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Heavy Metal Concentrations in Fish from a Pristine Rainforest Valley in Peru: A Baseline Study Before the Start of Oil-Drilling Activities

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Pristine, unaltered ecosystems provide a valuable and rare source of baseline information on variables measuring habitat quality and environmental health. Information from these ecosystems is critical to our interpretation of habitat quality and contamination of environments affected by human activities. In particular, when human industrial activity commences in highly diverse, pristine and sensitive environments, it is critical to obtain early measures of habitat quality and contamination, for comparison and monitoring of changes with time. The information provided by such a monitoring system can be used to minimize negative impacts on the environment by encouraging changes in the industrial activity.

The rainforests of southeastern Peru are known to be some of the most pristine and biologically diverse natural habitats remaining on the planet (Wilson and Sandoval 1996). One of the most isolated regions in the southeastern Peruvian rainforest is the Candamo valley, located in Bahuaja-Sonene National Park. Prior to the last century, the Candamo valley was probably very sparsely and only seasonally populated by indigenous peoples. During the last century the valley experienced sporadic and slight resource exploitation during the rubber boom (1900-1940), and at the end of this period all human activity within the valley ceased (Portillo 1914; Bernales et al. 1993). Therefore, the Candamo valley can be considered a highly pristine, unaltered ecosystem. The only potential industrial factor is alluvial gold-mining, which has been present in the outskirts of Bahuaja-Sonene National Park for at least 2 decades, although the Candamo valley itself has not been mined within recorded history.

In 1996, a consortium of oil companies led by Mobil Corporation signed a contract with the Peruvian Government for the exploration and production of hydrocarbons in Block 78, a 1.5 million hectare area that reached from the Bolivian frontier to the border of Manu National Park. Block 78 covered a large part of the Tambopata-Candamo Reserved Zone (TCRZ), including the Candamo valley. Seismic exploration commenced in May of 1996, and ended in October of 1997. One exploratory well was drilled in the headwaters of the Candamo valley (May 1998-May 1999), and a large gas field was discovered. In August of 2000, however, the oil consortium pulled out of Block 78, and the southern part of the

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TCRZ, including the Candamo valley, was incorporated into Bahuaja-Sonene National Park (Peruvian Supreme Decree 048-2000, September 2000, Fig. 1). Although it is unlikely that hydrocarbon exploration will continue in the near future, at some time the importance of the natural gas in Candamo may again spark industrial interest.

Conservation International (CI), a Washington-DC based non-governmental organization with an active conservation program in Peru, has worked toward conservation and sustainable development in Bahuaja-Sonene and surrounding areas since 1990. Much of CI's conservation strategy is based on participation and consensus of the various participants interested in the natural resources in Bahuaja-Sonene. The hydrocarbon consortium appeared as a new actor in 1996, and CI determined to approach and coordinate with the consortium in order to monitor, evaluate, and minimize negative environmental impacts within Block 78. The result of this effort in coordination was the EISA project (*Evaluation of Social and Environmental Impacts of Hydrocarbon Exploration in Block 78-Tambopata*), which began in September of 1996 and ended in May of 1999.

