The decline of black bream in the Blackwood River Estuary: is restocking an ongoing requirement?

A Workshop Report - April 2007

Western Australian Fish Foundation

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Introduction

The Western Australian Fish Foundation (WAFF) convened this workshop on February 26, 2007 at the Fremantle Maritime Museum to discuss the implications of the recently-completed project entitled "Restocking the Blackwood River Estuary with the Black Bream *Acanthopagrus butcheri*", which was funded by the Fisheries Research and Development (FRDC) Corporation. The Workshop was convened by the WA Fish Foundation and sponsored by WAFF, the FRDC, Challenger TAFE, Murdoch University, the WA Department of Fisheries and the Blackwood Basin Group.

The aim of the Workshop was 1). to discuss the results and implications of the above study on Black bream and of the current environmental condition of the Blackwood River Estuary, 2). to consider whether it would be appropriate to continue restocking this estuary with Black Bream and 3). to determine what associated issues should be addressed in the future.

This report comprises the Synoptic Overview by Dr Peter Rogers followed by the Workshop Summary. A number of relevant speakers (see Appendix 1 for the Workshop Schedule) presented during the morning with the Workshop being conducted during the afternoon. Attendance was by invitation (50) and the list of the 48 participants can be found at Appendix 2. Power point presentations and/or summaries from the speakers can be found at Appendix 3 and additional Workshop Notes at Appendix 4.

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1: The Synoptic Overview by Dr Peter Rogers

On 26th February 2007, a workshop was held at the Fremantle WA Maritime Museum to consider the issue of Black Bream stocks in the Blackwood River and the need for restocking.

The evidence presented pointed to a general decline in the health of the environment of the riverine and estuarine waters of the Blackwood River Estuary over an extended period since the early 1970s. This was linked to declining average rainfall (approximately 30%), consequential reduced run off and river water flow, exacerbated by increased use of freshwater entrapment for viticulture and other agricultural purposes, rising soil salinity, increasing concentration of nutrients, particularly nitrogen and phosphate, and, within the Scott River catchment area, rising acid leaching from acid-sulphate soils.

This combination of factors has significantly reduced freshwater flows into the Blackwood and has led to increased periods of stratification of oxygen-depleted water, which are detrimental to those fish occupying the deeper reaches of the river. Evidence of eutrophication has also been apparent since 2000 through increasing nutrient levels and the appearance of harmful blue green algae and dinoflagellates that has culminated in an increasing incidence of "fish deaths" and occasional ulcerated fish around Molloy Island and upstream.

This picture of declining health of the riverine and estuarine system of the Blackwood, and the knowledge that further development of the catchment, long-term climate change and falling rainfall levels are likely to occur, suggests that this detrimental environmental trend will continue.

Black Bream stocks in the Blackwood River Estuary are believed to have declined markedly during the last two to three decades, on the basis of anecdotal community advice that catches of this species have continued to fall and little evidence of significant recent recruitment of juvenile Black Bream. Survey work undertaken by Murdoch University (Beckley *et al.* in press) points to a significant reduction in Black Bream catch by recreational fishers from the river and estuary to about one sixth of that taken in 1973/74 in 2005/2006.

This fall in catch is despite similar orders of magnitude of fishing effort being applied over both surveys.

World-acclaimed research on a restocking trial for Black Bream using aquaculture produced fingerlings, which were chemically tagged for identification and monitoring purposes, proved very successful. A total of 220,000 Black Bream juveniles were introduced in 2001 and 2002 at a cost of ~$0.50 per released fish. The restocked Black Bream were monitored and followed through to maturity. Because of high survival (i.e. 35% over 12 months and 16% to minimum legal length MLL of 250 mm), the cost of each stocked fish that survived to reach the MLL was estimated to be only $1.60, exclusive of the cost of monitoring. Monitoring and chemical tagging increased the cost to $2.19 per fish for each recruit entering the fishery. Restocking of Black Bream in the Blackwood was thus very cost effective and therefore potentially a viable ongoing management option.

The participants at the workshop, when considering the results presented and their implications for management of the Black Bream stocks, made the following observations:

➢ The limited annual Black Bream recruitment in the Blackwood River Estuary over recent years was not apparent in other permanently open south-western Australia estuaries or indeed in other intermittently open estuaries such as Stokes Inlet, Pallinup River and the Moore River.

➢ There is some as yet unidentified unique aspect of the current Blackwood estuary environment and its impact on the Black Bream population that has led to limited recruitment since the early 1980s.

➢ The high survival of restocked fish and subsequent high contributions (in excess of 80%) of these fish to total catches over 3 years, demonstrates that the residual abundance of wild Black Bream in the Blackwood River Estuary is low. Low reported commercial and recreational catches support this view.

➢ The workshop postulated that failure of recruitment could be a result of environmentally-induced changes which;

(a) results in unusually high mortality of larval and/or juvenile wild Black Bream, or

(b) produced conditions that were not conducive to spawning and therefore led to very low levels of breeding stock and thus limited ability to generate sufficient eggs and juvenile fish to allow population recovery. Continued fishing of residual stocks will exacerbate this problem.

➢ Management options to provide for the recovery of the black bream fishery in the Blackwood estuary include:

- a temporary cessation of all black bream extraction;
- a significant pulse of restocking at an order of magnitude greater than that undertaken in the research program; or
- an ongoing annual program of lower-level restocking over years.

It was noted that the first two management alternatives were aimed at addressing an inadequacy of breeding stock. An ongoing program of restocking would be necessary if some environmental factor in the river or estuarine system, which affected larval survival or recruitment of wild bream juveniles in early life stages, was irreversible or too costly to effect.

➢ Each of these management options have pros and cons and may need further evaluation which was beyond the scope of the workshop. This could include a level of risk evaluation. However, practically, the earlier that management action is taken, noting normal population lag effects, the greater the benefit and the sooner that Black Bream stocks may return to historical levels.

➢ A one or two year pulse restocking of juvenile black bream into the Blackwood estuary, at a magnitude of scale greater than that which occurred in 2001 and 2002, offers an immediate pathway for adaptive management and potentially greater social and economic benefits. This approach, linked with a program of monitoring and research, could assist in evaluating the following objectives:

(i) Assess and identify any environmental factors affecting larval and early juvenile Black Bream survival in the Blackwood River Estuary.

(ii) Determine timing and optimum sizes for restocking juvenile black bream.

(iii) Identify any density-dependent factors from restocking impacting on survival, growth and recovery of restocked fish into the Blackwood estuary and subsequent contribution to the fishery.

(iv) Assess lower cost options for mitigation of any environmental factors identified impacting on black bream larvae or juvenile survival.

(v) Identify lower cost breeding and hatchery options *in situ* at the Blackwood River Estuary for ongoing restocking in the event that ongoing restocking remains the only viable long-term management alternative.

(vi) Consultation with and involvement of the community in the development of adaptive management solutions for maintaining and improving the Black Bream fishery in the Blackwood River Estuary for community benefit. This could require further assessment of different management and funding options not considered thus far for restocking and environmental mitigation. Options should include various tagging and licensing approaches, which could assist in management, monitoring and fishing.

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2. The Workshop Summary

2.1 Restocking in estuarine and marine environments

Stock enhancement and restocking into estuarine and marine environments is a relatively new discipline, marked by the publication of the Blankenship and Leber (1995) paper on responsible approaches to stock enhancement and restocking and the first International Symposium on Stock Enhancement and Sea Ranching (ISSER) in 1997 (Bergen, Norway, Howell *et al.* 1999). Formal definitions for stock enhancement and restocking are currently being developed following the third ISSESR in 2006 (Seattle, United States, Bell *et al.* in prep.). Currently, the working definitions for these terms are:

Restocking - the release of cultured juveniles into wild population(s) to restore severely depleted spawning biomass to a level where it can once again provide regular, substantial yields. This may involve re-establishment of a species where it is locally extinct to rebuild a fishery, or for conservation purposes.

Stock enhancement - the release of cultured juveniles into wild population(s) to augment the natural supply of juveniles and optimise harvests by overcoming recruitment limitation. Note that recruitment limitation is the rule, rather than the exception for marine species with pelagic larvae in open ecosystems, even when spawning biomass is at the desired level (Doherty, 1999; Bell et al., 2005).

From the workshop proceedings, the spawning biomass of the Black Bream population in the Blackwood River Estuary is probably severely depleted and this species warrants consideration as a case for a major restocking program in the Blackwood (see below).

2.2 Black bream in the Blackwood

The Black Bream *Acanthopagrus butcheri* is an estuarine species that is highly prized by recreational and commercial fishers in temperate Australia. During the workshop, it was reported that over 60% of the people using the Molloy Island Caravan Park and over 50% of recreational fishers interviewed in 2005-06 were seeking to catch Black Bream (Beckley and Prior, this workshop). Recreational fishing on the Blackwood is a major attraction to the

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region, with an estimated 10,000 people visiting the Blackwood in 2005-06 to fish on the river (Beckley and Prior, this workshop). In 2005-06, anglers spent an estimated 72,000 h fishing, catching about 132,000 fish and releasing about 70,000 of these fish. Catch rates of recreational fishers in 2005-06 were much lower (only about 10%) than those recorded in 1974 (Caputi 1976, Lenanton 1977, Beckley and Prior, this workshop).

Black Bream is found in many of the estuaries along the west and south coast of temperate Western Australia and from genetic studies, there is little movement of fish between estuaries (Potter et al. in press). This species spawns in the upper reaches of estuaries in south-western Australia and there appears to be a link between spawning success, juvenile recruitment and the level of freshwater flow in these systems. In the Gippsland Lakes, Victoria, spawning of this species takes place in waters of 20 ppt salinity and the juveniles are found in shallow waters with aquatic vegetation (Hindell, this workshop). It is significant that, in recent years, environmental flows in the Blackwood have typically been lower than in the 1970s, resulting in marine water moving further up the estuary. The estuary has subsequently become more stratified and periods of low dissolved oxygen have been recorded (Robb and Forbes, this workshop, see below).

Since the major survey of the Blackwood in 1974, fish have been surveyed again in the 1990s and since 2002 as part of a trial restocking program in the Blackwood (Potter *et al.* in press, Jenkins *et al.*, this workshop). These surveys have found very few 'wild' juvenile Black Bream. Anecdotal reports from the workshop indicate that fish in spawning condition are present in the estuary. This species is also known to spawn under a variety of conditions once water temperatures reach those required for spawning (Jenkins, Sarre, pers. comm. at the workshop). These reports suggest that the low numbers of juveniles recorded in the Blackwood in recent times may be due to poor survival at the larval or juvenile stages of development. Workshop discussions supported investigating factors contributing to the successful survival and growth of the larval and juvenile stages of Black Bream in the Blackwood and in an estuary on the south coast where healthy populations of bream are currently found, e .g. the Pallinup.

2.3 Environmental conditions in the Blackwood

Extensive sampling of the water quality in the Blackwood has been carried out by the Department of Water over the last five years (Robb and Forbes, this workshop) and provides a basis for comparison with conditions in 1974 (ref from Anne Brierley, this workshop). In general, recent conditions in the region have been characterised by low rainfall and thus also river flow. Marked differences in salinity and dissolved oxygen levels of the surface and bottom waters of the Blackwood have been found over many months, *i.e.* the estuary becomes stratified and poorly mixed for extended periods (Robb and Forbes, this workshop). The very low levels of dissolved oxygen in the bottom waters reported over several months are cause for great concern as they are likely to affect the populations of fish and benthic invertebrates. Although the levels of nitrogen and phosphorus in the system are relatively low, acid discharges have been recorded and the catchment of the Blackwood has extensive areas of acid sulphate soils (Hales, this workshop).

The Blackwood Basin Group has identified the following threats to the system (Hales, this workshop):

1. salinity;
2. exotic/feral fish (redfin, yabbies);
3. increasing sediment and nutrient loads;
4. increasing acidification arising from exposure and disturbance of acid sulphate soils, noting that the Hardy Inlet is surrounded by these soils, particularly along the Scott River, where extensive clearing has taken place; and
5. increasing potential for ground water extraction from the Blackwood catchment.

Overall, the water quality in the Blackwood is poor and has declined significantly since 1974 (Robb and Forbes, this workshop).

2.4 Trial restocking and potential for further restocking

A very successful collaborative FRDC project between Challenger TAFE (Fremantle) and Murdoch University has investigated restocking Black Bream into the Blackwood River (Jenkins et al. this workshop, Potter et al. in press). Mature fish were taken from the Blackwood, spawned and the larvae reared at Fremantle and marked using a chemical mark of the ear-bones (otoliths). A total of 70,000 juvenile Black Bream (70 mm in total length and about 6 months old) were released in 2002 and 150,000 fish (smaller and younger fish) in 2003. The recapture rates of the released fish were very high compared to those of the wild fish (3 to 10 times higher). The released fish also grew well, although slightly slower than wild fish, and reached maturity in the Blackwood, indicating that they are likely to contribute to the spawning stock in the estuary. The costs of producing released fish and monitoring them in the Blackwood have been estimated as AUD$2.19 per fish ($1.60 per fish if they are not monitored). The marks in the fish are still evident 5 to 6 years after marking, showing that the populations could continue to be monitored. The results of the trial restocking are very encouraging and received international recognition of the quality of the work and the potential for restocking to rebuild the Black Bream population at the 3rd International Symposium on Stock Enhancement and Sea Ranching (*Jenkins et al.* this workshop). The next logical sequence of research to build towards a major restocking program would be to:

1. continue to monitor the 2002 and 2003 releases over the next 2 years;
2. collect and evaluate information on the genetic composition of the wild population and the released individuals;
3. investigate reasons for slower growth and for later and possibly reduced maturation of restocked fish;
4. investigate larval and juvenile survival in the system;
5. discuss with various groups the potential for a major responsible restocking program to:
    a. define objectives;
    b. establish protocols;
    c. identify risks.
6. Build support for a major program of responsible restocking (Blankenship and Leber 1995, Leber 2002, Molony et al. 2003).

2.5 References

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Appendix 1: The Workshop Schedule 26 February 2007

The decline of black bream in the Blackwood River Estuary: is restocking an ongoing requirement?

0930	***Opening by Dr Patrick Hone - Executive Director Fisheries Research and Development Corporation***
0935	***Ian Stagles – Chair of the WA Fish Foundation*** Introduce topic and set the scene for the morning
0945	***Dr Patrick Hone (Fisheries R&D Corporation)*** Priorities For stock enhancement, fish stocking and stock recovery in Australia
1000	***Professor Neil Loneragan (Murdoch University)*** Outcomes from the 3rd International Symposium on Stock Enhancement and SeaRanching in Seattle, USA September 2006
1015	***Dr Anne Brearley (University of WA)*** Historical insights of the Blackwood River Estuary
1030	***Dr Malcolm Robb/Dr Vanessa Forbes (Department of Water)*** Environmental Report on the Blackwood River, including the 2006 fish-kill
1045	***Morning Tea***
1115	***Greg Hales (Blackwood Basin Group)*** Environmental impacts on the Hardy Inlet – a community perspective
1130	***Paul Close (Department of Water)*** Managing estuarine systems for biodiversity – the influence of environmental flows
1145	***Dr Rod Lenanton – WA Department of Fisheries*** Management of fishing activities in degraded estuaries
1200	***Dr Lynnath Beckley (Murdoch University) and Sheryn Prior*** Blackwood River creel survey
1215	***Dr Jeremy Hindell (Dept of Primary Industries – Victoria)*** Black bream in the Gippsland Lakes
1230	***Greg Jenkins (Aquaculture Development Unit - Challenger TAFE)*** Restocking the Blackwood River Estuary with black bream *Acanthopagrus butcheri*
1245	***Lunch***
1345	***Ian Stagles/Dr Patrick Hone*** Summary of presentations and scene setting for the workshop
1355	***WORKSHOP - Facilitator Dr Bernard Bowen***
1630	***Summary of the workshop and the next step***
1645	***Close***

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Appendix 2: The Workshop Participants

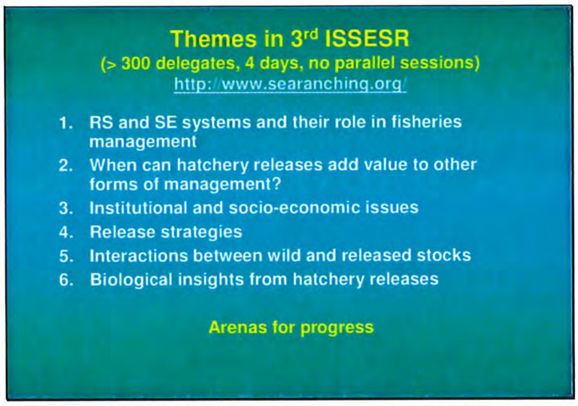
Dr Bernard Bowen (Facilitator)
Mr Ian Stagles (Chair - WAFF)
Mr Frank Prokop (Recfishwest/FRDC)
Dr Anne Brearley (UWA)
Mr Greg Jenkins (ADU)
Mr Wally Parkin (WAFF Board Member)
Mr Matt Barwick (FRDC)
Mr Barry Dawes (Augusta Rec. fisher)
Mr Dan Machin (ACWA)
Dr Patrick Hone (ED - FRDC)
Dr Peter Rogers (Former ED - DOF)
Mr Richard Stevens (WAFIC/FRDC)
Dr Steve Blake (WAMSI head)
Dr Gavin Sarre (CYOC TAFE)
Mr Trevor Blinco (Chair - ACWA)
Dr Jeremy Hindell (Victoria DPI)
Mr Trevor Price (Augusta Com. Fisher)

