An investigation into the use of the freshwater crayfish marron (cherax tenuimanus) as a flagship for the restoration of the Blackwood River

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An investigation into the use of the freshwater crayfish Marron (*Cherax tenuimanus*) as a Flagship for the Restoration of the Blackwood River

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Abstract

The Marron (Cherax tenuimanus) *is arguably the most easily identified and ecologically important aquatic animal species in south-western Australian rivers. In fact it is quintessientially south-western Australian, endemic to the south-west corner of the continent and supporting a recreational fishery and commercial aquaculture industry within the state. Marron have keystone qualities as hosts of various epiphytic flora and fauna, and are central to the food web within south-west rivers. Their sensitivity to depleted oxygen conditions have also made them a potential "indicator" for water quality degradation. The study investigated these qualities in reference to the marron's potential as a flagship species for the restoration of the Blackwood River. Marron could, as flagships, provide direction and understanding for an already community driven catchment group, and provide a focal point for research, landcare, and foreshore restoration along the Blackwood River. According to a list of criterion for flagship species selection the study reviewed the literature on the scientific knowledge and ecological, cultural and economic value of marron within the south-west. The marron's ability to recover from threatening processes within the Blackwood River was investigated, based on an earlier study in 1973. Seven pools within the Middle Catchment (the study area) were sampled for marron using a competitive density of drop nets within each pool, followed by the mapping of cross-sectional dissolved oxygen profiles. The upper limit of marron distribution was confirmed to be approximately 100km below the original upper limit maintained until the late 1950's. Depleting oxygen concentration associated with persistent stratification and organically enriched sediments and high water temperatures were identified to have the potential to lock marron out of pools, at certain times of the day during the summer months. These threatening conditions could be ameliorated with daily or seasonal holomixis and the flushing effect of winter rain, thus enabling marron recovery. A face to face questionnaire sampling the Middle Blackwood Catchment community was used to test the marron's ability, to evoke public sympathy and pride, and assess marron popularity and appeal. Marron fulfilled all criteria tested, with significant variation in opinion and attitudes identified between shires, gender of respondent, river use and those involved in the recreation of marron fishing. The study found marron to be an appropriate flagship species for restoration of the Blackwood River. It represents an appealing icon for tangible community understanding of the restoration process, and a biological indicator for monitoring change as restoration becomes effective, providing direction for restoration action, milestones for the community, and an endpoint for the restoration programme.*

Declaration

"I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text".

Signiture.

Date.....10/2/97..........................

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INTRODUCTION AND BACKGROUND LITERATURE REVIEW

1.1 General Introduction and Outline

Southwestern Australia has been blessed with a rich diversity of rivers, varying in length, flow volume, and the landscape and natural vegetation through which they pass. In recent years there has been growing concern in the community about the deteriorating state of the rivers (Olsen and Skitmore, 1991). The water environment of the south-west has increasingly been altered in terms of flow regime, water purity and ecological balance, through various forms of land use practices within catchments (Williams, 1992). The natural heritage and diversity associated with south-west rivers has often been taken for granted by the user. This is reflected in the increasing occurrence of symptoms associated with environmental abuse.

Today a number of community groups and catchment management groups have evolved to reverse the demise of south-west rivers. This research stems from the recognition of increasing community awareness and the grassroots demand for quality river conservation and restoration (Wood, 1989). It recognises that efforts to establish river restoration programmes will require community involvement and support as well as a clear understanding of what constitutes a successful restoration endpoint. The study examined the possibility of using a high profile riverine species as a means of providing community understanding of the restoration process.

The following sections within Chapter 1 provide a detailed description of the study area, the Blackwood River Catchment and its community, the fundamentals of restoration, and define a relatively new priority conservation category: the flagship species or group. The chapter concludes with the study's aim and objectives.

1.2 The Blackwood River Catchment

1.2.1 The Blackwood Catchment Defined

The Blackwood River typifies most rivers occurring within the south-west of Western Australia, in respect to geomorphology, hydrology, land use and environmental degradation. The Blackwood River catchment is the largest catchment within the south-west of Western Australia and virtually bisects the south-western land area (Morrissy, 1974). It covers 28,000 square kilometres from the shire of Dumbleyung to Augusta and contains diverse land uses and interests supporting a population of 30,000 people living in 19 shires (Negus, 1995).

The Blackwood River and its tributaries stretches approximately 300km from Kukerin to Augusta, making it the longest river in the south-west (Negus, 1995). It displays a reversed longitudinal salinity, which involves an increasing salinity with increasing distance from the coast, a phenomenon characteristic of the major rivers draining the south-west (Morrissy, 1974). The explanation for the unusual salinity features has been identified by Morrissy (1974) as relating to the catchment's transition from a mature to a young valley form, where the water becomes fresher with increasing catchment vegetation cover and annual rainfall towards the coast. As shown in Figure 1.1 the Blackwood River Catchment can be divided into three geomporphological zones which reflects this unusual longitudinal transition and the diversity of landuses and interests in the catchment.

The broad Upper Catchment of old drainage to the East of the Meckering Line zone (Mulcahy, 1973) is characterised by salt lake chains associated with poor drainage, high evaporation and infrequent flow (Hodgkin, 1978). The average rainfall ranges from 375 to 450mm and nourishes the scrub-heath, Mallet, Mallee, Wandoo and Tea-tree species common to the area. The Upper Catchment covers 13 shires in the State's Wheatbelt and has been extensively cleared for agriculture (Syme, Butterworth, & Nancarrow, 1993).

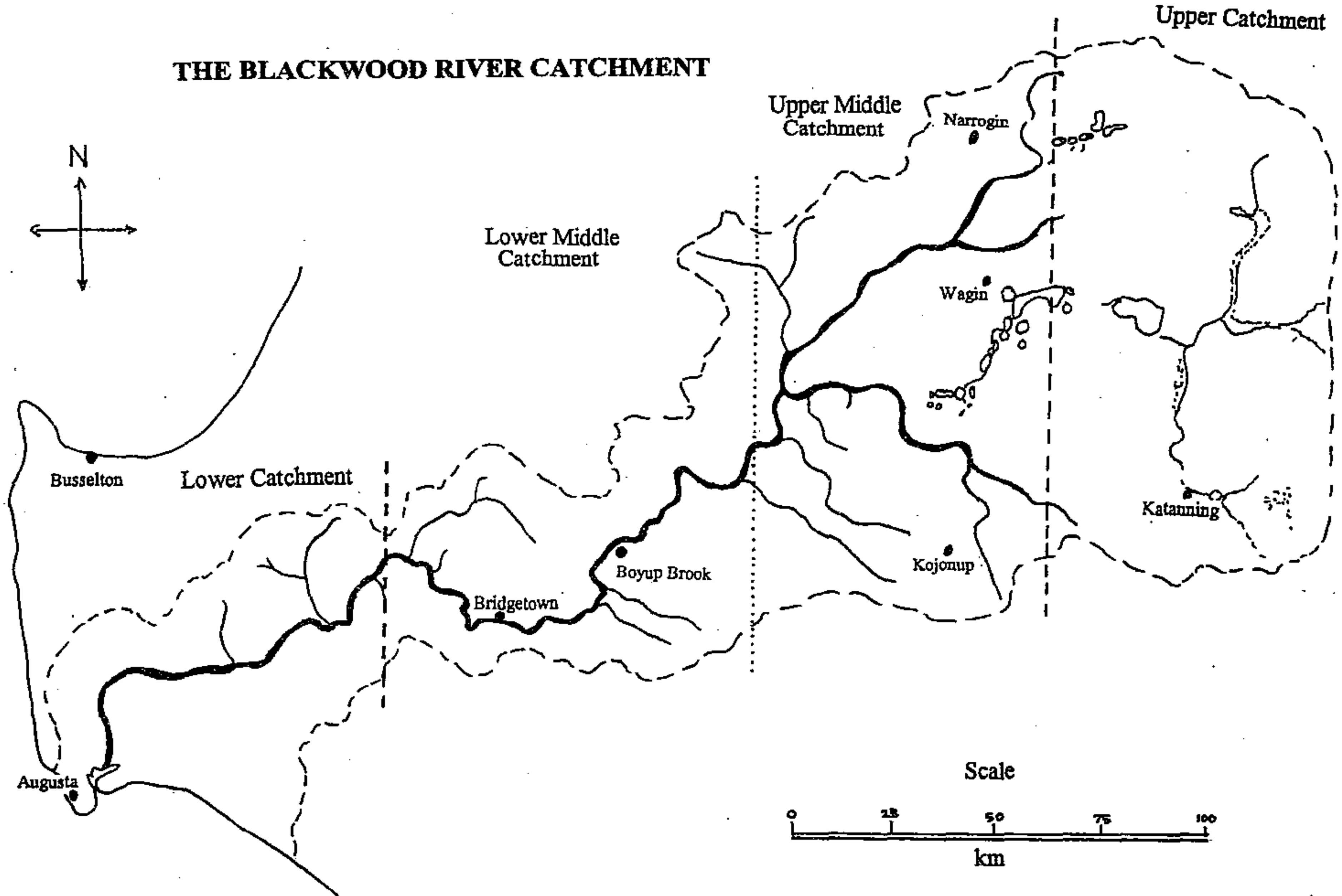


Figure 1.1: Zones which divide the Blackwood River Catchment reflecting topography, soils and land-use.

The Middle Catchment, the focus of this research has been, described by Hodgkin (1978) as a zone of mature drainage, consisting of U-shaped valleys, exposed laterite and rainfall between 400 to 1000mm, providing seasonal river flow. This zone has recently been divided into an upper and lower region by Negus (1995).

The Upper Middle Catchment is east of the Darling Ranges, includes the towns of Narrogin, Arthur River and Kojonup and has been identified as the Zone of Rejuvenated Drainage which transforms sluggish drainage lines into clearly incised courses in winter (Negus, 1995). The land has been extensively cleared and is considered a mixed farming zone producing wool, meat and stock feed (Negus, 1995). The natural vegetation consists of Jarrah/Marri forests, Flooded River Gums and Blackbutt along the streambanks, Jam Wattle, Sheoak, Wandoo, York Gum (Negus, 1995).

The Lower Middle Catchment (The Darling Range Zone) is approximately 125km wide. In the east the landscape consists of a broad undulating lateritic plateau 250 to 300m above sea level, forming the centre of the so called "Sheepbelt" and supporting the shires of West Arthur and Boyup Brook (Negus, 1995).

In the west the Blackwood Plateau drops 60 to 100m as part of the Darling Scarp. The Blackwood River cuts through the landscape forming deep sided valleys through the towns of Bridgetown and Nannup. State forest covers a major portion of this area, with clearing for agriculture (sheep and beef) being restricted to the river valleys. The area also involves some horticultural development and large areas have been planted with pine and Tasmanian Blue Gum for the timber industry (Negus, 1995).

The Lower Catchment is also referred to by Negus (1995) as The Donnybrook Sunkland Zone which extends westward from Nannup 120m above sea level to the coast at Augusta. The Blackwood River dissects gently undulating plains to form a relatively shallow valley system which supports natural Jarrah/Marri forests, paper-bark woodland and coastal peppermint scrub as the river becomes estuarine (Negus, 1995). The average annual rainfall in the region ranges between 900-1100mm.

1.2.2 The Middle Blackwood River Catchment: Its history and transition

Following the initial settlement (~1857), the district's population continued to increase gradually as new pastoral leases were taken up. By the end of the century tin had been discovered near Greenbushes and the sawmill industry and railway were established (Christensen, Pentony, & Schmidt, 1981). Sheep and cattle remained the predominant interest within the Middle Catchment. As leases were subdivided and shrank many settlers attempted to increase productivity by clearing more land. By 1888, extensive tracts of land had been or were being cleared by ringbarking (Christensen *et al*, 1981).

At the turn of the century the character of the Middle Catchment and its community had changed rapidly. Crops extended into grazing lands and ringbarked paddocks were common. Introduced pasture species competed with the native flora under an ecological imbalance created by the application of superphosphate. The timber industry had begun to log the region into a patchwork landscape. In little over half a century the district had been transformed into one of the state's most productive mixed farming areas, promoted by the post-war boom in farm mechinary (Christensen *et al*, 1981).

The fortunes of the Middle Catchment began to change in the late 1950's with a slump in all agricultural products, forcing farmers to over stock, clear more land, and even drain land for more farming. As Christensen *et al* (1981) outlines a number of farmers sold out to the Forestry Department for pine plantation introduced to the catchment in the 1950-60's. Those who had toiled for years to clear the land for farming were ironically to sell the land for the purpose of growing trees; an omen for the future.

Since European arrival within the catchment there has been a dramatic transformation of the Middle Blackwood Catchment. Large tracts of land have been cleared, replaced with exotic species or left bare to support an unsustainable head of stock. Artificial nutrient has been added to the naturally infertile soil which along with the pesticides is inevitably washed into the rivers and streams from the bare, salt scarred paddocks. Not only has the land been affected, but the river has been manipulated through river "training" and damming to supply towns and irrigate crops (Christensen, et al, 1981).

1.2.3 Current Land Use in the Blackwood Catchment

Half of the working population within the Blackwood River catchment are engaged in agriculture and forestry while those remaining are generally involved with various service industries (education, retail, hospitality etc) (Negus, 1995). Understandably agriculture is the predominant form of economic production within the catchment, on which much of the town based industries and retailing is dependant. A total of 60% (1.63 million ha) of the whole catchment area is utilised by 1500 farm businesses (Negus, 1995). Most of which is inappropriately located in the Upper and Upper Middle Catchment area.

Of the Catchments total area (2.3 million ha) there is a total of 771,900 hectares of forest consisting of state forest, national parks, private remnant vegetation, and plantations, most of which is located in the Lower and Lower Middle Catchment. The purpose of such forested areas range from catchment protection, wildlife and flora protection, recreation, landscape values, to the production of timber and other wood products (Negus, 1995). Bunnings is the major private sector of forest industry within the catchment, while CALM looks after the state forest, and farmers are encouraged to participate in agro-forestry using mainly blue gums and pines, integrated with traditional grazing (Wallis, 1993).

The Middle Catchment has a long association with the tin, tantalite and spodumene mining at Greenbushes which was worth $19 million in 1992/93 (Wallis, 1993).

Tourism has become an increasingly important activity in the Middle Blackwood Catchment, for a range of reasons. These reasons involve recreational opportunities such as camping, bushwalking, fishing, and picnicking (Negus, 1995); the attraction of wineries, marron and trout farms, and early heritage; and the intangible aesthetics of the catchment, including the beauty of the landscape, peace and quiet, and the bush experience (Wallis, 1993). As indicated by Wallis (1993) tourism is an indirect measure of the importance people place on the area. The Blackwood Catchment is also the focus of a number of well known annual events, including the Blackwood and Moodiarrup Marathons, the Blackwood Classic Powerboat Race and Art and Music Festivals. In economic terms the Blackwood Catchment makes up 23% of the profits generated by tourism in the south-west annually. This amounts to $53 million per year and represents approximately 380,000 visitors to the catchment each year (Wallis, 1993).

1.2.4 Land Degradation in the Middle Catchment

1.2.4.1 Clearing

Clearing within the catchment has predominantly been for agriculture purposes and is therefore on private land (Purfleet, 1993). Reflective of this, the total area of remnant vegetation on farms in the Blackwood Catchment is about 235,000ha while 536,000 ha exists in public reserves. Therefore a total of 771,000 ha of native remnant vegetation remains within the catchment which represents only 35% of the total catchment area (2.3 million ha) (Negus, 1995). There is a clear trend of reducing amounts of remnant vegetation as you move up the catchment from Bridgetown. Most of the remnant vegetation is situated within Public reserves in the Lower catchment, followed by a slightly higher 18% and 10% existing within the Lower Middle Catchment zone and Upper Middle zone respectively, while only 5% of the Upper Catchment is vegetated (Negus, 1995).