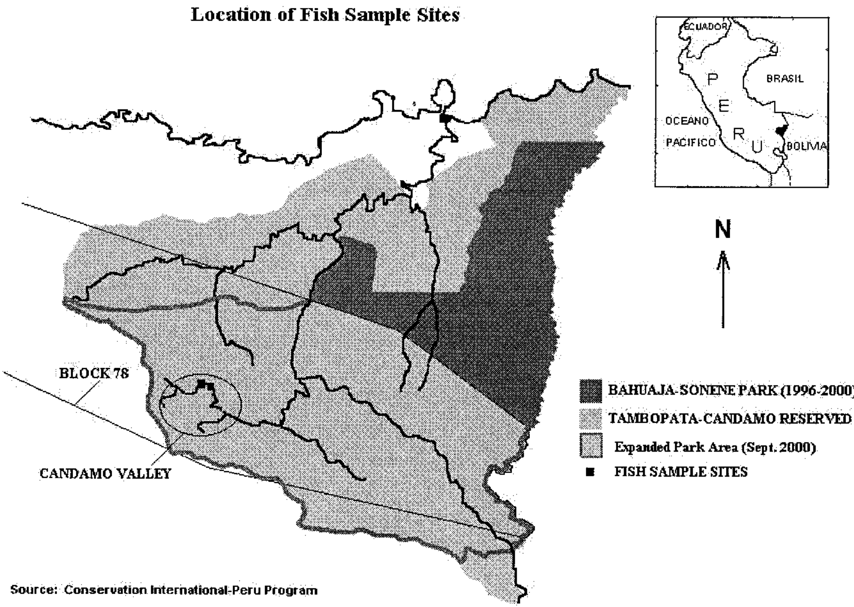

Figure 1. Study area

As part of the EISA project, an evaluation of baseline levels of heavy metals in fish tissue samples from locations within the Candamo valley was undertaken during seismic exploration, but before the start of oil-drilling activities. Metals are common contaminants released by hydrocarbon exploration activities, and as such should be included in environmental monitoring systems (Walsh Peru 1997). Fish were chosen as the target group for bioaccumulation because fish form the dietary base for many bird, reptile and mammal species in rainforest. Detection of possible contamination within a basically undisturbed tropical environment is important for future monitoring of ecosystem health at all trophic levels.

MATERIALS AND METHODS

The geographic location of the Candamo River valley is 13° 24' 99 S and 69° 54' 54 W, and the total area is approximately 140,000 hectares (Ormachea 1997). The Candamo River runs from approximately 475 to 420 meters above sea level. Annual precipitation averages 5400 mm per year, with the majority falling during November through March (Conservation International, 1998). Streams are typically crystal clear in the dry season, and muddied by rains and floods during the wet season.

The fish community of the Candamo valley is a mixture of lowland rainforest and lower Andean slope species, in keeping with the geology of the valley that juxtaposes steep hills with a central floodplain. Sampling of the fish community during 3 separate expeditions from December 1996 to August 1997 yielded a total of 80 species (Chang 1997.)

All samples were taken from a 2 km stretch of the Candamo River and adjacent streams in August 1997. Muscle samples from 5 fish species, namely Boquichico (*Prochilodus nigricans,* n=1), Sabalo (*Brycon melanopterus*, n=3), Huasaco (*Hoplias malabaracus*, n=4), Doncello (*Pseudoplatystoma sp.*, n=1) and Bagre (*Pimelodus ornatus*, n=8) were preserved in 96% alcohol. *Prochilodus nigricans, Brycon melanopterus*, and *Hoplias malabaracus* are members of the family Pimelodidae (long whiskered catfishes) whereas the other two species belong to the family Characidae (characins). The species varied in terms of dietary habits, from detritivorous bottom feeders (Boquichico, Bagre) to omnivores that eat fruit and meat (Sabalo) to true carnivores (Huasaco, Doncella).

Fish muscle samples were digested with 65 % HNO_3 using a microwave system A 301 (PROLABO, Paris) and were analysed with a Hitachi Z 8100 atomic absorption spectrophotometer (HITACHI, Kyoto). Arsenic, lead, cadmium, cobalt, chromium, molybdenum, nickel, selenium and thallium were analysed using a graphite furnace atomiser. Copper, iron, manganese and zinc were analysed by mean of a flame atomiser. Mercury was analysed using a hydride formation system HF-2 (Hitachi, Kyoto). Details on the analytical conditions, detection limits of the methods used and on quality assurance using standard reference materials have previously been published for most of the elements of this study (Gutleb et al. 1997, 1998). For other elements reported we followed the producers manual (Hitachi 1988).

RESULTS AND DISCUSSION

Tissue concentrations for arsenic and selenium (Mason et al. 2000), cadmium (Andres et al. 2000, Mason et al. 2000), cobalt and iron (Lazos et al. 1989), copper, manganese and nickel (Lazos et al. 1989, Wren et al. 1983), molybdenum (Wren et al. 1983), and zinc (Schmitt and Brumbaugh 1990) were lower than those found in fish from polluted rivers or that were reported as background levels in these studies.