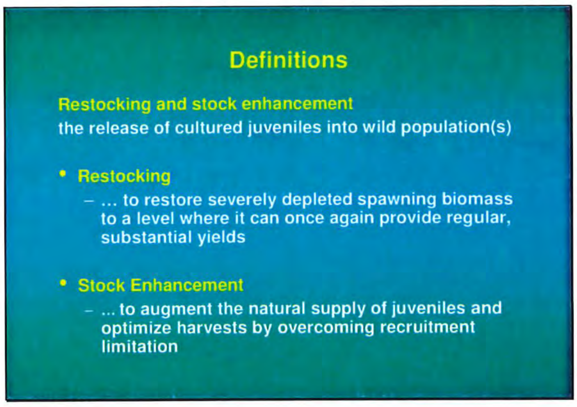
Professor Neil Loneragan (MU)
Professor Ian Potter (MU)
Dr Lynnath Beckley (MU)
Dr David Morgan (MU)
Ms Sheryn Prior (MU)
Professor Norm Hall (MU)
Mr Dan French (MU)
Dr Alex Hesp (MU)
Dr Steve Beatty (MU)

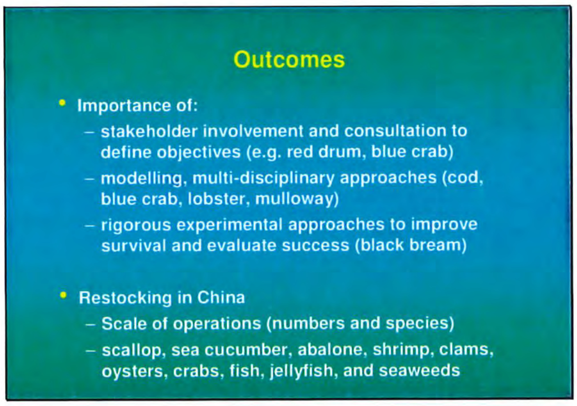
Dr Rod Lenanton (DOF)
Dr Kim Smith (DOF)
Mr Ian Curnow (DOF)
Dr Gary Jackson (DOF)
Mr Michael Burgess (DOF)
Mr Andrew Cribb (DOF)
Dr Simon de Lestang (DOF)
Mr Craig Astbury (DOF)
Mr Jason Froud (DOF)

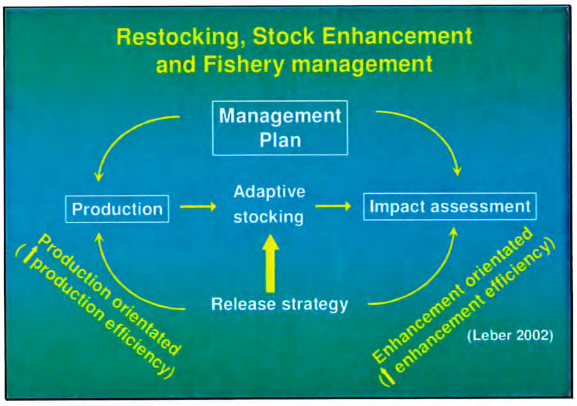
Mr Greg Hales (Blackwood Basin Group)
Ms Jackie Hasler (NRM – Blackwood)
Dr Malcolm Robb (DOW)
Dr Vanessa Forbes (DOW)
Mr Paul Close (UWA)
Ms Leanne Thompson (DEC)
Dr Ernie Stead-Richardson (AMRS)
Ms Linda Raynor (Blackwood Basin Group)
Ms Joanna Hugues Dit Ciles (SW Catchments Council)
Ms Barbara Dunnet (Pres. of Nannup Shire)
Ms Verity Steptoe (DEC)
Mr Paul McCluskey (DEC)
Mr John Lloyd (DEC)

Appendix 3: Presentations/Summaries





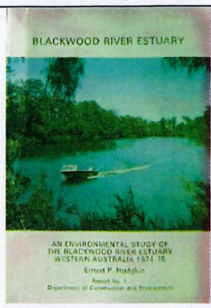




Historical insights of the Blackwood River Estuary - Hardy Inlet

Dr Anne Brearley
School of Plant Biology

The University of Western Australia



Objections

- Life style changes with 'heavy industry Augusta (retirement, tourism, holiday town)
- Aesthetics of mining
- Destruction of natural fish & bird populations.

Why Study the Blackwood in 1974?

Applications for mining mineral sands (east near mouth & dredging (estuary near Augusta & Molloy Is)

'Little is known about the ecology of Hardy Inlet and the possible effects of the mining proposal on it. No scientific references can be found relating to this particular estuary and only limited research has been done in other possibly comparable areas. Most of this latter work has been specific to particular organisms rather than the overall structure and balance of the estuary system.'

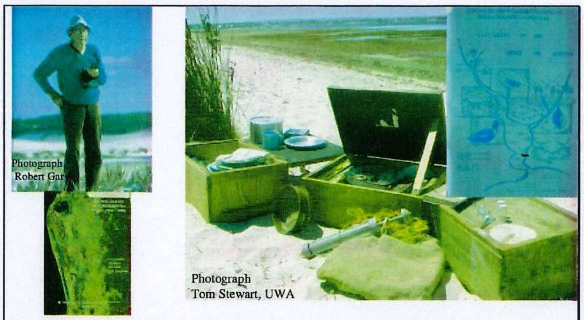
The study had two primary objectives:
Short term. 'To attempt to predict the probable effects of mining and dredging in the estuary and environs'.
Long term 'To understand the working of the Blackwood estuary ecosystem as the basis for making decisions about the management of this and other estuaries of south west Australia'.

Studies undertaken and coordinated by Hodgkin were primarily a general assessment of the estuary ecosystem

A separate report '*The anticipated Effects of dredging in the Blackwood Estuary*' was prepared by the Estuarine and Marine Advisory Committee (EMAC) and submitted to the EPA.

Components of the Study

- Hydrographic survey, ocean tide recording and prediction Dr W.S. Andrews, Mr D.F. Wallace and specialist staff. Harbours and Rivers Branch Public Works Department
- Water characteristics: Dr J. Imberger, Mr H. J. Agnew, Dr J. Billings, Dept Mathematics and mechanical Engineering, UWA with assistance Mr E.M. Copley of Augusta
- Sedimentary studies; sedimentary history and granulometric analyses: Dr B.W. Logan & Mr Z.A. Sas, Geology Dept. UWA, Sediment cores by Harbours and Rivers Branch Public Works Department
- Aquatic flora and plant nutrient: Mr R.A. Congdon, R.A. Dr A.J. McComb, Botany Dept. UWA
- Invertebrate aquatic fauna: Mr J. Wallace and Mr R.C.J. Lenanton WA Dept of Fisheries and Wildlife.
- Fish biology: Mr R.C.J. Lenanton
- Water birds: Mr J.A.K. Lane WA Dept of Fisheries and Wildlife.
- The fishery: Mr R.C.J. Lenanton, R.C.J. & Mr N. Caputiwith assistance of Mr G. Blowfield of Augusta to operate the 'Creel Census'.
- Recreational Use of the are; data from holiday log registers Mr N. Caputi, N. & Mr R.C.J. Lenanton.
- Tourism: Miss C.R. Bayley-Jones, School of Environmental and Life Sciences, Murdoch University.
- Social and demographic characteristics and population attitudes. Mr B.E. Woller, Department of Social Work, and Mr K.J. Frawley, Department of Geography UWA.
- Economic aspects. Mr F.A. Fulbrook, Department if Economics, UWA
- Coordination Dr E.P. Hodgkin, WA Department of Conservation and Environment



Ernest Hodgkin explorations of SWANLAND - the South Coast trips - *Blue Books*

An interest continued until his death in 1998 aged 89, and after with the publication of his final paper: Hodgkin, E. P. & Hesp, P. (1998) Estuaries to salt lakes: Holocene transformation of the estuarine ecosystems of south-western Australia, *Marine and Freshwater Research*, **49**, 183–201. And his bequest through the National Trust.

Increasing salt & decline of freshwater species noted

Upstream of Bridgetown 1,000>. 3,000 ppm in 50 years Peck *et al.* 1973

Blackwood River Catchment 23,000 km^2,
Lake Grace & Lake Dumbleyung 300 m above sea level, 325 km in the east (Old and Mature Drainage), Rejuvenated Drainage (Boyup Brook to Nannup),
Bunbury Trough (Donnybrook Sunklands) (between the Darling Scarp and Dunsborough Fault)
Winter flow from wetter lower catchments. Floodwaters from all parts of catchment

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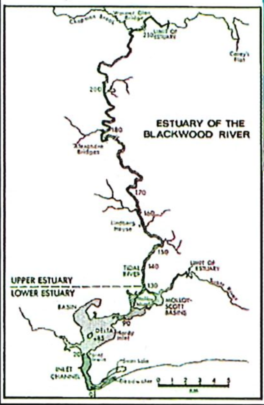
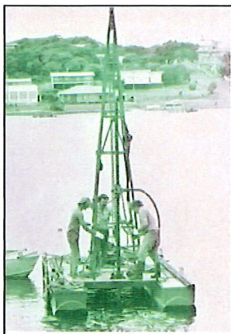
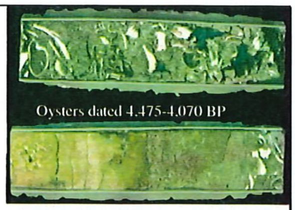
The System 1974

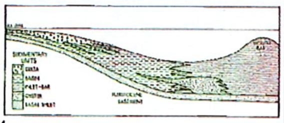


Upstream limit of marine water - 42 km (Warner Glen) rock bar. Tidal influence to Carey's Flat (55 km)

Some deep holes (22 m Stn. 150)Mouth and sea bar - wave built bar of mobile sand with a narrow deep tidal channel







Hardy Inlet Augusta, 1974.

Investigating the sediments - Evolution of the estuary

Lessons for the future - Relevance to predictions of sea level rise

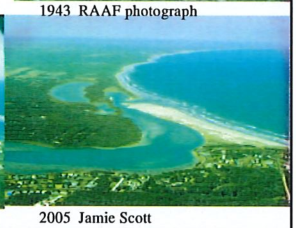
Adapted from Hodgkin, 1978

A story of moving sands

1833 Thomas Turner, Private Collection

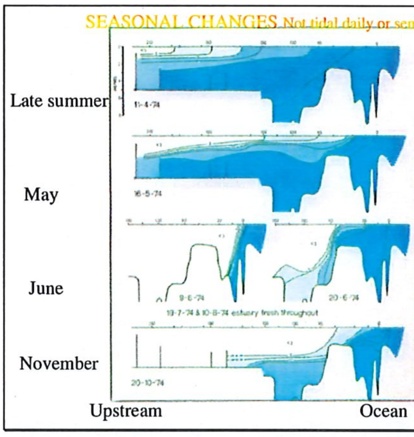
1943 RAAF photograph

1974 E.P. Hodgkin



2005 Jamie Scott

SEASONAL CHANGES Not tidal daily or semi daily tidal



Late summer: Marine water upstream to Warner Glen. Some freshwater at surface

May: Some freshwater flow

June: Freshwater throughout - marine water excluded - salinity profiles vertical

November: Freshwater flow declines. Salty marine water moves upstream along the bottom - Inlet is stratified (difference top to bottom - sharp difference Halocline

The water

Winter river flow

Summer 'tidal' influence (astronomic & barometric pressure)

inlet and basin about 30‰ salinity i.e. slightly less than seawater

Water column **mixing - winds** in main basin (resuspension of sediment)

Little wind mixing in remainder of system. Some mixing due to tidal flows creating turbulence

Stratification surface to bottom - most extreme to Alexander Bridge 10 ‰ at surface and bottom 25 ‰ for five months

Temperature - seasonal changes with some solar heating in shallow basin. Heating of deep tidal river: sun heats low salinity surface water & cools at night (well mixed), but upper salty water also warmed and moves upstream by tidal flows, trapped and does not mix and cool.

Oxygen (poorly studied) and deoxygenation only below halocline in tidal river in summer. CSIRO 1945-1952 Alexander Bridge, Rochford & Spencer 1953, 1955, 1956

Nutrients in Water & Sediments

- Phosphorus and Nitrogen relatively low concentrations during summer saline state
  - high during winter freshwater phase
- Sediment nutrients high relative to water column throughout the year
- Plant communities large mineral-nutrient pool

Identification, description and quantification of the role of fringing vegetation

Rushes (*Juncus krausii*) 300-1,300 g m^{-2} yr^{-1} or 1,000-4,500 tonnes dry weight
Paperbarks (*Melaleuca* sp.) 430 g m^{-2} yr^{-1}
Samphires (*Sarcocornia*)

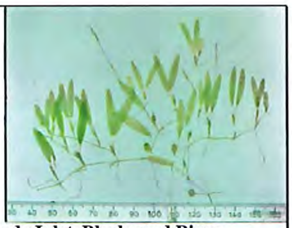
Little *Juncus* or *Melaleuca* detritus in water - presumed trapped *in situ*
Build up of organic matter and nutrients. Potential for discharge of nutrients when disturbed.

Larger aquatic plants - macrophytes

Algae
Not abundant, except for spring & summer blooms of
- Stonewort *Lamprothamnium* (Molloy Is)
- Green algae *Rhizoclonium* (Swan Lakes & Deadwater) washed into lower estuary

Green algae *Cladophora* & *Chaetomorpha* which grow excessively in (Swan, Peel & Walpole) were never abundant in the Blackwood
- Why? Adequate light for growth
- Absence due to short saline phase & lack of hard substrates
- No mention of nutrients

Seagrasses
Swan grass *Ruppia* in shallows & Deadwater (like Wilson Inlet)
Lepilaena
Ribbon weed *Potamogeton* (Molloy Is.)
Halophila decipiens (deep areas)
- Absence of *Halophila ovalis* (species in west coast estuaries, Albany & coastal bays



Hardy Inlet, Blackwood River
Deep, dark with muddy fine sediments.
Fresh to saline conditions
Seasonal appearance and disappearance
Halophila decipiens
John Kuo & Hugh Kirkman 1980s

No paddle weed *Halophila ovalis* Why not in the Hardy?Major sp in Swan, Peel-Harvey, Leschenault, Oyster Harbour, not in Wilson Inlet but in coastal bays

Phytoplankton
- Mainly diatoms
- No blooms in three years
- Low concentrations in open water Chlorophyll *a* 1.98 μL^{-1}
- Sediments higher Chlorophyll *a* concentrations
- Attributed to low nutrient concentrations when light flux high and water flowing

Macroscopic plants
- twenty species,
- most obvious summer marine phase, patchy, small biomass

Ruppia 700-1,900 tonnes (dry weight) yr^{-1}, *Juncus* 1,000-4,500, Paperbark (*Melaleuca*) 800 tonnes yr^{-1} - organic material > detritus,

Only *Ruppia* grazed (invertebrates, fish & birds) (Congdon & McComb 1981))

Invertebrates

Ecological Groupings
Benthic: 55 species of which 42 resident (breeding)
- •Confined to the tidal river and basin (3 species)
- •Throughout the estuary (9 species)
  - 3 polychaete worms
  - 1 bivalve mollusc
  - 3 amphipod crustaceans
  - 1 shrimp
  - I insect (Midge)
- •Only Lower Basin (4 species)
- •Rush fauna (5)

Greatest number species downstream (marine)
Decrease species upstream
Upstream increase in species with incursion of marine water (sun
Individual species habitat & biology
Food preferences
Benthic microalgae, bacteria, debris OR phytoplankton & suspended particles
Foraminifera
Zooplankton: Low abundances, Copepods (8 sp), Other Crustaceans (4 sp.), larvae of larger invertebrates

Stepped Venus clam or cockle *Katelysia scalarina* - common in the lower Blackwood estuary. Also found in south coast estuaries and occurred in west coast estuaries 3,500- 6,000 years ago
E.P. Hodgkin

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Fish

57 species 1974-75
found throughout the south west
more in common with other south coast estuaries than those of west coast
Lenanton 1974, 30 species -some not caught in 1974-75 survey

Groupings

Stenhohaline marine: water of 30-40‰ 17 sp e.g.Flathead, Mulloway
Euryhaline I: seawater to 15‰ 6 sp. e.g. garfish, sprat (2), old wife
Euryhaline II: seawater to 3‰ 11 sp. e.g. Aus. herring, Trevally, flounder (2)
Euryhaline III: seawater to <3 ‰
Resident: 5 sp. e.g. Black bream, gobies (3), hardyheads
Non resident: 7 sp. e.g. Mullet yelloweye & sea, whiting(2), silver bream, striped perch, long finned goby

18 species most abundant (bulk biomass) Euryhaline II & III.
Species considerably tolerant of reduced salinity.
Some Stenohaline marine species summer saline phase e.g. garfish.
23 of Stenohaline Euryhaline I species, essentially marine that use estuary as sheltered marine situation when salinity is favourable.
Two crab species and one prawn not common. Recruitment know to vary.

