Massive mortalities of the black bream *Acanthopagrus butcheri* (Sparidae) in two normally-closed estuaries, following extreme increases in salinity

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Salinities in some normally-closed estuaries in the central south coast of Western Australia are now frequently becoming highly elevated. This is due to: (1) high evaporation rates in water volumes that, by summer, are already low as a result of atypically dry winters; and (2) increased salt run-off following vegetation clearing in the catchments. A few black bream (*Acanthopagrus butcheri*) died in the basin and lower reaches of the main tributary of Culham inlet when salinities reached ~77 and 67, respectively, and an estimated 1.3 million black bream died in the tributary during the next two months when salinities continued to increase. All black bream in the basin and the lower reaches of the tributary of another estuary were apparently killed when salinities reached ~83–85. It is proposed that *A. butcheri* becomes stressed at salinities of 60 and typically die before they reach ~85. In both estuaries, a rock bar in the tributary prevented black bream from moving to refugia in upstream areas where salinities were lower.

INTRODUCTION

Estuaries in south-western Australia typically comprise a narrow and shallow entrance channel, a wide central basin and the saline lower reaches of the tributary rivers. Although some of these estuaries remain permanently open, others are closed, either seasonally, intermittently or normally, by a sand bar at their mouths (Potter & Hyndes, 1999). Many estuaries on the central south coast of Western Australia, such as the Culham and Hamersley inlets, are normally-closed and open to the ocean only when, under exceptional circumstances, discharge increases so markedly that the bar at the estuary mouth becomes breached (Hodgkin & Hesp, 1998).

The fish faunas of these normally-closed estuaries are depauperate and represented predominantly by individuals of the Atherinidae and Gobiidae (e.g. Hodgkin, 1997; Young & Potter, 2002), which are generally small and short lived (e.g. Prince & Potter, 1983; Gill et al., 1996). However, south-western Australian estuaries also contain substantial numbers of the black bream *Acanthopagrus butcheri*, which can attain total lengths, weights and ages of >450 mm, 2000 g and 20 years, respectively, in these systems (Sarre & Potter, 2000). This sparid is confined to estuaries in south-western Australia (Chaplin et al., 1998), among which it grows at different rates (Sarre & Potter, 2000), apparently reflecting differences in environmental conditions rather than genetic variation (Partridge et al., 2004). The black bream is one of the most important recreational and commercial fish species in south-western Australian estuaries and was once the single most important commercial fish species in Culham inlet, in which its annual catch exceeded 70 tonnes in 1992/1993 (Hodgkin, 1997).

During recent years, the winter and early spring months when most rainfall typically occurs in south-western Australia, have been unusually dry along its central south coast (Western Australian Bureau of Meteorology). Consequently, evaporation has led, during the ensuing warm and dry months, to marked reductions in the water levels of normally-closed estuaries. The resultant increases in salt content have often been augmented by an increase in salt run-off from surrounding catchments as a consequence of extensive clearing of vegetation (Pen, 1999).

This paper describes the very high mortalities to which *A. butcheri* was subjected in Culham and Hamersley inlets on the central south coast of Western Australia following extreme increases in salinity and provides estimates of the range of salinities over which this species is likely to die.

MATERIALS AND METHODS

The basin of Culham inlet, which is 11 km² in area, has one major tributary, the Phillips River (Figure 1). The sand bar at the mouth of its short ‘entrance channel’ is located only ~0.3 km from its point of connection with the basin. The only years in which this bar was recorded as breaching naturally are 1849 and 2000 (Hodgkin, 1997; S. Hoeksema, personal records). The latter occurred after seasonally atypical rainfall in the early summer of 1999 to 2000. The basin of Hamersley inlet has an area of 2.3 km² and is fed solely by the Hamersley River (Figure 1). There are only nine records of the bar at the mouth of its short entrance channel being breached between 1915 and 1990 (Hodgkin & Clark, 1990). Our capture of the marine species *Arripis georgiana*, *Arripis truttaea* and *Mugil cephalus* in Hamersley inlet demonstrates that the bar at the mouth of this estuary must have been breached during recent years. However, the mouth was never open during the many visits we made to this estuary between...
October 2001 and October 2004. When water levels are low, rock bars in the Phillips and Hamersley rivers, at distances of \( \sim 7 \) and \( 4 \) km upstream of their basins, respectively, disrupt flow between these rivers and their basins.