Even though remnant bushland represents the remaining gene pool of the catchment's original plant species providing essential habitat for native fauna, most existing on farmland is not fenced off for stock exclusion to enable regeneration and is severely degraded due to factors such as rising saline water tables, old age, and insect attack (Wallis, 1993). Regardless of the knowledge that widespread clearing has devastating impacts on catchment hydrology vegetation clearing for agriculture continues. According to Negus (1995) remnant vegetation is currently being lost at 2% to 4% per year without being replaced, most of which is occurring within the Middle Catchment.

It seems that the short term economic benefits of agricultural production continues to blind people to the debt owed to the once vegetated valleys and undulating hills of the catchment. The environmental cost of widespread clearing has been expressed indirectly as raised ground watertable, waterlogging, salinity problems for both soil and rivers, increased erosion and silting, and the removal of the riparian buffer from parts of the Blackwood river and its tributaries (Williams, 1992). These symptoms are outlined below in terms of their impact on the land and the river components of the catchment.

1.2.4.2 Erosion

Devastating wind and water erosion events occur on average every second year, enhanced by clearing which leave the late summer and autumn paddocks bare (Negus, 1995). Poor land use management has compounded these processes with farmers increasing the area of pea and lupin crop providing poor stubble protection, and over grazing slopes of the Middle Catchment valleys resulting in severe water erosion problems during summer thunderstorms events (1 in 2 year frequency) (Wallis, 1993). Severe sheet, rill and gully erosion effect 8 to 15% of the steep gravel slopes within the Middle Catchment (Negus, 1995).

Wind erosion is a particular problem in the Middle Catchment along the Beaufort and Arthur Rivers (Negus, 1995). The "sheep belt" of the lower Middle catchment has probably the highest stocking rates in W.A, thus paddocks are commonly grazed "to the bare boards" (Negus, 1995) in late summer and autumn, exposing them to thunderstorms or strong wind events.

1.2.4.3 Waterlogging and Dryland Salinity

The devastated hydrology of the Upper Catchment has not been contained within the district, having widespread repercussion on the Middle Catchment region, which today suffers a rising watertable of about 50cm per year (George, 1995). Waterlogging has caused landslides on steep slopes within the Bridgetown District, and regular flooding in the Middle Catchment during heavy rainfall, increasing surface runoff to the already water logged areas (Negus, 1995). Significant waterlogging of crops with rising watertable, has reduced the crop yield on average by one tonne per hectare. According to Negus (1995), this loss is worth $33 million each year. Today many farmers have resorted to further scarring the land with drains, moving water faster towards the river.

The impact of waterlogging is the steady loss of land to salinity, especially along streamlines and on flats near the main rivers. As indicated by Negus (1995), hillside salt seepage is widespread in the Middle Catchment zone, with the saline areas contributing soluble salts directly into the main tributaries flowing into the Blackwood, with no salt lakes like the Upper Catchment to act as temporary buffers.

In 1979 a total of forty-seven thousand hectares of saltland existed, today 59 thousand hectare are affected (Negus, 1995). Obviously the area of salt-affected land is steadily increasing, with the major increases occurring after very wet years within the Upper Catchment. The wetlands and streams within the Middle Catchment are significantly effected with a number of the remaining freshwater lakes between Boyup Brook and Kojonup (Boree Gully chain of lakes) threatened from the fate of many other wetlands within the agricultural area (Negus, 1995).

The salinity problem stems from the dramatic increase in catchment recharge which prior to clearing totalled around 500,000 litre of water per hectare, but today it has been calculated at one million litres of waters contributing to the watertable, moving under every hectare of land (George,1995). Resources once protected by perennial plants in the Upper Catchment area are now being bled from the landscape each year as irreplaceable quantities of water, salt, nutrients and sediment, to become concentrated down river in the Middle Catchment (George, 1995).

1.2.5 The Blackwood River and its Value

The Blackwood River is known for its extraordinary variability, where an annual flow of 2 million and 20 million cubic metres was recorded in 1972 and 1974 respectively (Hodgkin, 1978). The river and its tributaries have been developed for irrigation and urban, rural, industrial and recreational uses, and to support a fishing industry (Wallis, 1993). A few of the Lower Middle and Lower Catchment tributaries are still an important water sources for local towns, providing drinking, irrigation and domestic water (Wallis, 1993). The Blackwood River also has intrinsic value, maintaining the quality of the natural landscape, including the flora and fauna, important to residents and visitors to the catchment. However these values are being progressively threatened, as the river degrades to the extent that it meets few of the criteria set by CSIRO for a "healthy river" (see Appendix 1). The following outlines the main processes threatening the Blackwood River, with a focus on the Middle Catchment.

1.2.6 River Degradation in the Middle Catchment

1.2.6.1 Salinity

In the past 30 years the river's salinity has increased by more than 170 percent, with a rising salinity level of 52mg/litre/year, equal to 37,000 tonnes a year (George, 1995). In 1992 the W.A Water Resources Council officially classified the streams in the Upper and Middle Catchment as saline and the river in the Lower Catchment as brackish (Wallis, 1993). The bulk of the salt load has been identified as emanating from the lower portions of the Upper Catchment into the Middle Catchment (Negus, 1995).

The Upper Catchment streams are now considered of little use to humans, live stock and irrigation, however tributaries feeding the Blackwood within the Middle catchment are used for sheep and cattle watering, increasingly down catchment (Negus, 1995). Below Nannup the water quality in streams running from the forested area is excellent (150-400mg/l), while the Blackwood River itself is in the 1500 to 3000mg/l total soluble salt range (Wallis, 1993).

1.2.6.2 Riparian zone degradation

One of the major impacts on the Blackwood River environment has been the loss of natural fringing (riparian) vegetation from streams and river banks as a result of waterlogging, salinity, and stock and human. The riparian zone is an essential component of the riverine habitat. Within the Middle Blackwood Catchment riparian zone function and value has either been eliminated or threatened (this function will be discussed in detail within section 1.3.6.1).

1.2.6.3 Eutrophication, organic pollution and algal blooms

The water quality in the Blackwood River between Moodiarrup and Boyup Brook has deteriorated over the past 20-25 years due to salt and organic matter pollution. Sheep manure contains 1% Phosphorus and is swept off bare paddocks, along with fertiliser and crumbed crop stubble, into the rivers and tributaries during summer thunderstorms and early winter rain.

Within the Middle Catchment around Bridgetown and Nannup eutrophication is evident in the summer months with the increased occurrence of toxic algal blooms over recent years. According to Negus (1995), organic nutrient inflow into the river, comes from dairy farms, beef cattle feedlots, septic tank systems and fertiliser input from agriculture, horticulture and viticultural enterprises.

The summer pools are now a shade of their former selves, chiefly threatened by excess nutrients applied to the land. One-off events like summer storms can be particularly destructive in that a pulse of organic enrichment during summer can result in the rapid depletion of oxygen in the water, and the death of aquatic life within the vulnerable pool environment. Health warnings are issued to stop people swimming in the river during summer, threatening the tourist industry.

1.2.6.4 Flooding

Within the Upper Catchment flooding occurs about 1 in 10 years leading to severe crop damage. This can be attributed to the fact that many Wheatbelt valleys have virtually no natural stream channels to cope with increased runoff since clearing (Negus, 1995). Flooding in the Boyup Brook and lower Balgarup Creek within the Middle Catchment occurs fairly regularly during heavy summer or winter rainfall events, flooding 120 hectares with salty water (Negus, 1995). The last major flood occurred in January 1982, causing severe erosion, silt loads and mass mortalities of aquatic biota such as perch and marron.

1.2.6.5 Silt load

Removal of vegetation has exposed the precious few centimetres of topsoil within large areas of the catchment. Increased run-off of rainwater has transported sediments to streams, conveyed the silt down river and deposited in river pools, the estuary or out to sea. Today the high silt load from the Middle Catchment is a serious threat to the deep pools in the Middle and Lower catchment, smothering the bottom dwelling biota and important river habitat (Williams, 1992). As the sediment builds up the pools become shallower and water temperature rises, making a dramatic difference to the pool's ability to support life (Williams, 1992).

1.2.6.6 Flora and Fauna

There has been a translocation of a diversity of foreign and native flora within the catchment due to changes in habitat. Many species have come to invade the river banks and farm land remnant at the expense of the original native species. The weeds included watsonia species, blackberry, arum lily, annual grass and introduced exotic tree species such as pines, poplars, tagasaste and even bluegums (Williams, 1992).

Changes to the landscape included an introduction of exotic species, the most notable being pastoral stock. The typical "feral" creatures were introduced including the fox, mouse and rabbit while the river was contaminated with a proliferation of hardy exotic pests including the fish, *Gambusia affinis* (Morrissy, 1978b), water snails and possibly the yabby (*Cherax destructor*) (Morrissy, 1992).

As a consequence of the dramatic changes forced on the Middle Catchment and the introduction of new species, increasing stress on the ecological balance within the catchment has caused a number of native species to disappear or become threatened. There are 43 declared rare and endangered species of flora in the Blackwood Catchment (Grein, 1995), while two plants: *Acacia kingiana* and *Tetratheca fasciculata*, are thought to be extinct in the Blackwood Catchment around Wagin. The catchment is thought to support a number of declared threatened animals including the chuditch, red-tail phascogale, numbat, western mouse, the barking owl and two rare frogs (Wallis, 1993).

With the degradation in river water quality there has been a notable reduction in the distribution of a number of species once common to the upper and middle reaches of the Blackwood, including freshwater mussels, native fish, leeches, redfin perch, water rat (M. Cusack per.comm, 1995) water birds (Wallis, 1993), and marron (Morrissy, 1978b).

1.2.7 The Blackwood Catchment Community

Not only does the Blackwood Catchment involve land and river, but also 30,000 people who live in and share a common interest within its boundaries, making up the Blackwood Catchment Community. Over the last 30 years change has not only occurred to the catchment environment, but also its community. There has been rapidly increasing awareness and concern about environmental issues like those expressed above. According to Wood (1989), the catchment community now expects a high standard of conservation management, rehabilitation and monitoring of threatening activities and processes within the local area. Simultaneously they expect greater opportunities for recreation, a profitable economic basis and positive development within the catchment (WAWRC, 1994).

Consequently the public demands on the river catchment are manifold and intertwined. State and local government, along with many government agencies and private companies have been preoccupied with the economic demands of the community, leaving the environmental problems to manifest in the hands of scientists and concerned citzens. This lack of response to environmental degradation and the community's call for quality conservation and restoration, has encouraged a grassroots movement, involving a cross-section of the Blackwood Catchment community.

The problems within the catchment have become too big for the individual farmer, the shire communities, or any one group, therefore the Blackwood Catchment Coordinating Committee (BCCG) was formed. In February 1990, 250 people met in Bridgetown to initiate a combined fight to save the river system and address the Landcare problems of the catchment as a whole. The BCCG was formed to bring together "key players" within the catchment; the farmers, foresters, government agencies, conservation groups, local government and land conservation district committees (LCDC's) (Negus, 1995).

Since 1992 the BCCG have developed a vision, mission and goal statements, adopted a constitution and become incorporated. Policies on river foreshore management, drainage and remnant vegetation have been developed through a series of community workshops. These have given the broader community the opportunity to voice their concerns about the river and its catchment, workshopping creative solutions on how to overcome them (Nabbin, 1993). In 1995 the BCCG produced a Land Conservation Strategy which led to $2.5 million funding from the Federal Government National Landcare Programme, to be used for catchment research, farm demonstration, rehabilitation schemes and river foreshore restoration (Davis, 1996).

The Blackwood River Catchment is recognised as one of the most active communities in Australia engaged in both the Landcare process and organisation (Negus, 1995). This can be attributed to the BCCG recognition that the community is of paramount importance. They believe that the only way to manage the local environment is through a community representative group, but nevertheless appreciate the importance of a partnership with government agencies (Negus, 1995). According to Mr Reid, current chairman of the BCCG, the group realised early that saving the Blackwood would mean sustaining the link between ecological responsibility and management, and economical viability (Davis, 1996).

The natural heritage and diversity of the Blackwood River has in the past been taken for granted, allowing environmental abuse to manifest itself. The grassroots community has taken charge of defending their demand for environmental integrity and the various threatened values associated with catchment and river degradation. People value the Blackwood River for different reasons, these reasons provide motivation, energy, resources, dedication, and endurance. Reflective of this Mr Reid states, "It gives us hope that we can look forward to a time when the river will be restored to its former pristine condition" (Masterson, 1996).

1.3 River Restoration

1.3.1 Restoration Defined

The dependence of human society and its economy on surface waters for irrigation, industry, potable supplies, and recreation has been threatened by expanding human populations and technology, to the extent that protection, management and restoration of freshwater has become critical, though poorly recognised and understood. The functions of aquatic ecosystems have become so manipulated by anthropocentric land use that natural recovery of an increasing number of systems is no longer possible. *Recovery* is best viewed as the natural process of return to an ecosystem which closely resembles unstressed surrounding areas or to an unstressed condition (Petts and Calow, 1996).

Restoration as distinct from *recovery* is a process that involves management decisions and manipulation to enhance the rate of recovery, a technique used to enable disturbed ecosystems to stabilise at a rate higher than that through natural physical and biological recovery processes (habitat development and colonisation) (Petts & Calow, 1996). As outlined by Cairns, Dickson, and Herricks (1977), the characteristics of a restored ecosystem can be bound by two significantly different perceptions: the public perceived restoration to "usefulness" and the scientifically documented restoration to original structure (physical, chemical, and biological characteristics) or function or both. During the 1975 International Symposium on the recovery of Damaged Ecosystems, restoration was defined three ways:

1. restoration to usefulness as perceived and defined by the general public;
2. restoration to original functional and structural conditions although the species that comprise this structure may be significantly different than those present originally;
3. restoration to the original structural and functional condition with original species (Cairns et al, 1977).

The difficulties created by differences in social perception and scientific documentation require restoration programmes which integrate these diverse views.

Restoration unlike *rehabilitation*, *enhancement* and *reclamation* is a holistic long term process which aims to restore a target aquatic ecosystem's structure and function, to emulate a natural, self-regulating system integrated ecologically within the landscape in which it occurs (Berger, 1990). The terms rehabilitation, reclamation, and enhancement imply putting a landscape to a new or altered use to serve a particular human purpose (National Research Council (NRC), 1992). Often natural resource restoration requires one or more of the following processes: reconstruction of elapsed physical hydrologic and morphologic conditions; chemical cleanup or adjustments; and biological manipulations including revegetation and introduction or reintroduction of species (NRC, 1992).

Restoration is often advocated as impossible to achieve with the level of degradation observed within ecosystems today, but as indicated above, the diverse definition has allot to do with this. Berger (1990) sums up the reality of restoration:
" It is axiomatic that no restoration can ever be perfect; it is impossible to replicate the biogeochemical and climatological sequence of events over geological time that led to the creation and placement of even one particle of soil, much less to exactly reproduce an entire ecosystem. Therefore, all restorations are exercises in approximation and in the reconstruction of naturalistic rather than natural assemblages of plants and the animals within their physical environment".