Fish Biology

Food and Feeding **Reproduction and recruitment**

The cobbler is thought to breed in the Swan and other estuaries but there no evidence that it can do so under the more extreme conditions of the Blackwood.

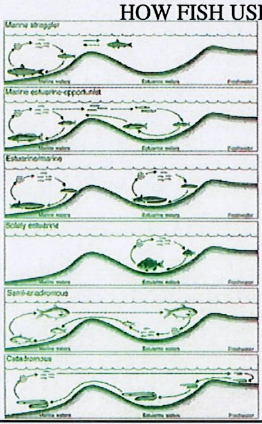
***Black bream** It should be noted that although the time and place of breeding is not known with certainty and **no juveniles** of this true estuarine species were caught, it almost certainly breeds in the estuary, probably in the upper reaches where young fish live among snags along the margins of the tidal river and are inaccessible to the sampling techniques used.*

*Favoured **nursery ground** by many common species, even though many common species spawn in it. Juvenile fish...a large proportion of the seine net catches* - importance of **Deadwater**

Fishing industry - commercial and recreational

Licenses: six 1979-1987, two Oct. 1998, one 2003.
1978 -2002 Catch 10-34 tonnes, black bream 1983 (3.6 t)
Recreational: black bream (20 t), yellowfin (13 t), Aust, Herring (9 t)

HOW FISH USE ESTUARIES



fan-bellied leatherjacket
giant herring
striped trumpeter

whiting
yellow-eye mullet
sea mullet
banded toadfish (blowie)

estuarine catfish - cobbler

Black bream
Yellow-tailed trumpeter
Hardyheads, some gobies

Perth herring

eels (not found in south-west)
Anadromous Passing through - pouched lamprey

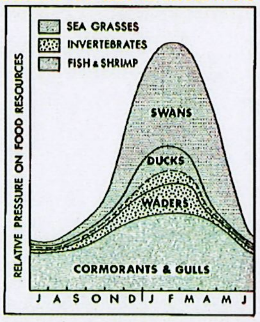
(Adapted from Potter and Hyndes, 1999.

Birdlife of the Blackwood

Resident species

Migratory waders

Waterfowl numbers increase over the summer months as inland waters dry out. Part of much larger populations.



Use of food resources throughout the year
Lane 1975, Hodgkin, 1978 Courtesy DoE

Why was the Blackwood study Special & Different?

First of this Scope - Range of expertise

Examined and synthesised information already available

New research by many different specialist & community involvement
Regular interaction between researchers

Unlike the Peel-Harvey and other studies since, there were no major environmental changes or decline in health of the system already evident (albeit comment on salinity &turbidity)

Foundations ongoing work of Hodgkin 25 + years - estuary form and evolution.

Development of Government Agencies expertise and responsibilities

Following consideration of the EMAC report on the Anticipated Effects of Dredging the EPA recommended that the dredging and mining applications should not be approved.
The mining company advised the Department of Mines that it did not wish to contest the various objections and, on its recommendation, the Mining Warden refused the applications on the 12 January 1977.

Similar mining undertaken at Beenup north of the Scott River subsequently developed, closed and the area currently undergoing rehabilitated.

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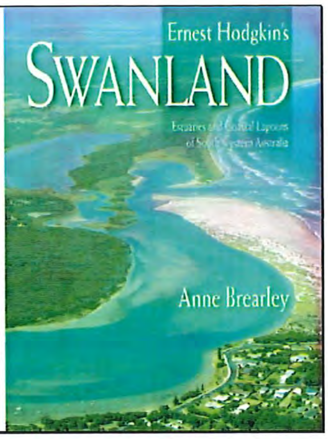
Born Madagascar 1908
Died Swanland1998

Ernest Hodgkin Trust

National Trust (WA)

UWA PRESS



Dr Ernest Pease Hodgkin - 'Hodge'

Born: Madagascar 1908

Died: Perth, Western Australia 1998

Educated in England

Work in Malaysia on mosquitoes as vectors of malaria

WW II moved Kuala Lumpur to Singapore

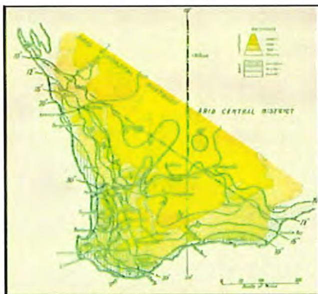
Mary and 4 children evacuated to Fremantle

Ernest interned in Changi Civilian Prison

Postwar at UWA - Ernest Zoology Dept. Mary Anthropology Dept.

Retirement? 1974

Consultant & Collaborator: Science of nutrients & algal blooms, Estuarine Study Series 'Blue Books', Member of the EPA, Chairman of the Museum Board



SWANLAND: Griffith Taylor 1915

'temperate region in Western Australia with a rainfall over 10 inches(250 mm) per annum'

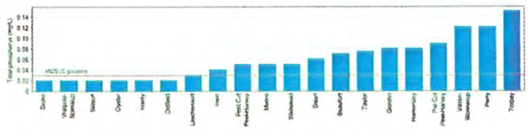
Mediterranean Climate - Winter rainfall

Jutson 2nd Edition 1934. The Physiography (Geomorphology) of Western Australia

Beenup Mine on the Scott River tributary of the Blackwood River, 2003

Mining ceased in 1999 following problems with acid sulfate soils. The sites is being rehabilitate.

Courtesy BHP Billiton



Total phosphorus in the estuaries of Swanland

Courtesy WRC (DoE)

Note Total nitrogen and Chlorophyll *a* graphs are similar but the rank orders of estuaries differ - dependant on the catchment soils and landuse

BUT ESTUARIES RECEIVE NUTRIENTS NATURALLY

THEY ARE PRODUCTIVE SYSTEMS - FISHERIES

GETTING THE BALANCE

Lake Dumbleyung, Blackwood River Catchment, October 1974

E.P. Hodgkin

Stages of isolation

- Permanently Open (Swan, Peel-Harvey, Hardy, Nornalup, Princess Royal, Oyster Harbour)
- Seasonally Open-closed (Wilson, Broke, Irwin)
- Normally Closed (Intermittently Open) (North: Bowes. South-east: Beaufort, Wellstead, Gordon, Fitzgerald, Dempster, Hamersley, Oldfield, Stokes)
- Permanently Closed (salt lakes)* (Culham??, Jerdacuttup)
  - *unusual rain events, rise in sea level, prolonged storms from one direction - Relevance of Climate Change

Implications

Oceanic exchange - salinity, entry of fish
Salinity, residence time of water
Build up of salt and nutrients

Types of algae, seagrass & animals

Technical reports

- Dynamics: Imberger, J., Agnew, H.J., Billings, J. & Wallace D.F.
- Holocence Sedimentation: Sas, Z.A.
- Botanical Studies: Congdon, R.A. & McComb, A.J.
- Macrobenthic Fauna: Wallace, J.
- Food of the Fish: Wallace, J.
- Ecology of Fish and Commercial Crustaceans: Lenanton, R.C.J.
- Birdlife: Lane, J.A.K.
- Estimation of Catches by Amateur and Professional Fisherman 1974-75: Lenanton, R.C.J. & Caputi, N.
- Survey of the Recreational Usage of the South Coastal Estuaries Caputi, N. & Lenanton, R.C.J.
- Perception of Environmental Change of Augusta: Frawley, K.J.
- Attitudes Towards Environmental Change in the Blackwood River Area: Wooller, B.E.
- Augusta Tourism May 1975: Bayley-Jones, C.R.
- Recreation versus Sand Mining. An economic appraisal: Fulbrook, F.A.
- Surface geology and Economic Mineral Prospects Hardy Inlet and Hinterland: Geol. Survey
- Anticipated Effects of Dredging in the Blackwood River Estuary: Estuarine & Marine Advisory Committee

Chapter 6
Hardy Inlet and estuaries of the Naturaliste-Leeuwin Ridge

Drawn by Thomas Turner, 1851

Courtesy Art Gallery of Western Australia

The report 1974-75

BLACKWOOD CATCHMENT

Climate Geomorphology Hydrogeology vegetation of the catchment Fauna of the river

THE ESTUARY - PHYSICAL FACTORS

Geomorphology Hydrographic survey Sediments River Flow Tides and other Water level changes Dynamics of te estuary Hydrology

BIOLOGICAL ASPECTS

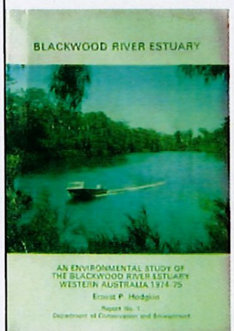
Character of the biotic environment Objectives of the study estuarine habitats

Trophic levels of the estuarine biota Vegetation and plant nutrients Zooplankton Detritus and the smaller benthic fauna Resident aquatic macrofauan Non-resident aquatic macrofauna Waterbirds Man An ecological assessment Singel species studies

SOCIAL ASPECTS

Demographic data
The resident population
Tourists and tourism
Historical: human impact on the environment

THE RETIREMENT YEARS?!



More students

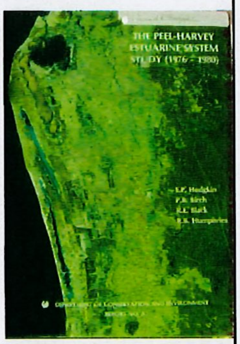
Consultant & collaborator

Science of nutrients & algal blooms

Estuarine Study Series 'Blue Books'

Member of the EPA

Chairman of the Museum Board



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Hardy Inlet Condition Summary
Dr Malcolm Robb

Current information on the Hardy Inlet shows the system to be eutrophic (nutrient enriched) and under stress, suffering symptoms of stratification and deoxygenation, increased algal growth, with the occurrence of potentially toxic algae and fish deaths. Specific areas in the Inlet that are a concern are the upper reaches of the Inlet around Molloy Island and the estuarine reaches of the Blackwood River.

Conditions of concern for the Inlet highlighted in this document include: sources of nutrients from the Blackwood and Scott River catchments, sources of nutrients released from the organic rich sediments, the increase in macroalgae along the shores of urban impact areas, sedimentation around the mouth of the Inlet, reduced flow into the Inlet (drying climate), fish kills and potentially toxic algae.

Survey and process understanding studies of biotic (plant and animal) response and sediment enrichment from organic loading and nutrient enrichment are required in conjunction with assessment of social values of the local community. Capture of this information type is required before a complete assessment of the current condition of the Inlet and predictions for the future can be made.

The drying climate in conjunction with increased water abstraction is exacerbating the symptoms of organic loading. For example water levels in, and flows from, the Scott River are at historical lows and the water is clear of tannin colouring. With the lack of flushing and increased light penetration algal growths are occurring in the vicinity of Molloy Island, possibly in response to septage discharge from the island.

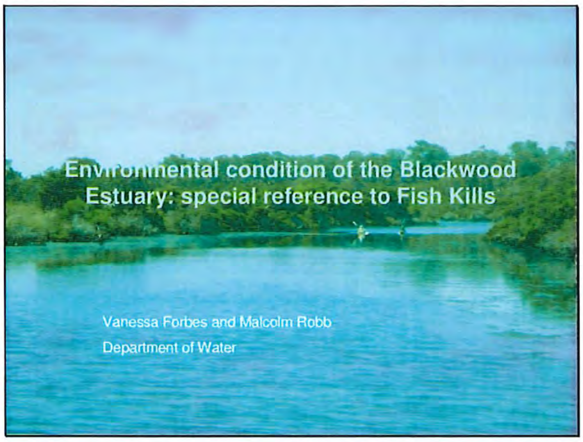
Low flows from the Blackwood and increased salt water intrusion is leading to increased density stratification which has the effect of preventing wind mixing of oxygen through the water. The organic rich sediments consume oxygen when they break down leading to low oxygen (hypoxia) or no oxygen (anoxia) in reaches above Molloy Island resulting in fish deaths and the growth of potentially toxic dinoflagellates which favour stratified conditions.
Management Actions should focus on reducing losses of nitrogen, phosphorus and organic matter from the catchment. Resource condition targets for Total Nitrogen (TN) and Total Phosphorus (TP) can be set for the catchment. Immediate attention should be given to taking the residents of Molloy Island off septic tanks.

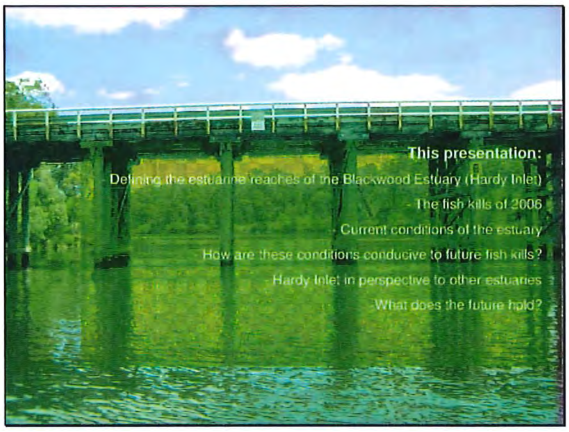
For the estuary resource condition targets can be set for oxygen in the area from Molloy Island upstream and algal occurrence in the vicinity of Molloy Island. It is recommended that studies on sediment nutrient accumulation and release be made from which resource condition targets for denitrification can be set as a measure of the success in reducing nutrient and organic loading.

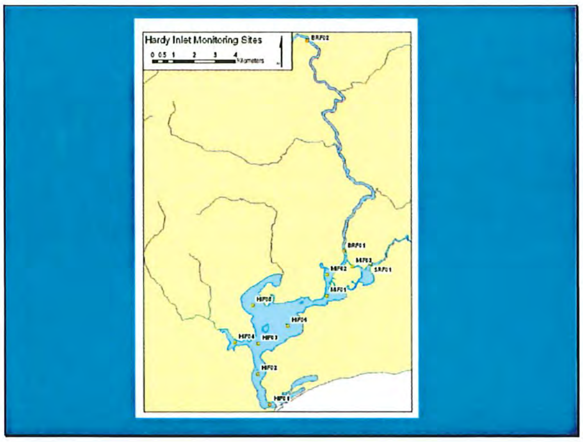
Surveys of seagrass and macroalgae coverage, depth distribution and condition should be made to understand the plant response and vulnerability of the estuary and possibly to develop targets. Maintaining the biodiversity of fringing vegetation communities is important.
Approximately 78 % of the Hardy Inlet catchment (Blackwood River catchment and the Scott Coastal Plain) has been cleared. The Blackwood River catchment and the Scott coastal plain are both heavily modified by land-use and economic activity, including a diverse suite of agricultural activities, such as vegetable and fruit production, cut flowers, cropping and stock farming.

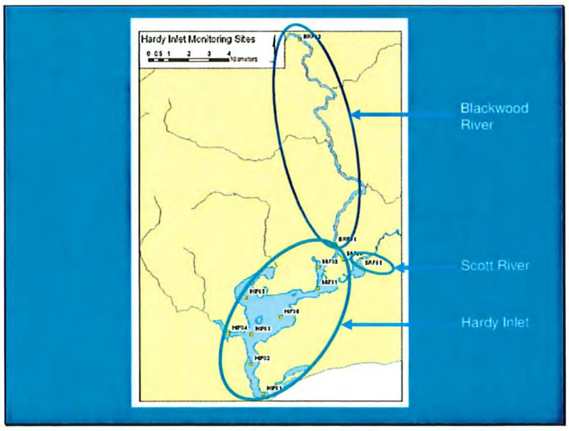
Progressive clearing of the catchment and changes in land use have changed the characteristics and quality of river flow in the catchment of the Hardy Inlet. Conditions of concern in the catchment include contributions of nutrients, sediments and salt loads to river flow which reaches the Inlet, a reduction in flow as a result of groundwater abstraction and land use practises that increase the risk of exposure of acid sulphate soils.

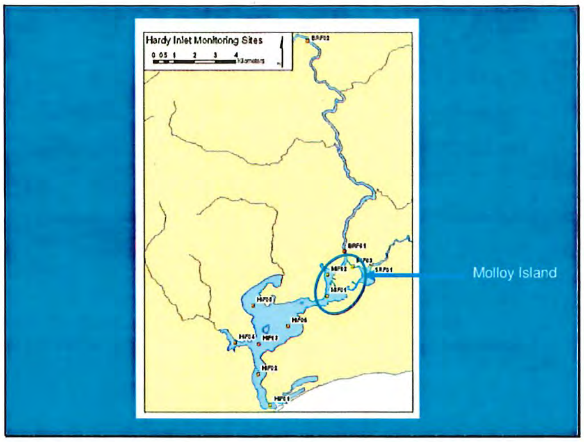
Fish kills from low oxygen land and nuisance algal growth can be expected for the foreseeable future under low flow conditions. Only concerted effort in substantially reducing nutrient and organic loading to the estuary will ameliorate the deterioration of the estuarine water quality. Much of this effort is catchment based. Immediate attention should be given to taking the residents of Molloy Island off septic tanks.