The mortalities in Culham inlet were observed during visits made at two or three month intervals in 2001 to establish sampling sites for studying the ichthyofauna of this estuary and Hamersley inlet in 2002–2004. A 41.5 m seine net (9-mm mesh) was employed for limited sampling.
in 2001, while a seine net and composite gill-nets (20 m long panels with meshes ranging from 38 to 102 mm) were employed seasonally in 2002–2004. Salinity, temperature and dissolved oxygen were recorded using a Yellow Springs International Model 85 conductivity meter.

Computer enhancement of photographs, taken in April 2001, was used to count the dead fish in one metre long transects along the bank of the Phillips River (Figures 2 & 3). These counts were used, together with the lengths of the stretches of dead fish along that bank, to estimate the total number of dead fish.

RESULTS

The very large discharge that followed exceptionally heavy rainfall in the early summer (December) of 1999 led, in the following month, to the breaching of the sand bar at the mouth of Culham inlet and thus to a marked reduction in the water level in its basin. Rainfall during the ensuing months of 2000 was very low and the water level thus declined even further during the following summer.

In February 2001, a few dead black bream were found along the banks and in the waters of the basin of Culham inlet and lower part of the Phillips River. At this time, maximum water levels in the basin and river had declined to less than 1 m and salinities were 77 and 67, respectively. The total length (TL) of dead fish ranged from 63–152 mm, with a mean ±SE of 112 ±9.9 mm. Seine netting of ~270 m² of nearshore waters of the middle part of the Phillips River yielded 57 *Acanthopagrus butcheri*, ranging in TL from 49–95 mm, with a mean ±SE of 76 ±1.3 mm.

In April 2001, when salinities in the basin and river had increased to ~82 and 95, respectively, very large numbers

**Figure 2.** Photograph of band of dead *Acanthopagrus butcheri* lining the banks of the Phillips River.

**Figure 3.** Photograph of accumulation of dead black bream just downstream of the rock bar on the Phillips River and close-up (top right-hand corner) of area denoted by the rectangle.
of dead black bream were found lining ~5.8 km of the shore of the estuarine reaches of the Phillips River (Figures 2 & 3). The TL of a subsample ranged from 38–174 mm, with a mean ±SE of 77 ±6.2 mm. It is assumed that, following their death, these fish had floated to the surface and then been transported by wind-driven currents to the waters lining the river bank. Subsequent rapid lowering of the water level, through high evaporation, resulted in the dead fish forming an approximately 0.3 m wide band along the bank (Figure 2). From photographic analyses, 1.3 million ±100,000 black bream were estimated to have died in the estuarine reaches of the Phillips River during the high salinities that developed in late summer to mid-autumn of 2001 (see Figures 2 & 3). Seine netting at regular intervals along the Phillips River in April 2001 yielded only three black bream, all of which were caught directly downstream of the natural rock bar on that river and which, because of low water levels, would have prevented black bream moving upstream at this time. These fish were lethargic and the largest (332 mm) possessed numerous, large salt sores on its body and tail. Thus, few A. butcheri survived the very high salinities that developed in the lower Phillips River in late summer to mid-autumn of 2001 and the few that did survive were in poor condition. Examination of sectioned sagittal otoliths of the dead black bream collected in February and April, 2001 showed that these fish belonged to the 0+ or 1+ age-classes. They were thus spawned in the springs of 2000 and 1999, respectively (see Sarre & Potter, 1999, 2000 for details of ageing and reproductive biology of black bream). The single large individual caught in the Phillips River in April 2001 was nine years old.

