Characteristics of the ichthyofaunas of offshore waters in different types of estuary in Western Australia, including the biology of Black Bream *Acanthopagrus butcheri*

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Declaration

I declare that this thesis is my own account of my research and contains, as its main content, work which has not previously been submitted for a degree at any tertiary education institution.

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The sand bar at the mouth of Broke Inlet on the south coast of Western Australia.

Abstract

This thesis has addressed the following three main areas of research. 1) The physico-chemical characteristics of eight selected estuaries on the south coast of Western Australia that represent different estuary types, 2) the ichthyofaunal characteristics of the basin and riverine regions of offshore, deeper waters of five of those estuaries and 3) aspects of the biology of the iconic Black Bream *Acanthopagrus butcheri* in each of those estuaries in which it was abundant.

Although four of the estuaries on the south coast of Western Australia remain permanently open to the ocean, the others only become open when the volume of river discharge is sufficient to breach the prominent sand bars that form at their mouths. The sand bars of the latter estuaries are breached either annually following heavy winter and early spring rainfall (seasonally-open estuaries) or infrequently after exceptionally heavy discharge (normally-closed estuaries). The work for this thesis was undertaken in the permanently-open Oyster Harbour, the seasonally-open Broke, Irwin and Wilson inlets and the normally-closed Wellstead Estuary and Hamersley, Culham and Stokes inlets, which are all located within a *ca* 500 km stretch of coastline.

In permanently and seasonally-open estuaries, pronounced haloclines and oxyclines were present in their narrow riverine regions, but not in their wide basins where the waters are subjected to wind-driven mixing. The extent of cyclical seasonal fluctuations in environmental conditions differed markedly among the three seasonally-open estuaries and between years in one of those systems. These differences reflected variations in the relationship between the volume of fluvial discharge, which is determined by a combination of the amount of local rainfall, catchment size and extent of clearing of native vegetation, and the amount of intrusion by marine waters, which is largely controlled by the size and duration of the opening of the estuary mouth. The mean seasonal salinities in the basins of three of the normally-closed estuaries increased over three years of very low rainfall to 64 in the deepest

estuary (Stokes Inlet) to 145 in Hamersley Inlet and to 296 in the shallowest estuary (Culham Inlet).

Gill netting seasonally for two years at sites in the basin and saline lower reaches of the main tributary of the seasonally-open Broke, Irwin and Wilson inlets, the permanently-open Oyster Harbour and the normally-closed Wellstead Estuary yielded 22 329 fishes representing 58 species. Overall, and irrespective of estuary type, the species compositions of the basins and rivers differed markedly. This was attributable to consistently greater abundances of *Mugil cephalus*, and usually also of *A. butcheri*, in the riverine region of each estuary and to the restriction of a range of species largely to the basins. However, the ichthyofaunal compositions in the basins of the five estuaries varied markedly, reflecting, in part, differences in the extent and duration of the opening of the estuary mouth and/or whether extensive growths of macrophytes were present. Changes in the ichthyofaunal composition of the normally-closed Wellstead Estuary between the first and second years of the study were attributable, in particular, to the movement of two mugilid species into offshore waters as they increased in size. Cyclical changes in ichthyofaunal composition were conspicuous in both the basin and riverine regions of the estuary that underwent the most pronounced seasonal variations in environmental conditions. In each estuary, species richness was greater in the basin than river, where salinities were more variable and fell to lower levels and were thus less conducive to the immigration of most marine species. Catch rates were least in Broke Inlet, which had the lowest primary productivity, and were particularly high in Wellstead Estuary, which is highly eutrophic.

