

CONTAMINANT CONCENTRATIONS AND BIOMARKER RESPONSES OF PISCIVOROUS AND BENTHIVOROUS FISH IN THE COLORADO RIVER BASIN

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ABSTRACT

The Large River Monitoring Network (LRMN) of the Biomonitoring of Environmental Status and Trends (BEST) Program measured tissue concentrations of selected contaminants and evaluated biomarker responses in black bass (*Micropterus* sp.), common carp (*Cyprinus carpio*), and channel catfish (*Ictalurus punctatus*) at 14 locations within Colorado River Basin (CRB) in 2003. Major tributaries including the Yampa, Green, Gunnison, San Juan, and Gila Rivers were also sampled. Organic and inorganic contaminants were measured in whole-body composite fish samples, and the H4IIE bioassay determined dioxin-like activity in these samples. Fish health indicators (condition factor, somatic indices), immune system indicators (macrophage aggregate parameters), various molecular biomarkers (EROD, vitellogenin), and reproductive indicators (steroid hormones, gonadal histology) were measured in individual fish. Mean microsomal EROD activity was greatest in carp (>9 pmol/min/mg) from Phoenix, AZ, in channel catfish (>10 pmol/min/mg) from Vernal, UT and Grand Junction, CO, and in bass (>60 pmol/min/mg) from Vernal, UT. Fish health indicators including macrophage aggregates and oocyte atresia indicated poor health of carp in the Lake Mead area. High health assessment index (HAI) values in bass, channel catfish, and carp collected throughout the CRB were attributed to abnormalities of the liver, kidney, and spleen. Histological examination of the gonads revealed several intersex fish. Previous contaminant studies in this basin have a wide range of focus from high concentrations of selenium in irrigation return flows to emerging contaminants downstream of Las Vegas. Other concerns include dropping water levels in the lower Colorado River and the reestablishment of endangered species within the CRB. The goal of this BEST LRMN project is to help characterize fish health and contaminant concerns in the CRB.

INTRODUCTION

The BEST LRMN of the USGS has measured and assessed contaminants and their effects on selected fish species in multiple U.S. river basins including the Mississippi River Basin (1995), Rio Grande Basin (1997), Columbia River Basin (1997), and Yukon River Basin (2002). The CRB, one of the largest basins in the western U.S., was sampled in 2003 (Fig. 1). Sources of contaminants in the CRB include selenium (Se) in irrigation return flows, pesticides from agricultural practices, and urban runoff downstream of Las Vegas. Effects of these contaminants may be exacerbated by drought, basin geology, and flow reduction from state water allocations. Many studies in the CRB have examined specific contaminant sources for a particular fish species, many of which focus on endangered species. Our project was designed to provide information on contaminant concentrations and biomarker responses in several fish species throughout the CRB. Results from this project will also be compared to biomonitoring results from previous LRMN projects in order to establish national benchmarks for many biomarkers. Moreover, results from this study may identify areas that warrant further investigation into the effects of chemical contaminants in the CRB.



Figure 1. BEST LRMN sampling sites on the Colorado River near Moab, UT (left) and the Gila River near Arlington, AZ (right).

METHODS

Fourteen sites in the CRB were sampled in the fall 2003 (Fig. 2). Forty fish (10 of each gender, two species) from each site were collected by hook and line or electroshocking. Black bass (*Micropterus* sp.) and channel catfish (*Ictalurus punctatus*) were collected as the piscivorous species, and common carp (*Cyprinus carpio*) were collected as the benthivorous species. Alternative species [white sucker (*Catostomus commersoni*); brown trout (*Salmo trutta*); flathead catfish (*Pylodictus olivaris*)] were collected if preferred species were unavailable. Fish were held alive until the field health assessment was performed (Fig. 3). The suite of selected methods responds to a wide variety of contaminants (Table 1).



Figure 2. Sampling sites in the CRB in 2003.



Figure 3. Electroshocking with FWS near Willow Beach, AZ (320). USGS crew processing fish near Yuma, AZ (322).