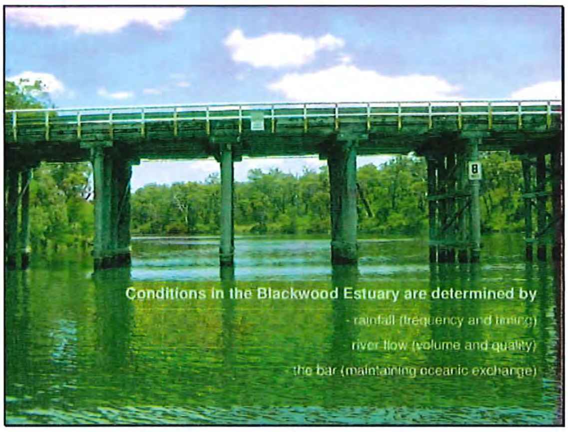


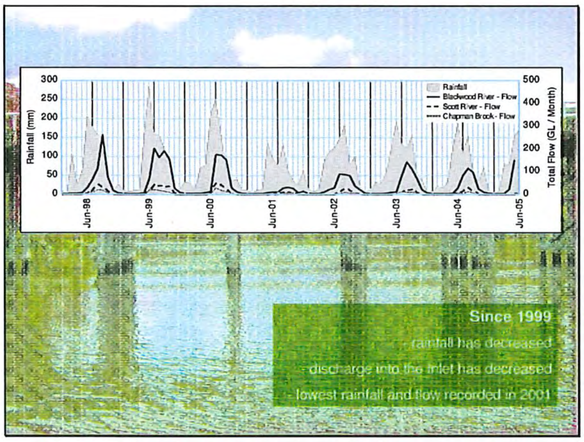


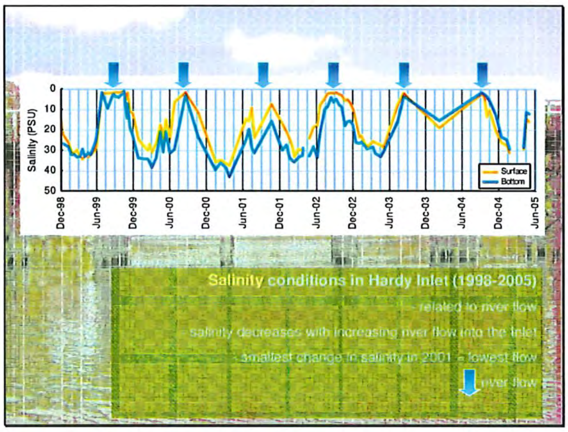


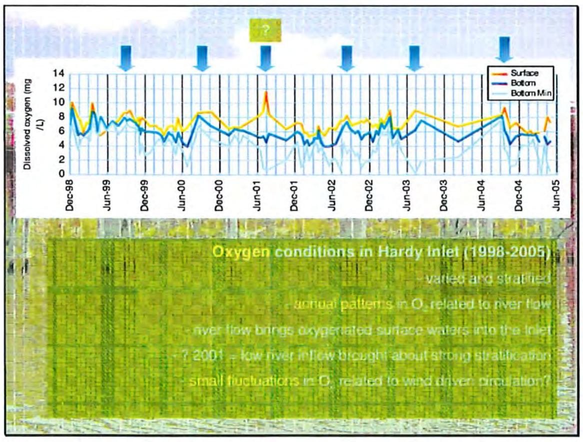


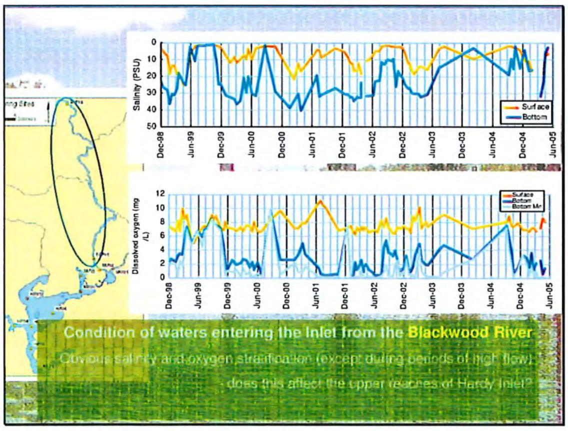












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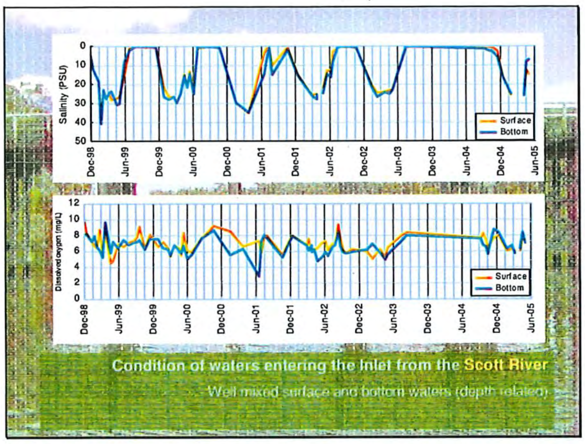

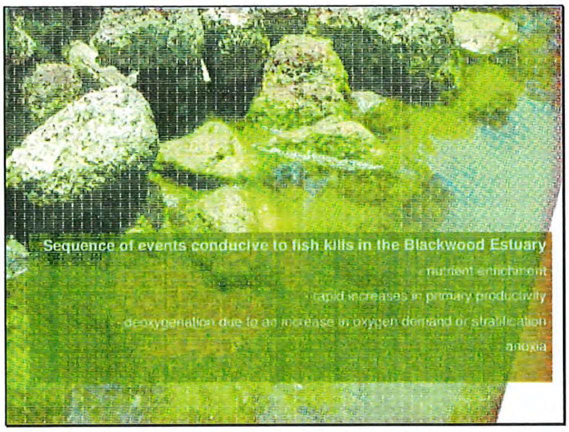

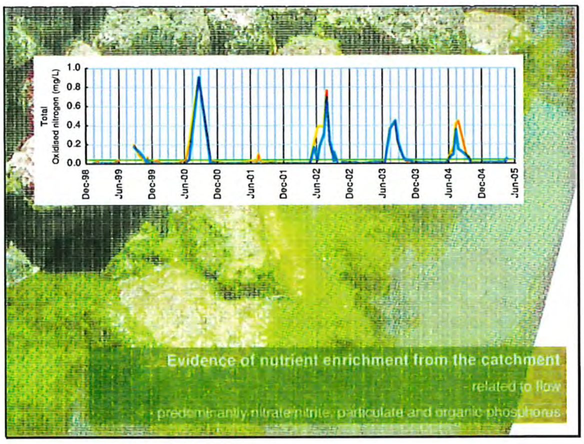

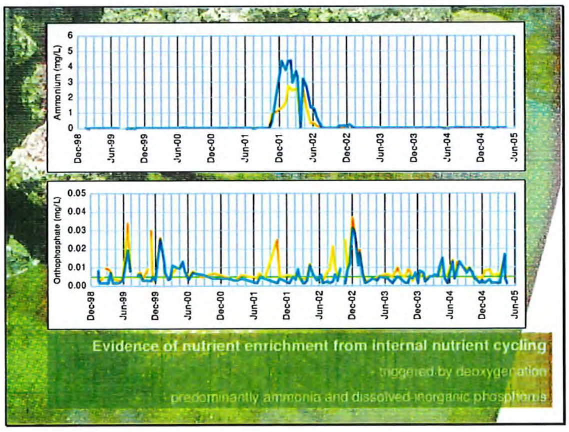

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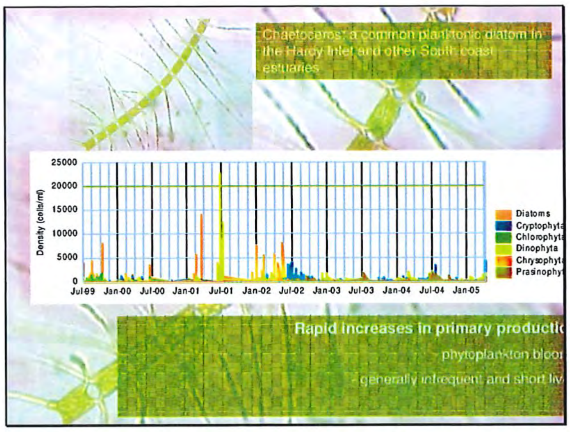

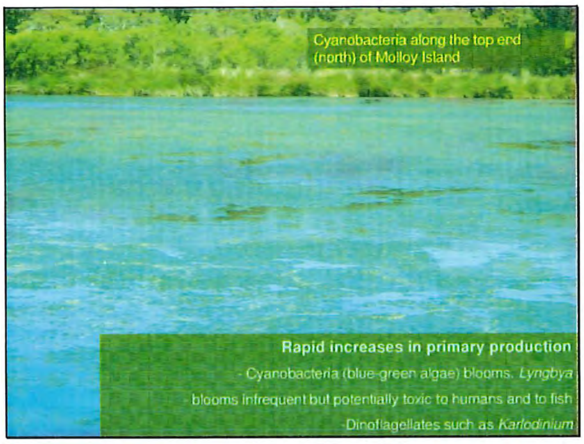

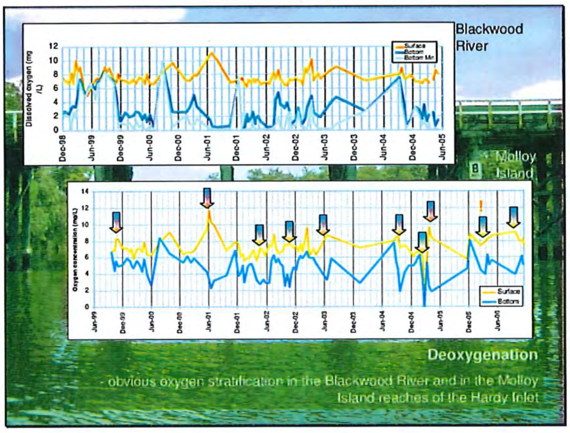

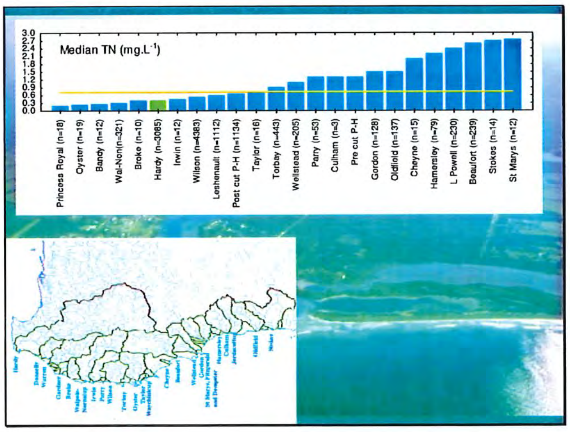

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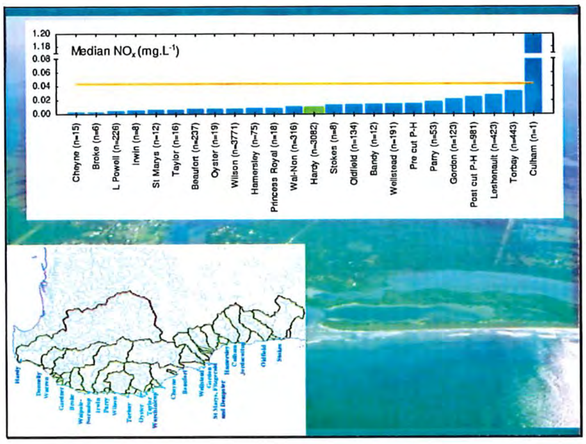

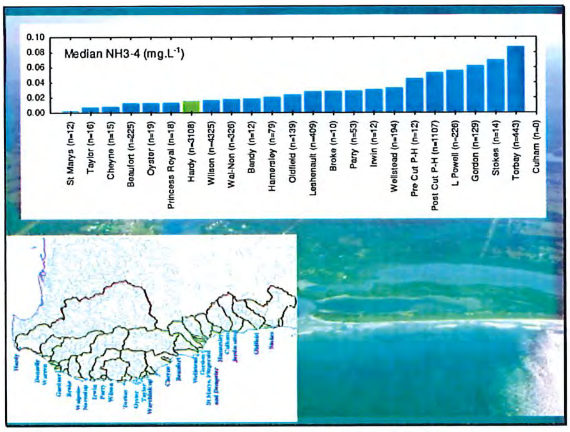

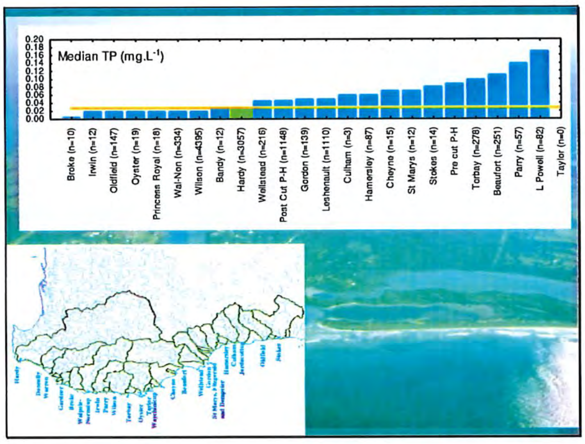

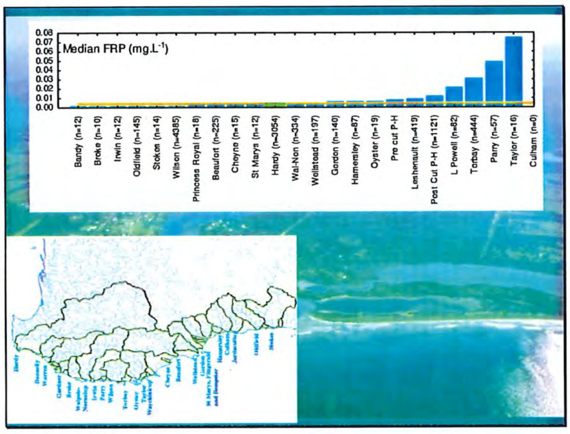

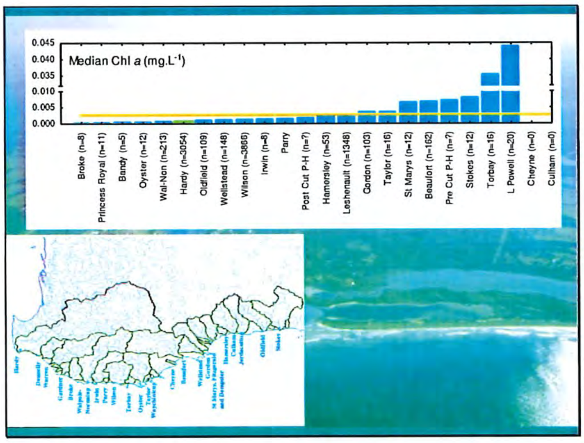

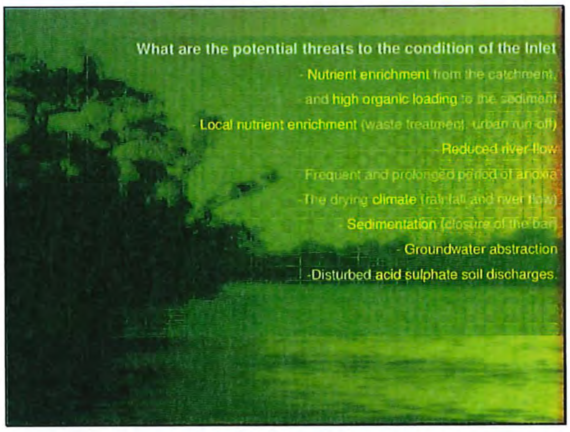

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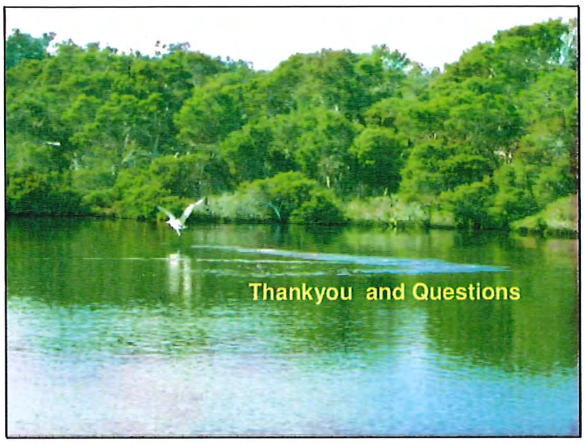

