Estuaries Vol. 25, No. 6B, p. 1406–1415 December 2002

Impacts of Hydrological Changes on Phytoplankton Succession in the Swan River, Western Australia

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ABSTRACT: The Swan River estuary, Western Australia, has undergone substantial hydrological modifications since pre-European settlement. Land clearing has increased discharge from some major tributaries roughly 5-fold, while weirs and reservoirs for water supply have mitigated this increase and reduced the duration of discharge to the estuary. Nutrient loads have increased disproportionately with flow and are now approximately 20-times higher than pre-European levels. We explore the individual and collective impacts of these hydrological changes on the Swan River estuary using a coupled hydrodynamic-ecological numerical model. The simulation results indicate that despite increased hydraulic flushing and reduced residence times, increases in nutrient loads are the dominant perturbation, producing increases in the incidence and peak biomass of blooms of both estuarine and freshwater phytoplankton. Changes in salinity associated with altered seasonal freshwater discharge have a limited impact on phytoplankton dynamics.

Introduction

The ecology and biodiversity of estuarine and coastal waters in many parts of the world are under threat from increasing anthropogenic inputs of nutrients (Nixon 1995; Cloern 2001). Many of these threats can be attributed directly to expansion of human populations along riparian zones and coastal catchments (Cooper and Brush 1993). The threats to coastal ecosystems are especially exacerbated in Australia where 80% of the population lives within 50 km of the coast and the major land drainage basins have undergone large-scale land clearing and hydrological modification since European settlement (Harris 2001). Declining water quality and high rates of sedimentation are the most obvious manifestations of nutrient enrichment and land clearing (Zann 1995).

Knowledge of the nutrient assimilative capacity of coastal and estuarine ecosystems is essential for management and rehabilitation. Globally, current large-scale efforts to control eutrophication are based largely on the premise that improvements in biodiversity and water quality will be linked directly to reductions in nutrient loads. Such assessments give only rudimentary consideration to response times, hysteresis effects, and hydrological controls, thereby neglecting possible non-linear responses to changes in nutrient loading (Harris 1999).

While the major focus of eutrophication management has been on nutrient control strategies, it is also important to consider hydrological modifications that may have an impact on the eutrophication response. On the Australian continent, weirs and dams have contributed directly to algal blooms by increasing residence times and stratification of the impounded waters (Sherman et al. 1998) and decreasing flushing of downstream estuaries (Davies and Kalish 1994), even though some dredging or estuary opening strategies have improved water quality through increasing flushing with marine water (Hearn and Robson 2000; Ranasinghe and Pattiaratchi 2000). The complexities of the interactions among freshwater flow and composition, estuary topography and hydrodynamics, and human alterations of these features indicate that numerical models may be important in quantifying the hydrological responses of estuaries and the resultant changes in water quality.

The objective of this study was to develop a quantitative understanding of the way in which the hydrology and water quality of a Western Australian estuary, the Swan River, have been altered by changes in watershed land use patterns and tributary regulation associated with European settlement and development. We use a coupled hydrodynamic-ecological model to make assessments for pre-modification and post-modification cases, with the major focus placed on the likely changes to phytoplankton biomass and species composition.

Study Site

GENERAL DESCRIPTION

The watershed of the Swan River is large (121,000 km^2) and dominated by the Avon River

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