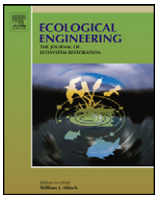
Ecological Engineering 37 (2011) 1901–1904

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng



Short communication

Engineered water level management facilitates recruitment of non-native common carp, *Cyprinus carpio*, in a regulated lowland river

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ARTICLE INFO

Article history:
Received 6 March 2011
Received in revised form 29 May 2011
Accepted 29 June 2011
Available online 30 July 2011

Keywords:
River Murray
Environmental engineering
Freshwater fish
River regulation
Exotic species
Acid sulfate soils
Environmental water allocation

ABSTRACT

River regulation can advantage non-native aquatic biota at the expense of native species. Nevertheless, flow regulating structures are sometimes used with the aim of achieving positive environmental outcomes in aquatic ecosystems. In the lower River Murray, Australia, drought-induced water level recession and acid sulfate soil exposure prompted the construction of an earthen levee, isolating a section of river channel (the Goolwa weir pool (GWP)) within which water levels were managed to mitigate a risk of water body acidification. The present study aimed to determine the impact of water level management on the fish community by investigating variation in species abundance and recruitment between sites subject to water level management in the GWP and unmanaged sites in Lake Alexandrina. Prior to levee construction, in August 2009, the abundance of the non-native common carp was similar in the GWP and Lake Alexandrina. Following water level management, in December 2009 and April 2010, the abundance of common carp in the GWP was approximately 1000 and 250 times greater than abundance in Lake Alexandrina, as a result of recruitment of young-of-year fish. No native freshwater species were significantly more abundant in the GWP in August 2009, December 2009 or April 2010. The results of this study suggest that the isolation of a river reach and a managed rise in water level facilitated spawning and recruitment of a non-native fish species. As such, the ecological benefits and risks of restoration and mitigation projects that involve the construction of flow regulating structures and water level management should be carefully considered.

1. Introduction

Extensive regulation of many of the world's large rivers has altered natural hydrological regimes with profound consequences for aquatic biota (Puckridge et al., 1998; Nilsson et al., 2005). The impacts of flow regulating structures (e.g. dams and weirs) and changes to natural flow regimes on fish have been discussed worldwide (Pringle et al., 2000; Gehrke and Harris, 2001; Hu et al., 2008). River regulation typically leads to a reduction in the diversity of fish communities (Ward and Stanford, 1979) and can create conditions suitable for non-native species at the expense of native species (Gehrke et al., 1995; Moyle and Light, 1996). One such species, the common carp (*Cyprinus carpio* L.), thrives outside its natural range in regulated rivers around the world (Lever, 1996), including in Australia's Murray–Darling Basin (MDB), where it is implicated in competing with native species, increasing turbidity and impacting aquatic vegetation (King et al., 1997; Roberts et al., 1995).

Despite the many apparent negative effects of river regulation on aquatic ecosystems, flow regulating structures and water level management have also been used to achieve positive environmental outcomes, particularly for vegetation and waterfowl (Galat et al., 1998; Jenkins et al., 2008), and their use is becoming increasingly common in the MDB (e.g. URS, 2007).

The Murray–Darling river system, in south-eastern Australia, is Australia's longest river system and drains an area of approximately 1,073,000 km^2. The MDB is highly regulated and high rates of water abstraction result in a mean end-of-system discharge that is approximately 39% (4723 GL) of natural (12,333 GL) (CSIRO, 2008). Prior to discharging to the Southern Ocean, the River Murray flows into a large lake system (>900 km^2) comprised of Lakes Alexandrina and Albert (the 'Lower Lakes'). The lakes are separated from a narrow estuary (the Coorong) and the Southern Ocean by a series of man-made tidal barriers (constructed in the 1930s) (Fig. 1). Collectively the Lower Lakes and Coorong are recognised as a wetland of international importance under the Ramsar Convention (1985) and support the most diverse fish assemblage in the MDB (>40 species), reflecting the co-occurrence of estuarine,

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doi:10.1016/j.ecoleng.2011.06.046

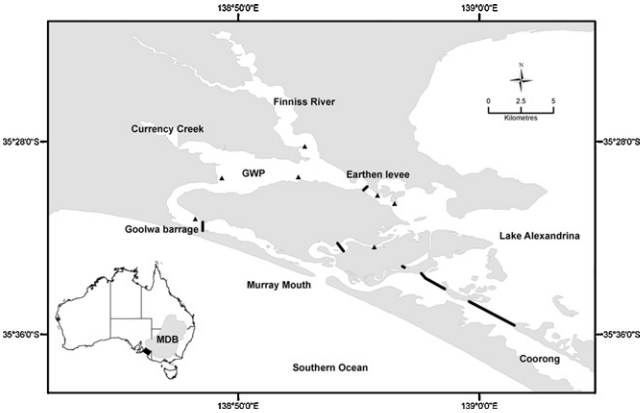

Fig. 1. Map of the study area in the western region of Lake Alexandrina, showing the position of the tidal barrages and earthen levee (solid black lines), the Goolwa weir pool (GWP), tributaries (Currency Creek and the Finniss River) and sampling sites (solid triangles).

diadromous and obligate freshwater species (Wedderburn and Hammer, 2003; Zampatti et al., 2010).