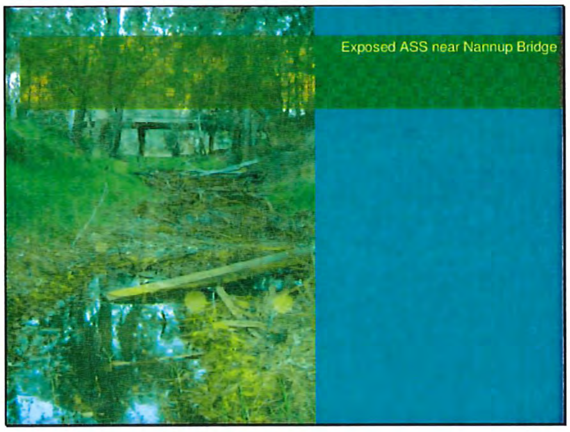

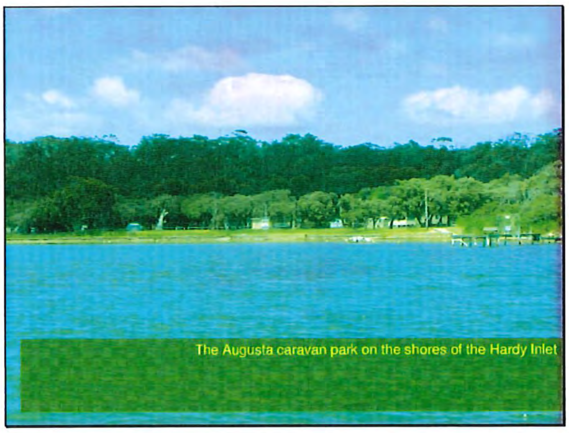

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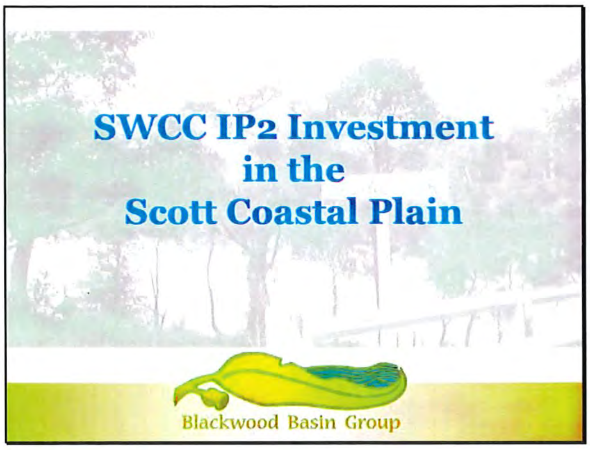

Environmental Threats

- Salinity
  - Over I million tonnes per year.
  - Investigations occurring into release of hypersaline water from Lake Dumbleyung
- Feral Fish
  - Redfin, Yabbies on way (salinity will drive demographics)
  - Already a reduced range for Marron
- Nutrients
  - Sand Plugs filling in river pools and habitat
  - Natural process exacerbated by land practices
- Acidity
  - Hardy Inlet surrounded by ASS

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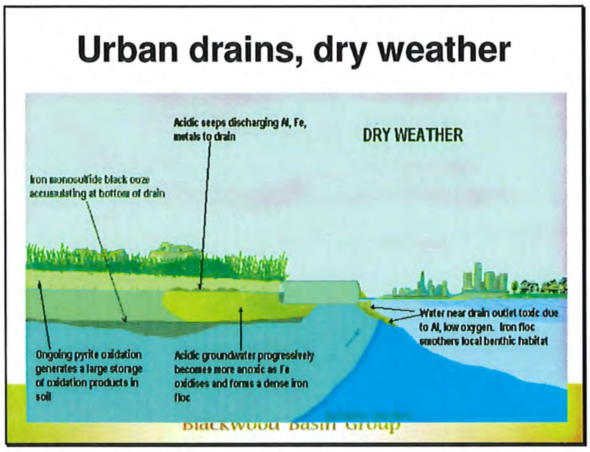

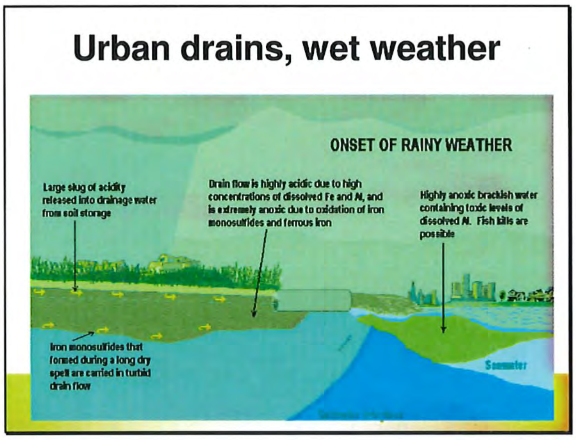

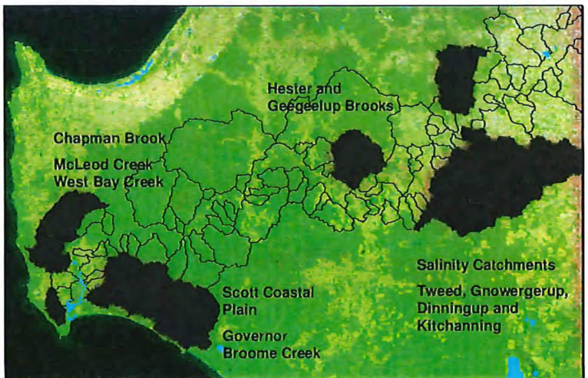

11 Location of Current projects to protect the Blackwood Estuary

Caring for Water - 1

Blackwood River Mouth Study

Investigation of Options to Reduce the Risk of Closing of the Blackwood River Mouth:

- To prepare an Report detailing the options available for a permanent mouth opening at the Hardy Inlet.
- Indications are that the River mouth will close off in summer, resulting in flooding of the Turner Caravan Park and some riverside residential areas. This report will investigate the options available for modifying the flow regimes to reduce the risk of Mouth closure, As well as identify the preferred site for an opening.
- To provide recommendations to Key Stakeholders, including the Shire of Augusta Margaret River and Dept Planning and Infrastructure, on the preferred option.
- The consultancy will communicate widely with all stakeholders, including the community on socioeconomic benefits of a permanent opening.

Blackwood Basin Group

Caring for Water -2

Improving Water Quality in the Scott River and Hardy Inlet

1. Water quality improvement and management and on-ground works:
   - River restoration focussing on creek stabilisation and reducing erosion. -
   - Working with landholders and regulators to assist in the effective implementation and monitoring of agricultural Best Management Practices to reduce or eliminate nutrients leaching from farms. -
   - The work will also target some rural drainage issues. -
2. DSS and Monitoring: -
   - To establish, operate and maintain an integrated monitoring program
   - To develop and refine a DSS for the Scott Coastal plain.-
   - To develop decision support systems at farm and catchment scale specific to the area and also specific to the needs of land managers and support professionals.

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Caring for Water -3

Improving nutrient management on farms in the Scott River:

- Review existing nutrient management projects to establish Best Management Practices
- Augment existing soil testing to establish baseline conditions and repeat over time to monitor efficacy of treatments
- Audit BMP implementation and conduct farm scale nutrient balance studies and landuse to feed into DSS
- Promote and implement small catchment pilot projects to demonstrate BMPs
- Water quality monitoring for small catchments to examine efficacy of BMPs
- Promote BMPS through
  - Workshops
  - Demonstration sites
  - Written materials

Blackwood Basin Group

Other Programs in the Scott

Acid Sulphate Soils:

- Review existing management projects to establish Best Management Practices
- Augment existing soil testing to establish baseline conditions and repeat over time to monitor efficacy of treatments
- Promote and implement small catchment pilot projects to demonstrate BMPs
- Water quality monitoring for small catchments to examine efficacy of BMPs
- Promote BMPS through
  - Workshops
  - Demonstration sites
  - Written materials

Blackwood Basin Group

Thank you

Greg Hales

Program Manager

Phone (08) 9765 1555

Email gregh@westnet.com.au

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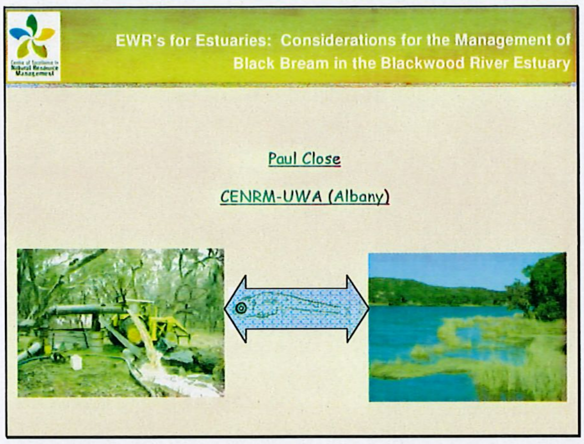
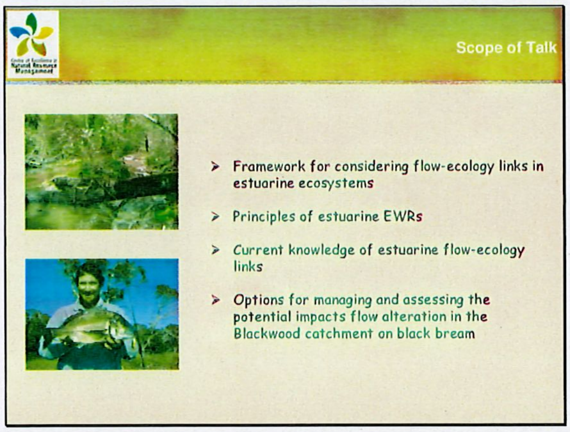
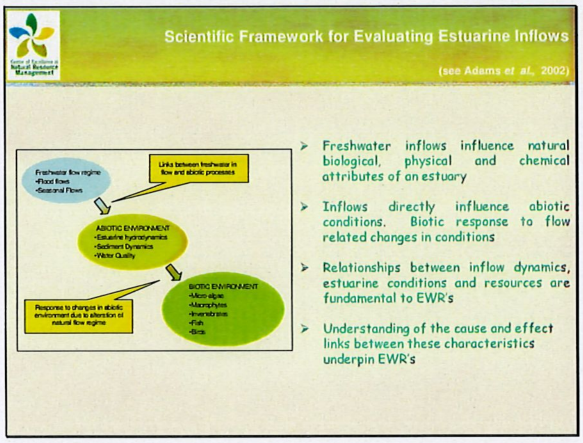


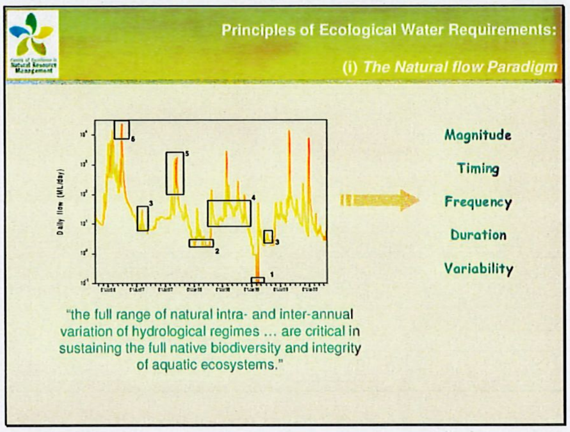
EWR's for Estuaries: Considerations for the Management of Black Bream in the Blackwood River Estuary
Paul Close
CENRM-UWA (Albany)



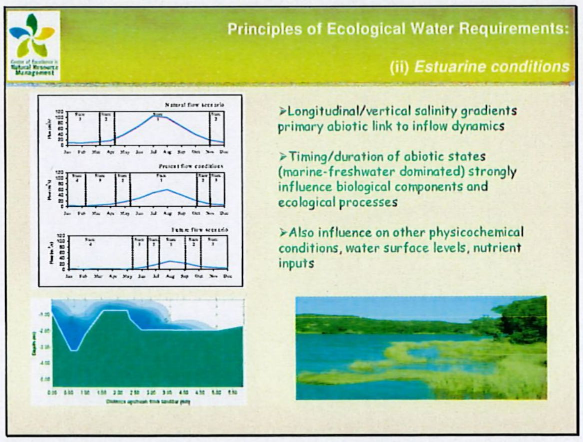
Scope of Talk
Framework for considering flow-ecology links in estuarine ecosystems
Principles of estuarine EWRs
Current knowledge of estuarine flow-ecology links
Options for managing and assessing the potential impacts flow alteration in the Blackwood catchment on black bream



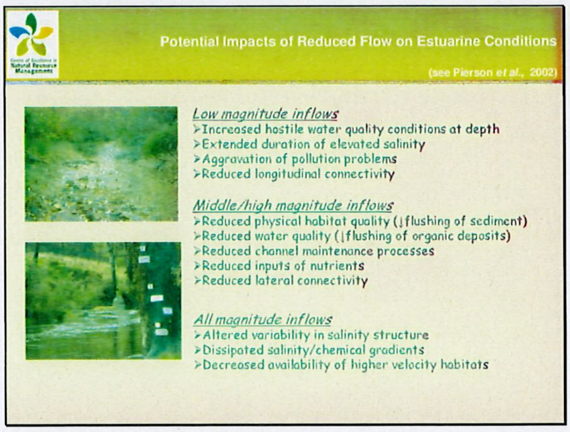
Scientific Framework for Evaluating Estuarine Inflows
(see Adams et al., 2002)
Freshwater flow regime
-Flood flows
-Seasonal Flows
Links between freshwater in flow and abiotic processes
ABIOTIC ENVIRONMENT
-Estuarine hydrodynamics
-Sediment Dynamics
-Water Quality
Response to changes in abiotic environment due to alteration of natural flow regime
BIOTIC ENVIRONMENT
-Micro-algae
-Macrophytes
-Invertebrates
-Fish
-Birds
Freshwater inflows influence natural biological, physical and chemical attributes of an estuary
Inflows directly influence abiotic conditions. Biotic response to flow related changes in conditions
Relationships between inflow dynamics, estuarine conditions and resources are fundamental to EWR's
Understanding of the cause and effect links between these characteristics underpin EWR's



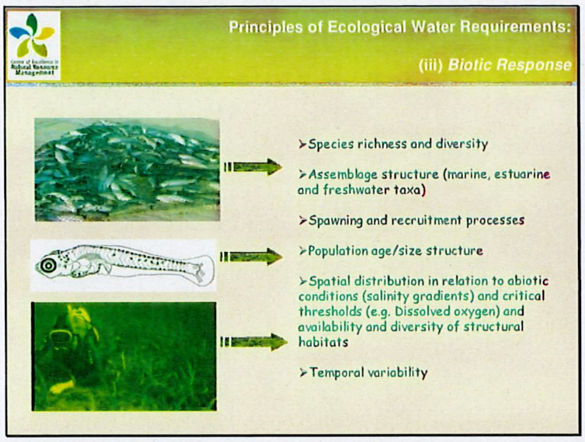
Principles of Ecological Water Requirements:
(i) The Natural flow Paradigm
Daily flow (ML/day)
Magnitude
Timing
Frequency
Duration
Variability
"the full range of natural intra- and inter-annual variation of hydrological regimes … are critical in sustaining the full native biodiversity and integrity of aquatic ecosystems."

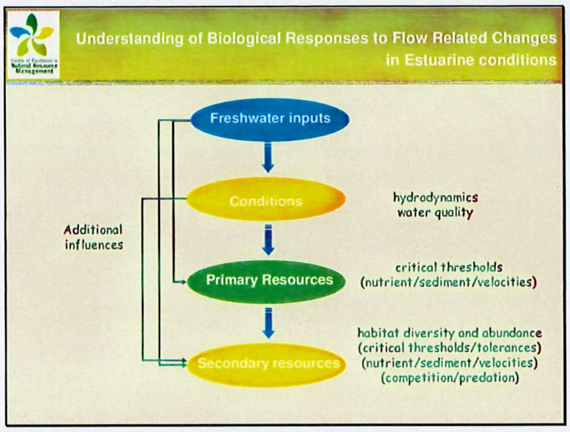


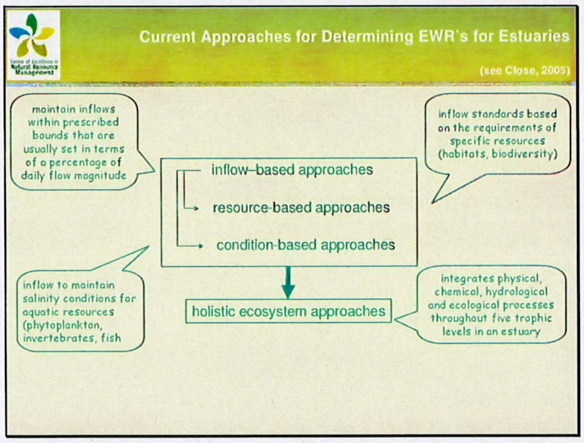
Principles of Ecological Water Requirements:
(ii) Estuarine conditions
Natural flow scenario
Present flow conditions
Future flow scenario
Longitudinal/vertical salinity gradients primary abiotic link to inflow dynamics
Timing/duration of abiotic states (marine-freshwater dominated) strongly influence biological components and ecological processes
Also influence on other physicochemical conditions, water surface levels, nutrient inputs

