metal concentrations in oysters have been undertaken in recent years. Table 1 compares our results with those of the reported studies. Our values were calculated on the basis of yearly (1988-1991) observations. Comparisons of levels must be made with caution, however, because of variations in the quality of analytical data. Additionally, differences in the sampling season, size (age) and gonadal maturation of organisms may influence the results (NAS 1980). Most values obtained in this study are generally comparable with those noted by other authors for the genus Crassostrea from different areas of the world (Table 1). The average copper concentration was substantially higher in the two oyster species from Altata-Ensenada del Pabellón lagoon than Mazatlan Harbor or Navachiste lagoon; only C. virginica from the Gulf coast of the U.S.A. (Goldberg et al. 1983) has a level comparable. In respect to zinc, the values found were intermediate. Oysters from the Altata-Ensenada del Pabellón lagoon complex are moderately contaminated with copper and zinc, especially at the mouth of the Culiacán River and the Ensenada del Pabellón lagoon section. This partially corroborates results where mussel M. strigata revealed significant levels of manganese, iron and zinc (Páez-Osuna et al. submitted), which

Table 1. Average metal concentrations in oysters from different areas. Concentrations are expressed in ($\mu g.g^{-1}$) dry weight.

Oyster	Area	Cd	Cu	Fe	Mn	Ni	Zn	Ref.
C. gigas	Knysna Estuary (South Africa)	3.7	52	128	16	1.6	396	(a)
C. commercialis	Thailand Gulf (Thailand)	3.2	100	124	-	0.8	571	(b)
C. virginica	Gulf Coast (USA)	5.1	134	258	13.5	2.6	1741	(c)
S. iridescens	NW Coast (México)	3.6	20	93	9.4	1.7	402	(d)
C. corteziensis	Mazatlán Harbor (México)	1.1	55	181	16.5	4.0	1328	(e)
C. corteziensis	Navachiste lagoon (México)	10.3	67	232	7.2	2.6	509	(f)
C. corteziensis	Altata-E.P.lagoon (México)	3.9	147	139	13.6	1.9	727	(g)
C. palmula	Navachiste lagoon (México)	10.3	104	161	4.8	2.3	1190	(f)
C. palmula	Altata-E.P.lagoon (México)	8.2	150	150	12.9	2.9	943	(g)

(a) Watling and Watling (1976); (b) Phillips and Muttarasin (1985); (c) Goldberg et al. (1978); (d) Páez-Osuna and Marmolejo-Rivas (1990b); (e) Páez-Osuna and Marmolejo-Rivas (1990a); (f) Páez-Osuna et. al. (1991b); (g) This study.

might be expected in a coastal body that receives several discharges from agricultural and suburban areas.

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