The successful restoration of the Thames is testimony to the reality of restoration. It illustrated that a grossly polluted river can be restored sufficiently to support a diversity of fauna, to conserve wildlife in urban areas, and provide recreational potential for people (Cairns et al, 1977). As outlined by Chapman (1992) the success can be credited to:

- a very thorough scientific evaluation of the state of the river and a comprehensive understanding of the river's physical characteristics which enabled a mathematical model to be constructed for predictions, due to an outstanding accumulation of data;
- a series of objectives providing the basis for the river quality desired concentrating on dissolved oxygen and a diversity of aquatic biota as indicators;
- a thorough monitoring programme;
- a socio-economic driving force, including the culture and tourism value of the Thames;
- a considerable degree of cooperation and consultation, and public participation compounded by an increase in environmental awareness.

Even so, the science of restoration ecology is still young and rapidly evolving with restoration ecologists developing an expanding array of technologies reflective of a growing range of environmental problems impacting many areas of society. This explains the unusual knit of people involved in the restoration process. It includes not only the scientist but consultants, students, environmentalists, industries, the government, community groups, youth organisations and the individual citizen (Berger, 1990).

1.3.2 Restoration Planning

As stated by the NRC (1992), aquatic ecosystems are interconnected and interactive, requiring efforts to be conducted on a large scale so as to include all significant components of a catchment. In addition aquatic restoration must be long term to ensure goals are achieved and that the system can endure the stress of episodic natural events. Priorities often need to be set due to the lack of resources, when selecting restoration projects (NRC, 1992).

Planning a restoration project starts with specifying the project mission, followed by goals and objectives which become the basis for the evaluation assessment criteria (NRC, 1992). The mission is the overall general purpose, such as the restoration of the Blackwood River and its catchment. The goals are prioritised in respect to their importance, and may include for example restoring water quality and riverine fauna. Objectives are derived from the goals, giving for example specific characteristics of water quality to be achieved, or species composition required. Finally specific performance indicators must be constructed linked to each objective, enabling measurements of the extent to which objectives are being achieved. In the case of water quality, indicators such as dissolved oxygen or secchi disk visibility may be used (NRC, 1992).

Following the identification of objectives and their performance indicators, restoration managers must identify the project schedule (expenditure and time) and scale, as well as propose an assessment and monitoring program to enable post restoration evaluation. These must be appropriate in sampling frequency, scale and intensity to measure the performance indicators accurately and reliably (NRC, 1992).

Assessment and monitoring generally includes both structural (state of: water quality, soil condition or biota) and functional attributes (process of: nutrient cycling, oxygen production or sediment transport) (NRC, 1992). As stated by the NRC (1992) this should cover populations, community, ecosystem and landscape. Post restoration evaluations enable managers and scientists to determine when, and to what degree, the system has become self-regulating, and whether or not the restoration attempt was effective.

It is very dangerous to extrapolate the successful restoration of one system to that of another similar system. As Cairns et al (1977) point out each situation is different, and it necessary to define for each particular situation what is meant by restoration. Before restoration can be initiated managers need to know how far the community wants to go back, in what form, and at what price in terms of management problems (Platt, 1977). In the end society may not want what was there before, but something which will serve a better or more appropriate use.

Humankind has altered the environment such that if some kind of control is not exerted , many systems cannot survive. As Platt (1977) identifies, if restoration returns a system back to its true condition, then nature will run the system, but if it is restored into a different form then money and energy must be spent to manage it.

1.3.3 Constraints on achieving Restoration

There are several constraints on achieving 100% success in returning aquatic ecosystems to their ideal predisturbed condition. The most important of these appears to be the degree of disturbance to the site and its landscape, where those most degraded and removed from their original state are less likely to be returned to their original condition through restoration.

Ecological constraints exist, for example when a target ecosystem is dominated by long-lived perennial plants or complex peaty soils. Biological constraints can be encountered when attempting to establish threatened species, and through the threat of exotic species (NRC, 1992).

Institutional constraints generally govern where, and how effective restoration can be, encompassing legal, political, and economic constraints. As outlined by the NRC (1992), political decisions may determine whether funds are available for restoration and legal issues often concern land ownership and regulatory processes.

Problems encountered during restoration generally involve every aspect of construction, ranging from site selection, inadequate nutrient supplies for plant growth, to pest invasion. The result is that many projects fall short of the intended goal, promoting a degree of controversy on the issue of restoration. The most pessimistic view comes from those with less faith in society, indicating that restoration will be used to excuse new assaults on the environment (Berger, 1990).
A number of critics contend that the repair of ecological damage must wait until the more pressing task of natural resource conservation has been accomplished (Berger, 1990).

However, as Berger (1990), points out restoration and conservation are in general interrelated and complementary, for example:

- failure to arrest deteriorating conditions through restoration can lead to the loss of biological diversity with the extinction of endangered species dependent on the habitat being lost;
- degraded properties left in an ugly and unappealing condition are sometimes more susceptible to being developed and lost to conservation since their natural resource values are less evident, and thus have fewer defenders;
- by restoring resources an alternative to overusing or consuming the few unspoiled natural areas left can be given to society;
- failure to restore damaged resources may damage pristine resources.

In general if deterioration is not arrested, repair becomes progressively more expensive and difficult.

Despite the concern it is already apparent and encouraging to see that restoration technology, along with traditional conservation efforts (preservation and pollution control), can greatly ameliorate many of our environmental problems. For this reason the demand for restoration is increasing and is likely to continue growing into the future.

Berger (1990) forecasts that restoration is likely become a multi-million dollar global enterprise in the future.

The following looks at restoration of the agricultural and river ecosystem associated with the Blackwood River Catchment, and identifies various restoration techniques appropriate for the catchment

1.3.4 Restoration of Agricultural Land

Agricultural ecosystems are highly unnatural, as stated by Platt (1977), "modern agriculture is a suicidal system which is slowly deteriorating the soils of the earth". Therefore restoration of agricultural land is generally "to usefulness" due to the degree of environmental degradation associated with such land use.

The causes for the decline in agricultural land productivity have been outlined within section 1.2.4. The deterioration of agricultural land is generally measured by reduced productivity of desirable plants, alterations in biomass and diversity of the micro and macro fauna, accelerated soil erosion, and increased risk to humans (Berger, 1990). However, according to Berger (1990), restoring abandoned and marginal agriculture lands can be relatively easy and economical by utilising conventional farming equipment. Thousands of hectares of abandoned agriculture land in United States have been restored into productive rangelands, where livestock carrying capacity has in fact doubled.

Restoration of agricultural land will often include: the breakup of compacted soil to facilitate root growth; decreased emphasis on chemical input, using manure, mulch, and compost; conservation tillage and rotation programme; promoting diversity of crop and stock production; wind breaks and drainage channels to control erosion, along with paddock monitoring (Berger, 1990).

The development of Landcare within the Blackwood Catchment is working to improve the understanding of ecological principles and sustainable land management within the general community. The BCCG are promoting what may be considered restoration of degraded farmland to "usefulness", progressively incorporating, into land management, the planting of perennial grasses, windbreak and ecological corridor construction, revegetation, alley-farming systems, adoption of minimum tillage and stubble management. These activities have been outlined within the "Blackwood Catchment-Regional Land Conservation Strategy" making up the "action plans" to address the key landcare issues identified by the community (Negus, 1995).

1.3.5 Restoration of the Blackwood River-Riparian Ecosystem

The restoration of rivers degraded by urban, industrial and agriculture development is now a priority for the developing nations. Societal acceptance of rivers as suitable environments for convenient and inexpensive waste disposal has been the major driving force behind river degradation. As ecological damage has become more severe, the possibility of self-cleansing has become limited, impairing a river's value to humans and its essential environmental services (NRC, 1992).

Restoration as a holistic process aims to restore the river's ecosystem structure and function, both within the lateral linkage between river and riparian zone, and longitudinally within a catchment perspective. As stated by the NRC (1992), rivers, their riparian zones and catchments are so intimately linked that they must be understood, managed, and restored as integral parts of a single ecosystem.

Before a restoration programme can be established, baseline and reference data must be collected, for comparison during and after restoration (NRC, 1992). The structure and functioning of a healthy, undisturbed river-riparian ecosystem, such as outlined in the CSIRO "healthy river" criteria (see Appendix 1), is used as a reference and often represents the goal of restoration. Baseline data are generally collected through water quality monitoring and biological assessment.

The gathering of baseline information has become a significant pastime for stakeholders within the Blackwood River Catchment, as evident in the popularity of LCDC activities and the Bunnings Ribbons of Blue Watercare Program which has been incorporated into the school curriculum (Negus, 1995). Farmers now repeatedly monitor the water for its suitability for stock and irrigation, and scientists frequent the system regularly to take detailed measurements. Biological monitoring of the river is another component of the Ribbons of Blue program using macroinvertebrates. A national monitoring river health strategy has incorporated the Blackwood river catchment into its research on establishing nationwide baseline information. Continued scientific research on dryland salinity, erosion, waterlogging and eutrophication has provided much needed accumulative baseline data for land users within the catchment.

Along with baseline and reference data, successful management and restoration of a river requires the manager to recognise the concepts of river flow and retention, openness, dynamism, patchiness, resistance and the river's resilience (NRC, 1992). This degree of knowledge is available for some rivers in the south-west but specific data for the Blackwood still requires further research.

To achieve long term success, aquatic ecosystem restoration must address the causes, not just the symptoms of ecological disturbance (NRC, 1992). The locus of the problem can be in the catchment, along the riparian zone, or in the channels or pools (or all of the above).

Restoration should begin with improved land management practices involving sustainable agriculture , protection of remnant vegetation, and erosion control programmes, to ameliorate some of the causes of degradation and allow some opportunity for the natural restoration of the river. (NRC, 1992).

The goal of fluvial restoration is to restore the river to a dynamic equilibrium, not to "stabilise". However, given the economic value of rivers and associated human facilities, river restoration is no exception to the exercise in approximation as defined earlier (section 1.3.1) by Berger (1990). It is unlikely that natural sediment and water regimes , and naturally dynamic channels will be completely restored. Restoration of larger systems is more problematic because of their size and complexity. (NRC, 1992).

However, under the broad goal the objectives are set and usually involve, to some specified level, the following:

1. restoration of water quality;
2. restoration of natural sediment and water regime;
3. restoration of natural channel geometry;
4. restoration of the natural riparian plant community;
5. restoration of native aquatic plants and animals (NRC, 1992).

Associated with each objective is a set of assessment criteria, as mentioned earlier.

1.3.6 River restoration techniques

The next step in a restoration programme is to identify appropriate techniques to achieve the restoration objectives and goal. Essentially the requirements of restoration are based on removing the legacy of uniformity and creating diversity that is characteristic of natural channels (Hey, 1996). There are two approaches to restoration: non-structural and structural restoration.

The discussion which follows outlines just some of a multitude of restoration techniques available to restore a river. Those selected for further discussion represent alternatives possible within the Blackwood River Catchment.

1.3.6.1 Non-structural restoration techniques

Non-structural techniques refer to the establishment of natural features within a river which had been previously degraded (Hey, 1996). These methods generally do not involve physical alteration of natural features (e.g. channel realignment) or the construction of some other structure (e.g. dam). The non-structural approach can be either in-stream or out-stream. Instream examples can involve a number of engineering techniques, such as the restoration of meanders, pools, riffles and vertical banks. For example a pool-riffle sequence is often constructed to preserve and enhance existing degraded habitats using stones and gravel and minor dredging to recover the pools (Hey, 1996).

Artificial aeration is another nonstructural instream technique generally used to modify the causes of eutrophication by recycling nutrients, and more importantly to counter hypolimnetic anoxia in standing waters, similar to the summer pool environment of the Blackwood River (Cooke, Welch, Peterson and Newroth, 1993). This is achieved by either maintaining aerobic conditions throughout the water body by total mixing (Artificial Circulation) or through aeration of the hypolimnion only, without thermal destratification (Hypolimnetic Aeration) (Fast, 1977).

Artificial Circulation is one of the most common techniques used to control the eutrophication of lakes and shallow waters that are not nutrient limited and where oxygen depletion is a threat to warm water organisms. The best recorded improvements have been observed with DO, Fe and Mn content, ammonium, and pH (Cooke et al, 1993), also providing an increase in suitable habitat for aerobic organisms (Fast, 1977). This technique is inexpensive relative to other restoration techniques, costing around $390/ha for the first year of operation (Cooke et al, 1993).

Out-stream examples of non-structural restoration can involve legislative and administrative approaches. Reserving flow for in-stream uses such as for fisheries, wildlife, and recreation is an example of a legal approach to restoration where water is in short supply and often committed to withdrawals for crop irrigation , stock watering, or public water supply (NRC, 1992). The legislative approach is supported by the controls, regulations and standards designed to protect the environment from point source pollutants. Another non-structural approach to river restoration is the purchase of easements and land to prevent construction and the removal or relocation of structures detrimental to the river environment (NRC, 1992).

The exclusion of stock by fencing from the riparian zone has in many cases allowed the recovery of riparian vegetation, channel morphology and fish population. (NRC, 1992). The restoration of river margins functions to sustain the biological integrity of both the riverine and terrestrial systems. Riparian vegetation provides a buffer between the watercourses and the variety of land uses within the catchment (Large et al, 1996). Therefore the restoration and protection of the riparian zone should have high priority in catchment-based river management for reasons outlined below.

Water Quality control: the restoration of riparian vegetation whether natural or not has been proven to effectively reduce diffuse source pollution. In particular reference to the Blackwood River Catchment, riparian vegetation can significantly influence the quality of water passing from the agricultural system into the aquatic system (Large and Petts, 1996). A simple grass buffer has been shown to reduce phosphorus and nitrogen inputs to streams by 80-87%, but even this limited buffer is absent from the banks of the Blackwood, especially during summer. The riparian zone acts as a biological filter, intercepting sediment-bound nutrients, pesticides and organic pollution transported by surface runoff from paddocks (Pen, 1993). As stated by Malanson (1993), the riparian strip also functions to recycle crucial nutrients back into the aquatic system.

Wildlife conservation: The riparian zone provides an important linear habitat connecting corridors through the catchment landscape (Pen, 1993). As outlined by Large & Petts (1996), the riparian zone can support some of the richest terrestrial invertebrate fauna, and its removal has been shown to result in a 95% reduction in the number of bird species.

Protection of instream habitats: The riparian zone is especially important in determining instream habitats. It provides shade, regulating water temperature and influencing light availability, and controlling nuisance algal production (Large & Petts, 1996). Cover and protection is made available to aquatic organism in the form of overhanging vegetation and submerged logs. As indicated by Large & Petts (1996) the riparian zone supplies organic matter to the aquatic system which is important for invertebrate populations and represents the basic fuel running an aquatic food-web. The roots of trees serve to bind the soil of the stream bank preventing it from subsiding into the river (Pen, 1993). The riparian zone controls the erosion of the river bank and functions to reduce the input of catchment silt (Williams, 1992).

Recreation and Amenity: The riparian zone functions to improve landscape qualities, incorporating a degree of naturalness and diversity pleasing to the community (Large, 1996). The zone also has lifestyle value associated with the potential for multiple use.

The following provides a brief overview of the riparian restoration process, adapted from Pen (1993). Initially an evaluation of the site is required to determine the history of flooding and degree of restoration possible. For example a deep V-shaped drain offers little opportunity to plant along the embankment, but a shallow creek may be developed into a full riparian ecosystem. A timetable needs to be constructed along with site preparation which generally includes water quality, disturbance and pest control, weed suppression and soil preparation. Following this, trees and shrubs can be planted or direct seeded, along with the transplanting of sedges and rushes. The selection of native species for restoration is encouraged, in preference to introduced species since local species establish and adapt easier, and will support the local fauna. Native plant species are also more likely to regenerate, which must be encouraged within the restoration process along with animal life.