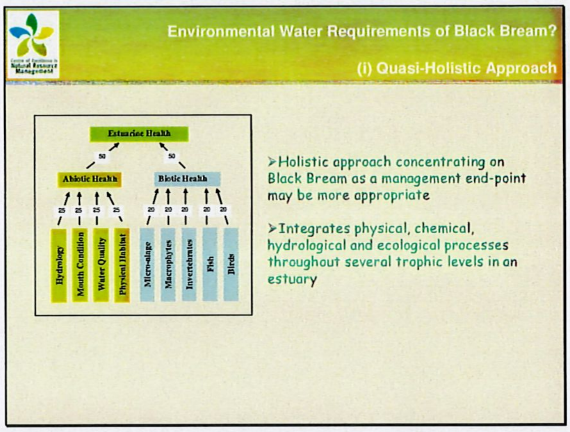


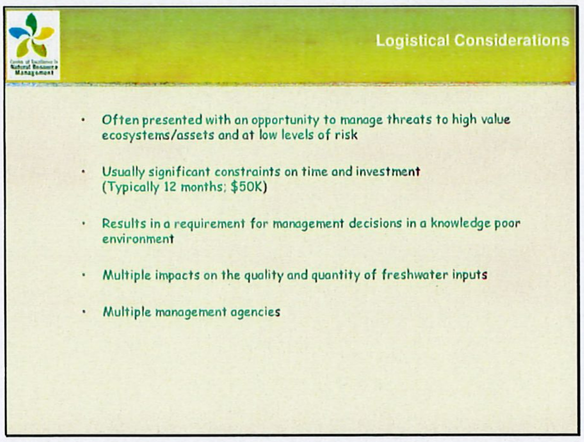
Potential Impacts of Reduced Flow on Estuarine Conditions
(see Pierson et al., 2002)
Low magnitude inflows
Increased hostile water quality conditions at depth
Extended duration of elevated salinity
Aggravation of pollution problems
Reduced longitudinal connectivity
Middle/high magnitude inflows
Reduced physical habitat quality (↓flushing of sediment)
Reduced water quality (↓flushing of organic deposits)
Reduced channel maintenance processes
Reduced inputs of nutrients
Reduced lateral connectivity
All magnitude inflows
Altered variability in salinity structure
Dissipated salinity/chemical gradients
Decreased availability of higher velocity habitats

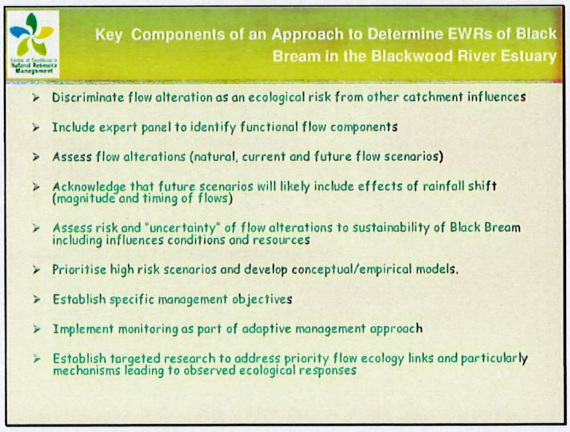

Principles of Ecological Water Requirements:
(iii) Biotic Response
➢Species richness and diversity
➢Assemblage structure (marine, estuarine and freshwater taxa)
➢Spawning and recruitment processes
➢Population age/size structure
➢Spatial distribution in relation to abiotic conditions (salinity gradients) and critical thresholds (e.g. Dissolved oxygen) and availability and diversity of structural habitats
➢Temporal variability


Understanding of Biological Responses to Flow Related Changes in Estuarine conditions
Freshwater inputs
Conditions
Primary Resources
Secondary resources
Additional influences
hydrodynamics
water quality
critical thresholds
(nutrient/sediment/velocities)
habitat diversity and abundance
(critical thresholds/tolerances)
(nutrient/sediment/velocities)
(competition/predation)


Current Approaches for Determining EWR's for Estuaries
(see Close, 2005)
maintain inflows within prescribed bounds that are usually set in terms of a percentage of daily flow magnitude
inflow standards based on the requirements of specific resources (habitats, biodiversity)
inflow-based approaches
resource-based approaches
condition-based approaches
holistic ecosystem approaches
inflow to maintain salinity conditions for aquatic resources (phytoplankton, invertebrates, fish
integrates physical, chemical, hydrological and ecological processes throughout five trophic levels in an estuary


Environmental Water Requirements of Black Bream?
(i) Quasi-Holistic Approach
Estuarine Health
50
50
Abiotic Health
Biotic Health
25
25
25
25
20
20
20
20
20
Hydrology
Mouth Condition
Water Quality
Physical Habitat
Micro-algae
Macrophytes
Invertebrates
Fish
Birds
➢Holistic approach concentrating on Black Bream as a management end-point may be more appropriate
➢Integrates physical, chemical, hydrological and ecological processes throughout several trophic levels in an estuary


Logistical Considerations
• Often presented with an opportunity to manage threats to high value ecosystems/assets and at low levels of risk
• Usually significant constraints on time and investment (Typically 12 months; $50K)
• Results in a requirement for management decisions in a knowledge poor environment
• Multiple impacts on the quality and quantity of freshwater inputs
• Multiple management agencies


Key Components of an Approach to Determine EWRs of Black Bream in the Blackwood River Estuary
➢ Discriminate flow alteration as an ecological risk from other catchment influences
➢ Include expert panel to identify functional flow components
➢ Assess flow alterations (natural, current and future flow scenarios)
➢ Acknowledge that future scenarios will likely include effects of rainfall shift (magnitude and timing of flows)
➢ Assess risk and "uncertainty" of flow alterations to sustainability of Black Bream including influences conditions and resources
➢ Prioritise high risk scenarios and develop conceptual/empirical models.
➢ Establish specific management objectives
➢ Implement monitoring as part of adaptive management approach
➢ Establish targeted research to address priority flow ecology links and particularly mechanisms leading to observed ecological responses

Management of Fishing Activities in Degraded Estuaries

Rod Lenanton
Josh Brown
Sue Turner
Research Division
Department of Fisheries
Government of Western Australia

Fish for the future

Outline

- Management of estuarine finfish resources
- "Decision rules" for the application of fisheries management tools to restore depleted estuarine finfish stocks
- Examples of the approach used to manage some Western Australian estuarine finfish resources in WA
- Some issues to consider in the ongoing management of the Blackwood River Estuary finfish stocks

Fish for the future

Background

- Identification of "Blackwood/Hardy Inlet" issues came from public submissions from FMP 131 (1999) – "Management direction for WA's estuarine and marine embayment fisheries"
- This led to the release of FMP 169 (2004) – "Hardy Inlet Estuary Fishery Management issues and options"
- Other key sources of information:
  - Arlighaus, R., Mehner, T. & Crowx, I.G. (2002) Reconciling traditional inland fisheries management and sustainability in industrialized countries, with the emphasis on Europe *Fish and Fisheries* 3, 261-316.
  - Molony, B.W., Lenanton, R., Jackson, G. & Norris, J. (2003) Stock enhancement as a fisheries management tool. *Reviews in Fish Biology and Fisheries* 13, 409 - 432

Fish for the future

Management of Estuarine Finfish

- The "traditional" assessment of the status of marine finfish stocks usually assumes that the environment/habitat is not degraded
- However assessment of the status of estuarine/inland stocks must, by definition include consideration of the condition of the fish habitat, which in most cases is degraded to some extent (i.e.stocks below optimum productivity)

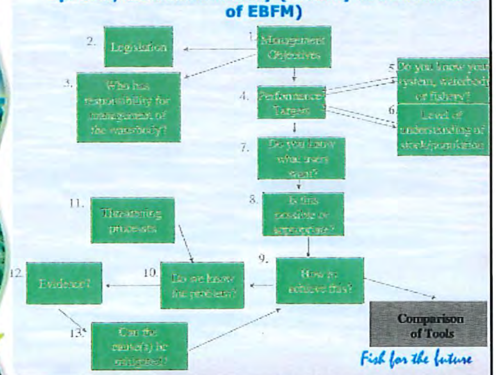
Fish for the future

Application of Fisheries Management Tools

- 4 major steps involved in the decision to modify or introduce management arrangements to restore depleted finfish resources.
  1. Review of all information on the ecosystem, species, stock and fishery
  2. Comparison and identification of appropriate management tools
  3. Implementation of the chosen approach
  4. Monitoring and further refinement of management

Fish for the future

1. Review of all information of the ecosystem, species, stock and fishery (broadly in the context of EBFM)



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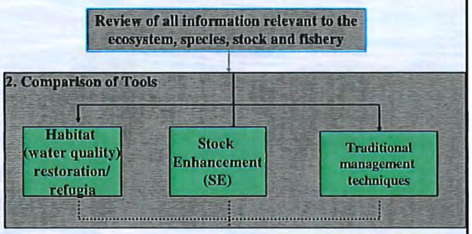
Comparison of Fisheries Management Tools



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Management of WA Estuarine Finfish

Commercial Fishing

- West Coast Estuarine Interim Managed Fishery - Swan, Peel Harvey & Blackwood River Estuaries
- Effort Reduction

	1996	2006
Peel Harvey	24	11
Blackwood	4	1

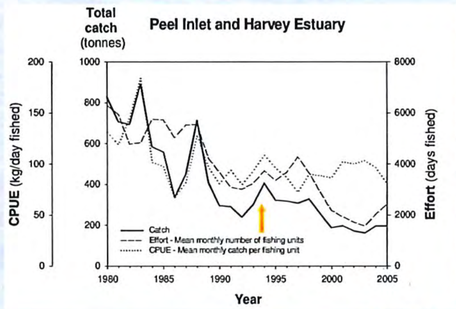
  - Latent effort
  - Real effort related to declining abundances in part due to degraded habitat
  - Adjustment to catch shares

Recreational Fishing

- Rec fishing is regulated, but explicit catch levels unmanaged

Fish for the future

Management of WA Estuarine Finfish



Fish for the future

Management of WA Estuarine Finfish

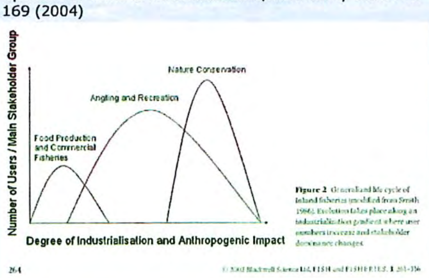
- Dawesville Channel construction designed to improve "quality" of the estuarine environment
- System became more marine
- Reinforced further by climate change
- Shift towards marine species
- Severely compromised recreational amenity as a result of the dominance of blowfish
- Ongoing "status" of fish stocks is often a consequence of non-fisheries (eg urban/rural/environmental) management issues

Fish for the future

Management of Fish Resources of the Blackwood

Some key issues that need to be considered:

- Update the views of all stakeholders/community since FMP 169 (2004)



Fish for the future

Management of Fish Resources of the Blackwood

- Management arrangements must lie within the broad framework of the objects of the Fish Resources Management Act, 1994
  - Need to develop specific fishery management objectives for the Blackwood. However the requirements of other Acts (DEC)may need consideration
- The commercial sector under formal (administrative) management plan with performance built around target catch range and the sustainability of key indicators (black bream, cobbler & King George whiting)
  - The recreational sector is regulated, but explicit catch levels unmanaged.

Fish for the future

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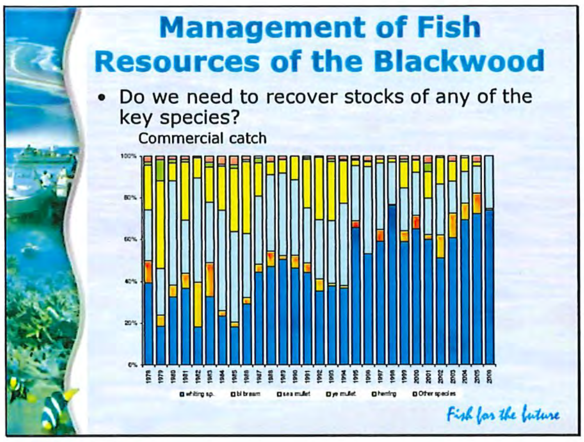

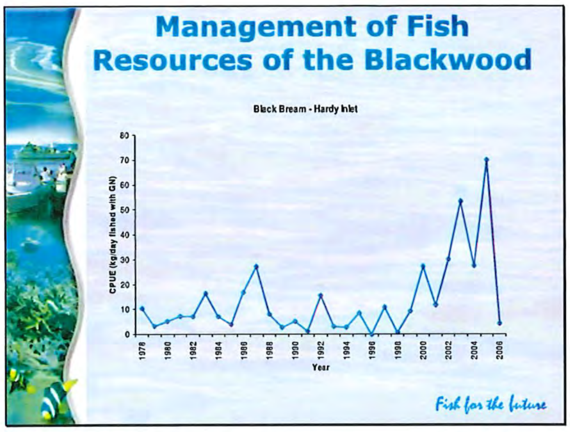

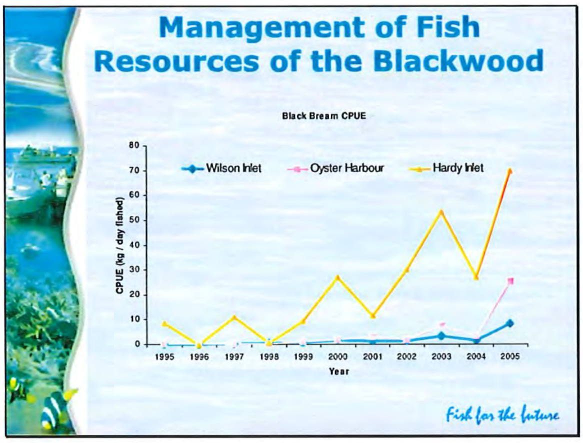

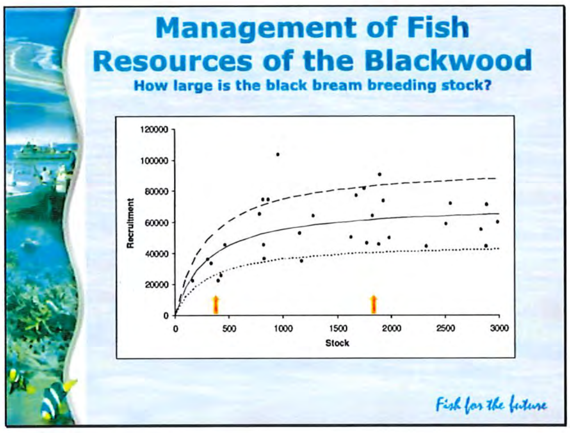

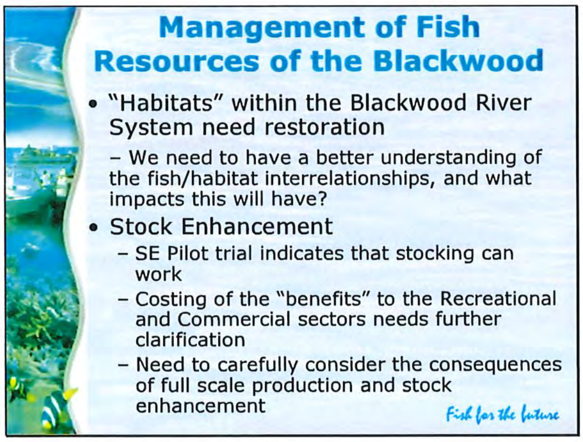

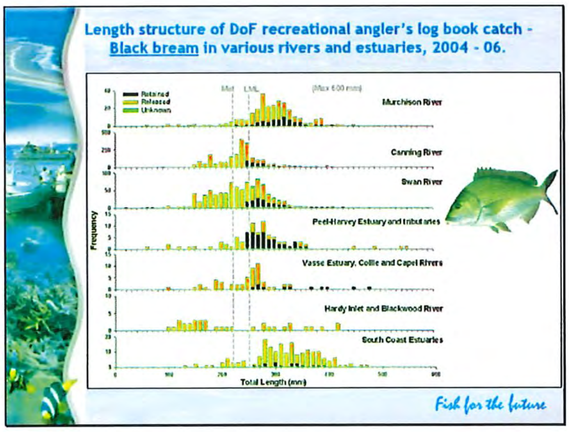

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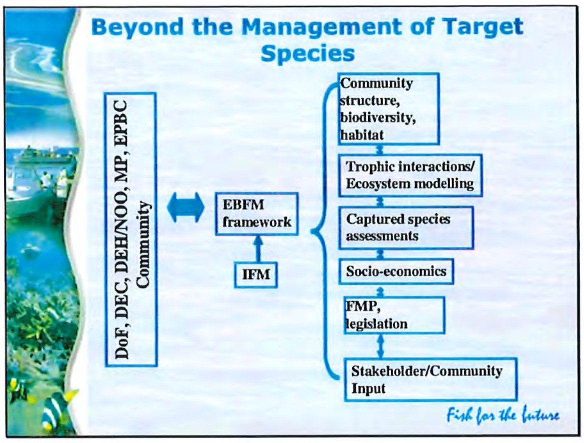
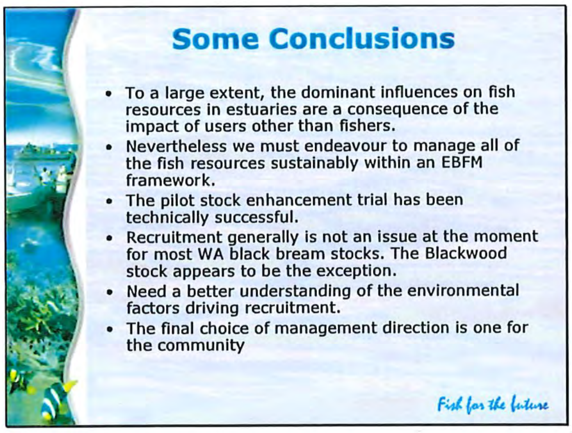

Beyond the Management of Target Species
DoF, DEC, DEH/NOO, MP, EPBC
Community
EBFM framework
IFM
Community structure, biodiversity, habitat
Trophic interactions/ Ecosystem modelling
Captured species assessments
Socio-economics
FMP, legislation
Stakeholder/Community Input
Fish for the future


Some Conclusions
• To a large extent, the dominant influences on fish resources in estuaries are a consequence of the impact of users other than fishers.
• Nevertheless we must endeavour to manage all of the fish resources sustainably within an EBFM framework.
• The pilot stock enhancement trial has been technically successful.
• Recruitment generally is not an issue at the moment for most WA black bream stocks. The Blackwood stock appears to be the exception.
• Need a better understanding of the environmental factors driving recruitment.
• The final choice of management direction is one for the community
Fish for the future

Black bream in the Blackwood: 2005-06 recreational fishing creel survey

Lynnath E. Beckley and Sheryn P. Prior
Centre for Fish & Fisheries Research, Murdoch University, 90 South Street, Murdoch, Western Australia 6150

The status of the recreational fishery in the Blackwood Estuary, south-western Australia, was quantitatively assessed via a boat-based creel survey from September 2005 to August 2006. Sampling was stratified by both season and day-type and, in total, was conducted on 144 days over the 12-month period. Daily sampling consisted of a count of number of anglers throughout the estuary (for fishing effort), and surveys of catches by boat-based and shore-based recreational anglers.

