



# Sperm quality biomarkers complement reproductive and endocrine parameters in investigating environmental contaminants in common carp (*Cyprinus carpio*) from the Lake Mead National Recreation Area<sup>☆</sup>

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## ABSTRACT

Lake Mead National Recreational Area (LMNRA) serves as critical habitat for several federally listed species and supplies water for municipal, domestic, and agricultural use in the Southwestern U.S. Contaminant sources and concentrations vary among the sub-basins within LMNRA. To investigate whether exposure to environmental contaminants is associated with alterations in male common carp (*Cyprinus carpio*) gamete quality and endocrine- and reproductive parameters, data were collected among sub-basins over 7 years (1999–2006). Endpoints included sperm quality parameters of motility, viability, mitochondrial membrane potential, count, morphology, and DNA fragmentation; plasma components were vitellogenin (VTG), 17β-estradiol, 11-keto-testosterone, triiodothyronine, and thyroxine. Fish condition factor, gonadosomatic index, and gonadal histology parameters were also measured. Diminished biomarker effects were noted in 2006, and sub-basin differences were indicated by the irregular occurrences of contaminants and by several associations between chemicals (e.g., polychlorinated biphenyls, hexachlorobenzene, galaxolide, and methyl triclosan) and biomarkers (e.g., plasma thyroxine, sperm motility and DNA fragmentation). By 2006, sex steroid hormone and VTG levels decreased with subsequent reduced endocrine disrupting effects. The sperm quality bioassays developed and applied with carp complemented endocrine and reproductive data, and can be adapted for use with other species.

## 1. Introduction

Lake Mead, the largest reservoir by volume in the U.S., was formed by the impoundment of the Colorado River by Hoover Dam. It is a major supply of municipal, domestic, and agricultural water for over 22 million users and is the major source of the drinking water for Las Vegas (LaBounty and Horn, 1997). As part of the Lake Mead National Recreational Area (LMNRA) (Fig. 1), it is one of the most heavily used National Parks, supporting recreational fisheries and endangered species such as razorback suckers (*Xyrauchen texanus*) and bonytail chubs

(*Gila elegans*) (Tuttle and Orsak, 2002). Surface runoff into Lake Mead from Las Vegas Valley flows into Las Vegas Bay (LVB) through Las Vegas Wash (LVW), and is comprised primarily of tertiary-treated sewage effluent (Covay and Leiker, 1998), non-potable groundwater, and urban overland flow (LaBounty and Horn, 1997). Lake Mead's volume and water quality are also influenced by reductions in flows of the Colorado River, droughts affecting surface water hydrology and stream flows (Benotti et al., 2010; Kolpin et al., 2004), as well as released inflows from Lake Powell (Benotti et al., 2010).