Salinities in the basin of Hamersley inlet rose sharply from 54 in October 2002 to 83 in January 2003. A massive mortality of black bream occurred in this estuary shortly thereafter in February 2003 (G. Bastyan, Department of Environment, Western Australia), when, due to some rainfall, salinities had remained similar to those in January 2003. Although fish were still present on the banks during our next visit in April 2003, they had decomposed to such an extent that they could not be counted. As this species has not been recorded in Hamersley inlet during seasonal sampling below the rock bar on its tributary in the two years since February 2003, all of the black bream in that part of the system are assumed to have died as a result of those extreme salinities. The fact that our gill-netting throughout Hamersley inlet between the summer of 2002 and just prior to the fish kill yielded on average 129 black bream per season emphasizes the extent of that mortality.

DISCUSSION

Although cultured juveniles of Acanthopagrus butcheri could be maintained in the laboratory in salinities of 60, they were osmotically stressed and grew far slower than in salinities <35 (Partridge & Jenkins, 2002). Furthermore, we have observed salt sores on black bream in Stokes inlet, ~120 km east of Culham inlet, when salinities reached ~60. From the above observations, and the salinities when black bream died in Culham and Hamersley inlets, A. butcheri apparently become stressed as salinities reach 60 and typically do not survive salinities beyond 85. Laboratory studies have shown that the critical salinity maximum of the congeneric Acanthopagrus latus ranged from 54–69 and decreased with increasing temperature (Jian et al., 2003) and that another sparid Rhabdosargus holubi can not tolerate salinities greater than 70 (Blaber, 1973).

In the basin of Wellstead estuary, ~80 km to the west of Culham inlet, Atherinosoma elongata was apparently the only fish species to survive when salinities rose to 122 (Young & Potter, 2002). A remarkable example of salinity tolerance is provided by Cyprinodon variegatus, which can live in salinities ranging from 0 to 142 (Haney, 1999). However, laboratory studies showed that the routine metabolism of this species decreased in salinities >50, possibly due to a reduction in the osmotic permeability of particularly the gills and thus of the potential for oxygen uptake (Nordlie et al., 1991).

The mortalities of black bream in Culham and Hamersley inlets occurred in mid-summer to early autumn, when water temperatures attain their maxima of ~25°C and dissolved oxygen concentrations were <4 mg l⁻¹ and would have thus increased the stress to which this species was subjected to at this time. Moreover, the rock bars in the Phillips and Hamersley rivers prevented Acanthopagrus butcheri from moving further upstream and thus away from regions of very high salinity. Such a movement in response to high salinities was exhibited by black bream and other mobile fish species in the Beaufort inlet and Wellstead estuary (Lenanton & Hodgkin, 1983; Young & Potter, 2002) and by a suite of fish species in the St Lucia estuary in South Africa (Wallace, 1975). However, more than 6000 fish, representing at least 11 species, died as salinities rose above 90 in the Seekoei estuary in South Africa when it was temporarily closed (Whitfield, 1999).

In Culham inlet, the dead black bream collected from the banks in February 2001 were significantly longer than those caught live in that month and those collected dead in April 2001 (both P<0.05). This suggests that large fish are more susceptible than smaller fish to high salinities, which is consistent with juvenile fish typically being able to tolerate a greater range of salinities and more pronounced salinity fluctuations than older fish (Kinne, 1964).

The massive mortalities of black bream Acanthopagrus butcheri we recorded in two normally-closed estuaries on the central south coast of Western Australia demonstrate that increases in salinity to levels between ~65 and 85 have a highly detrimental impact on the populations of this sparid and can even result in the ‘extinction’ of a population of this species in an estuary. Although high salinities developed largely due to high rates of evaporation in relatively shallow waters, it was enhanced by an increase in the salt load in run-off as a result of extensive land clearing. Thus, for conserving black bream, sufficient vegetation must be maintained or replanted in the catchments of estuaries on the central south coast of Western Australia to restrict the amount of surface salt available for run-off. It should also be recognized that black bream will be particularly susceptible to highly elevated salinities when barriers restrict its upstream migration to riverine areas of lower salinity which can act as refugia.
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REFERENCES