In total, interviews were completed with 1 212 angling parties. The retained catch of 2 631 fishes comprising 17 species was dominated by yellow fin whiting (47%) and Australian herring (17%). Although black bream only constituted 6% of the catch it was the most frequently targeted species (27%). Only 41% of the boat-based angling parties and 37% of the shore-based angling parties surveyed had retained fish at the time of interview. Nevertheless, compliance with minimum legal length regulations was found to be an issue, particularly for Australian salmon and King George whiting.

Fishing effort was greatest during summer and over the Easter period, when there were influxes of tourists to the region. More anglers were recorded on weekends and public holidays than weekdays in every month of the year except for December and January. Fishing from boats was recorded throughout the estuary, while shore angling was mainly concentrated in accessible locations near Augusta.

The overall catch rate was 0.835 (±0.044) fish retained/ angler/ h. Mean catch rate for black bream was 0.032 fish retained / angler/ h but for those specifically targeting black bream it was higher at 0.092 fish retained/ angler/ h. Total annual fishing effort was estimated to be 71 565 angling hours and total harvest was calculated to be 61 311 fishes. Approximately 8 tonnes of fish was harvested from the Blackwood Estuary by recreational anglers over the survey period, of which 1.26 tonnes was black bream.

Comparison with a similar 12-month creel survey conducted in the Blackwood Estuary in 1974-75 (Caputi 1976) showed some major differences. Catches were much lower in 2005-06, with the total estimated harvest (number of fish) less than a quarter of the previous study. Black bream dropped from the third most abundant species in the catch in 1974-1975 to sixth in 2005-2006. Although total annual fishing effort in the two surveys was remarkably similar, there was more shore-based effort in 2005-2006. The overall catch rate for 1974-75 was almost five times greater than the overall catch rate recorded in 2005-06.

Although coastal fish stocks in Western Australia are known to exhibit inter-annual variations in abundance, and effects of fishing in estuarine areas are difficult to distinguish from human-induced changes to the environment, the marked decline in the recreational catch and catch rates in the Blackwood Estuary over the past three decades is cause for serious concern.

Black Bream in the Gippsland Lakes
Dr Jeremy Hindell

The Gippsland Lakes system is one of Australia's largest estuaries. The Gippsland Lakes support valuable recreational and commercial fisheries. The most important species supporting these fisheries is black bream.

Commercial catch figures suggest that the black bream population is in decline. Recreational catch figures also support this. It is thought that the decline is related to recruitment failure – either because of spawning or larval/juvenile survival failure. There are some sectors of the fishery, however, that believe catches have decreased as a result of fish moving to areas where they are harder to catch. For the commercial fishery, this means up the rivers, where commercial fishing is not allowed.

A large acoustic telemetry program was initiated to determine the degree to which fish were likely to use the rivers versus the lakes. Thirty acoustic receivers were placed at strategic locations throughout the lakes system. Sixty fish were implanted with acoustic transmitters. The study was run over two years.

Results are preliminary, but there are several main findings:
1. Black bream survive surgery well – low mortality
2. Fish move extensively throughout the Gippsland lakes – some fish are moving more than 3000 km in a year
3. Fish move throughout the estuarine regions of rivers, and often move between rivers
4. During the study period, fish spent an average of 70% of their time in the rivers.

So, it is plausible that reduced commercial catches could be a reflection of fish spending more time up the rivers during a period of drought. However, most recreational catch is taken in the rivers, and this has also declined – despite fish spending more time in the rivers. It is likely, therefore, that the population of bream has declined.

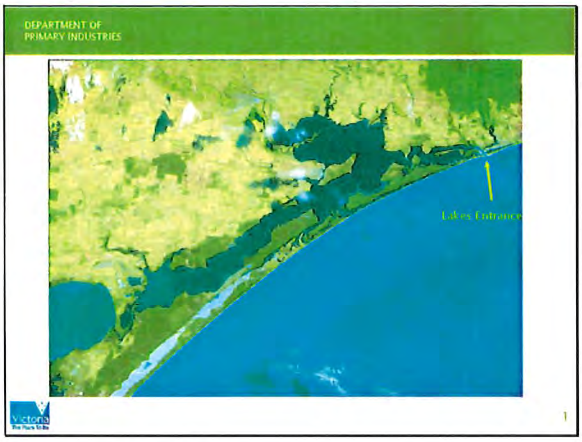
Reasons for the decline are unknown, but it is thought that early life-history failure due to unfavorable environmental conditions is a primary candidate. A new research program has been launched to investigate links among freshwater flows, water quality and early life-history dynamics.

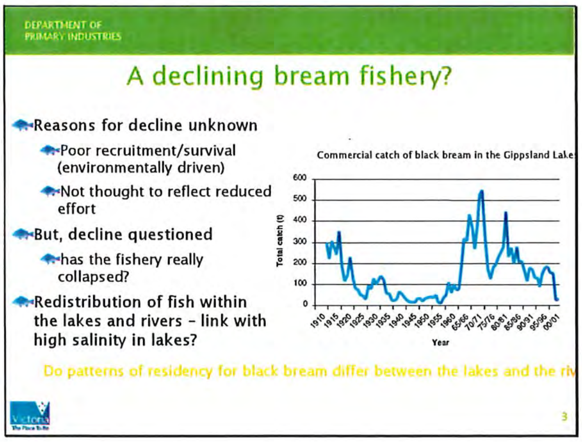
There is community and political interest in stocking of Victorian estuaries, based on the expectation that stocking will help to sustain wild fish populations and/or enhance recreational fishing opportunities. Stocking in Victorian waters is subject to:
- 1999 National Policy for the Translocation of Live Aquatic Organisms (to which Victoria is a signatory)
- Guidelines for Assessing Translocations of Live Aquatic Organisms in Victoria (released jointly by DPI and DSE in December 2003), which require adequate and balanced risk assessment to identify and minimise the potential adverse impacts of stocking, and a need to monitor the outcome of stockings – not only to measure any impacts, but also to measure survival and subsequent benefits to recreational fishing.

20,000 juvenile black bream were released at three sites in the Gippsland Lakes during April 2004. This was the first known release of cultured black bream into Victorian public waters. Fish were produced by PIRVic from Lake Tyers broodstock. The Minister's media release indicated 'it was a trial to determine the benefits of bream stocking, and that it was the 'first step in a long term program' to ensure adequate supplies of bream in the Gippsland Lakes for both recreational and commercial fishing'.

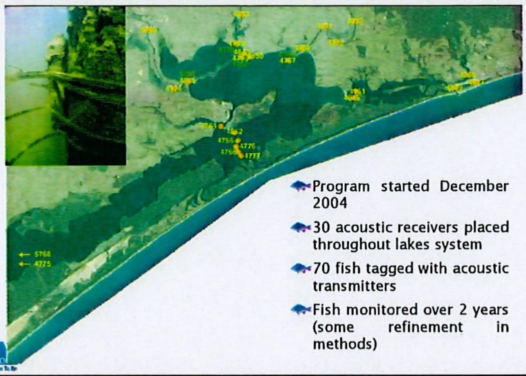
Future proposals to stock bream in the Gippsland Lakes (or any other Victorian public waters) must be:

- subject to a comprehensive risk analysis and evaluation
- accompanied by an adequate monitoring program to evaluate the benefits of stocking and to assess the effectiveness of translocation management measures designed to minimise identified risks
- used as a research tool to help improve understanding of the habitat and environmental factors that may be contributing to poor spawning success or recruitment of wild bream stocks.





DEPARTMENT OF PRIMARY INDUSTRIES



- Program started December 2004
- 30 acoustic receivers placed throughout lakes system
- 70 fish tagged with acoustic transmitters
- Fish monitored over 2 years (some refinement in methods)

5

DEPARTMENT OF PRIMARY INDUSTRIES

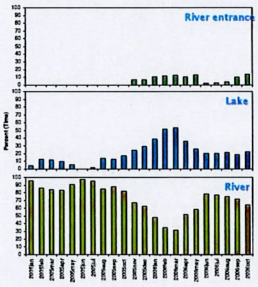
Results from acoustic tracking

- All fish survived surgery - and, high survival after release (>90%)
- All fish moved among rivers, and therefore spent at least some time in the Lakes
- Fish move extensively throughout the Gippsland Lakes
- Movements > 3000 km/year common
- Patterns of movement change with habitat (e.g. Large Woody Debris), diel and seasonal periods

6

DEPARTMENT OF PRIMARY INDUSTRIES

- River use > Lake use
- Influence of changes in the environment likely to be significant – but needs further research
- http://www.dpi.vic.gov.au/vro/fishtrack



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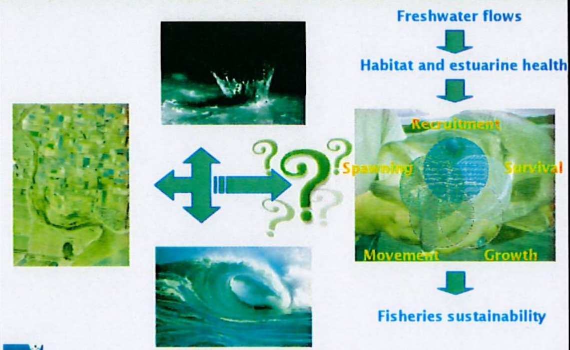
DEPARTMENT OF PRIMARY INDUSTRIES

So…has the population of black bream 'declined'?

- Bream are spending the majority of their time up the rivers – probably because of reduced freshwater inputs.
- But, fish regularly move into the lakes (probably to feed), and some fish spend extended periods in the lakes system
- Possible that these movement patterns could reduce commercial catches (no commercial fishing in the rivers), but recreational catches and fishery independent survey results also suggest a decline in fish abundance (or catchability)
- Plausible that bream populations have declined
- Changes to the environment and effects on spawning and early life history dynamics probably the key factor – but no real evidence!

8

DEPARTMENT OF PRIMARY INDUSTRIES



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DEPARTMENT OF PRIMARY INDUSTRIES

- New research program funded through ARC Linkage program
- Key State management agencies as industry partners
- Strategic partnership between University of Melbourne and PIRVic scientists
- 4 year, $700k research program
  - Modeling estuarine hydrodynamics
  - Assessing patterns of movement of juvenile and adult fishes
  - Identifying spawning locations and estimating reproductive output
  - Monitoring recruitment patterns, growth and survival of post-settlement stages
- Not just confined to bream – also includes other estuarine species

10

DEPARTMENT OF PRIMARY INDUSTRIES

Policy for Restocking in Victorian estuaries

- Community and political interest in stocking of Victorian estuaries
- Expectation that stocking will help to sustain wild fish populations and/or enhance recreational fishing opportunities
- Stocking in Victorian waters is subject to:
  - 1999 National Policy for the Translocation of Live Aquatic Organisms (to which Victoria is a signatory)
  - Guidelines for Assessing Translocations of Live Aquatic Organisms in Victoria (released jointly by DPI and DSE in December 2003)
    - adequate and balanced risk assessment to identify and minimise the potential adverse impacts of stocking
    - There is also an identified need to monitor the outcome of stockings - not only to measure any impacts, but also to measure survival and subsequent benefits to recreational fishing.

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11

DEPARTMENT OF PRIMARY INDUSTRIES

Stocking black bream in the Gippsland Lakes

- 20,000 juvenile black bream were released at three sites in the Gippsland Lakes during April 2004
  - First ever known release of cultured black bream into Victorian public waters
- Fish were produced by PIRVic from Lake Tyers broodstock
- Minister's media release indicated '*it was a trial to determine the benefits of bream stocking, and that it was the 'first step in a long term program' to ensure adequate supplies of bream in the Gippsland Lakes for both recreational and commercial fishing'*
- Future proposals to stock bream in the Gippsland Lakes (or any other Victorian public waters) must:
  - be subject to a comprehensive risk analysis and evaluation
  - be accompanied by an adequate monitoring program to evaluate the benefits of stocking and to assess the effectiveness of translocation management measures designed to minimise identified risks
  - be used as a research tool to help improve understanding of the habitat and environmental factors that may be contributing to poor spawning success or recruitment of wild bream stocks

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12

DEPARTMENT OF PRIMARY INDUSTRIES

Acknowledgements

- Fisheries Victoria - including regional staff
- Bureau of Rural Sciences - Land and Water Australia
- Victorian Recreational Fishing Licence Trust
- East Gippsland Catchment Management Authority
- Barry (Doc) McKenzie
- Nicholson Angling Club

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13

DEPARTMENT OF PRIMARY INDUSTRIES

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14

Mr Ian Stagles (Chair), PO Box 362, Mount Hawthorn, WA, 6915, Telephone 08 9244 3411, fax 08 44501737, email: ians@enlite.net

Restocking the Blackwood River Estuary with Black Bream
Mr Greg Jenkins

Increases in commercial and recreational fishing pressure in recent decades have led to over-exploitation of many valuable fish species. This problem in estuaries has sometimes been exacerbated by the detrimental effects that have occurred in these systems through adverse anthropogenic changes. Species whose entire life cycle is restricted to estuaries, such as the recreationally and commercially-important Black Bream in Western Australia, are especially vulnerable as their numbers are unlikely to be enhanced by recruitment from outside the estuary. The impact that fishing can exert on a species, such as Black Bream, which is restricted to estuaries, is demonstrated by the fact that the relative abundance of the older individuals of this species is less in estuaries subjected to a substantial amount of fishing than in those in which fishing is far more restricted (Sarre and Potter, 2000).

The sole commercial fisher and regular recreational fishers in the Blackwood River Estuary consider that the abundance of Black Bream in this system has declined in recent times. This view is supported by the fact that the numbers of Black Bream we obtained through extensive sampling in the Blackwood River Estuary were far lower than those caught during a detailed study of the fish fauna of this estuary in the 1970s (Lenanton, 1977). Widespread concern that the numbers of Black Bream had declined in the Blackwood River Estuary resulted in the initiation of a carefully-designed research program aimed at determining whether it would be feasible and economically worthwhile to stock Black Bream in this large and important estuary.

Our initial sampling demonstrated that Black Bream is largely found in the riverine component of the Blackwood River Estuary and particularly in its upper reaches. The abundance in those upper reaches is greatest in spring. As spawning occurs in this season, and the samples from these upper reaches contained many maturing, mature and spent Black Bream, it is concluded that *A. butcheri* migrates some distance upstream as it matures and spawns mainly in those upstream waters of the estuary in spring.

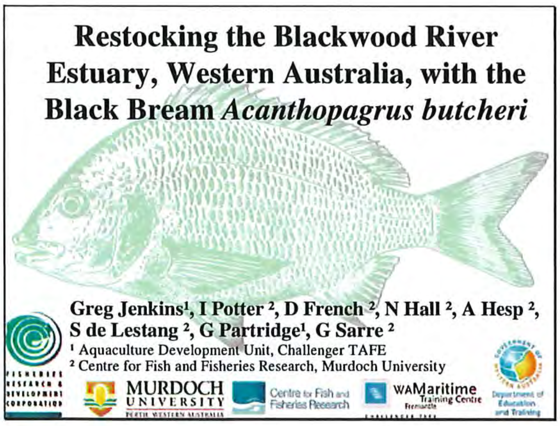
For our restocking research, 56 females and 50 males were collected from the Blackwood River Estuary to act as brood stock for producing juveniles for restocking this estuary. The otoliths (ear bones) of the cultured juveniles were tagged by immersion of the fish in a solution of alizarin complexone (ALC). The resultant pink stain on the otoliths of cultured Black Bream was still clearly visible more than three and a half years after the otoliths had been tagged with ALC. The cultured individuals were certified as disease free prior to release into the upper reaches of the Blackwood River Estuary in which Black Bream had previously been identified as being most abundant. The fish were introduced at several sites over a distance of *c.* 20 km.

