Food-web structure in the hypertrophic Rietvlei Dam based on stable isotope analysis: Specific and general implications for reservoir biomanipulation

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ABSTRACT

Fish predation on zooplankton is the basic foundation for top-down biomanipulation of lacustrine ecosystems. To test this premise, we determined stable isotope (SI) values ($\delta^{13}C$ and $\delta^{15}N$) of representative samples of major planktonic (phytoplankton, zooplankton), benthic (submerged macrophytes and associated epiphytes, benthic macro-invertebrates) and nektonic (fish) food-web components, collected from 3 to 7 shallow inshore locations (with additional plankton samples at 1 or 2 deep offshore sites) in Rietvlei Dam over a period of 30 months. The resulting $\delta^{13}C$ values did not indicate significant consumption of zooplankton by fish, while the $\delta^{15}N$ values for fish confirmed their wide trophic separation from zooplankton. Instead, SI values indicated that fish relied mostly on food resources of benthic origin (through direct consumption or piscivory). The SI signatures of individual fish species were consistent with their known feeding habits. The lack of trophic couplings between zooplankton and fish accords with previous gut content analyses of fish and analyses of zooplankton abundance and size structure in hypertrophic reservoirs. Marginal utilisation of zooplankton by indigenous reservoir fish is attributable to their native origin as riverine species unaccustomed to feeding on zooplankton. These findings indicate that top-down biomanipulation is unlikely to be effective as a management tool in eutrophic South African reservoirs. Primary producer components exhibited surprisingly wide and unsystematic temporal fluctuations in both $\delta^{13}C$ and $\delta^{15}N$ values; some potential contributory factors are considered. Changes in phytoplankton $\delta^{13}C$ values were broadly tracked by zooplankton – their nominal consumers. Some questions arising from the study, and some apparently anomalous findings are identified and discussed.

Keywords: $\delta^{13}C$, $\delta^{15}N$, trophic structure, plankton, benthos, fish, warm-water ecosystems, South Africa

INTRODUCTION

Nutrient pollution or cultural eutrophication is recognised as posing the major threat to water quality of inland fresh and coastal saline waters globally (Smith and Schindler, 2009). This well-known, serious and intransigent problem is symptomatically manifest in the excessive growth of primary producers released from intrinsic natural nutrient limitation, and generates a cascade of qualitative and quantitative changes in food-web structure and ecosystem functioning (e.g. Carpenter, 2005). In affected lacustrine ecosystems, 'blooms' of 'phytoplankton' (both eukaryote protistan algae and/or prokaryote bacterial cyanophytes) commonly develop. Apart from resulting taste and odour problems and aesthetic considerations, water quality is seriously impaired; treatment costs for potable water increase, while cyanophyte toxins, released during bloom conditions, can seriously compromise human and animal health, sometimes with lethal consequences (Codd et al., 2005; Poste et al., 2011).

Eutrophication is a growing problem in South Africa, and poses a critical threat to the inland water resources of this water-scarce nation, largely reliant on water stored in river impoundments (DWA, 2013). At least 35% of water stored in such reservoirs is already classed as eutrophic or hypertrophic, with an additional 30% bordering on the eutrophic status (Harding et al., 2009). Since this nutrient pollution is largely attributable to wastewater effluents (Harding, 2008), the problem can be constrained by enforcing appropriate wastewater treatment and effluent discharge restrictions. In practice, such 'preventative' treatment has been largely ineffectual (e.g. DWA, 2009), leading to proposals to implement 'curative' measures – notably 'biomanipulation' (Shapiro et al., 1975) – to rehabilitate highly eutrophic systems such as Hartbeespoort Dam (Anon. 2004a, 2004b; Harding et al., 2004).

Biomanipulation is well known as a management tool for eutrophic systems (e.g. Gulati et al., 1990; Moss, 1998; Hansson et al., 1998) which relies on a logical but deceptively simple approach, namely, the restriction of excessive phytoplankton growth by enhancing the 'grazing' pressure exerted by 'herbivorous' zooplankton, particularly large-bodied *Daphnia*, through removal or reduction of zooplankton predators, especially zooplankton-feeding fish (hereafter termed zooplanktivores). Such 'top-down' biomanipulation through food-web restructuring has featured prominently in global attempts to fight eutrophication, especially in shallow natural lakes, although its success has been variable (e.g. Gulati et al., 1990), and of questionable sustainability (e.g. Benndorf, 1992; Shapiro, 1995; Rask et al., 2002; Gliwicz, 2005; Søndergaard and Jeppesen, 2007; Sierp et al., 2011). Of greater contextual relevance to this study, its suitability in warmer waters is increasingly questioned (Jeppesen et al., 2005, 2007, 2010; Iglesias et al., 2011; Akhurst et al., 2012).

A fishery assessment of Hartbeespoort Dam (Koekemoer and Steyn, 2005) revealed a dominance of 'coarse' fish

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