In the 1990's, environmental contaminants identified at levels of

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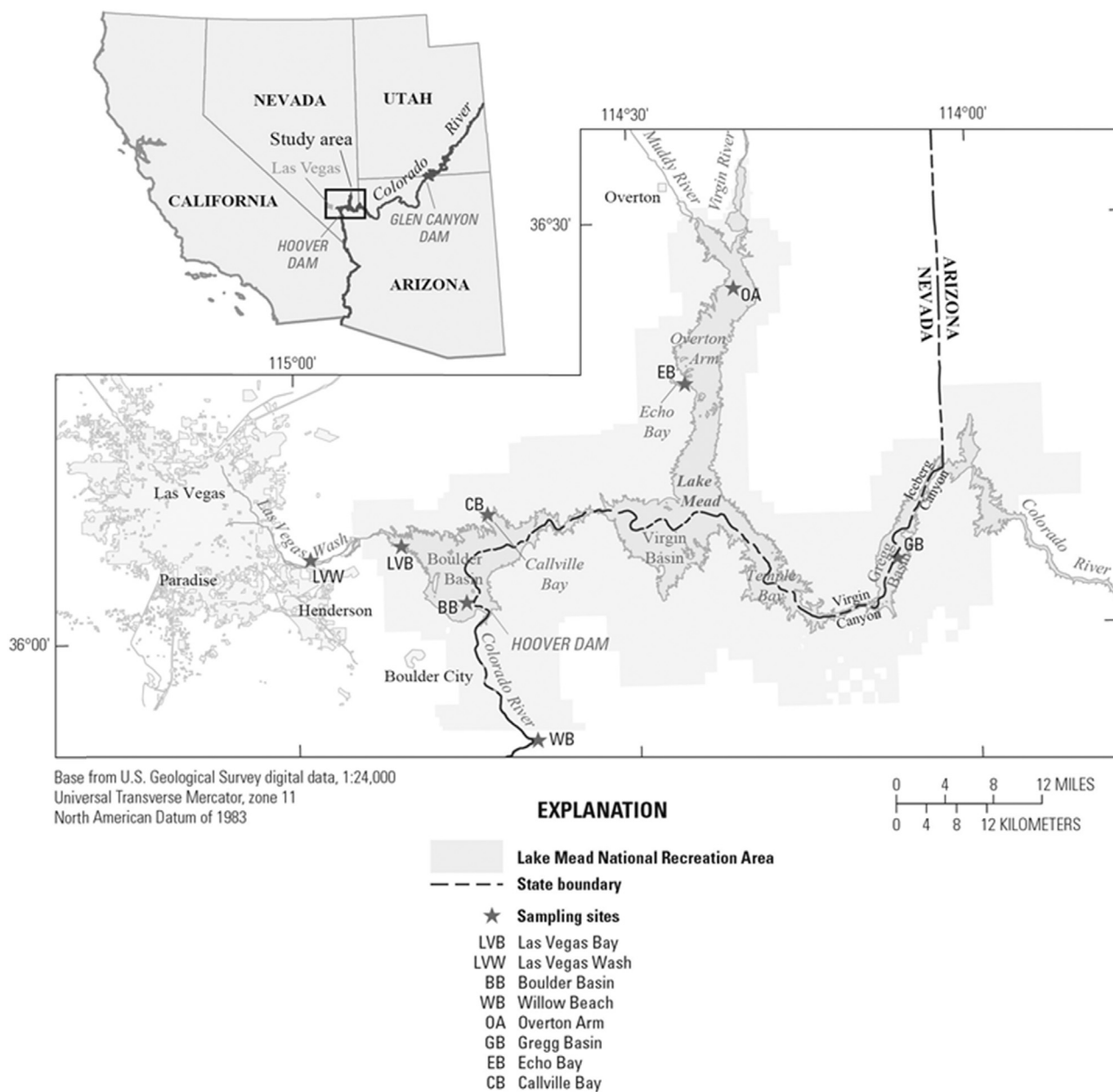


Fig. 1. Map of sampling sites for common carp (*Cyprinus carpio*) in the Lake Mead National Recreation Area, 1999 – 2006.

concern in the water, sediment, and biological tissues from LVB, LVW, and downstream of Hoover Dam, indicating that aquatic conditions were not conducive to healthy populations of fish and wildlife (Bevans et al., 1996; Patiño et al., 2003; Tuttle and Orsak, 2002). Organochlorine pesticides, dichlorodiphenyl trichloroethane (DDT) metabolites, polychlorinated biphenyls (PCBs) (Tuttle and Orsak, 2002), total suspended solids, perchlorate, selenium, and eutrophication processes were noted in LVB, with DDT being previously manufactured along LVW (Rosen et al., 2012; Ryan and Zhou, 2010). Complex mixtures of organic wastewater contaminants, pharmaceuticals, and personal care products are more prevalent in urban receiving waters during low flow conditions (Kolpin et al., 2004); in LVW and Boulder Basin (BB) in 1997 and 1999, personal care products concentrations were as high as 1500 ng/L (Snyder et al., 2001). Aquatic organisms can have perpetual life-cycle exposures when effluents discharged into the system exceed chemical half-lives (Daughton and Ternes, 1999).

Diverse contaminant and endocrine disrupting compound (EDC) profiles occur among sites in LMNRA water, biota, and sediment.

Individual chemicals and complex chemical mixtures can act as EDCs, altering hormone production, metabolism, and/or hormone action by direct or indirect means (Keith, 1997; Tabb and Blumberg, 2006). Chemical analytes captured by passive water sampling devices showed that the laterally and vertically oriented plume of synthetic organic chemicals originating from LVW distributed along the lake bottom each spring and was detectable 10 km into the lake in BB, but it was not apparent in the farther sub-basins of Overton Arm (OA) or Gregg Basin (GB) (Rosen et al., 2010). Likewise, male common carp (*Cyprinus carpio*) tissue from LVB and semipermeable membrane device contents from LVW contained analogues of the antibacterial, antifungal triclosan (2,4,4'-trichloro-2'-hydroxydiphenyl ether) (Goodbred et al., 2007a; Leiker et al., 2009) which has been shown to decrease sperm counts and induce vitellogenin (VTG) in Western mosquitofish, *Gambusia affinis*, and impact thyroid hormone concentrations in rats (Raut and Angus, 2010; Zorrilla et al., 2009). In 1995, lower numbers of organochlorines and semi-volatile industrial compounds were found at the a reference site Callville Bay (CVB) in water, sediment and carp tissue than at other

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