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Performance and contribution to commercial catches and egg production by restocked *Acanthopagrus butcheri* (Sparidae) in an estuary

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ABSTRACT

This study has explored whether the restocked fish of a species, which is confined to an estuary, perform as well as its wild stock, and has estimated their contribution to the commercial fishery and egg production. The biological characteristics of the 2001 and 2002 year classes of *Acanthopagrus butcheri*, which had been cultured and introduced into the Blackwood River in south-western Australia at seven and four months old, respectively, were thus determined from samples collected regularly between 2002 and 2014. The restocked fish could always be distinguished from the wild stock because their otoliths retained the pink colouration of the alizarin complexone with which they had been stained prior to release. Detailed analyses demonstrated the growth and maturity schedules of restocked fish were only slightly inferior to those of the wild stock and the mean gonad weights of the females of these two groups did not differ significantly in any month. As increasing numbers of restocked *A. butcheri* attained the MLL of 250 mm for retention, their contribution to the commercial fishery increased from 6% in 2005 to 74% in 2010. That contribution subsequently declined to 39% in 2012 and 10% in 2014, due predominantly to the introduction of the very strong 2008 year class in the commercial catches, the first substantial recruitment into the population since 1999. Restocked fish were estimated as contributing ~55% to the eggs produced in 2008, suggesting that substantial numbers of the 2008 year class were derived from spawning by restocked fish. The results of this and a previous genetic study imply that restocking is an effective and appropriate way for replenishing stocks of an estuarine species such as *A. butcheri*, especially as its recruitment is highly episodic.

1. Introduction

Restocking is increasingly being used to restore fish stocks that have become depleted through over-exploitation and to meet the global demand for seafood (*e.g.* Bell et al., 2006; Gomez and Mingoa-Licuanan, 2006; Strøttup et al., 2008; Loneragan et al., 2013). The use of restocking overcomes the need to impose politically and socially less acceptable options for the recovery of a depleted stock, such as reducing size limits and total allowable catch and closing areas to fishing (Travis et al., 1998; Bell et al., 2006). The introduction of the cultured fish of a species can have, however, a negative effect on the wild population of that species through, for example, increasing inbreeding, introducing diseases and leading to a decrease in the abundance of wild fish (Einum and Fleming, 2001; Lorenzen et al., 2012; Camp et al., 2014).

Restocking is a particularly useful method of replenishing a depleted stock of those species that complete their life cycle within estuaries or inland waters and whose stocks cannot thus be augmented naturally by recruitment from outside that system (Lenanton et al., 1999; Taylor et al., 2005; Eby et al., 2006; Ward, 2006). Furthermore, if restocking does have a deleterious impact on the genetic composition of a species in such water bodies, it is restricted to the population within the system into which the individuals were introduced (Potter et al., 2008; Gardner et al., 2013).

The Black Bream *Acanthopagrus butcheri* is an iconic recreational fish species in southern Australian estuaries and is fished commercially in some of these systems (Lenanton and Potter, 1987; Kailola et al., 1993; Prior and Beckley, 2007; Jenkins et al., 2010). This sparid, which can live for ~30 years (Morison et al., 1998; Potter

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et al., 2008), completes its life cycle within its natal estuary and typically spends most of the year in its upper reaches, where it spawns during spring and early summer (Potter and Hyndes, 1999; Sarre and Potter, 1999; Williams et al., 2013).

Several stocks of *A. butcheri* in south-western Australia were reported by Lenanton et al. (1999) to have become depleted. It is not clear, however, whether increased fishing pressure and/or environmental changes were responsible for the decline in the abundance of this species in the Blackwood River Estuary, which supports a recreational fishery and a small commercial gill net fishery (Prior and Beckley, 2007; Gardner et al., 2013). As the recruitment of *A. butcheri* into a population can be highly episodic, the recreational and commercial fisheries in some systems rely almost entirely on a few year classes (Morison et al., 1998). Concern for the status of the stock of *A. butcheri* in the Blackwood River Estuary led to a study aimed at determining the efficacy of using restocking to replenish the population of this species in this system (Potter et al., 2008; Gardner et al., 2013). Brood stock from this estuary were thus used in 2001 and 2002 to culture juveniles, whose otoliths were stained with alizarin complexone to allow these fish to be distinguished from the wild stock in samples collected in years following their release (Potter et al., 2008). This marking method has been successfully employed with other species, such as the Chum Salmon *Oncorhynchus keta* and the Pink Salmon *Oncorhynchus gorbusha* (Sato et al., 2011) and the Black Rockfish *Sebastes schlegeli* (Nakagawa et al., 2007).

Comparisons of data derived from sampling *A. butcheri* in the Blackwood River Estuary, between the introduction of the cultured fish in 2002 and 2003, and the years up to 2010, indicated that, in comparison with wild fish, the cultured fish, on average, had not grown quite as rapidly as the wild stock (Potter et al., 2008; Gardner et al., 2013). While there were indications that the restocked fish reached maturity at a slightly greater length and age, this was not tested statistically. Analyses of commercial gill net catches between 2005 and 2010 demonstrated that many restocked *A. butcheri* exceeded the minimum legal length (MLL) for retention of 250 mm and thus made an important contribution to the commercial fishery for this species in the Blackwood River Estuary and therefore, presumably, also to its recreational fishery (Gardner et al., 2013). However, the age structure of *A. butcheri* in those catches demonstrated that there had been little or no recruitment of year classes into the fishery since the introduction of the restocked fish.