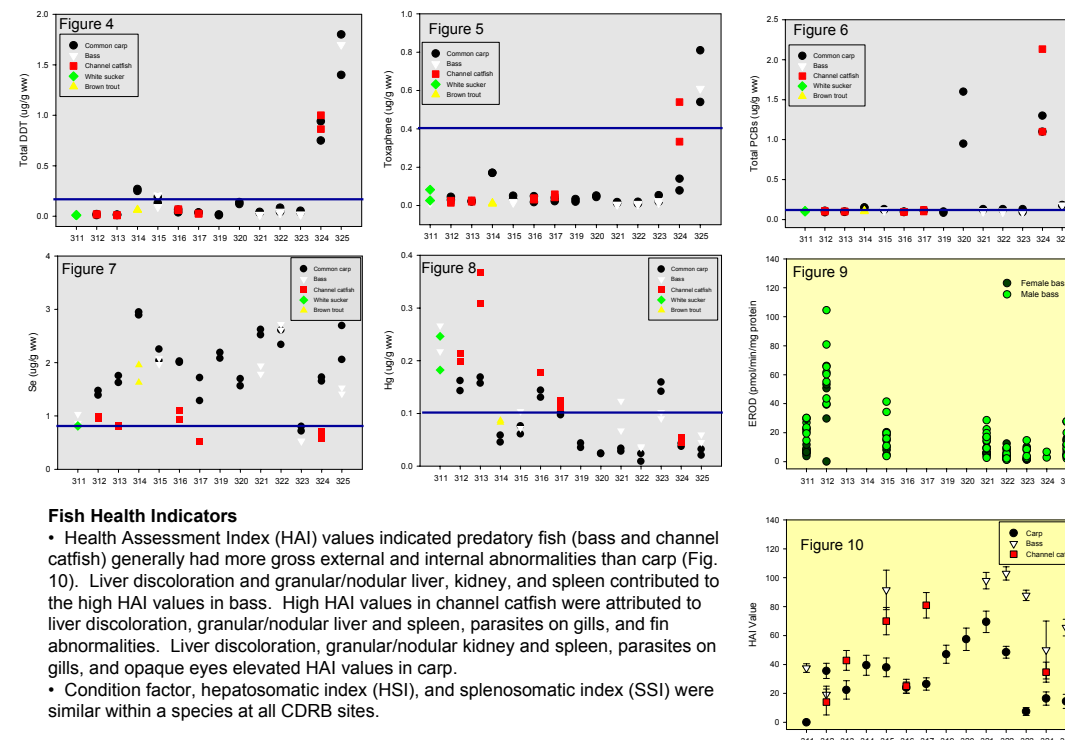
Table 1. Methods incorporated into the CRB project.

Chemical and Biological Indicators	Description	Sensitivity
Contaminants and EROD		
Tissue contaminant concentrations	Contaminant assimilation	Organochlorine (OCs), inorganic compounds
H4IIE bioassay	Screening tool for planar halogenated compounds	PCBs, dioxins and furans
Ethoxyresorufin O-deethylase (EROD) activity	Induction of cytochrome P450 enzymes	PCBs, PAHs, dioxins and furans
Fish Health Indicators		
Fish health assessment	Visual assessment of external/internal anomalies	Overall fish health and contaminants
Somatic indices (including HSI and SSI)	The relative mass of selected organs	Overall fish health and contaminants
Histopathology	Microscopic examination for lesions	Overall fish health and contaminants
Macrophage Aggregate (MA) analysis	Cellular-level immune response	Contaminants including PAHs, metals
Reproductive Biomarkers		
Plasma Vitellogenin (Vtg)	Egg yolk precursor synthesized in the liver	Endocrine modulating compounds
Steroid Hormones (estradiol (E), 11-ketotestosterone (KT))	Reproductive health and status	Endocrine modulating compounds
GSI and gonadal histopathology including reproductive stage and oocyte atresia	Reproductive health and status	Endocrine modulating compounds

RESULTS

Contaminants and EROD

- Concentrations of organochlorine compounds were low in fish from most sites except Phoenix, AZ (324) and Arlington, AZ (325) in the Gila River. Concentrations of total DDT, PCBs, and toxaphene in fish from these sites exceeded toxicity or wildlife criteria. Concentrations of total chlordane and HCH were also higher at these two sites compared to other CRB sites but did not exceed available criteria. Blue lines identify toxicity criteria in Figs. 4-6.
- Concentrations of total DDT in fish from Phoenix, AZ (0.8-1.0 µg/g ww) and Arlington, AZ (1.4-1.8 µg/g ww) are potentially harmful to sensitive piscivorous wildlife (Fig. 4).
- Toxaphene concentrations were >0.4 µg/g ww, a concentration shown to have acute and chronic effects in freshwater fish, in male channel catfish from Phoenix, AZ (324) and female bass, male carp, and female carp from Arlington, AZ (325) (Fig. 5).
- Total PCB concentrations ranged from 0.95-1.6 µg/g ww in carp from Willow Beach, AZ (320) and 1.1-2.1 µg/g ww in carp and channel catfish from Phoenix, AZ (324) (Fig. 6).
- Concentrations of inorganic chemicals in CRB fish were below toxicity criteria except for Se and Hg (Figs. 7 & 8). Blue lines identify toxicity criteria in Figs. 7 & 8.
- Concentrations of Se were >0.8 µg/g ww, a concentration that may be toxic to fish, in one or more fish composite samples from all sites (Fig. 7).
- Concentrations of Hg were >0.1 µg/g ww, a concentration suggested to protect piscivorous mammals in fish from Craig, CO (311), Vernal, UT (312), San Rafael, UT (313), Moab, UT (316), Farmington, NM (317), Needles, CA (321), and Hayden, AZ (323) (Fig 8).
- EROD activity in carp and channel catfish were similar among sites. EROD activity in bass from Vernal, UT (312) were consistently greater than those from other CRB sites (Fig. 9).