Table 1. Concentrations of metals in fish muscle (μg g^{-1} dry weight - all metals; Hg is given in μg g^{-1} wet weight)

		As	Cd	Co	Cr	Cu	Fe	Hg	Mn	Mo	Ni	Pb	Se	Tl	Zn
Brycon	omnivorous														
melanopterus		0.057	0.071	0.127	0.187	4.12	43.83	0.107	20.75	0.073	0.943	0.441	0.142	0.468	23.75
		0.101	0.010	0.032	0.071	1.79	19.85	0.427	5.19	0.026	0.414	0.091	0.107	0.667	26.29
		0.015	0.019	0.017	0.118	1.62	26.55	0.132	2.91	0.032	0.290	0.064	0.076	0.550	27.03
Hoplias	carnivorous														
malabaracus		0.005	0.027	0.304	0.190	3.04	46.39	0.080	11.27	0.080	0.557	0.043	0.445	0.373	72.61
		nd	0.029	0.032	0.077	2.93	17.45	0.151	3.81	0.041	0.334	0.069	0.221	0.639	27.86
		nd	0.014	0.026	0.070	2.43	8.67	0.244	1.21	0.045	0.174	0.078	0.282	1.076	52.54
		0.018	0.007	0.053	0.091	1.98	49.11	0.154	8.82	0.039	0.246	0.100	0.105	0.667	55.05
Pimelodus	detritivorous														
ornatus		0.115	0.036	0.054	0.120	3.76	36.94	0.324	2.45	0.061	1.254	0.543	0.403	1.122	26.48
		0.053	0.004	0.104	0.030	0.81	4.36	0.042	0.44	0.011	0.036	0.019	0.186	0.246	11.96
		0.008	0.006	0.302	0.043	2.22	10.90	0.077	1.29	0.030	0.136	0.040	0.245	0.726	27.52
		0.201	0.024	0.401	0.176	3.60	11.19	0.077	1.20	0.037	0.242	0.333	0.318	0.600	24.57
		0.110	0.022	0.285	0.122	2.85	13.22	0.120	1.22	0.0323	0.320	0.107	0.242	0.373	36.81
		0.133	0.013	0.441	0.208	2.38	17.04	0.236	1.83	0.026	0.806	0.244	0.249	0.686	28.97
		0.090	0.026	0.317	0.240	2.50	139.23	0.198	4.42	0.057	0.560	0.449	0.173	0.705	34.03
		nd	0.015	0.408	0.321	2.83	19.99	0.612	1.41	0.035	0.374	0.095	0.400	0.523	0.038
Prochilodus	detritivorous														
nigricans		0.063	0.052	0.458	0.141	3.63	42.41	0.063	4.57	0.078	1.463	3.002	0.566	0.708	27.75
Pseudo-	carnivorous														
platystoma sp.		0.055	0.015	0.050	0.210	2.88	91.69	0.455	1.98	0.026	0.431	0.103	0.453	0.763	80.36

nd = not detected

Chromium concentrations are comparable to background levels from the unpolluted Jacarepaguá Lagoon in Brazil (Fernandez et al. 1994).

Lead concentrations were similar or even lower to those reported for fish from unpolluted rivers (Lazos et al. 1989; Schmitt and Brumbaugh 1990, Weber 1985) with the exception of 3 $\mu g\ g^{-1}$ dry weight found in a Boquichico.
Concentrations of thallium were in the same range than those recently reported for fish from the Great Lakes, which were assumed to place anglers with a high fish consumption at risk for chronic thallium poisoning (Lin et al. 2001).

Relative high levels of total mercury were found in most fish species with a level of 0.61 $\mu g\ g^{-1}$ fresh weight in a Bagre, which is higher than the standard of 0.5 $\mu g\ g^{-1}$ fresh weight for human consumption in Brazil (Brazil 1975), the only regulated value for Amazonian countries known to the authors. 12 out of 17 fish were exceeding the proposed safe level of 0.1 mg kg^{-1} for the Eurasian otter (*Lutra lutra*) (Hovens 1992), a top predator whose fish-dominated diet resembles those of tropical predators feeding on fish. The high levels of mercury may induce mercury intoxication in top predators such as the Giant otter (*Pteronura brasiliensis*), or even in the local human population depending mainly on fish as source of dietary protein (Branches et al. 1993). The high amounts of mercury in fish may either be the results of earlier gold mining attempts within the area, long-range atmospheric transport of mercury from mining areas or migratory behavior of fish, that may have lead to accumulation of mercury outside the study area.

Our data can serve as background levels for fish in case that oil- and gas-drilling activities will start again in the Candamo valley and for other Amazonian areas. As seasonality has been reported for concentrations of at least some elements in fish (Mason et al., 2000; Phillips, 1980) in any follow-up study fish should be sampled in the same season.

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