Within the Blackwood river catchment a number of programmes have been initiated in an attempt to protect and restore riparian vegetation. These have involved fencing remnants, research into level of riparian degradation, and planting trees. Some of the most recent programmes include the Save the Bush Program, One Billion Trees, Ribbons of Green, The Lake Toolibin Recovery Plan and the more recent and progressive Stream Foreshore Assessment in farming areas (Grein, 1995).

1.3.6.2 Structural restoration techniques

These techniques generally refer to a range of artificial instream structures used speed up the restoration process. Structural restoration can involve amendment to existing man-made structures such as dams and levees, and to the instillation of fish ladders (NRC, 1992). Hey (1996) outlines a range of artificial structures (weirs, deflectors, and submerged veins) which function to create ponded reaches and sand bars, and to prevent siltation. Structural modification is also used to restore the river-riparian ecosystem through costly bank sloping and riprap methods (NRC, 1992).

Structural restoration is particularly useful when natural restorative processes (non-structural) take decades or even centuries, and when full restoration is not possible within a heavily engineered environment, but habitat diversity is required (Hey, 1996). As outlined by Hey (1996), river restoration is best achieved using non-structural techniques, where the natural character of the river can be recreated. By establishing natural habitat features non-structural restoration allows a rapid recolonisation of instream and riparian flora and fauna. As outlined by Hey (1996) , freshwater crayfish, were observed to recolonise restored riffle during their construction.

1.3.7 Indicator end-points of system recovery

The establishment of acceptable end-points for restoration is a complex issue and of immense importance in the management of river recovery. The indicator or set of indicators must be acceptable to the community associated with the site, including such parties as the river manager, developers, the polluter and the general public. The end-points are potentially different according to the nature of the disturbance and stakeholder values. As stated by Milner (1996) the identified end-point must reflect some characteristic of the system at some spatio-temporal scale of observation, usually involving some biotic and/or abiotic characteristic.

Biotic recovery is principally examined at the community level where there are both functional processes (e.g. feeding groups) and structural attributes (e.g. density, diversity, similarity indicies). The structural attributes of a community may also include indicator species which indicate the well-being of a habitat or water quality (Milner, 1996), examples being certain macro-invertebrate species and salmonoids. Keystone species are also used as indicators of restoration end-points. These species are of special significance to the riverine community and may have important recreation, commercial and conservational value. An example of such includes valuable fish species (trout and salmon) and the otter (Milner, 1996). Like the salmon, a species could potentially be both an indicator and keystone species. As stated by the NRC (1992), much of the restoration of small streams and rivers has come about as a result of species-centred restoration.

Abiotic end-points to restoration include parameters such as physical habitat and water quality (Milner, 1996). Habitat quality may involve sediment size and heterogeneity of the substrate, while water quality parameters generally include dissolved oxygen levels, pH and heavy metal concentration, all of which are generally set by a regulatory body (Milner, 1996). The end-points selected largely influence the rate of restoration recovery (Milner, 1996).

1.3.8 The Blackwood River Catchment and Community Involvement in Restoration

The valuable impetus increasing demand for effective restoration of river ecosystems is the heightened public awareness of the environment. As outlined in section 1.2.7, this promoted the grassroots foundation of the BCCG within the Blackwood River Catchment and embodies a potentially effective institutional arrangement for river restoration. As outlined by Chapman (1992), a community dependent on the catchment environment for essential economic activity (primary industry) will often work out a system that achieves regulation over the commons. The potential role of the BCCG in river restoration is further enforced by the group's vision and mission statements as follows:

Vision: To achieve a Blackwood Catchment and River System which is balanced, functional, productive, and efficiently managed.

Mission: To inspire the sustainable management of the Blackwood Catchment's resources for the benefit of current and future generations through coordination and education (Negus, 1995).

In tune with the mission statement, it is generally agreed that the current emphasis on resource stewardship and restoration cannot succeed without public understanding and support. Thus before restoration can be initiated educational programs are required, aimed at raising the level of public knowledge and comprehension of river restoration rationale, goals, and methods. The concept of restoration is diverse and often confusing to the general public, thus restoration education require some means of clarifying the process and its end-points.

1.4 Flagship Species

1.4.1 Flagship Species Defined

Community and stakeholder involvement and commitment is vital for the initiation and success of a river restoration programme. As outlined in section 1.2.7, the Blackwood Catchment Coordinating Committee has recognised and promoted this, by insisting that the views of the community are of paramount importance in catchment management decisions (Negus, 1995). Therefore, with improvements in baseline data, research into catchment specific restoration techniques and end-points, funding, and development of a concrete institutional arrangement, the scene may be set for river restoration within the Blackwood Catchment.

As indicated in section 1.3.1 restoration is not solely about the ecology between the river and its surrounding catchment and the knowledge of the scientist, but is a community based project as well, associated with anthropocentric values and demands functioning to define restoration.

However, before the community can define restoration and be instrumental in the river restoration process, a clear understanding of what constitutes a successful restoration and its endpoint is required. Getting people to sympathise with and support a 20% increase in dissolved oxygen or a 50% decrease in salt, as an objective of restoration is very difficult. Such measures of restoration will be neither tangible nor valuable to the local community. In recognition of the diverse concept and complexities associated with restoration this project emphasises the need for an icon to direct and clarify the restoration process.

The use of a high profile riverine species as an icon, or more technically apt "flagship", can promote a clearer understanding of river restoration within the community. It has the ability to provide a driving force and direction for the restoration process, an element often lacking. A flagship can provide hurdles to jump so as to map progress, not only for scientific monitoring but for community education and satisfaction in that their efforts are working, promoting commitment. So what is a flagship species?

The flagship species or group concept is another priority conservation grouping which is relatively new compared to the keystone, umbrella and indicator groupings. Today, the increased need for community awareness and involvement in conservation and restoration programmes has led to the popularity of the flagship species concept in relation to its theoretical and practical application.

A flagship species or group, as outlined by New (1995), gains public and political sympathy, based on its charismatic appeal which serves to increase public awareness. The main value of a flagship taxon is its ability to influence public policy; as people value the organism concerned, they desire its survival, and support moves, even at some cost, to ensure it. Effective conservation management can therefore be communicated tangibly which helps to engender positive change in the form of conservation (New, 1995).

Using flagship species for restoration has not been so common, compared to those enlisted for conserving biodiversity, but this is expected to improve with the increasing need for restoration, as indicated in section 1.3. Nevertheless, community involvement in restoration of the Thames River was inspired by the ongoing return of salmon, a flagship species, providing the community with evidence that their money was being well spent (Chapman, 1992). In fact one of the endpoints to the restoration process was to raise dissolved oxygen to a level that allowed the passage of salmon up the river (Chapman, 1992).

The following provides a brief review of other flagship species identified world wide and their role in conserving biodiversity. Possibly the most publicised and controversial flagship species established so far is the endangered northern Spotted Owl. The species dwells exclusively within old-growth forests in the Pacific Northwest of United States. As stated by Miller (1992), the owl has become a symbol of the clash between the timber company logging the forests, and environmentalists who aim to protect the remaining old growth forest. The threatened owl has become the best tool available to the environmentalist in achieving this goal and has been the focal point for many radical environmental demonstrations within the forest (Manes, 1990).

The conservation of species dependant on forest ecosystems, has not been the only method used in raising public awareness of the value of forest conservation. Recently forests have been recognised as flagships in their own right. Giant trees all over the world such as the California Coast Redwood and the Douglas Fir are commonly referred to as "Flagships of the Forest" (Ring, 1995).

The Golden Lion Tamarin, a strikingly beautiful squirrel sized monkey, is one of the most endangered primate species on earth. It occurs naturally within the rainforests of Brazil, and is therefore severely threatened by habitat destruction. However, this small and endangered species has become the flagship for the most successful conservation effort yet to arise in Brazil, with grassroots foundations establishing an internationally recognised organisation (Golden Lion Tamarin Conservation Project, 1995).

The Asian Elephant has been identified as the incomparable symbol of tradition and heritage in many Far-Eastern countries, and more recently has been considered the ultimate flagship for broader conservation concerns (JB care for rare, 1995). Ironically, this charismatic and keystone species faces substantial decline due to habitat destruction, illegal capture, and poaching. However, the flagship nature of the Asian elephant has provided a window to address biological diversity by looking at the conservation of elephant populations in a holistic sense, since properly designed areas for elephant conservation must be biologically diverse (JB care for rare, 1995).

Waterbirds occupy a special place in human culture, having passive and active recreational value and public appeal, attracting many tourists. Regardless of the fact that waterbirds are also often the subject of international agreements, their wetland habitat has been threatened in arid zone areas principally by irrigation and water diversion. This has encouraged Kingsford and Halse (1996) to propose the use of waterbirds as flagship species to demonstrate the ecological value of arid zone wetland systems, thus providing an effective focus for their conservation.

The paramount invertebrate group utilised so far as flagship species is the butterfly, in particular the beautiful and very appealing swallowtail and birdwing forms, constituting the family Papilionidae (New, 1995). Yen et al (1996) identify that the popularity of the dragonfly has the potential to be used to promote the concept of aquatic invertebrate conservation with Australia.

This review demonstrates that there are a number of characteristics common to those species or groups selected as flagships for the conservation of biodiversity. The following outlines the established criteria for selecting flagship species according to New (1995).

1.4.2 Criteria for Flagship Selection

Flagship species require a well known taxonomy to allow easy public recognition; they must belong to a relatively diverse and widespread group, but with localised endemic taxa which can be used to monitor provincial ecosystem health and to foster local community pride; they should frequent an array of different habitats and respond to changes, and in so doing combine features of an indicator and umbrella species; and they should have the ability to engender public sympathy for their well being, based on some aesthetic and/or commodity value (New, 1995).

Regardless of how well the biology of an organism is understood, and how ecologically important it is, it must have political and public acceptance before it can be used as a flagship species (Yen et al, 1996). The main function as a taxon for conserving biodiversity is to influence what has become a very subjective, and at times reactive, and highly politically based concern. An ideal flagship has direct significance to human affairs and its survival promotes the conservation of a variety of other creatures and economic development of human communities (JB care for the rare, 1995).

1.5 Aims of the Research

1.5.1 The Research Aim

To establish whether the use of a high profile riverine species has the potential to be effective in providing the *community* with a tangible *understanding* of the restoration process and its objectives, by acting as a key *indicator* for change as restoration becomes effective, and as a *flagship* for the restoration process.

1.5.2 The Research Question

Does marron (*Cherax tenuimanus*) fulfil requirements of a flagship species for the restoration of the Blackwood River?

1.5.3 Research Objective and Flagship Selection Criteria

The objective of the study was to evaluate marron against each the following criteria adapted from New (1995) and Yen *et al* (1996), in order to answer the research question and identify areas of knowledge, education, and community value which required attention prior to the marron's conscription as a flagship species.

The following table (Table 1.1) outlines the criteria and the methodology used to evaluate each, while indicating the pertinent chapters within the thesis.

Table 1.1: Criteria for Flagship selection and methodology used to evaluate and critique the appropriateness of marron (*Cherax tenuimanus*) as a flagship species within the chapters outlined.

Chpt	Selection Criterion	Methods
II	**1**: Diverse and widespread group	**Literature Critique**
	2: Known taxonomy	
	3: Localised endemism	
	4: Functionally important - (keystone species)	
	5: Biology sufficiently known to define habitats	
	6: Relatively sedentary	
	7: Cultural value	
	8: Economic value	
	9: Indicator of habitat change - (indicator species)	**Marron Sample**
	10: Ability to recover from a threatening process	**Water Quality**
III	**11**: Evoke public sympathy	**Oral History and Questionnaire**
	12: Identifiable to the public	
	13: Evoke community pride	
	14: Aesthetic appeal	
	15: Popular	

Chapter 2

EVALUATING FLAGSHIP CRITERIA: KNOWLEDGE, VALUE AND CONSERVATION STATUS OF MARRON

2.1 Scientific Knowledge and Ecological, Cultural and Economic Value of Marron

The thesis is based on the proposition that the marron (*Cherax tenuimanus*) is a charismatic icon with the potential to be used as a flagship for the restoration of south-west rivers, particularly the Blackwood. This chapter will test and critique the marron's performance in reference to the criteria for selection of a flagship species as outlined in Table 1.1. Section 2.1 is devoted to the evaluation of flagship criteria which pertain to current knowledge available on marron and their ecological, economic and cultural value within the south-west (criteria 1 to 9).

2.1.1 Criterion 1: Diverse and Widespread Grouping

Freshwater crayfish in Australia all belong to the family *Parasticidae* which has a Gondwanan distribution. They are abundant and diverse in a wide variety of lowlands to sub-montane habitats, creeks, rivers and swamps where they are typically the largest animal form present (Knott, 1996). The genus *Cherax* is very speciose, distributed within Australia and New Guinea. Twenty-two species have been recognised within Australia, five of which are native to Western Australia (Austin, 1996). Morphological and ecological variation is great between these south-west species and has been identified to be associated with habitat variation (Austin and Knott, unpublished).

The marron, *Cherax tenuimanus* (Smith), is the most distinct and largest of the five WA species. In fact marron is the third largest freshwater crayfish in the world surpassed only by the Tasmanian species *Astacopsis gouldi*, and the Murray Crayfish (*Euastacus armatus*) (Geddes, 1993).

