Ecological Applications, 18(8) Supplement, 2008, pp. A257–A283

ANTHROPOGENIC STRESSORS AND CHANGES IN THE CLEAR LAKE ECOSYSTEM AS RECORDED IN SEDIMENT CORES

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Abstract. Sediment cores were collected to investigate multiple stresses on Clear Lake, California, USA, through the period of European occupation to the present day. Earlier workers suggested the hypothesis that the use of mechanized earthmoving equipment, starting in the 1920s and 1930s, was responsible for erosion, mercury (Hg) contamination, and habitat loss stresses. Cores (~2.5 m in depth) were collected in 1996 and 2000 from each of the three arms of the lake. Carbon-14 dating suggests that these cores represent as much as 3000 years of the lake's history, beginning long before European settlement. Total mercury (TotHg) and methylmercury (MeHg), dry matter, water, carbon, nitrogen, phosphorus, sulfur, and the stable isotopes ^{13}C and ^{15}N were measured at 5-cm intervals. Nearly all parameters show major changes at depths of 58–135 cm, beginning at ca. 1927 (dated with ^{210}Pb). Accepting this date for concomitant major changes in seven cores yields an estimated 8.6 mm/yr average sedimentation rate after 1927. Pre-1927 sedimentation rates were ~1 mm/yr. Total mercury and MeHg, dry matter, phosphorus, and ^{15}N increase significantly, whereas nitrogen, sulfur, carbon, and water content decrease significantly above the 1927 horizon. Both TotHg and MeHg show extremely large increases (roughly 10-fold) above the 1927 horizon. A peak in inorganic deposition rate and minimum values for percentage of water is present at depths corresponding to ca. 1970. Interestingly, the first 75 years of European settlement in the Clear Lake basin (including the most productive years of the Sulphur Bank Mercury Mine) appeared to have had undetectable effects on lake cores. Changes since 1927 were dramatic. The large increase in Hg beginning about 1927 corresponds to the use of heavy equipment to exploit the ore deposit at the mine using open-pit methods. Increases in sediment deposition from increased earthmoving in the basin and sulfate loading from the mine are the most likely explanations for the dramatic changes seen in the post-1927 sections of the cores.

Key words: ^{14}C; Clear Lake, California, USA; dichlorodiphenyldichloroethane (DDD); human impacts; ^{210}Pb; mercury; mining; sediment cores; Sulphur Bank Mercury Mine; watersheds.

Introduction

Data presented here from several sediment cores collected in 1996 and 2000 at Clear Lake, California, USA, represent one component of a larger ecosystem-level study that traces the origin and pathways of mercury (Hg) from the ore body at an abandoned Hg mine, through the abiotic (sediment and water) matrices, to lower trophic level species (benthic invertebrates and plankton) and ultimately to higher trophic level species (e.g., fish, birds, and mammals). This paper provides both historic (1800s to present) and prehistoric (to ~3000 years before present) data that define the variability of Hg loading and other stressors to Clear Lake before and after European settlement in the Clear Lake Basin. Our objective is to describe the temporal pattern of anthropogenic stresses on Clear Lake in order to better evaluate proposed causal connections between stressors and effects.

Sediment cores have been used extensively over the past several decades to aid in the reconstruction and evaluation of impacts to aquatic ecosystems from a wide variety of disturbance events and processes (Engstrom et al. 1985, Von Gunten et al. 1997, Brush 2001). Some have focused on contaminants in general (Gearing et al. 1991, Macdonald et al. 2000, Gallagher et al. 2004), while others have targeted the historical accumulation of Hg, primarily as a result of atmospheric deposition (Swain et al. 1992, Engstrom et al. 1994, Benoit et al. 1998, Lockhart et al. 1998, 2000, Heyvaert et al. 2000,

Manuscript received 12 October 2006; accepted 30 July 2007; final version received 26 September 2007. Corresponding Editor (ad hoc): B. Henry. For reprints of this Special Issue, see footnote 1, p. A1.

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