The maximum ages of *Acanthopagrus butcheri* ranged downwards from 13 to 15 years in Wilson Inlet, Wellstead Estuary, Culham Inlet and Stokes Inlet, 9 years in Oyster Harbour and only 5 years in Irwin Inlet and Hamersley Inlet. Growth of *A. butcheri* varied markedly among the various estuaries, probably reflecting differences in the density of *A. butcheri*, quality/quantity of food and/or salinity regime. The relationship between fish length and otolith radius varied between sexes and among estuaries. The width of the annual growth zones of otoliths was shown, however, to vary among years, particularly in Stokes Inlet, in which the growth zones were widest in years of relatively high rainfall and thus when salinities were presumably below that of full-strength sea water. The trends exhibited throughout the year by the gonadosomatic indices and the prevalences of each of the sequential stages in gonadal development demonstrate that *A. butcheri* spawns mainly in spring in estuaries on the south coast of Western Australia. The lengths at maturity (L_{50}s) of *A. butcheri* in the four estuaries from which it was possible to obtain substantial reproductive data were not significantly different (all $p > 0.05$), with the values for females, for example, ranging only from 146-161 mm. While no fish matured at the end of their first year of life in those estuaries, the majority of fish did mature at the end of their second year of life (73-100%). The vast majority or all fish were mature by 200 mm, which is well below the minimum legal length (MLL) for retention of this species in Western Australia, thus providing the potential for all fish that survive to the MLL to reproduce before being legally retained. Recruitment of *A. butcheri* varied markedly among years and estuaries. Recruitment in the seasonally-open Wilson Inlet was greatest in years of below average rainfall and thus presumably also relatively elevated salinities and reduced stratification and associated deoxygenation of the bottom water layer in the rivers. Although massive mortalities of *A. butcheri* in two of the normally-closed estuaries prevented comparisons across this estuary type, it appears that strong recruitment in these estuaries is related to years of relatively high rainfall and presumably the lowering of salinities in these estuaries to below that of full-strength sea water. Total mortality (Z) of *A. butcheri* appeared to be slightly higher in estuaries with the greatest fishing pressure.

The species composition and diversity of the diets of *A. butcheri* in three normally-closed estuaries, *i.e.* Hamersley, Culham and Stokes inlets, which vary markedly in the extents to which they become hypersaline during dry periods, were compared. Although a wide range of taxa, including macrophytes, polychaetes, molluscs, crustaceans, insects and teleosts, were ingested by *A. butcheri* in each estuary, the frequencies of ingestion and volumetric dietary contributions of these taxa varied greatly among the fish in these estuaries.

Thus, for example, relatively greater contributions were made to the diet by polychaetes and crustaceans in Stokes Inlet, by macrophytes in Hamersley Inlet, and by insects (mainly chironomid larvae) in Culham Inlet. The relatively greater contribution of teleosts to the diets of *A. butcheri* in the Hamersley and Culham inlets than in Stokes Inlet, and also differences in the main teleost species ingested in the first two estuaries, are consistent with differences in the densities of fish overall and of the main fish species in those estuaries. The diversity of the diet was far greater in Stokes Inlet than in the other two far more variably saline estuaries, presumably reflecting a greater diversity of food. The dietary compositions of *A. butcheri* in upstream pools in the tributary of Culham Inlet, which offer refuge when salinities increase markedly in the main body of the estuary, differed from those in downstream regions, further emphasising the opportunistic nature of the feeding behaviour of *A. butcheri*. The dietary compositions of *A. butcheri* underwent size-related changes, but the taxa contributing most to those changes varied greatly among estuaries. Size-related changes would be particularly beneficial in reducing intraspecific competition for food in the two estuaries that vary greatly in salinity and would thus be likely to contain a less diverse range of prey.

In summary, this thesis has demonstrated that the physico-chemical characteristics of estuaries on the south coast of Western Australia vary markedly even among estuaries of the same type, *i.e.* seasonally open and normally closed, and has elucidated the basis for those differences. While the characteristics of the ichthyofaunas in the offshore waters of the various estuaries on that coast differ markedly, those differences were not as marked as the overall difference between the basin and riverine regions of those systems. Finally, the iconic Black Bream *Acanthopagrus butcheri* is characterised by very different growth and recruitment patterns in the various estuaries and highly opportunistic feeding behaviour. The great plasticity of *A. butcheri* helps account for the success of this species in the range of very different environments found in south coast estuaries.

Table of contents

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