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Metals in Shrimp Culture Areas from the Gulf of Fonseca, Central America. I. Sediments

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Shrimp aquaculture is a prominent industrial activity in the Gulf of Fonseca, which is shared by Honduras, Nicaragua and El Salvador. The shrimp culture area in Honduras is widely extended and mainly located in the Departments of Valle and Choluteca, receiving waters from Choluteca, Sampile, Goascoran, Nacaome and Negro Rivers. Three thousands tons of shrimps were produced during 1993. In Nicaragua the production areas are located in the Estero Real where 3000 tons were obtained in 1993.Salvador does not have intensive culture atreas but there are collection areas containing wild larvae cultured in other countries. The main cultured species is the white shrimp, *Penaeus vannamei,* a tropical species distributed in the Pacific Ocean, but also wild larval, mainly *P. stylirostris* and *P. vannamei* are also used.

Intensive aquaculture has been reported as a significant source for anthropogenic stress in coastal areas. Organic matter, phosphorous along with nitrogen compounds, and metals are the most significant chemicals related to pollution from aquaculture facilities. The impact of shrimp culture has received limited attention (Pruder 1992; Hopkings et al 1993). Food, fertilization, and bottom liming are potential sources. A recent study (Teichert-Coddington, 1995) has reported the water quality conditions in the shrimp culture area of Honduras, however, the study did not cover metals. Some metals are essential constituents of the diet or used as therapeutic agents. For metals, sediment quality is a good indicator of water pollution (Ferreira et al 1996). Metal concentrations in sediments depend primarily upon the nature of the input sources and the distance from anthropogenic influences. When unbalanced, intensive aquaculture may contribute to the increase of metals in sediment. Metals may be released by redox-processes and move up to the water column leading to the exposure of aquatic organisms. This study presents the levels of several metals (Fe, Zn, Cu, Mn, Cr, Cd, Li, Pb and Hg) in sediments from aquaculture areas located in Nicaragua and Honduras.

MATERIALS AND METHODS

Intensive culture areas from Nicaragua and Honduras were selected, Figure 1. In Nicaragua, six sampling areas were selected along the Estero Real, the main aquaculture zone. Five additional sites were sampled in Honduras. Rearing ponds or connecting channels were selected for sampling.

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Figure 1. Sampling points for sediments (**0**)

Sediment samples were digested in aqua regia (6M HCl and 16M HNO_3, 3:l) (Berrow and Stein, 1983). For Hg, samples were digested in HCl and heated at 65°C for two hours. In all cases, standard metal solutions were prepared containing all reagents. Determinations of metals were performed with a Perkin-Elmer, 3030B atomic absorption spectrophotometer, equipped with deuterium background and a heated graphite atomizer HGA-300. Hg was analyzed by Mercury/Hydride System MSH-10. Methodology has been previously used for metal analysis in marine areas (Tarazona et al 1991).

When required, the Student "t" test was employed to check differences between the sampling sites located in each country. Pearson correlation coefficients were used to determine significant metal interrelationships. Statistical analyses were performed using Statgraphics and SPSS. Statically significant differences were expresed as $p < 0.05$.

RESULTS AND DISCUSSION

Table 1 Nicaragua and Table 2 Honduras, show sediment metal concentrations.

Tablal 1. Metal concentrations (expresed as µg/g dry-weight, except Fe as mg/g) in sediments from the Gulf of Fonseca (Nicaragua)

Metal (µg/g)	Sampling 1	Sampling 2	Sampling 3	Sampling 4	Sampling 5	Sampling 6
Cd)	0.095	0.083	0.083	0.065	0.051	0.044
CU	46	29.6	36.6	46.9	43.1	51.2
Zn	84.9	85.4	96.6	98.2	93.9	84.1
Cr	20.1	21.6	26.2	30.4	24	22.1
Pb	2.3	1.8	9	9	9.9	2.9
Mn	535	449	647	635	694	626
Li	66.3	0	0	28.6	88.8	36.1
Hg	0.012	0.013	0.015	0.016	0.015	0.013
Fe	2.96	2.58	3.13	2.89	2.82	2.64

Tablal 2. Metal concentrations (expresed as µg/g dry-weight, except Fe as mg/g) in sediments from the Gulf of Fonseca (Honduras)

Metal (µg/g)	Sampling 7	Sampling 8	Sampling 9	Sampling 10	Sampling 11
Cd	0.033	0.083	0.083	0.065	0.051
CU	37.7	29.6	36.6	46.9	43.1
Zn	59.8	85.4	96.6	98.2	93.9
Cr	5.5	21.6	26.2	30.4	24
Pb	3.9	7.8	9	9	9.9
Mn	197	449	647	635	694
Li	2	0	0	28.6	88.8
Hg	0	0.15	0.019	0.059	0.101
Fe	2.96	2.58	3.13	2.89	2.82

In general, similar ranges were obtained among sampling sites from Nicaragua and Honduras. Fe concentrations ranged from 15.5 to 43.5 g/kg, followed by Mn, 197 to 694 µg/g. Zn concentrations ranged from 59.8 to 122.4 µg/g; and Cu from 26 to 51.2 µg/g.

