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Effects of hydrology and river management on the distribution, abundance and persistence of cyanobacterial blooms in the Murray River, Australia

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ABSTRACT

Major cyanobacterial blooms (biovolume > 4 $mm^3 L^{-1}$) occurred in the main water reservoirs on the upper Murray River, Australia during February and March 2010. Cyanobacterial-infested water was released and contaminated rivers downstream. River flow velocities were sufficiently high that in-stream bloom development was unlikely. The location has a temperate climate but experienced drought in 2010, causing river flows that were well below the long-term median values. This coupled with very low bed gradients meant turbulence was insufficient to destroy the cyanobacteria in-stream. Blooms in the upper 500 km of the Murray and Edward Rivers persisted for 5 weeks, but in the mid and lower Murray blooms were confined to a small package of water that moved progressively downstream for another 650 km. *Anabaena circinalis* was the dominant species present, confirmed by 16S rRNA gene sequencing, but other potentially toxic species were also present in smaller amounts. Saxitoxin (*sxtA*), microcystin (*mcyE*) and cylindrospermopsin (*aoaA*) biosynthesis genes were also detected, although water sample analysis rarely detected these toxins. River water temperature and nutrient concentrations were optimal for bloom survival. The operational design of weirs and retention times within weir pools, as well as tributary inflows to and diversions from the Murray River all influenced the distribution and persistence of the blooms. Similar flow, water quality and river regulation factors were underlying causes of another bloom in these rivers in 2009. Global climate change is likely to promote future blooms in this and other lowland rivers.

1. Introduction

The Murray Darling Basin, located in the south-eastern corner of the Australian continent, is the largest river catchment within Australia, draining over one million km^2 or one-seventh of the Australian land mass (Mackay and Eastburn, 1990). It contains extensive areas of semiarid lowlands, but also Australia's two longest rivers, the Murray and Darling Rivers. Many of the Basin's rivers have been impounded and flow is regulated for anthropogenic use. The Basin is also the most important agricultural production area in Australia, and these land uses plus the clearing of native vegetation have had considerable impacts on water quality within the rivers, especially in terms of eutrophication (Mackay and Eastburn, 1990; Young, 2001).

The flat terrain and temperate dry climate has led to long slow flowing rivers which, coupled with the impoundments and eutrophication, have created ideal conditions for cyanobacterial blooms. Baker and Humpage (1994) showed that toxic cyanobacteria were widespread throughout the Basin. In 1991, a major bloom impacted over 1000 km of the Barwon-Darling River system (Bowling and Baker, 1996), and other major blooms have also occurred in weir pools along the lower Murrumbidgee River (Webster et al., 1997; Sherman et al., 1998). Major cyanobacterial blooms in rivers appear to be unusual, although they have been

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reported in the Nakdong River, South Korea during drought periods (Ha et al., 1999, 2002; Jeong et al., 2007), the Fitzroy River, Queensland Australia (Bormans et al., 2005), in tidal lowland sections of the Potomac River (Krogmann et al., 1986) and Neuse River (Lung and Paerl, 1988) in the United States, and in slow flowing sections of the Guadiana River in Spain and Portugal (Rocha et al., 2002; Moreno et al., 2004). Such blooms are of major management concern because of their potential detrimental impacts on the health of humans and their livestock (Kuiper-Goodman et al., 1999; Falconer, 2001).

Recently, the Murray River in New South Wales (NSW) has also been subjected to problematic cyanobacterial blooms, where total cyanobacterial biovolume exceeded 4 $mm^3 L^{-1}$. This is the Red alert threshold for recreational water use in Australia prescribed by the National Health and Medical Research Council (2008), and where bloom management actions commence in New South Wales. A bloom in the headwaters reservoir Lake Hume in 2007 led to contamination of the river for 150 km downstream, as extreme drawdown of the reservoir permitted cyanobacterial infested water to be released downstream (Baldwin et al., 2010). More extensive blooms impacted almost 1100 km of the Murray River from Lake Hume to Euston in March and April 2009, as well as much of the Gulpa Creek-Edward River-Wakool River distributary system (Al-Tebrineh et al., 2012a). An extensive cyanobacterial bloom again occurred in the same rivers in February 2010 that differed in many respects from the 2009 bloom. This paper reports on this second bloom occurrence and its taxonomy, toxicity, and toxigenecity and compares it with the bloom of the previous year. It also examines the effects of hydrology and river regulation used to manage flows on the distribution, abundance and persistence of cyanobacterial blooms throughout this river system.

