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Environmental contaminants and biomarker responses in fish from the Rio Grande and its U.S. tributaries: Spatial and temporal trends

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Abstract

We collected, examined, and analyzed 368 fish of seven species from 10 sites on rivers of the Rio Grande Basin (RGB) during late 1997 and early 1998 to document temporal and geographic trends in the concentrations of accumulative contaminants and to assess contaminant effects on the fish. Sites were located on the mainstem of the Rio Grande and on the Arroyo Colorado and Pecos River in Texas (TX), New Mexico (NM), and Colorado. Common carp (*Cyprinus carpio*) and largemouth bass (*Micropterus salmoides*) were the targeted species. Fish were examined in the field for internal and external visible gross lesions, selected organs were weighed to compute ponderal and organosomatic indices, and samples of tissues and fluids were obtained and preserved for analysis of fish health and reproductive biomarkers. Whole fish from each station were composited by species and gender and analyzed for organochlorine chemical residues and elemental contaminants using instrumental methods, and for 2,3,7,8-tetrachloro dibenzo-*p*-dioxin-like activity (TCDD-EQ) using the H4IIE rat hepatoma cell bioassay. Overall, fish from lower RGB stations contained greater concentrations of organochlorine pesticide residues and appeared to be less healthy than those from sites in the central and upper parts of the basin, as indicated by a general gradient of residue concentrations and biomarker responses. A minimal number of altered biomarkers and few or no elevated contaminant concentrations were noted in fish from the upper RGB. The exception was elevated concentrations [up to 0.46 μg/g wet-weight (ww)] of total mercury (Hg) in predatory species from the Rio Grande at Elephant Butte Reservoir, NM, a condition documented in previous studies. Arsenic (As) and selenium (Se) concentrations were greatest in fish from sites in the central RGB; Se concentrations in fish from the Pecos River at Red Bluff Lake, TX and from the Rio Grande at Langtry, TX and Amistad International Reservoir, TX exceeded published fish and wildlife toxicity thresholds. In the lower RGB, residues of

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p,p′-DDT metabolites (≤1.69 μg/g ww), chlordane-related compounds (≤0.21 μg/g ww), dieldrin (≤0.0.05 μg/g ww), and toxaphene (≤2.4 μg/g ww) were detected in fish from most sites; maximum concentrations were in channel catfish (*Ictalurus punctatus*) from the Arroyo Colorado at Harlingen, TX. Concentrations of one or more residues exceeded toxicity thresholds for fish and wildlife in fish from this site and from the Rio Grande at Mission, TX and Brownsville, TX; however, concentrations were lower than those reported by previous studies. In addition, the proportional concentrations of *p,p′*-DDT at all sites were low, indicating weathered DDT rather than the influx of new material. Concentrations of total PCBs (<0.05 μg/g ww) and TCDD-EQ (≤6 pg/g ww) were comparatively low in all samples. Hepatic ethoxyresorufin *O*-deethylase (EROD) activity in some fish was elevated relative to reference rates at most sites, but was generally lower than previously reported activity in fish from heavily contaminated locations. The comparatively low PCB and TCDD-EQ concentrations together with elevated EROD activity may reflect exposure to polycyclic aromatic hydrocarbons. Reproductive biomarkers were consistent with chronic contaminant exposure at lower RGB sites; comparatively large percentages of intersex male largemouth bass, relatively low gonadosomatic indices, and elevated plasma vitellogenin concentrations in male fish were noted at three of the four stations. Large percentages of atretic eggs were also observed in the ovaries of female common carp from the Rio Grande at Brownsville, TX. Although many of the conditions noted may have other causes in addition to contaminant exposure, the biomarker results for the lower RGB sites are consistent with subtle responses of fish to contaminants, an interpretation supported by the chemical data of this and other investigations.

Keywords: Arsenic; Selenium; Mercury; Pesticides; Organochlorine chemicals; Ethoxyresorufin *O*-deethylase (EROD) activity; Health assessment index, (HAI); Biomarkers; Ovotestis; Vitellogenin

1. Introduction

The Rio Grande is the second longest U.S. river; it is approximately 3059 km long and drains an area of some 924,300 km^2 (Texas Natural Resources Conservation Commission (TNRCC), 1997; Fig. 1). The Rio Grande also represents the international boundary between the United States and Mexico from El Paso, Texas (TX) to the Gulf of Mexico, a distance of about 2053 km (Fig. 1). About 69% (231,317 km^2) of the Rio Grande Basin (RGB) lies within the United States, with the remainder in Mexico. Although much of the RGB is desert, the area supports a rapidly expanding human population conservatively estimated at 10 million in 1992 (TNRCC, 1997) as well as a unique river-dependent biota. The Rio Grande and its tributaries therefore represent a vital source of water to both the human population and the ecological resources of the region. Heavy demands are placed on the Rio Grande and its tributaries for irrigation and for the water supply and waste disposal needs of population centers in the United States and Mexico. Water quality is affected by natural, agricultural, industrial, and urban erosional processes, which contribute to high sediment loads, and dams and diversions have dramatically altered flow regimes (e.g., Ong et al., 1991; TNRCC, 1994a, 1997; Davis et al., 1995; Levings et al., 1998). Chemically intensive irrigated agriculture is practiced in much of the RGB, parts of which are also highly mineralized and underlain by petroleum-rich geologic formations. Consequently, pesticides, oil, and potentially toxic trace elements such as arsenic (As), selenium (Se), and heavy metals are available for mobilization and transport. The rates of the processes controlling the release and distribution of these constituents have been profoundly altered by human activities such as irrigation, mining, oil and gas extraction, and complex systems of dams and diversions, which have profoundly affected the flux of water and sediments and their associated contaminants. Elevated concentrations of metals, metalloids, and organochlorine pesticides have been documented in sediments and river-dependent organisms throughout the RGB (Gamble et al., 1988; Ong et al., 1991; U.S. Environmental Protection Agency (USEPA), 1992; TNRCC, 1994a,b, 1997; Davis et al., 1995; Carter and Anderholm, 1997; Mora, 1997; Mora et al., 1997; Van Metre et al., 1997; Mora and Wainwright, 1998; Levings et al., 1998; Schmitt et al., 1999b; Moring, 1999).

We sampled the largest U.S. rivers in the RGB during late 1997 and early 1998 as part of the U.S. Geological Survey (USGS) Biomonitoring of Environmental Status and Trends program, which monitors