From 1997 to 2010, south-eastern Australia experienced severe drought resulting in reduced inflows to the MDB (Murphy and Timbal, 2008). By early 2009, a combination of reduced system-wide inflows and over-allocation of water resources resulted in reduced flow to the Lower Lakes (<600 GL yr^{-1} in 2007 and 2008), causing a reduction in water level of >1.5 m. Water level in Lake Alexandrina is typically regulated at approximately +0.75 m AHD (Australian Height Datum) but fell below sea level for the first time in recorded history, reaching approximately −1.0 m AHD (Kingsford et al., 2011). Water level recession was accompanied by the drying of fringing wetland habitats, a reduction in submerged vegetation cover (Marsland and Nicol, 2009) and exposure of extensive areas of lake bed that were susceptible to the formation of acid sulfate soils (Fitzpatrick et al., 2009). Acid sulfate soils may impact water quality by causing acidification and mobilising heavy metals, and posed a significant risk to the aquatic ecosystem of the Lower Lakes (Fitzpatrick et al., 2009).

In order to limit the exposure of acid sulfate soils and reduce the risk of water body acidification in the western region of Lake Alexandrina (i.e. the Goolwa Channel), higher water levels were maintained by the construction of a temporary regulating structure (SA Water Corporation, 2009). Whilst this intervention was undertaken with the primary objective of mitigating the threat of water body acidification, it secondarily aimed to provide an area of adequate freshwater habitat for freshwater dependent biota to mitigate the impact of low water levels on the ecology of the region (SA Water Corporation, 2009). The use of such structures to isolate and manage water levels in a main river channel is a novel and unprecedented approach to the mitigation of acid sulfate soils and habitat conservation.

This paper presents fish abundance and size structure data from an ongoing investigation which aims to determine the response of fish assemblages to water level management within the newly created Goolwa weir pool (GWP). Variation in species abundance and recruitment between sites subject to water level management in the GWP and those not subject to management in Lake Alexandrina were used to evaluate the influence of constructing the regulatory structure and managing water levels within the GWP on the resident fish community.

2. Methods

2.1. Study site and water level management

A temporary regulating structure (earthen levee: length = 375 m, width = 40 m, height = 3 m) was constructed across the Goolwa Channel (35°29′56.64″S, 138°55′19.74″E) creating an impounded area approximately 16 km in length and 0.3–1.5 km wide (referred to as the Goolwa weir pool (GWP)), hydrologically isolating this region from the rest of Lake Alexandrina (Fig. 1). The GWP also remained isolated from the Coorong by the Goolwa Barrage (Fig. 1). Between August and November 2009, water level in the GWP was raised from approximately −0.9 m AHD to +0.7 m AHD by pumping approximately 27 GL of freshwater from Lake Alexandrina, over the levee, and capturing seasonal inflows from tributaries. Following evaporation from December 2009–April 2010, water level receded to approximately −0.1 m AHD. Water level in Lake Alexandrina was reliant on flow from the River Murray and ranged from −0.9 to −0.3 m AHD over the same period.

2.2. Fish sampling

Fish assemblage data were collected in the GWP (centroid: 35°29′35.02″S, 138°50′27.99″E) and in Lake Alexandrina (centroid: 35°30′32.81″S, 138°56′14.32″E) in August 2009 (water levels −0.9 m AHD at both locations), December 2009 (water level in the GWP: +0.7 m AHD and in Lake Alexandrina: −0.9 m AHD) and in April 2010 (water level in the GWP: −0.05 m AHD and in Lake Alexandrina: −0.55 m AHD). Sampling was timed to capture fish assemblages prior to water level management (August 2009) and following peak water levels in the GWP (December 2009), and to examine evidence of recent recruitment (April 2010), as the majority of resident species spawn in the austral spring/summer (Lintermans, 2007).

In August 2009, three sites were sampled in the GWP and one was sampled in Lake Alexandrina. In December 2009 and April 2010 four sites were sampled in the GWP and three were sampled in Lake Alexandrina. On each occasion, sites were sampled overnight using four single-wing fyke-nets (6 m wing length, 0.6 m diameter entry, 0.003 m stretched mesh) and three multi-panel gill-nets (three panels: 0.076, 0.102 and 0.127 m stretched mesh × 5 m length × 1.5 m height). All fish were identified to species and enumerated, and a sample of up to 50 individuals of each species per gear type was measured for length (total length (TL) or fork length (FL) depending on tail morphology).

Uni-variate PERMANOVA (Anderson et al., 2008) was used to detect differences between the abundance of the most numerous species in the GWP and in Lake Alexandrina.

3. Results

A total of 46,717 fish were captured from 23 species (35,699 fish, 21 species in the GWP and 11,018 fish, 18 species in Lake Alexandrina). The estuarine small-mouthed hardyhead (*Atherinosoma microstoma* (Günther)) and lagoon goby (*Tasmanogobius lasti* Hoese), freshwater bony herring (*Nematalosa erebi* (Günther)), Australian smelt (*Retropinna semoni* (Weber)) and flat-headed gudgeon (*Philypnodon grandiceps* (Krefft)), and non-native common carp (*Cyprinus carpio* L.) were the most abundant species, and comprised approximately 95% of all fish sampled.

The abundance (fish fyke-net^{-1} h^{-1}) of the most numerous native freshwater species, namely Australian smelt ($t_{1,14} = 8.54$, $p = 0.012$) and flat-headed gudgeon ($t_{1,14} = 28.86$, $p < 0.001$) was