2. Material and methods

Samples from the 2010 bloom were collected on a weekly basis in Lake Hume and at 19 sites along the Murray River from Albury, immediately downstream of Lake Hume, to Lock 8, just upstream of where the river flows into South Australia, a distance of 1432 km. Five sites were sampled on the Edward River system and two on the Mulwala Main Canal (Fig. 1). Collection time varied between 7:00 AM and 6:00 PM depending on travel time between sites. Samples from the river sites were collected from 0.25 m depth from off the river bank using sample bottles attached to a

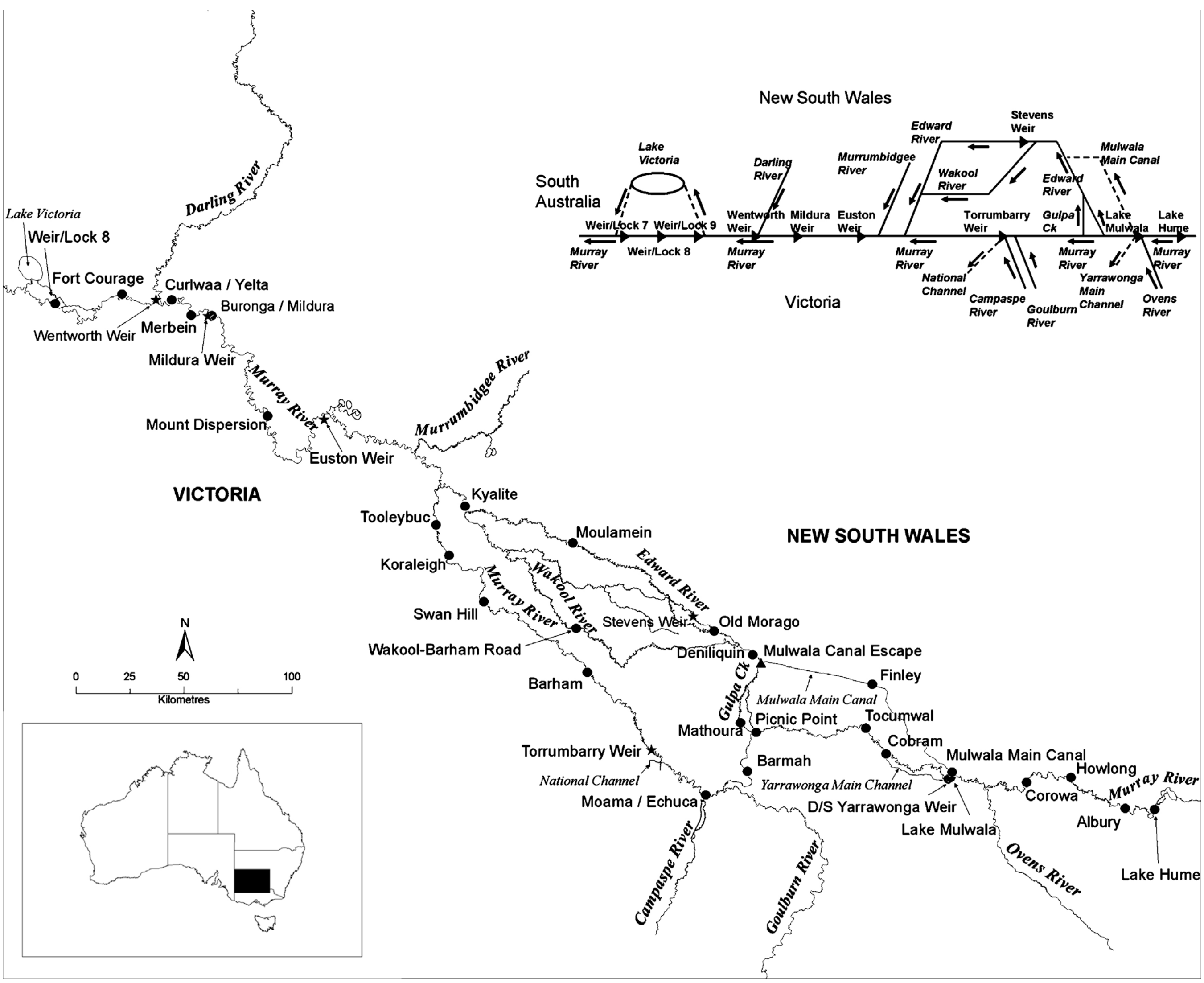

Fig. 1. Location of weirs and sampling sites. Black dots = locations sampled during the 2010 bloom; black triangles = additional river flow gauging sites; stars = location of weirs; (D/S = downstream). Inset shows a schematic of how water flows through the river system (solid lines = natural water courses; dashed lines = diversions).