2.1.2 Criterion 2: Known Taxonomy

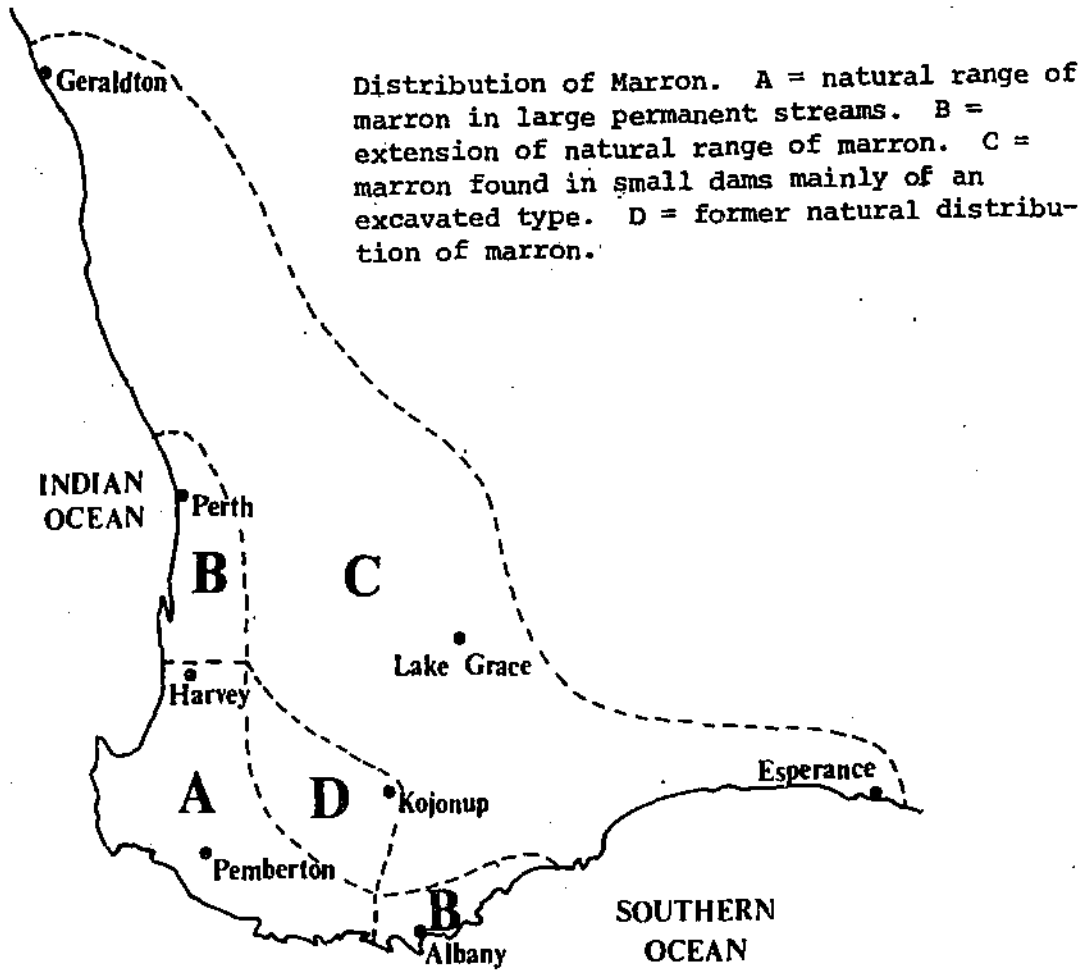
According to Riek (1967) marron were one of the few *Cherax* species identified which involved no confusion either to specific identity or to name. Only one species of marron is formally recognised today, *Cherax tenuimanus*, but different strains of wild marron are said to exist in various river systems within the south-west, notably the Margaret River subspecies recognised by Austin (1996). The large juveniles and adults are quite distinctive in appearance from other local species, usually jet black at larger sizes, and brown to bluish when young (Dept of Fisheries WA, 1993). Marron can be positively identified at any age by the presence of a pair of median spines on the telson (central tail fan). There are five ridges on the back of the head (cephlon section of the carapace) and the claws are notably pincer like (Mills, 1989).

2.1.3 Criterion 3: Localised Endemism

Marron is a temperate species with a small natural distribution endemic to the south-west of Western Australia. Research by the Fisheries Department of Western Australia has identified that the natural range for marron existed in freshwater streams from the Murray River near above Harvey to the Kent River near Albany. However marron have now been established further afield and can be found in natural streams from as far north as Geraldton to coastal streams within the Albany region (Morrissy, 1978*b*).

The artificial range has been extended even further as marron have been introduced into farm dams and large domestic and irrigation water supply dams, and have become the basis of a growing aquaculture industry within Western Australia. International interest in marron farming has led to the species being introduced into South Africa, Zimbabwe, Japan, U.S.A, China and the Carribbean (Morrissy *et al* 1990). However, marron have been lost from a number of natural systems, especially within the upper reaches as water quality of rivers has become detrimental to marron survival (Morrissy, 1978*b*). Figure 2.1 shows the various ranges for marron in Western Australia as described above.

Figure 2.1: Range and Distribution of Marron within Western Australia



(Fisheries Department of WA, 1985)

2.1.4 Criterion 4: Functionally Important ("Keystone species")

A keystone species is defined as "those on which the local community or assemblage functionally depends" (New, 1995). The ecological importance of such a species is expressed in the understanding that if keystone taxa are harmed, the effects of their loss may have ramifications on the whole community.

The marron is a central component of the food web within south-west rivers. It is an omnivore, cannibal and detrital feeder (O'Brien, 1984). It is one of the few large freshwater animals which require no intermediate conversion of primary production, thus eating the dead plant animal and other detrital matter directly (Morrissy, 1974). Marron are commonly identified as non-selective feeders (Knott, 1996). Such a broad feeding niche ensures an energy source which can maintain a relatively large biomass. The biomass of marron has been identified as the most significant of any macrobiotic species present within south-west rivers (O'Brien, 1984).

The growth rate of marron like other freshwater crayfish depends upon factors such as population density, food availability, and temperature (Morrissy, 1976). The maximum size achieved is about 2.7kg and 38cm in length, taking over 5 years. Information on natural river populations suggest that population numbers range in density from 1.4 to 1.5 per square meter with a biomass ranging from 300 to 600 kg/ha (Mills, 1989). Males generally attain a larger size than females. There can be considerable difference between the growth rates of marron of the same age (Morrissy, 1992).

This biomass provides an abundant food source for several species of fluvifauna and avifauna such as the cormorant, water rat, tortoises, heron and egrets (Mills, 1989). Research by Pen and Potter (1994) indicated that predation by perch, introduced into a number of south-west rivers (including the Blackwood), not only threatened native fish stock but also freshwater crayfish. Since European settlement marron have been exploited for human consumption, and presumably prior to this by aboriginal people, as implied by Horwitz and Knott (1995).

Marron are host to a number of commensal organisms, having a symbiotic association with epiphytic flora and fauna, including temnocephalids (flatworms). As explained by

Evans and Fotedar (1996), these flatworms do not appear to affect marron health, but are indicative of suboptimal water quality.

The symbiont nature of marron not only provides a host for commensal organisms but also represents a habitat for a wide diversity of biota (Horwitz, 1990a). The symbiont role of Australian freshwater crayfish has prompted Lester, Cannon, and Sewell (1994) to identify that their conservation as a symbiont has ecological importance to the conservation of invertebrate biodiversity and their habitats.

From the above discussion it is conceivable that marron can have a considerable affect on the processes operating within the rivers of the south-west. According to O'Brien (1996) marron assist in maintaining water quality with their ability to consume large amounts of detritus and decaying material at the sediment interface. Therefore the absence of marron from an enriched river environment like the Blackwood River would more than likely have serious ramifications for other aquatic biota within these systems.

2.1.5 Criterion 5: Biology sufficiently known to define habitats.

In their natural distribution marron tend to occupy the broad deep moving waters of permanent streams and the large deep pools within the temporal rivers. Marron do not burrow like other native species and are restricted to permanent water bodies during extreme environmental conditions. Marron generally dwell under rocks, logs and other sunken debris within the favourable clear water pools (Morrissy, 1976a). According to Knott (1996) marron spend a good portion of the day partially buried in sediments. Different ecological requirements of the various size classes within a natural marron population allow them to utilise varying habitats (O'Brien, 1996). Within a natural system marron tend only to forage for food at night, leaving their shelter at sunset. According to Morrissy (1975b) the number of marron a habitat can support is directly related to the amount of shelter or refuge cover available.

The reproductive strategy of marron plays an important role in defining the habitat requirements of marron. Marron reproduction involves a seasonal concentration of mating during early spring (August to September). The berried females appear in October / November with egg and larvae development continuing for 12-16 weeks until release in early Summer (December to January). The bottom dwelling young are left to survive in what is generally identified as one of the harshest times of the year in terms of water quality. Females can incubate 400 to 900 eggs which develop into larvae, remaining attached to the pleopods under the female's tail until spawning (release) (Dept of Fisheries WA, 1995).

The newly released juveniles have an identical morphological appearance to adult marron (Evans et al, 1996). Females tend not to mate until they are approximately 2-3 years of age when the actual fecundity increases as the female becomes larger (Morrissy, 1976a). As outlined by O'Brien, marron release a lower number of juveniles with each mating compared to many other species of freshwater crayfish. This may be related to maternal predation, competition, disease and mechanical damage, or as a result of oxygen depletion (Mills, 1989). O'Brien (1996) outlines that the depletion of oxygen, below the tolerance of the rapidly metabolising eggs, can reduce the number of juveniles released. Even though this level is above the level lethal to the adult, it indicates the importance of a well oxygenated habitat for successful marron production.

However, considering that marron are unique and an important component of the states aquacultural industry and recreational fishery very little is know of the biology of wild marron populations. For thirty years marron has been officially recognised as important within Western Australia, and there still is little knowledge on the population structure of marron in a relatively undisturbed environment, or the feeding biology of marron , or the reproductive behaviour and life history of marron in the wild. This constitutes a loss of baseline data for the future, which needs to be retrieved now.

2.1.6 Criterion 6: Relatively Sedentary

Marron have been described by Morrissy (1976a) as " solitary mutually aggressive individuals", which maintain a home range of approximately 30m within a stretch of river, providing relatively easy sampling. Within this home range a "pecking order" exists with the larger individuals dominating the smaller ones when feeding (Morrissy, 1975). The importance of a sedentary lifestyle in reference to flagship species selection reflects the need for easy sampling and monitoring of such species. The fact that marron support an amateur fishery confirms its compliance to this criteria.

2.1.7 Criterion 7: Cultural Value

Marron is arguably the most easily identified and ecologically important aquatic animal species in south-western Australian rivers. In fact it is quintessentially south-western Australian, being endemic to only this corner of the continent. The large marron have provided a delicious meal, and sport and recreation for thousands of Western Australians, making the species a valuable element of the State's recreational fishery. In fact forming a world class amateur fishery (Morrissy, 1978a). No other native freshwater species has the potential to equal this popularity.

As Cribb (1989) vividly portrays, "...on summer evenings...along many south-west rivers, parties of marroners would spend a pleasant evening with scoop net and chook pellets, wading in the shallows...". Consequently, marron have been an integral part of south-west Australian culture. With such popularity it is easy to conceive marron as the numbat or the kangaroo paw of south-west Australian waterways, and could rightly be regarded as the State's aquatic emblem. It seems no other aquatic species could fill such a role more appropriately.

The following looks at the importance of the marron fishery in Western Australia, its role in providing fishable marron stocks for the community and ensuring the sustainability of wild marron populations within south-west rivers.

2.1.7.1 The Marron Fishery

In 1955 the increasing popularity of recreational fishery for marron forced wild stocks to be protected from commercial exploitation (Cribb, 1989). Since then the Department of Fisheries has established regulations to ensure that the worthwhile amateur fishery is both sustainable and equitably shared amongst its various user groups. These regulations have risen from a history of initiatives (trapping and methods) and increased popularity of marron fishing since 1955.

However after several seasons of plummeting catch rates and the closure of the marron season for two years (1987/88 and 1988/89), the original regulations were reviewed and updated into the following which provides a brief overview of current regulations dealing with the marron fishery to date.

A licence is required to legally catch marron within West Australian waters. To date there are no limitations on the total number of recreational fishing licences issued for the taking of marron. The revenue received from the licence fee ($8) is used to promote compliance with the new, tougher regulations and public education programmes (Fisheries Dept of WA, 1989).

An open season governs the timing of the fishery, which was reviewed in 1990, reducing the original 135 days to approximately 75 days. Over the last 5 years the open season has begun on the first Sunday in January finishing midday on 28 February (Dept of Fisheries. WA, 1989).
The reduction in season length was designed to ensure the recruitment of juveniles into the fishery and in addition to protect breeding females releasing young in late spring to early summer (Dept of Fisheries. WA, 1989).

Sustainable marron fishery is based on the notion of a minimum legal size and bag limit. Currently the sole legal method of size measurement is the orbital carapace length (OCL) , with a legal size of 76mm. This is based on a value judgement that represents the minimum size worth eating (Morrissy & Fellows, 1990). The regulations require participants tc return all undersized marron to the waters as well as those females caught in berry or carrying young (Morrissy & Fellows, 1990).

The daily bag limit was originally 30 legal sized marron per person per day, based on what most considered a "worthwhile feed for your family". The idea of a worthwhile catch was re-examined in 1978 based on the increased popularity of marroning. It was concluded that a bag limit of 20 was worthwhile for a "nuclear family", enforced since the 1980/81 season (Morrissy & Fellows, 1990). Recently the bag limit was reduced to 10 for the 1996 season due to further decline in the daily legal size catch.

Regulations have been enforced on the method of fishing, used by the licensee. Current regulation allows a single person to use either six drop nets, or one scoop net, or one pole snare to catch marron. It is illegal to use traps, boats and to dive for marron. However prior to 1990 no restrictions on the dimensions of the gear units existed (Fisheries Dept of WA, 1989).

In 1990 "new legal marron gear" was specified, which functioned to improve the escape of under-sized marron, without affecting the legal sized catch. The new drop nets were fitted with "marron mesh" (80mm x 32mm) and a larger top ring. The use of a standard (unmodified) crab scoop was enforced, while the use of snares were encouraged with the designation of snare only areas throughout the south-west (Fisheries Dept of WA, 1989).

Regulation of the marron fishery also involves a research monitoring program which has been conducted since 1971 on data collected from licensing information, voluntary log book programs and end-of-season telephone surveys established by the Fishery Department of Western Australia (Fisheries Dept of WA, 1989). The statistics obtained provide background information on the regulations, the change in fishing methods, the biology of marron, and the distribution of the fishery.

2.1.8 Criterion 8: Economic Value

As part of a world class fishery, marron have provided sport, recreation and a delicious meal for thousands of Western Australian, national and overseas visitors, thus contributing significantly to the economy of tourism in the south-west of Western Australia.

Stemming from the knowledge and interest generated by the recreational fishery, marron has become an aquacultural product. Using the technologies developed through research conducted by the WA Department of Fisheries, the commercial marron farming industry was initiated in 1976. Since that time there has been concerted government, university and industry based research focused on improving marron farming technology to assist marron farmers, who now export marron, "a gourmet delight", overseas at exceptional prices ($25/kg).

There are currently 50 licensed farms and a further 77 prospective farmers awaiting licence approval by the regulatory body, WA Department of Fisheries (Evans et al, 1996). Over the past ten years annual production of farmed marron has risen significantly, with total annual production in 1994 equalling 16.7 tonnes and 406,975 juvenile (0+) marron sold for stocking ponds within and outside Western Australia

(Evans et al, 1996). The commercial production of marron predominantly occurs within Western Australia, with increasing contributions from South Australia (Jones, 1996).

As indicated by O'Brien (1996), commercial viability in marron aquaculture depends on maximising production while minimising cost. In line with this, research has been conducted on key biological parameters which are known to influence aquaculture production, prompting exploration into the taxonomy, biology and environmental tolerances of marron.

2.1.9 Criterion 9: Indicator of Habitat change (Indicator Species)

In the broadest sense, any species "indicates" a particular suite of environmental conditions, those best fitted to its demands (New, 1995). However the term indicator species is often reserved for those species which have a narrow and specific environmental tolerances, so that they show marked responses to quite small changes in environmental quality (Abel, 1989). The presence, absence or relative abundance of a species may be used as indicators of environmental quality. Aquatic invertebrate taxa are particularly sensitive to definable changes and can be used to monitor the health of the river environment. Such groups provide sensitive early warnings of the effects of human activity (New, 1995).

Toxicological research associated with aquaculture, has identified the environmental tolerance of marron to a number of key physical and chemical components related to both artificial and more importantly natural water bodies. This provides a valuable source of information on the biology of marron and their requirements for survival in the wild. Through such research marron have been shown to display a slightly narrower tolerance range than other species of freshwater crayfish (Jones, 1996).

Table 2.1 represents the key physical and chemical components identified through toxicology tests as impacting on marron survival and aquacultural production. The following is a discussion of each parameter identified within the table.