The lowest values were found for Cd, ranging between 0.03 and 0.095 µ/g, and Hg ranged from zero to 0.15 µg/g. Greatest fluctuations were observed for Li.
Table 3 compared metal concentrations observed at the Gulf of Fonseca with those reported for other areas of the world. The concentrations detected in this study area were among the lowest reported in the literature suggesting that, nowadays, metals do not constitute a pollution problem in the shrimp culture area of Gulf of Fonseca. Particularly interesting were comparisons with the concentrations reported by Establier et al (1985) for the Bay of Cadiz, Spain. These authors studied metal contents in different areas of the bay including four salt-ponds used for fish culture. Levels of metals except for Cu were lower in Fonseca than in Cadiz. Similar situations were observed for other comparisons. Metals (Cu, Mn, Zn) and non-essential metals concentrations were lower than reported in other works (Establier et al 1985; Schintu et al 1991; Prudente et al 1994; McGee et al 1995); while concentration of Fe were similar to those reported in sediments at Cadiz, Manila and Chesapeake Bays (Establier et al 1985; Prudente et al 1994; and McGee et al

Table 3. Ranges of metal concentrations (μg/g dry weight, except Fe as g/kg) in sediments from Fonseca Gulf (Nicaragua and Honduras) and other references reported in the literature

Location	Cd	Cu	Fe (g)	Zn	Cr	Pb	Mn	Li	Hg	References
Nicaragua	0.044-0.095	29.6-46.9	25.8-31.3	84.1-98.2	20.1-30.4	2.3-9.9	449-694	0-88.8	0.012-0.016	Present study
Honduras	0.033-0.080	26-37.7	15.5-43.3	59.8-112.5	5.5-30	3.9-9.9	197-650	2-13.7	0-0.15	Present study
Olbia Bay (Italy)	0.2-8.0	1.5-15	1.2-24	14-118		2.2-20	600-2650			Schintu et al 1991
Coatzacoaltos estuary (Mexico)	0.6-2.4	4.9-44	12.8-84.7	21-131		17-91				Paez-Osuna et al 1986
Cadiz Bay Spain (salt-ponds)	1.13-1.62	23-41	27.6-45.2	96-308		43-68	329-473			Establier et al 1985
Cadiz Bay, (Spain)	1.13-2.29	15-49	17-45	96-341		39-86	260-413			Establier et al 1985
Manila Bay (Philippines)	0.7-7.7	32-118	11.4-40.9	60-329		6.0-95	291-1220			Prudente et al 1994
Chesapeake Bay (USA)	0.29-0.74	21.6-167	21.4-42.3	127-389	29.5-57.6	25.9-52.2			0.10-0.38	McGee et al 1995
Reviewed data	<0.05-8	1.3-372	1.2-84.7	9-1390		2.2-346	64-2650			Prudente et al (1994)*
Unpolluted areas	0.1-3	19-78	7-60	24-114	12-120	12-95	95-4030			Anderlini et al (1982)**
Manila Bay	0.7-7.7	32-118	11.4-40.9	60-329		6-95	291-1200			Prudente et al (1994)

(*) Range of metals reported by Prudente et al (1994) for some other world areas (n=10);(**) Range of metals described for unpolluted areas or as control

Table 4. Pearson correlation coefficients for metal interrelationships in sediments from Nicaragua and Honduras.

Parameter	Cd	Cu	Fe	Zn	Cr	Pb	Mn	Li	Hg
Cd	---								
Cu	-.2435 p=.471	---							
Fe	.3306 p=.321	-.8333 p=.001	---						
Zn	.3408 p=.305	-.0973 p=.776	-.1761 p=.604	---					
Cr	.1486 p=.663	.7045 p=.016	-.5986 p=.052	.4524 p=.162	---				
Pb	.1021 p=.765	-.2560 p=.283	.0599 p=.861	.7055 p=.015	.2254 p=.505	---			
Mn	.0656 p=.848	.7664 p=.006	-.7138 p=.014	.3777 p=.252	.8904 p=.000	.1728 p=.611	---		
Li	.2050 p=.570	-.0731 p=.841	.3281 p=.355	.5627 p=.090	.1725 p=.634	.1943 p=.591	.0220 p=.952	---	
Hg	.3949 p=.229	-.7222 p=.012	.9739 p=.000	-.4197 p=.672	-.4197 p=.199	.0801 p=.815	-.5659 p=.070	.1497 p=.680	---

