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Upstream dams and downstream clams: growth rates of bivalve mollusks unveil impact of river management on estuarine ecosystems (Colorado River Delta, Mexico)

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Abstract

We studied how the extensive diversion of Colorado River water, induced by dams and agricultural activities of the last 70 years, affected the growth rates of two abundant bivalve mollusk species (*Chione cortezi* and *Chione fluctifraga*) in the northern Gulf of California. Shells alive on the delta today ('Post-dam' shells) grow 5.8–27.9% faster than shells alive prior to the construction of dams ('Pre-dam' shells). This increase in annual shell production is linked to the currently sharply reduced freshwater influx to the Colorado River estuary. Before the upstream river management, lower salinity retarded growth rates in these bivalves. Intra-annual growth rates were 50% lower during spring and early summer, when river flow was at its maximum. Growth rates in *Chione* today are largely controlled by temperature and nutrients; prior to the construction of dams and the diversion of the Colorado River flow, seasonal changes in salinity played an important role in regulating calcification rates.

Our study employs sclerochronological (growth increment analysis) and geochemical techniques to assess the impact of reduced freshwater influx on bivalve growth rates in the Colorado River estuary. A combination of both techniques provides an excellent tool to evaluate the impact of river management in areas where no pre-impact studies were made.

Keywords: sclerochronology; growth rate; bivalve mollusk; freshwater; oxygen isotope; river management; Colorado River; Gulf of California

1. Introduction

Diversion and damming of rivers turned many arid and semiarid regions of the world into productive agricultural land. The upstream benefits from "reclamation" of land and irrigation were offset by immense downstream environmental costs. Reduced freshwater flow has seriously degraded wetlands and lead to loss of wildlife (e.g. Reisner, 1986; Kingsford and Thomas, 1995; Garba Boyi and Polet, 1996; Lemly et al., 2000). However, very little is known how the near-cessation of river flow affected the ecosystem of a river's estuary.

In the present study we examine the effects of upstream river management on the biota in the Colorado River Delta. Prior to the completion of Hoover Dam (southern Nevada, USA) in 1935, the Colorado River delivered approximately 18 million cubic meters of freshwater to its estuary every year (U.S. Bureau of Reclamation). The river also supplied an unknown amount of nutrients. Hoover Dam and other upstream dams have facilitated downstream river management, including the diversion of most of the river's flow for agricultural and domestic use in the United States and in Mexico. Since the 1960s, little to no water reached the Colorado's estuary in the northern Gulf of California (Lavín and Sánchez, 1999).

Although the diversion of river water before it reaches its estuary must have had a profound effect on the marine

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