Table 2.1: Environmental tolerance of marron for a number of key physical and chemical parameters

Physico-Chem Parameters	Condition	Reported tolerance	Author(s)
ph	optimal range	7 - 8.5	Morrissy (1976)
Calcium	optimal range	1.2 - 14 mg/L	Mills (1989)
Zinc	death - 96h LC50	139 mg/L	Lindhjem (1995)
Salinity	death decreased growth	20 ppt 6-8ppt	Morrissy et al. (1990)
Water Temperature	decreased growth optimal lethal high	12-13 °C 24 °C 30 °C	Morrissy et al. (1990) Morrissy (1992) Morrissy et al. (1990)
Dissolved Oxygen (20 °C)	lethal low critical threshold decreased growth optimal	7.5% 40% 70% 90%	Morrissy et al. (1990)
Ammonia (14 °C & pH 7.7)	death - 24h LC50	2.52 mg/L (N NH_3)	Constantine (1988)

2.1.9.1 pH

A pH range between 6-9 is generally considered acceptable to most species within the aquatic environment (Abel, 1989). For marron an optimal pH range is between 7 - 8.5 (Morrissy, 1976). Within the natural aquatic environment, pH can change considerably in association with the use of agricultural substances such as fertilisers and insecticides, which generally lower the natural pH of water. A resulting pH of 5 has the potential to mobilise heavy metals within the river sediment (Terry, 1995).

2.1.9.2 Heavy metal

Like other freshwater crayfish, marron are particularly sensitive to heavy metals and pesticides within the aquatic environment (Mills, 1989). As identified by Lindhjem (1995) marron death occurs when they are subjected to over 139mg/L of zinc, a heavy metal with the potential to be mobilised from the sediments with the lowering of water pH. Acute toxicity tests indicate that zinc accumulates in the gills of marron and heptapancreas causing malfunction of the organs (Evans et al, 1996). Research by Chamber (1994) has identified that acute toxicity of cadmium chloride on marron, may allow the species to be a suitable bio-indicator for cadmium in south-west rivers, when cadmium is introduced to the system as phosphatic fertilisers.

2.1.9.3 Calcium

Marron are tolerant to calcium between the range of 1.2 to 14mg/L (Mills, 1989). Within their natural range marron are generally free of toxic levels of calcium concentrations. Intolerance can however occur within aquacultural ponds (dams) if established within calcareous soils (limestone) near the coast.

2.1.9.4 Salinity

Salinity is of particular relevance in the salt-affected regions of Western Australia. The upper limit for ideal hyperosmotic regulation is 14ppt (Morrissy, 1978b), with deaths occurring at salinities of greater than 20ppt, a value exceeded only in the headwaters of the longer inland rivers (e.g. Blackwood). For marron farming it is recommended that stock be exposed to no more than 6-8 ppt as growth decreases with higher salinities (Morrissy, et al, 1990).

2.1.9.5 Temperature

Marron prefer the "Mediterranean" type climate, therefore as identified by Morrissy (1992) the optimal temperature for marron growth is 24°C. Temperatures either side of the optimum have a significant impact on marron survival, with the upper incipient lethal temperature identified at 30°C while growth ceases below 12-13°C (Morrissy *et al*, 1990).

Reduced survival is shown when marron are held within systems with temperatures consistently above the optimal range (Morrissy *et al*, 1990). No mass deaths have been known to occur simply due to high water temperatures. However, marron will die in large numbers when high temperature and low dissolved oxygen levels are combined.

2.1.9.6 Oxygen

Research indicates that oxygen levels have a significant effect on marron growth and survival. Marron have been shown to die after 14 h when held within water containing 4.9% oxygen at 20°C (Morrissy et al, 1990).

From incidental farm dam and laboratory observations it has been identified that avoidance of oxygen depleted areas of the bottom water, failure of breeding and death are related to a critical oxygen threshold of approximately 40% saturation (3.6ppm at 20°C), while depressed growth increments exist at less than 70% saturation (6.4ppm at 20°C) (Morrissy, 1976a). As a general principle marron farmers are advised to provide over 90% saturation for successful aquaculture production. The impact of oxygen levels on marron growth is clearly exemplified by a 10% improvement in marron growth when aerators and paddle wheels are used in marron aquaculture (Evans et al, 1996).

As identified by Bunn and Horwitz (1980), marron consistently consume oxygen at a higher rate than burrowing crayfish species. This has been attributed to the marron's physiological adaptation to a habitat of open water and high oxygen levels. Similarly a higher metabolic rate was identified in association with this adaptation (Bunn and Horwitz, 1980). The adaptation has made marron susceptible to low DO, enabling them to become an excellent indicator of degrading water quality, particularly associated with eutrophication.

2.1.9.7 Organic Input and Nutrients

The input of organic material is very important as a food supply for marron, enhancing growth and production. However detritus can also cause low oxygen levels to develop in the bottom water (Morrissy , 1976). Early winter rains and sudden heavy summer runoff from cyclonic downpours bring an over supply of organic material (crop debris and manure) from the surrounding water body catchment. The sudden large amounts of organic debris result in rapid decomposition with warm temperatures and a depletion in oxygen. Additional nutrients released from the sediments with deoxygenation promote blooms of green algae which further remove oxygen from the water overnight (Morrissy, 1976). Unless the water is mixed or rain continues to flush the water body then a hot, polluted, oxygen deficient environment will develop causing mass marron mortality.

2.1.9.8 Ammonia

Research by Constantine (1988), has identified that the accumulation of nitrogenous waste, in particular ammonia and nitrite may affect growth and survival of marron. This is especially so when the pH of the water body declines and the water temperature increases (Mills, 1989). Constantine (1988) concluded that ammonia is toxic to marron in both its chemical forms (NH3 and NH4+), where experimentation on juveniles indicated at 14°C, and 7.7pH, for 24h, an LC50 of 2.52mg/L of ammonia (Knott, 1996). Within deoxygenated bottom water, anaerobic denitrification converts ammonia to nitrogen gas, methane and hydrogen sulphide, all very toxic to most aquatic life (Harper, 1992), including marron.

2.1.10 Criterion 10: Ability to Recover from a threatening process

A flagship species must be able to recover from a threatening process. Marron have not been officially recognised as threatened, but are defined as "rare" according to CALM's threat categories, implying that the taxa has a small world population which is not at present "endangered" or "vulnerable" but is at risk (Horwitz pers comm, 1996). Nevertheless recent reviews of the conservation status of freshwater crayfish in Australia have suggested that marron should be regarded as threatened in natural waterways for three distinct reasons:

- the possibility for genetic pollution to take place;
- the depletion of stock through overfishing ;
- habitat and water quality degradation (Horwitz, 1990b, 1995c).

The following will outline the evidence for each threatening process.

2.1.10.1 The possibility for genetic pollution of marron stock

The justification of this threatening process is based on the assumption that continued unabated translocation of marron will eventually result in the loss of significant genetic and morphological variation through hybridisation. This concern is directed towards the potential interbreeding of the two genetically and morphologically distinct forms of marron, the Margaret River subspecies and the more widespread (most translocated) form of marron (Austin, 1986). Consequently, marron are under threat from the potential homogenising of stock, to the extent that genetic and geographical variation may no longer be discrete (Horwitz, 1995b).

An example of the reality of this threat, is the establishment of a captive population of the Margaret River subspecies in the Pemberton Hatchery by the Fisheries Department of Western Australia in 1985. The purpose was to maintain a stock of the subspecies, with the intention of ensuring its genetic integrity, given the threat of genetic pollution. However, as outlined by Horwitz (1994), hybridisation in fact manifested within the captive subspecies stock, either as a result of accidental pollution within the hatchery or within the Margaret River prior to capture. The latter is likely in light of the increasing occurrence of marron farms within the Margaret River area, and the high probability that marron have been translocated into the Margaret River within the last 100 years.

2.1.10.2 The depletion of stock through overfishing

Confirmation of the threat of overfishing on wild marron stocks is provided by the statistics generated by the Fisheries Department of WA based on licensing information, voluntary log book programs and end-of-season telephone surveys. The following outlines the main results incriminating the marron fishery as a threat to the survival of marron in the wild.

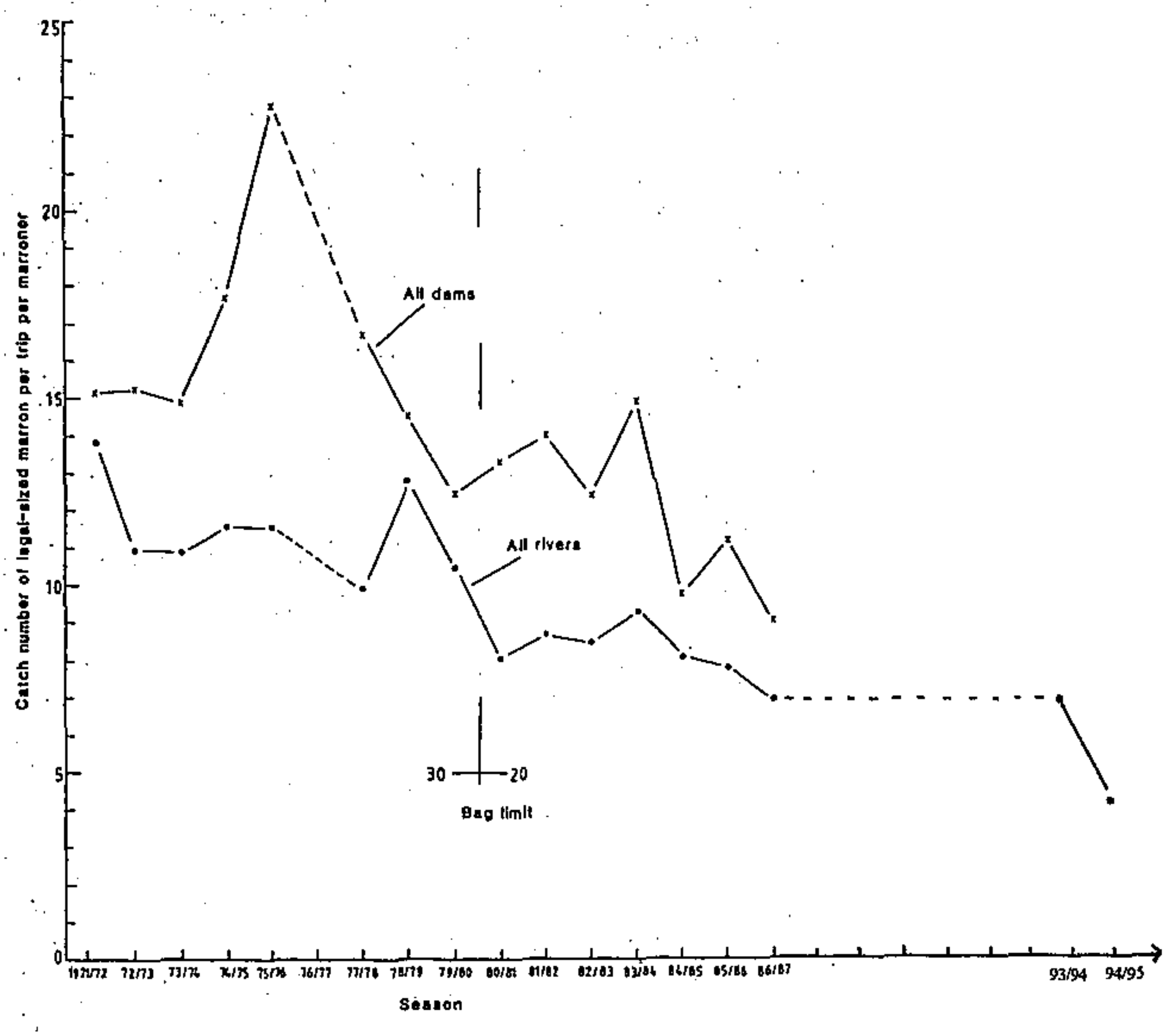
Firstly, statistics confirmed a general increase in the number of practicing marroners over the research period (1970 -1987). However, this trend was modified markedly in periods of drought, when fewer marroners went fishing, or did not purchase a licence during that period. This was especially so for country and experienced marroners who were more likely to stop marroning due to worsening water conditions (Morrissy and Fellows, 1990).

As indicated by Anon (1988), rivers were 2 to 3 times more popular for marron fishing than dams within the period 1971-1986. During this time marroners on average carried out between three to four trips per season (Anon, 1988). These results show an increasing popularity in marron fishing especially in rivers, which may have attributed to the following evidence for decline.

According to marroner log book information there has been a noticeable decrease in the average number of legal size marron taken per fishing trip for both rivers and dams since the 1971/1972 season (Anon, 1988). As shown by Figure 2.2 the average logbook catch number per trip over the period 1973 to 1976 was 13 legal sized marron and 9 for the 1984 to 1989 period (Anon, 1990). According to the most recent data (Fisheries Dept of W.A, 1995), the daily catch number of legal sized marron fell from 7 in 1994 to 4 in 1995. Note, these values relate to the catch made by regular (expert - log book) fisherpersons and potentially present a slightly more favourable picture than the catch made by marroners at large (Morrissy & Fellows, 1990). The slight increase in catch number for the season 1983-84 was associated with an improvement in river water quality during that period, after the 1982 flood (Anon, 1988).

Results showed that the average size of a legal sized marron caught in 1986-87 had fallen significantly compared to the average size caught in previous seasons. Similarly the proportion of under-sized to legal-sized marron captured was higher with progressive seasons. According to Anon (1988), rather than being indicative of an increasing marron stock, these results are in fact reflective of a decline in the catch of legal sized marron, with a 50% decline in the abundance of under-sized marron caught in both dams and rivers.

Figure 2.2: Catch numbers per trip per marroner in rivers and dams from 1971/72 to 1986/87 season (Anon, 1988), including recent statistics (Fisheries Dept of WA, 1995).



As indicated in the above results, statistical research of the marron recreation fishery, identifies a significant decline in stock abundance, suggesting that the number of marron that may be caught each year without seriously jeopardising the long term future of the fishery is limited. Nevertheless, the number of people wanting to fish for marron continues to grow each year (Anon, 1988); the disregard for regulations persists; and water quality continues to decline in rivers . All of these factors have contributed to an increased pressure on marron stocks directly responsible for the daily catch number in 1995 to only 4 legal-sized marron (Fisheries Dept of W.A, 1995).

This conclusion has prompted urgent questioning of the future of marron fishing as a sport. Since 1989 the Fisheries Department have attempted to increase public awareness of the abuse of the marron resource. "Marron conservation" is expressed along side the regulations of the fishery, but the future, according to Cribb (1989), for both marron fishing and the wild marron depends on whether Western Australians care enough about marron and future generations to stand by the sustainable yield principle.

2.1.10.3 Habitat and water quality degradation

As indicated within the discussion above, water quality and habitat degradation of rivers has implications for marron survival. Horwitz (1995c) has identified three main threatening processes which have caused a reduction in marron distribution within their natural range:

- agriculture;
- clearing and loss of riparian vegetation;
- instream alteration and river regulation.

These processes are typical of lowland riverine habitats susceptible to all changes occurring within the river catchment, especially those related to agricultural landuse.

Similar patterns of decline have been associated with a number of other freshwater crayfish in Australia, such as the Tasmanian giant, *Astacopsis gouldi* (Horwitz, 1995c) and most notably the Murray River spiny crayfish (*Euastacus armatus)* which has virtually disappeared from the lower Murray River below Mildura (Geddes et al, 1993) making it "vulnerable" (Walker, 1982). The Murray Crayfish was identified by Walker (1982) as a symbol of many people's concern about the community's relationship with the Murray River.

A decline in the fishery in the upper reaches of many longer inland rivers in the south-west, prompted the Fisheries Department of WA to investigate the past and present distribution of marron in a number of south-west rivers, including the Blackwood. In the 1973/74 spring to summer period marron sampling was conducted on a number of selected pools down the length of the Blackwood River, from the upper into the middle catchment of the Blackwood River.