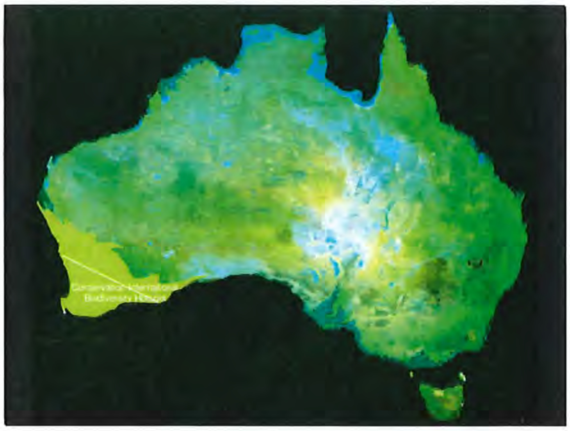
The maximum total length and age of wild Black Bream caught during our study was 440 mm and 31 years. The latter age is the maximum yet recorded for any estuary in Western Australia. Analysis of our length-at-age data demonstrated that, on average, the individuals of the wild population of Black Bream reach total lengths of 143, 200, 244, and 279 mm at the end of their first, second, third, and fourth years of life, respectively. This represents a particularly rapid rate of growth for this species in a Western Australian estuary. The lengths of the stocked fish at ages 1 to 4 were 119, 182, 219 and 242 mm, respectively, which were less than those for wild fish of those ages. Comparisons of mean lengths at successive age intervals confirm that wild Black Bream grow more rapidly than stocked Black Bream. However, the growth of Black Bream stocked in the Blackwood River Estuary is still substantial, as is illustrated by the fact that it is greater than that of wild stocks of this species in some other Western Australian estuaries (Sarre and Potter, 2000).

The average length of the females and males of wild Black Bream at first maturity were 178 and 155 mm, respectively. After adjustment to take into account the fact that a number of the larger stocked Black Bream had not reached maturity, the average length of the females and males of stocked Black Bream at first maturity were 202 and 189 mm, respectively. Thus, stocked Black Bream do not typically reach maturity until they have attained a larger size than wild Black Bream. The majority of females (84%) and males (94%) of wild Black Bream attained maturity by the end of the second year of life, whereas only 75 and 54% of the females and males of stocked Black Bream had reached maturity by the end of their third year of life. Some stocked fish will require further years to reach maturity and some may never achieve maturity.

The stocked Black Bream, that were cultured and released in 2001 and 2002, survived well and comprised 75 and 92% of catches of Black Bream of the 2001 and 2002 year classes, respectively.

In summary, this study has demonstrated that the abundance of Black Bream in the Blackwood River Estuary was enhanced markedly through the introduction of restocking. cultured fish. The Black Bream is a particularly suitable candidate for restocking estuaries in south-western Australia as it is confined to these systems and thus any stocked fish are unlikely to migrate to other estuaries. The ease and relatively low cost estimated for culturing Black Bream, the hardiness of this species and its restriction to its natal estuary make the restocking of Black Bream an economically viable and valid proposition when a stock of this species has become highly depleted. Thus, such restocking provides a further tool for fisheries managers to use to sustain the stocks of Black Bream in Australian estuaries.





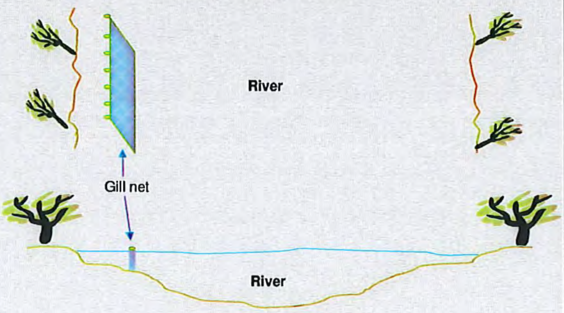
WHY RESTOCK THE BLACKWOOD?

- Black bream is the most popular recreational fish species in WA estuaries.
- Sampling by Fisheries WA in the early 1970s yielded large numbers of black bream.
- Fishers consider black bream to have declined greatly in abundance.

The results of our sampling indicate that the abundance of black bream has declined.

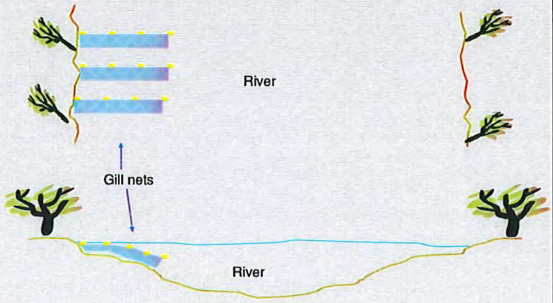
Gill netting used by Dr Lenanton in the 1970's.

Nets set parallel to banks.



Altered gill netting method for 2000

Nets set perpendicular to bank



Black Bream biology

- Euryhaline (fresh to > 60 ppt)
- Relatively long-lived and slow growing
- Reaches sexual maturity at ~ 2 years old and ~ 190mm
- Opportunistic feeder
- Spawns upstream from late spring to early summer
- Successful recruitment is affected by environmental conditions – in a changing world
- Black Bream remain within their natal estuary and is therefore potentially vulnerable to overfishing.

Black Bream culture in Western Australia

(since 1992)

WAMaritime Training Centre Fremantle

- Initial culture trials for aquaculture training and restocking.
- Semi-intensive green-water culture method
- Cost-effective culture with 80-90% surviving to 30 mm
- Hatchery manuals published in 1999 and 2003
- Development of 'hands-on' short course for culture

WESTERN AUSTRALIAN FISH FOUNDATION *ABN 15-258-462-080*
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Trial restocking of Black Bream in the Swan River in 1995[1]

WAMaritime Training Centre Fremantle CHALLENGER TAFE

Department of Fisheries Government of Western Australia

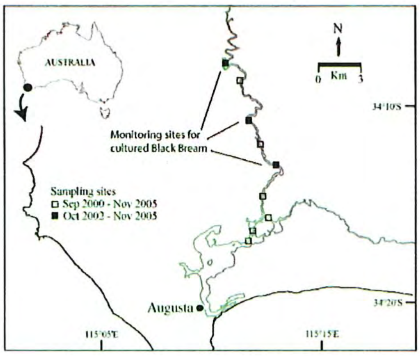
MURDOCH UNIVERSITY PERTH, WESTERN AUSTRALIA

DEMONSTRATED THAT THEY SURVIVED, GREW AND WERE CATCHABLE

1 Lenanton et al. 1999 (in Stock Enhancement and Sea Ranching)

Project Aims

- Determine whether restocked Black Bream will survive in the Blackwood River Estuary
- Determine whether the growth and length and age at maturity of the restocked fish would be the same as those of wild fish



Culture Objectives

1. Collect 100 black bream for broodstock
2. Produce 200 000 juvenile black bream
3. Tag the juvenile bream to enable monitoring to assess the effectiveness of the restocking

Culture and Tagging

106 brood stock were collected from the Blackwood

220 000 juvenile Black Bream were produced

CHEMICAL MARKERS

Alizarin complexone, Alizarin red, Oxytetracycline

Otolith marking trials determined that the best mark was produced by Alizarin complexone

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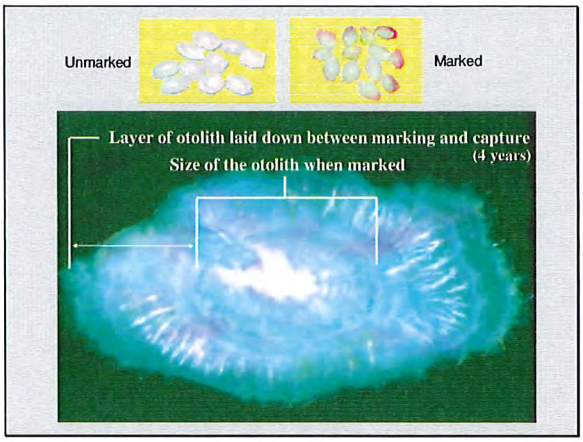

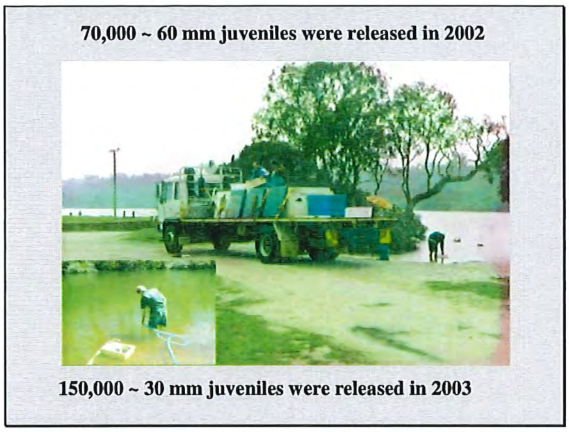

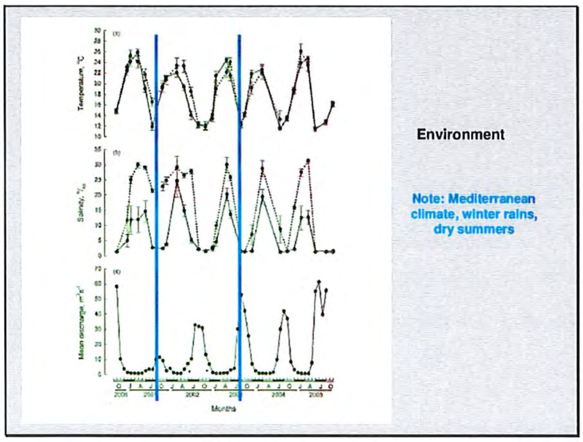

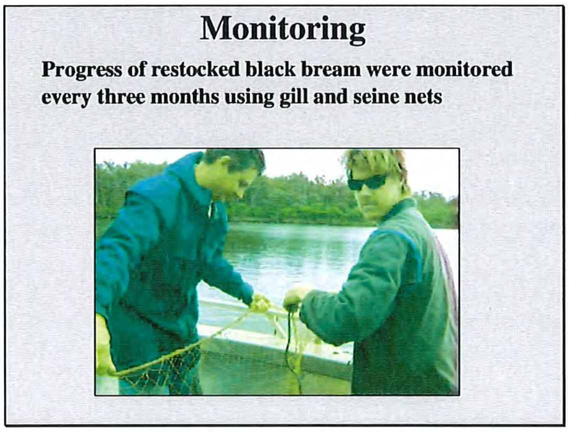

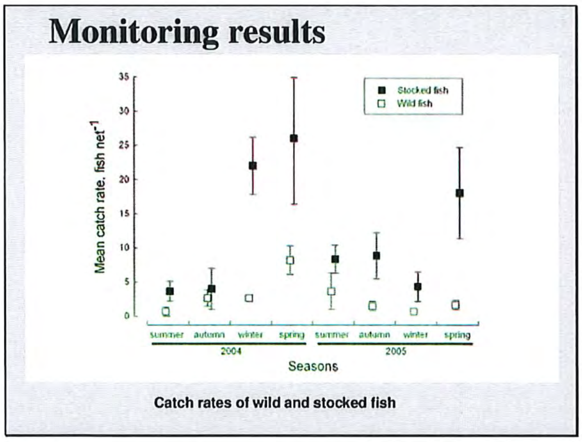

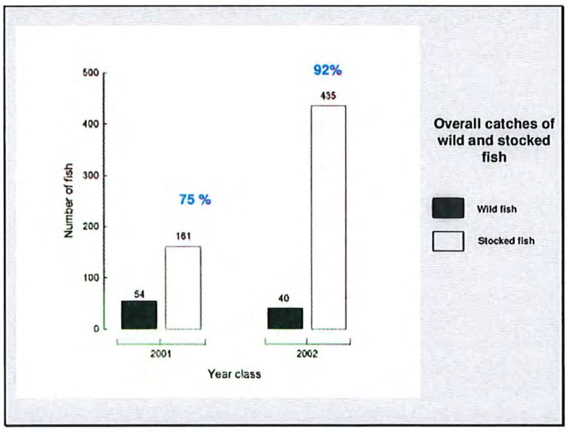

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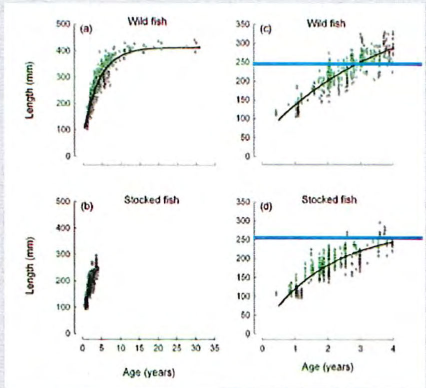
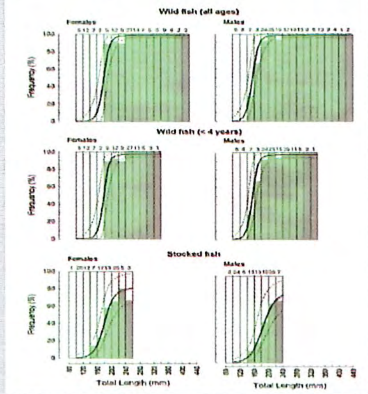


Growth of wild and stocked fish



Length at maturity of wild and stocked fish

Cost per fish that survives to reach legal size

For culture, tagging, release and limited monitoring

$2.05

For culture and release only

$1.60

Conclusions

Stocking of cultured black bream can greatly increase the abundance of a depleted stock in WA estuaries.

Conclusions

As Black Bream remain in their natal estuary, restocking will contribute to future generations of the stock.

Conclusions

Although the stocked fish did not perform quite as well as the wild stock, they still performed better than wild stocks in some other estuaries.

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Research required

Utilise the 'unique' opportunity of having identifiable cultured fish that are now 5 to 6 years old.

- Is the genetic composition of the restocked fish representative of the wild stock?
- How do the cultured fish perform over the typical life span of the species (reproduction and growth)?
- Others?

Research required

As restocking appears to be an inevitable future fisheries management strategy in estuaries, what are the implications of this study?

What protocols are required for future restocking (hatchery, release, monitoring, research)?

As the estuary is undergoing constant change due to anthropogenic influences, is the precautionary approach to restock?

What other research is required to facilitate the use of restocking as a management option?

What caused the decline?

Appendix 4: Additional Workshop Notes

Biological
What is the problem in the Blackwood?
Recruitment? Investigate all existing catch data and find if it is a stock/recruitment problem.
What is the size of the breeding stock?
Should restocking be an ongoing program?
Significance of the environment?

Is the poor state of the environment limiting larval survival? If so, then restocking is needed. It was noted that the restocked black bream in the Blackwood are spawning.

What is different about the Blackwood to other south-west estuaries? It was noted that it is deeper than other estuaries, the banks are steeper and it has little shallow wetlands associated with it. The upper reaches where spawning is likely to occur are unique in that they have steep sided banks. It was also noted that the black bream population structure is different in the Blackwood to other estuaries.

It was agreed that there is a critical need for research into the low level of recruitment. All of the existing data should first be complied and examined in an effort to determine the level of the stock depletion.

Black bream are hardy, have high numbers of eggs, have a very high survival rate in the hatchery in comparison to other species, are opportunistic feeders and hatchery released juveniles have a high survival in the wild. Is larval survival the bottleneck?

Research focus
- Location of spawning (in the Swan Estuary, and in Victoria they spawn in about 20 ppt);
- Environmental conditions at the spawning sites (shallow water?, weed?, is suitable habitat available?- waters behind Molloy?)
- Available food for larvae (ie copepods)
- Contrast with the highly productive Pallinup;
- Can you enhance habitat for larval survival;
- Can you improve the clarity of the water in the Blackwood;
- What are the constraints on recruitment?

Options for a stocking program and its monitoring
1 Restocking and monitoring to recover populations to historical (1970's) levels
2 Stop fishing for black bream – but at what cost to the Augusta community?

Other Research questions
- What is the level of the wild black bream stocks and is there a good genetic basis for broodstock for restocking
- Are other species in decline in the Blackwood?
- Is there a change from the 1970's from Ruppia to macroalgae?
- 30% reduction in rainfall (environmental flow) over last 30 years, will it reduce further and to what effect?

Social

- What are the social values to the community for restocking and the recreational fishery?
- It was suggested that 50 -60% of people fish for black bream in the Blackwood.
- The black bream fishery attracts people to the region.
- When there are low populations of black bream in the Blackwood then people visit other locations instead – such as Walpole for fishing.

Economic

- Rutledge – suggests that it costs $5 to stock a barramundi but it can return $191 to the community to catch.
- It was noted that the cost that can be attributed to each caught fish is closely linked to the survival of the juveniles –0 and that black bream had demonstrated high survival.
- Multipliers for stocking and recreational fishing examples can be found in USA and Australia.
- Nichols (DOF) data for economic return to wild capture communities suggest ~ 5:1.
- Lynnath's creel survey shows some economic data associated with both locals and tourists for the region for fishing.
- Conservation cost?

The essential elements of large scale restocking

- Genetics, should you use large broodstock numbers and retain them over time or use a smaller group that are captured every year?
- Large-scale O/S production for restocking uses more natural systems such as ponds.
- What is the optimal size at release, best timing and other release strategies?
- How many fish and over how many years to restock?
- Objectives of the restocking – catch rates?
- Who is gong to pay? Will it be economically sustainable and under what form of management?
- Fitness of hatchery black bream (lower growth, reproductive fitness)?