Fish Health Indicators

- Health Assessment Index (HAI) values indicated predatory fish (bass and channel catfish) generally had more gross external and internal abnormalities than carp (Fig. 10). Liver discoloration and granular/nodular liver, kidney, and spleen contributed to the high HAI values in bass. High HAI values in channel catfish were attributed to liver discoloration, granular/nodular liver and spleen, parasites on gills, and fin abnormalities. Liver discoloration, granular/nodular kidney and spleen, parasites on gills, and opaque eyes elevated HAI values in carp.
- Condition factor, hepatosomatic index (HSI), and splenosomatic index (SSI) were similar within a species at all CRB sites.

Reproductive Biomarkers

- Steroid hormone levels were normal in most fish. Female fish with E/KT <1.0 or male fish with E/KT >1.0 were found at all CRB sites except Craig, CO (311), San Rafael, UT (313), Pearce Ferry, AZ (319), and Willow Beach, AZ (320). Our results suggest hormone concentrations were abnormal in a few individual fish and dependent on reproductive stage.
- Fish identified as intersex, containing both ovarian and testicular tissue (i.e., ovotestes), were found at 7 of 14 CRB sites (Fig. 11). Multiple bass at Craig, CO (311), Yuma, AZ (322), and Hayden, AZ (323) contained ovotestes. All intersex bass and channel catfish contained primarily testicular tissue with few oocytes (Fig. 12). However, the intersex carp had primarily ovarian tissue with some spermatocytes.
- Vtg concentrations were normal in most fish. Intersex fish did not have abnormal vtg concentrations; most intersex fish had concentrations less than the detection limit.
- Most CRB sites had mean oocyte atresia >8% in carp and <5% in bass and channel catfish.

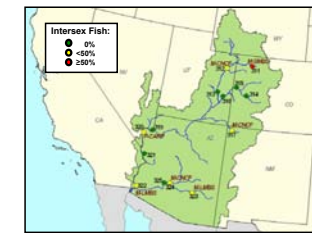


Figure 11. Location of intersex fish identified in the BEST LRMN project in the CRB.

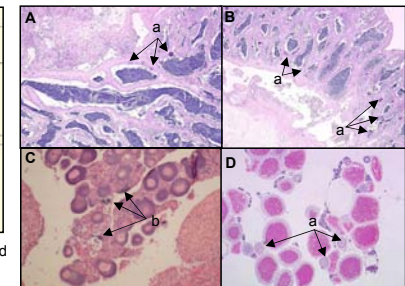


Figure 12. A. Mild occurrence of previtellogenic oocytes (a) in testicular tissue of a male bass from Craig, CO (311). B. Moderate occurrence of previtellogenic oocytes (a) in testicular tissue of a male bass from Craig, CO (311). C. Spermatocytes (b) in ovarian tissue of female carp from Willow Beach, AZ (320). D. Carp from Delta, CO (314) with high oocyte atresia (a).

SUMMARY

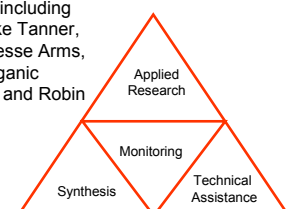
- Examining contaminant concentrations and biomarker responses will provide important information on fish health in the CRB.
- Concentrations of organochlorine chemicals were highest in fish from the Gila River. Total DDT, toxaphene, and PCB concentrations exceeded toxicity or wildlife criteria in the Gila River.
- Concentrations of Se and Hg exceeded toxicity or wildlife criteria and remain a concern in CRB fish.
- Preliminary results indicate that morphometric indices, steroid hormones concentrations, and vtg concentrations were normal in most CRB fish.
- A more indepth examination of the intersex fish from the CRB is planned.
- Other results including the H4IIE bioassay, general histopathology of CRB fish, and macrophage aggregate analysis will be available soon. Contaminant concentrations and biomarker responses will be compared when all data is available in order to identify relationships that may exist.

ONGOING PROJECTS

- The Mobile, Apalachicola, Savannah, and Pee Dee River Basins are currently being sampled in the southeastern U.S.
- Development of reference biomarker levels for carp, bass, and sucker are ongoing.

Acknowledgements

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To obtain more information on the LRMN

For information on the BEST Program visit: www.best.usgs.gov
 For public database: www.cerc.usgs.gov/data/best/search/index.htm
 For publications (in pdf): www.cerc.usgs.gov/pubs/pubs.htm
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