As shown in Figure 2.3, the results from the sampling effort and anecdotal information collected from local residents and marroners along the river, established that the original upper limit of marron distribution in the Upper Catchment had in fact deteriorated dramatically since the late 1950-1960's down river to Winnijup, below Boyup Brook in the Lower Middle Catchment. Above this point marron occurrence was limited to only a few larger survivors, which consequently led the Fisheries Department to set the new upper limit for marron distribution at Winnijup in 1974 where reasonable catches of legal-sized marron could still be attained.

Three main reasons for the shrinkage in marron distribution from the Upper Catchment were hypothesised by Morrissy (1978b) and investigated as to their validity, these included:

- overfishing of stock within the Upper Catchment;
- increasing salinity of the river;
- oxygen depletion in the summer pools of the Upper and Middle Blackwood.

The following outlines Morrissy's (1978*b*) conclusion as to the causality of each.

Overfishing of stock

Statistics showed that fewer and fewer larger marron were being caught within the Blackwood, along with less under-sized catches. These results are typical of overfishing, but as Morrissy points out, the popularity of marron fishing within the Upper Catchment had in fact declined with locals being more inclined to stock and fish from their farm dam. Locals living on the Upper Blackwood did not blame overfishing for the decline. This was supported by the lack of public access to many kilometres of river by property fences, and by the increasing size of the pools up the catchment, making it unlikely that competitive fishing would cause the observed depletion of marron stock in the Upper Catchment.

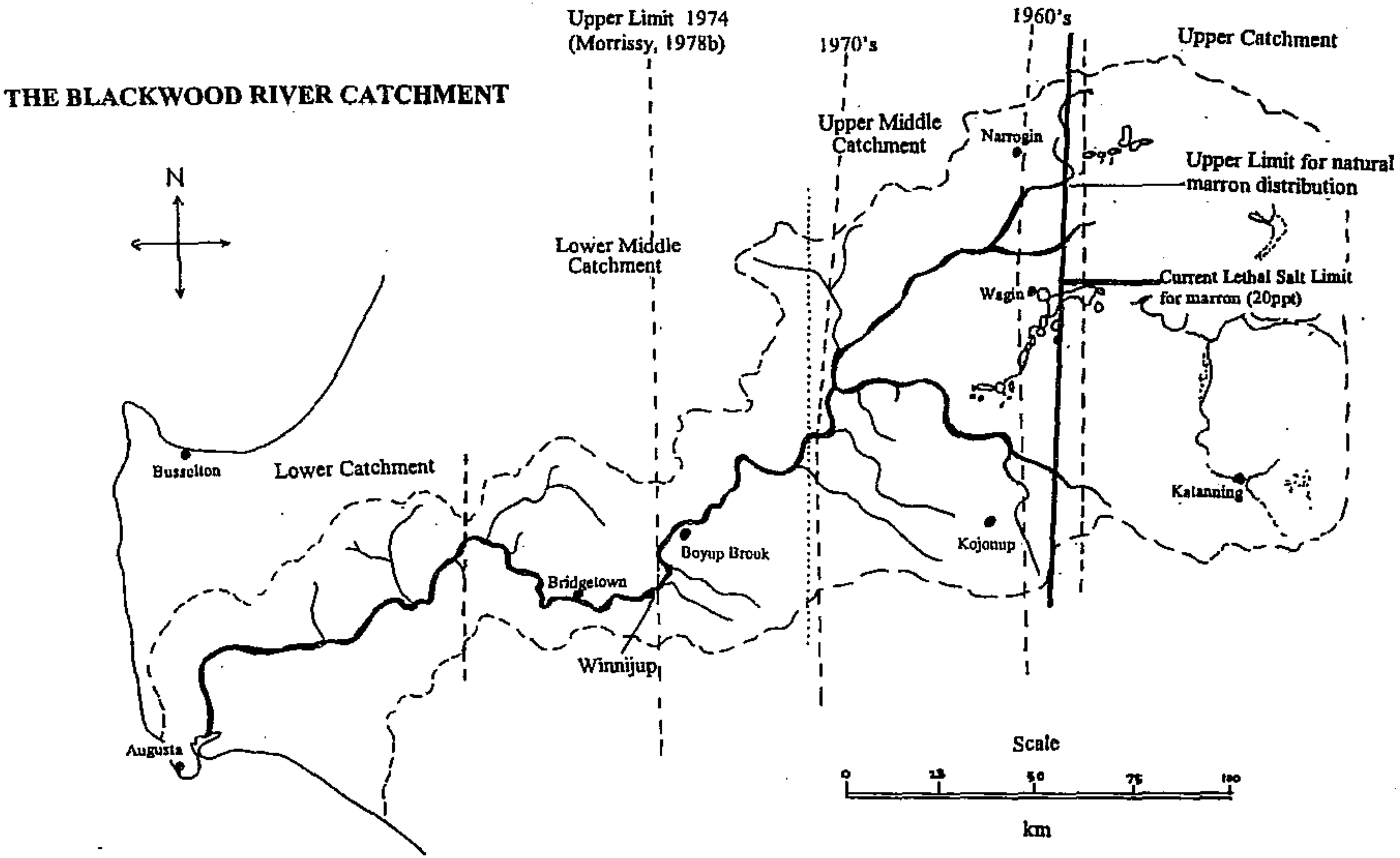


Figure 2.3: Distribution of Marron according to sampling effort and anecdotal information recorded during the 1973/74 study (Morrissy, 1978b). Dates indicate the approximate time marron disappeared from the river. The map also shows the location for the lethal level of salt (17-20 ppt) for marron in the Blackwood River.

Increasing salinity

Instead of overfishing the locals blamed the rising salinity level of the river. However as Morrissy (1978*b*) points out, the incipient lethal level of salinity (17-20ppt) for marron within the Blackwood occurs within the head waters of the river far upstream of the 1974 upper limit of marron distribution (see Figure 2.3)

Oxygen depletion in summer pools

Finally, Morrissy (1978*b*) concluded that oxygen depletion in the bottom water of the summer pools was the most likely and substantiated cause for the reduction of marron distribution from the Upper Blackwood. The surrounding catchment in this area provides excessive amounts of organic matter in the form of fertilisers, crop debris and stock waste, all associated with agricultural land use.

The cleared paddocks surrounding the pools provide a fast and direct route for organic and nutrient rich runoff, which effects the marron's summer pool refuge as described earlier in Section 2.1.9.7. This threatens marron survival with oxygen depletion extending to levels below their tolerance as indicated in Section 2.1.9.6. The symptoms of this threat are being expressed today, in the form of mass marron mortalities following summer storms and a marron population limited to adults and associated breeding failure.

Strangely, following such significant findings substantiating the threatened nature of marron as a species in the wild, no follow up research was conducted after the 1973/74 study (Morrissy, 1987*b*) until the present. Conservation of the species has been left to the rudimentary recreational fisheries regulations, while the Fisheries Department of Western Australia has devoted its attention to marron aquaculture, rather than further defining the threatening processes impacting on wild marron populations. This has persisted even though the seasonal marron catch continues to decline, and community recognition of the marron's vulnerability increases (see Chapter 3).

Considering over 20 years has elapsed since the 1973/74 study by Morrissy (1978*b*) it would be unwise to base the conservation status of marron, in fulfilment of criterion 10 for flagship species selection, on this potentially outdated data, especially since the reduction in marron distribution as defined in Figure 2.3 occurred in just over ten years.

Therefore this research has incorporated the following,:

- A survey of marron occurrence within the Middle Catchment, to confirm the upper limit of marron distribution (Section 2.2).

- An investigation of the degree of degradation within the water column of the summer pool habitat of marron (Section 2.3).

These studies will provide up to date information enabling confirmation of the threat to marron, and whether marron has the potential to recover from the threatening process, in fulfilment of criterion 10 for flagship selection.

2.2 The Upper Limit of Marron Distribution within the Blackwood River

To determine the current status of marron distribution in the Blackwood, a survey of the Middle Catchment was conducted to confirm or otherwise the upper limit of marron occurrence as identified by Morrissy in 1973. The survey was designed to establish whether marron distribution had improved within the natural range, or that increasing habitat and water quality degradation since the last survey (23 years) had continued to reduce marron distribution further down river as the 1973 trend suggested. The rationale, was to determine whether marron remained threatened, reduced within their original range thus violating of one of the maxims for conservation (Horwitz, 1995). This being an obvious requirement before marron's ability to recover could be identified to fulfil criterion 10 for flagship species selection: ability to recover from a threatening process.

2.2.1 Methodology

2.2.1.1 Study Area / Site Selection

A descriptive survey was conducted for marron occurrence, sampling seven permanent pools located within the Middle Catchment, involving the length of river and former distribution of marron between the Carrolup River east of Kojonup and the Blackwood above Nannup. Figure 2.4, shows the location of each pool of which all but two were sampled within the 1973 study. The additional pools were incorporated into the sampling to reduce the large gaps of river length, strangely omitted from the 1973 study. The Middle Catchment was selected for sampling because it contained the upper limit of marron distribution as outlined by Morrissy (1978b) which this study set out to test.

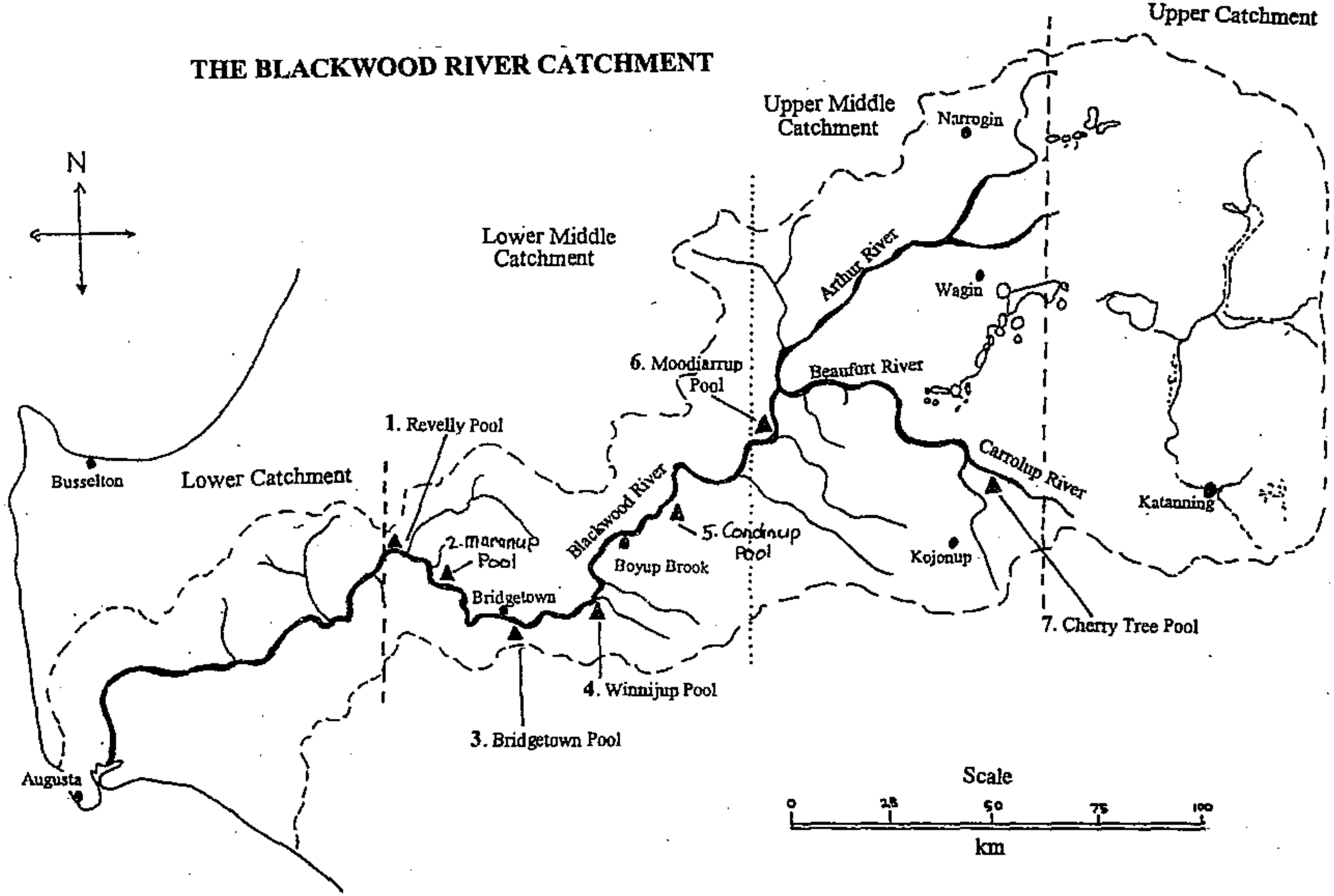


Figure 2.4: Map showing the location of the seven pools sampled within the study area (coloured pools represent those not sampled within the 1973/4 study.

2.2.1.2 Sample time

Official sampling was conducted from March 31st to April 6th after a reconnoitre to confirm accessibility and the logistics associated with each site. The marron season had in fact closed midday on February 1996, therefore a scientific licence was sought and obtained prior to sampling. Sampling at this time of the year not only overcomes the problem of sampling a flowing river, but is also identified as the most appropriate time for marron. The catchability of marron is positively related to the water temperature over the species favourable range for active growth, therefore summer is the most appropriate time to sample.

2.2.1.3 Sampling Procedure

Firstly, an assessment of marron habitat and protection was conducted at each pool using a present / absent inventory of marron remains, cormorant excreta, crayfish burrows, openness of the pool, leaf litter on bank, over hanging vegetation and fallen logs, evidence of erosion, runoff and stock access along bank. This was accompanied by visual estimates of the bank slope, pool width, maximum depth, width of the riparian zones, its percentage crown cover, distance from the water's edge and species composition.

In stream assessment included the presence of macrophytes, algal bloom, flow, turbidity (secchi measurement) and the presence of various habitats available to marron within the pool. A pole was used to probe the pool's bottom to give an indication of the presence of logs, rocks, sand and leaf litter, within the area of marron sampling.

2.2.1.4 Sediment Samples

Sediment samples were also taken, not only as an indication of organic input into the pool and food availability but also to provide descriptive information on benthic conditions to which marron are subjected. The sediment was sampled randomly five times across the pool's width using an Birge-Echman grab. Murdoch and MacKnight (1991), indicated that this was a suitable method for sampling fine grained, soft sediment, and is light weight for easy manipulation on a dingy. The sediment samples were further analysed (Loss-on-inanition analysis) along with water quality measurements taken at each pool in line with Section 2.3 which examined summer pool degradation within the Blackwood.

Weather conditions were described in terms of ambient temperature (dawn-6am and dusk-5pm), presence of wind, rain, phase of the moon and cloud cover. All of these, according to Morrissy (1975) can influence marron catchablility, especially light intensity which has resulted in sampling being standardised by operating only on the "dark phase" of the moon during the warmer months of the years (Morrissy, 1975). Sampling finished on the dark phase of the moon; and it was convenient that cloud cover was present during the brightest evenings, however some moonlight was present during most sampling.

2.2.1.5 Marron Sampling

Sampling for marron included three different methods so as to cover a range of habitats and increase the potential of sampling the range of age classes, if available, within the pool.

Microhabitat sampling

A standardised sweep within 1m square of habitat for 30 sec, was conducted within four microhabitats including either bank leaf litter, rocky pools, and over hanging vegetation within a 50m sample area. Unfortunately no marron were caught within the microhabitats for all seven pools sampled.

