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Mortality of larval Murray cod (*Maccullochella peelii peelii*) and golden perch (*Macquaria ambigua*) associated with passage through two types of low-head weirs

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Abstract. Determining factors responsible for increases in the mortality of freshwater fish larvae are important for the conservation of recruitment processes and for the long-term sustainability of freshwater fish populations. To assess the impact of one such process, Murray cod (*Maccullochella peelii peelii* Mitchell) and golden perch (*Macquaria ambigua* Richardson) larvae were arranged into treatment and control groups and passed through different configurations (overshot and undershot) of a low-level weir. Passage through an undershot weir resulted in the death of 95 ± 1% golden perch and 52 ± 13% Murray cod. By comparison, mortality was significantly lower in the overshot treatment and both controls. The relatively large number of undershot weirs within the known distribution of these species could impact upon recruitment over a large scale. It is therefore recommended that water management authorities consider the potential threats of operating undershot gated weirs on the survival of larval fish until further research determines appropriate mitigatory measures for these and other species.

Extra keywords: downstream dispersal, fish passage, larval drift, overshot, undershot.

Introduction

The construction of dams and weirs is recognised as a serious problem for aquatic organisms in Australia (Gehrke *et al.* 1995; Kearney *et al.* 1999; Gehrke *et al.* 2002; Pollino *et al.* 2004), and globally (Townsend 1975; Fjellheim and Raddum 1996; Holmquist *et al.* 1998; Rivinoja *et al.* 2001). A consequence of building these structures is the prevention, or obstruction, of migration pathways (Stuart and Mallen-Cooper 1999) and is an area that has received much attention in Australian freshwater systems (Reynolds 1983; Mallen-Cooper 1996; O'Connor *et al.* 2003). Sixty-six species of freshwater fish endemic to south-eastern Australia migrate to some extent (Kearney *et al.* 1999) and the proliferation of dams and weirs has been widely implicated as a major factor in widespread declines of these species (Cadwallader and Lawrence 1990; Allan and Flecker 1993; Wager and Jackson 1993). One of the major reasons for these declines may be recruitment failure (Langtry in Cadwallader 1977; Reynolds 1983; Rowland 1989) but no studies have attempted to identify specifically which recruitment processes are affected by the presence of dams and weirs.

Downstream dispersal is important for many fish species worldwide (Clifford 1972; Gale and Mohr 1978; Gallagher and Conner 1983; Muth and Schmulbach 1984; Brown and Armstrong 1985; Flecker *et al.* 1991; Harvey 1991; Winnell and Jude 1991; Jurajda 1998). Several recent studies have determined that downstream dispersal, during larval phases, is undertaken by several species of native fish in the Murray–Darling River system (Humphries *et al.* 1999; Humphries and Lake 2000; Humphries *et al.* 2002; Meredith *et al.* 2002; Gilligan and Schiller 2003). Two percichthyid species, Murray cod (*Maccullochella peelii peelii* Mitchell) and golden perch (*Macquaria ambigua* Richardson), have a dispersal phase where larvae drift downstream (Koehn and Nicol 1998; Gilligan and Schiller 2003). Both Murray cod and golden perch were historically widespread in the extensive Murray–Darling Basin and supported important commercial and recreational fisheries (Harris 1985; Gehrke 1988; McDowall 1996; Harris and Gehrke 1997). The many weirs constructed throughout the known distribution of these species (Mallen-Cooper 1996; Thorncraft and Harris 2000) could potentially affect the survival of larval and juvenile stages. However, the exact nature and extent of potential impacts remain unquantified for these and other native fish species.

Two types of weir, undershot (sluice) and overshot, have been constructed on Australian freshwater streams (O'Connor *et al.* 2003) and each design creates contrasting downstream hydraulic conditions. For example, overshot weirs discharge water over the crest, creating a plunging flow effect where water falls either vertically or down a sloping spillway (Clay 1995). In contrast, water released from undershot weirs travels exclusively below the gates from an area of elevated hydrostatic pressure, immediately upstream, to an

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spathula) larvae of similar sizes (14–16 mm) to Murray cod and golden perch examined during our study are known to exhibit reduced mortality in low-turbulence conditions (Killgore *et al.* 1987). Therefore, despite their small size, larval Murray cod and golden perch may be able to cope with the lower turbulence associated with low-head overshot weirs.

Murray cod larvae used in our trials were generally of greater length and later stage of larval development than golden perch. Lower overall mortality rates for Murray cod suggest that larger-bodied larvae are potentially less susceptible to the effects of undershot weirs. Size-dependent mortality attributed to turbulence and shear stress has been determined in larvae of many North American fish species, with larger individuals being less susceptible to injury (Killgore *et al.* 2001). Although not investigated during our study, determining the critical size of larvae where mortality rates reduce is important to develop mitigation methods specifically targeted at susceptible individuals.

Mortality of both species was substantially lower during the after-experimental observation period than immediately after the treatments. Delayed mortality rates also differed between golden perch and Murray cod, suggesting that observed effects might vary among different species. For instance, delayed mortality of carp larvae continued for at least two hours after conducting a similar experiment in Bangladesh (Marttin and DeGraaf 2002). Marttin and DeGraaf (2002) investigated an installation containing two gates, each of which were triple the size (3 m) of the weir investigated in the present study. The expected hydraulic differences associated with weirs of greater size may have contributed to additional longer-term increases in larval mortality because the altered hydraulic conditions would increase shear action, turbulence and subsequently, the risk of injury (Cada *et al.* 1999). Although similar investigations were beyond the scope of the present study, this observation suggests that mortality rates, even greater than those reported here, could be readily expected at larger weirs.

Golden perch and Murray cod are important recreational species within the Murray–Darling Basin and have a high conservation status (Rowland 1989). Therefore, controlling factors that increase mortality during larval development should be seen as an essential step in enhancing natural recruitment and ensure the long-term sustainability of wild populations. To achieve this goal, it is recommended that water management authorities consider the potential threats of operating undershot gated weirs on the survival of larval fish until further research determines appropriate mitigatory measures for these and other species.

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