Examination of *A. butcheri* in fishery-independent samples and commercial gill net catches obtained from the Blackwood River Estuary between 2012 and 2014, and thus after the completion of the previous study (Gardner et al., 2013), demonstrated that the alizarin complexone stain was still clearly visible in the central region of the otoliths of restocked fish and had thus persisted for 12–13 years. It also demonstrated that, for the first time for many years, a new and strong cohort of *A. butcheri* had recruited into the fishery and which, from its age, could have been derived, in part, from restocked fish.

During the present study, biological and commercial catch data for *A. butcheri* in the Blackwood River Estuary were obtained for 2012 to 2014 and collated with those for 2002 to 2010 (Potter et al., 2008; Gardner et al., 2013). These composite data, covering a period of more than a decade, were used to compare statistically the biological performance of cultured and wild *A. butcheri* and estimate the relative contributions of cultured and wild stock *A. butcheri* to commercial catches. Emphasis was placed on the following. (1) Extend comparisons of the growth of restocked and wild stock fish by including data for a further four years and explore more fully the basis for any differences between these two groups. (2) Determine whether the relationship between the lengths and ages at maturity of restocked fish differed significantly from those of the wild stock and, if so, the extent and basis for such differences. (3) Elucidate whether restocked fish are continuing to contribute substantially to the commercial catches of *A. butcheri* and the extent of any such contributions. (4) Ascertain whether restocked fish could have made a major contribution to total egg production by *A. butcheri* and if there was strong circumstantial evidence that the progeny of restocked fish could have contributed to commercial catches.

2. Materials and methods

2.1. Collection and identification of restocked and wild *Acanthopagrus butcheri*

Full details of culturing *A. butcheri* from brood stock obtained from the Blackwood River Estuary, the staining of the otoliths of the resultant juveniles with alizarin complexone and the timing of the release of the fish cultured in 2001 and 2002 are given in Potter et al. (2008). In brief, the 70,000 juveniles cultured in 2001 were released into the Blackwood River Estuary in the winter of 2002 at ~ seven months old, whereas the 150,000 cultured in 2002 were released at ~ four months old in autumn 2003. As mentioned previously, the purple colour in the central region of the otoliths of the cultured *A. butcheri*, which was produced by the alizarin complexone stain, enabled these fish to be clearly identified in samples collected in subsequent years.

Samples of *A. butcheri* were collected from the Blackwood River Estuary in each year between 2000 and 2014, except for 2008 and 2011. They were obtained using fishery-independent methods at six sites in the upper and 'riverine' region of the estuary and/or from the commercial gill net fisher who fishes in this region of the estuary (Fig. 1). This region is stratified and undergoes pronounced seasonal changes in salinity, with annual bottom salinities typically ranging from ~5 to 30 and surface salinities from ~0 to 15 (Brearley, 2013). The fishery-independent methods employed a sunken composite gill net and a seine net. The gill net typically comprised eight panels, each 20 m long and 2 m high and with different mesh sizes, ranging in approximately equal intervals from 35 to 127 mm. The seine net was 41.5 m long and contained a 1.5 m bunt made of 9 mm mesh and two 20 m long wings comprising 25 mm mesh. The sunken gill net of the commercial fisher was 20 m long and 2 m high and made of 105 mm stretched mesh. It was chosen by this fisher so that it essentially caught only *A. butcheri* with total lengths

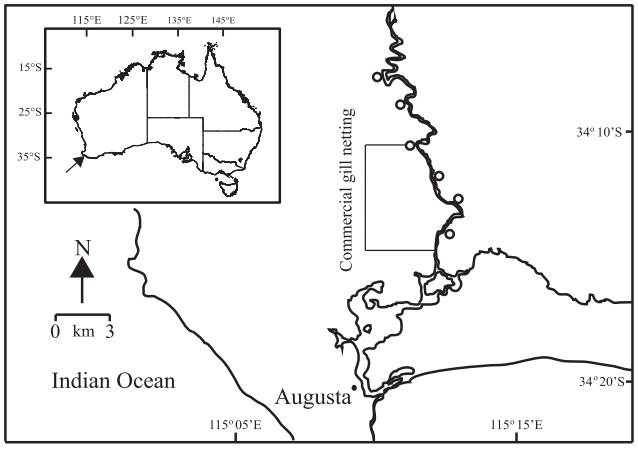

Fig. 1. Map showing the six sites at which *Acanthopagrus butcheri* was sampled in the Blackwood River Estuary by fishery-independent methods (open circles) and the stretch of the estuary in which the commercial gill net fisher typically operated. Arrow in insert map shows location of the Blackwood River Estuary in Western Australia.