(Coefficient / all cases n=11 / 2-tailed Significance)

1995). The concentrations of Cd and Hg in the sediments collected in the Gulf of Fonseca were particularly low. The highest concentrations of this metals were similar to the lowest concentrations reported by Anderlini et al (1982) for unpolluted areas.Relatively high Hg concentrations were detected in two Honduras' sampling points, suggesting local pollution problems. The possible source for this metal are the organomercurial fungicides used in agricultural practices or geological soil composition. The presence of metals in marine sediments is a consequence of both natural and anthropogenic contamination. Elevated concentrations in the marine environment are restricted to estuaries and the narrow coastal margin. In addition to the direct disposal of solid or liquid wastes, river runoff and ship-related inputs are the main source (Caldwell and Buhler 1983). The Choluteca river contributes a negatively higher amount of nutrients to the Gulf of Fonseca than does he shrimp culture (Teichert-Coddington et al 1995). For Hg and other metals the same situation could be expected. Nicaragua sediments showed the high concentrations for this Li.

For metals, two additional processes must be considered in the mass balance of aquaculture ponds: direct input of contaminants through aquaculture, and by animals. In the present study area, shrimps are fed a pelleted diet; inorganic fertilization and pond bottom liming are used occasionally (Teichert-Coddington 1995). Table 4 sumarizes the simple metal correlation analysis. Significant correlation were also found bewteen Fe-Hg , with a Pearson correlation coefficient of 0.97. Significant correlations were found for Cu/Mn, Cu/Fe and Fe/Mn; the Pearson correlation coefficients in these cases were positive for Cu/Mn but negative for the other two, suggesting that a common pollution source for these metals in the study area can not be expected. Table 5 includes the simple correlation matrix for the sediments of the Bay of Cadiz (calculated from the data published by Establier et al 1985). Positive correlations between Cu/Fe, Cu/Zn and Fe/Zn were observed for the aquaculture ponds but not if other samples were included. Similarly, Anderlini et al (1982) did not find correlations between Cu and other metals in sediments collected in unpolluted areas of Kuwait. These data confirm that positive correlations among metals should be expected for aquaculture polluted sediments. The lack of correlation observed for the Gulf of Fonseca would, therefore, suggest that shrimp aquaculture has a low impact on the sediment concentration of heavy metals in this area.

As a conclusion, the levels of metals in sediments from the shrimp culture area of the Gulf of Fonseca were, in general, lower than those reported for other zones of the world including reference unpolluted areas (Anderlini et al 1982). The lack of contribution from the shrimp culture was confirmed by the lack of correlation among essential metals. Only for Hg, relatively high concentrations were detected in two sampling sites. In-land Hg emission should be considered the most probable source for this metal. Data suggest that shrimp culture in the Gulf of Fonseca is, nowadays, developed according to the environmental sustainability of the area. A similar situation was reported for the contribution of nitrogen and phosphorous from the shrimp culture practice (Teichert-Coddington, 1995) in Honduras. The levels of metals in the sediments of the shrimp ponds should be regularly monitorized o check that this good observed situation is maintained in the future.

Table 5. Pearson correlation coefficients obtained by Establier et al (1985) for sediments in the Bay of Cadiz, Spain.

Parameter	Cd	Cu	Fe	Zn	Pb	Mn
Cd	---	.3212 p=.399	-.3727 p=.323	-.0898 p=.818	.5100 p=.161	-.1314 p=.736
Cu	**-.9683 p=.032**	---	.6449 p=.061	.6210 p=.074	.8919 p=.001	-.4781 p=.193
Fe	**-.9932 p=.007**	**.9470 p=.053**	---	.4364 p=.240	.5009 p=.170	-.1004 p=.797
Zn	**-.9741 p=.026**	**.9579 p=.042**	**.9422 p=.058**	---	.3705 p=.326	-.8575 p=.003
Pb	**-.7305 p=.269**	**.7446 p=.255**	**.7836 p=.216**	**.5750 p=.425**	---	-.2290 p=.553
Mn	**.5787 .421**	**-.7309 p=.269**	**-.4898 p=.510**	**-.7012 p=.299**	**-.2273 p=.773**	---

(Coefficient / 2-tailed Significance)
Normal type represents correlation for all sites sampling (n=9)
Bold type represents correlation for aquaculture ponds(n=4)

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