River bank torch light search

During the evening approximately 30m of river bank within the 50m sample area, was searched by torch light with bait (poultry pellets) set in 3 small patches (handfuls) at 10m intervals, similar to the standard method used for marron scoop netting in dams (Morrissy, 1980) and the method used by O'Brien (1984) for relative population estimates . Observations yielded information on the species and approximate size of crayfish. This sampling was conducted after dark between the drop net hauls.

Baiteu drop nets

Prior to dusk 20 drop nets (for detailed description see Morrissy, 1978a), with a mesh pore size of 2mm x 3mm, were baited using a doubled stocking filled with pellets.

Drop nets are the traditional method used to sample within rivers where they can be set from steep banks and into deep water of the pools. Mesh drop nets were used since wire has been proven to reduce catchability (Morrissy, 1989). The mesh pore size used within this study was smaller than the legal size "marron mesh" of 80mm x 32mm to allow sampling of both juveniles and adults.

The drop net is the least operator dependent method of legal sampling, in reference to skill and marron size selection. Morrissy (1975) has identified that the method of drop net sampling in fact has a higher catch number per occasion than other sampling units, even when traps are left over night, and that they take a more size representative, and numerically larger sample. Poultry pellets are the standard research bait since they are readily available, conveniently transported within warm conditions (unlike meat) and consistent in quality (Morrissy, 1970). Both the drop net and pellet sampling unit were used in the 1973 research.

The sampling intensity used within the study, followed the standardised sampling of rivers as defined by Morrissy (1975), at a competitive density of drop nets (10m or less apart). This sample design functions to ensure that the total catch is not limited by gear saturation and is not dependent upon the number of nets. Competitive sampling involves the overlapping of the immediate surroundings of the baited unit, where the area of attraction for a baited unit has been identified as a diameter of 12.2m (at least) (Morrissy, 1975).

Marron vary in vulnerability to capture depending on their feeding activity, which is influenced by light intensity (sampling on different phase of moon), water temperature, and degree of eutrophication and accompanying oxygen levels within the pool. Intrinsically catchability is influenced by moult stage, any recent experience of capture, by spawning activity and the social dominance hierarchy within the population (for detailed information on these, see Morrissy and Caputi, 1981).

Therefore, since marron vary in vulnerability to capture, unequal exposure to the sample units through a non-competitive sample design has the potential to increase the variability of capture, thus further supporting the need to employ competitive sampling and accepting Morrissy's (1975) conclusion, that random sampling or equal catchability commonly used for estimating population numbers from a sample is invalid for marron (Morrissy, 1975). The competitive sampling technique also overcomes the non-uniformity of catch rates for different net positions with field situations (Morrissy, 1975).

A dingy was used to place the drop nets within the pool following the grid system outlined in Figure 2.5, sampling the width of the pool representative of a range of habitats available to marron, over a length of approximately 50 meters. The drop nets were placed approximately 10-6m apart depending on the width of the pool (which varied from 23 to 45m).

Once situated, the nets were checked and replaced every half hour, from dusk until 8pm, then every hour until 11pm. Sampling of the marron was standardised by conducting the first haul immediately post sunset when the largest movement of marron occurs, out from the daylight shelters to feed at night. As pointed out by Morrissy (1975) the first haul after sunset provides the highest catch and largest marron with the catch number and marron size declining rapidly over successive hauls during the night. A review of the literature on freshwater crayfish sampling revealed a sampling time of 3 to 5 hours with pulls ranging from 30 minutes (Morey, 1988) to 1 hour (Morrissy, 1970). Therefore the survey aimed to sample for 5 hours, with maximum effort during the initial 2 hour after dusk, 30min which basically represented the time required to check and reset all drop nets for the next haul.

The recording procedure for each crayfish caught, involved: species identification according to Horwitz (1995*a*), orbital carapace length (OCL) using calipers, marron health by observing activity and presence of epiphytes and temnocephalans (flatworms), and finally sex and reproductive status of female by recording the presence of old egg sacs, berry, and hair around the gonopores. Each specimen was marked using paint (O'Brien, pers comm) so as to prevent counting the same marron twice.

A mark/recapture estimate of the population size was not conducted for three reasons. Firstly, because assumptions needed for the estimate were violated, with the considerable length of each pool (kilometres long) allowing marron to migrate in and out of the sample area, thus preventing random mixing of the marked and non-marked individuals (Growns, 1993). Secondly because a recapture was never made throughout the sampling

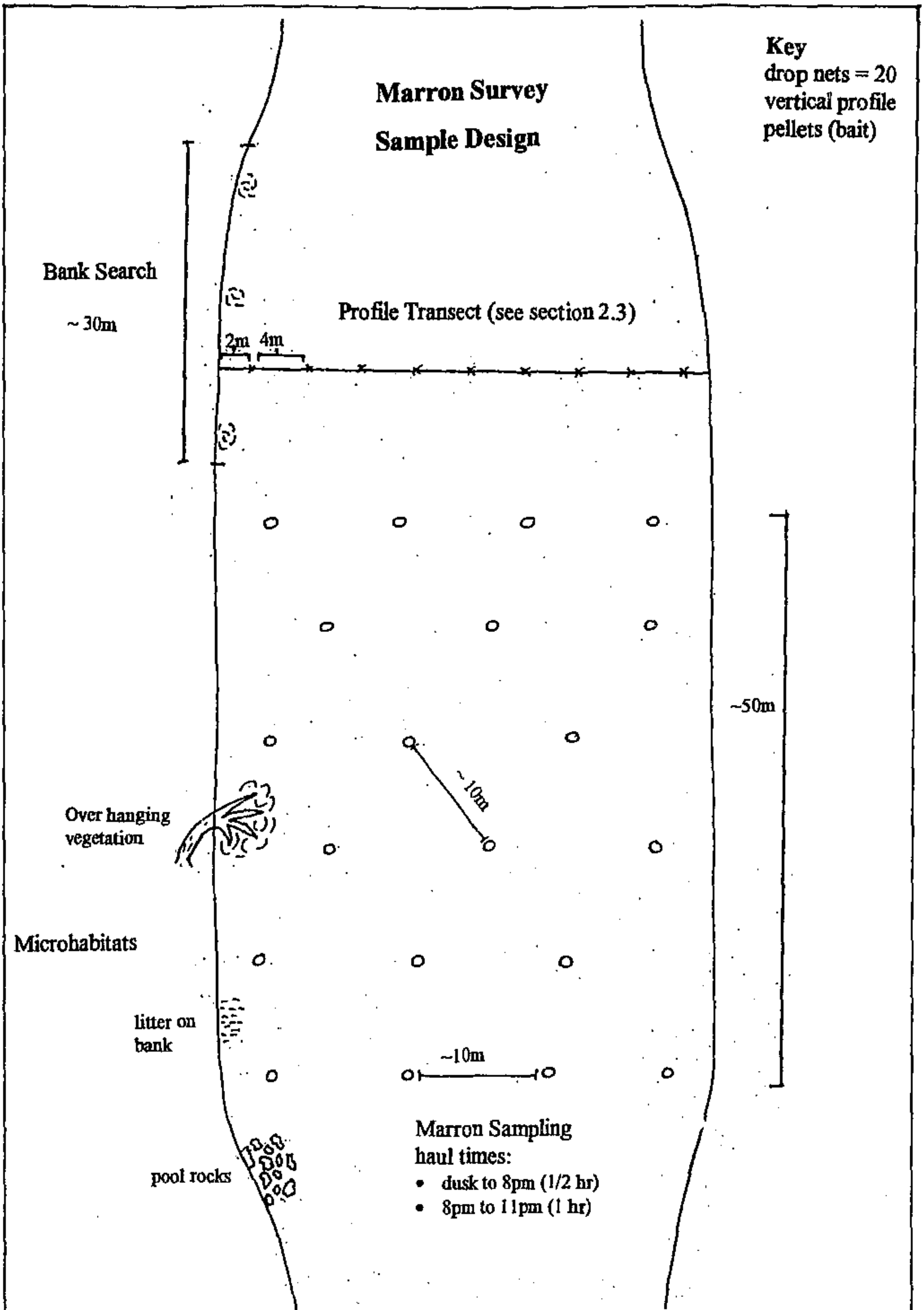


Figure 2.5: Sample Design for the Marron Survey conducted at each of the seven pools, also showing the relationship between the marron sample and the cross-sectional profile measurements taken at each pool (discussed in section 2.3).

period at any pools, and thirdly, because the study's purpose was only descriptive in terms of marron occurrence down the length of the Middle Catchment, population data was not required, but nevertheless remains a valuable focus for further studies.

2.2.2 Results

2.2.2.1 Site description

Table 2.2 represents a summary of the aquatic environment of each pool during the sampling period, involving a number of "visual estimates" based only on what was present within the 50m reach.

Table 2.3 shows that the pools were all subject to erosion with stock access occurring on one or both banks. Flow was not evident for any of the pools sampled, as expected at the end of summer. No marron remains were found along any bank, but there was evidence of predatory water birds at two pools (Maranup and Condinup). Emergent and submergent macrophytes were absent from the sample area within each pool, an important habitat for juvenile marron. Leaf litter varied over the seven pools with only those having enough to support juvenile marron, recorded as a "tick" within table 2.3 Similarly, rocks were not present at Winnijup and Moodiarrup pools.

The description of sediment samples was based on what was generally found within the pool. Coarse organic matter (OM) includes leaf litter, sticks, nuts etc, while fine organic matter refers to broken down detrital material. The "black smell organic silt" was predominant in the middle of the large pools further up the catchment. The sludge had a jelly like texture, noxious smell and left a burning sensation on the hands after sampling. The depth of the organic layer was approximated to 30 to 40mm.

The following provides information on pool location, time and conditions during sampling, condition of the riparian zone and nearby land use. This summary of each pool compliments the data shown in Tables 2.2 and 2.3 providing a description of each pool to be referred to throughout the thesis.

Table 2.2 : Site description and visual estimates of each pool within the 50m sample reach

SITE	Ambient Temp°C dawn/dusk		Pool Width (m)	Max Depth (m)	Turbidity (secchi) (m)	Bank Slope	Over Hanging Veg (%)	Width of Riparian Buffer (m)	Riparian Cover (%)	Land Use
Revelly	6	23	25	2.2	1.5+	45°	1	20 to 1000	60	pine plant'n
Maranup	8	24	24	1.8	1+	20°-45°	2	20	40	pine plant'n
Bridgetown	7	26	30	1.6	0.8	30°-45°	1	20	30	farm
Winnijup	12	30	42	2.9	0.8	45°	3	10-20	30 - 50	farm
Condinup	16	29	38	2.7	0.7	45°-90°	15	5 to 10	40	farm
Moodiarrup	9	18	48	4.2	0.4	45°-50°	0	3-5	15	farm
Cherry Tree	9	18	23	2.4	0.5	45°	3	20	50	farm

Table 2.3 : Present / Absent inventory of instream habitat available to marron, (OM = organic matter).

SITE	Erosion & runoff	Stock Access	Flow	Marron Remains	Pool Rocks	Sunken Logs	Bank Leaf Litter	Macrophytes	Sediment Description
Revelly	✔	✔	✖	✖	✔	✔	✔	✖	sandy with coarse OM
Maranup	✔	✔	✖	✖	✔	✔	✔	✖	sand with fine OM and algal cover
Bridgetown	✔	✔	✖	✖	✔	✔	✖	✖	sand with fine OM
Winnijup	✔	✔	✖	✖	✖	✔	✔	✖	black smelly organic silt
Condinup	✔	✔	✖	✖	✔	✔	✖	✖	sand with fine OM
Moodiarrup	✔	✔	✖	✖	✖	✔	✖	✖	black smell organic silt
Cherry Tree	✔	✔	✖	✖[1]	✔	✔	✔	✖	black smelly organic silt

Revelly Pool

Sampling was conducted on the 30th to the 31st of March 1996 during which a half moon was present . The weather was fine and wind absent during sampling. The riparian buffer ranged from 20 meters to 1km in width and existed no less than 1m to 4m from the waters edge. The degree of riparian cover was approximately 60%, consisting mainly of *Eucalyptus rudis, Melaleuca sp* (5%) and grassy understorey. The large surrounding eucalypts accommodated a closed pool, with long (2m) steep banks (45°) along which erosion, debris runoff and stock access (pig or sheep) were evident. The water was stained, but clear with a visibility of over 1.5m. Leaf litter, twigs and flood debris was present along the bank, whilst algal blooms and emergent macrophytes were absent within the reach. Instream habitats included rocks, sunken logs, and leaf litter along the bank.

Maranup Pool

Sampling was conducted approximately 4km below Maranup Ford, north-west of Bridgetown, within a pool continuous for more than 1km. Sampling was conducted from the 31st of March to the 1st of April, during which time a half moon was present. The riparian zone represented a sparse woodland (20m wide) grading into a large pine plantation. Within the 50m reach *Eucalyptus calophylla* (40%) and *Melaleuca sp* (20%) made up the riparian vegetation, providing approximately 40% cover. The remainder of this zone consisted of exposed grass areas (40%), illustrative of a reasonably open pool. Vegetation remained approximately 1 to 4m away from the water's edge, with only 2% of the reach containing over hanging vegetation. The bank slope ranged from 20° to 45°, along which erosion, debris runoff, and stock access were evident. The water was stained but clear to 1m and coarse debris lined the lower bank. Filamentous algae covered rocks and the sediment within the reach. Upstream (1km) thick mats of algae could be seen suspended within the water column. Instream habitats included a rocky bank (10m), sandy pool bottom, a small amount of detritus, and a few sunken logs.

Bridgetown Pool

The pool was located approximately 5km above Bridgetown on private property. Samples was conducted from the 1st to the 2nd of April. The weather was fine and the wind negligible while a three-quarter moon was present. The riparian vegetation consisted of *Eucalyptus marginata, Eucalyptus calophylla* and *Melaleuca sp*, providing 30% crown cover. The buffer was almost 20m wide and began 1m to 3m from the bank providing for a moderately open pool environment. Within the reach stock only had access to the opposite bank, while erosion and detrital runoff was present on both, along with leaf litter. The water was very stained and turbid and there was no sign of algae or emergent macrophytes within the reach which provided a sandy bottom, two or three boulders and sunken logs.

Winnijup Pool

The site was located at Clark's Pool on private property 5km above Winnijup Bridge. Sampling was conducted on the 2nd and 3rd of April during which time the weather was still and clear, with moonlight. The riparian zone was between 10 to 20m wide and consisted of *Eucalyptus rudis, Eucalyptus calophylla, Melaleuca sp*, reed and grass, providing 30 to 50% cover. Only 3% of the reach had overhanging vegetation, while the riparian zone occurred no more than 2m up the bank. The banks were reasonably steep (45°) consisting of exposed root systems, extensively eroded, runoff and sheep ruts in the bank . The pool was open with turbid, stained water, and a moderate amount of leaf litter concentrated at the water's edge, and no macrophytes. Rocks were absent, only a large log and sandy bottom were available for marron protection. Sheep were observed drinking from the river during sampling.

Condinup Crossing Pool

This site was located between Dinninup and Trigwell Bridge on private property below Condinup Crossing. The pool was approximately 500m long with sampling conducted at the lower end of the pool. The sampling period ran from the 3rd to the 4th of April, during over cast conditions, a slight north-westerly breeze and minimal moonlight. The riparian zone, 5m to 10m in width consisted mainly of *Melaleuca sp* (80%) with a number of *Eucalyptus rudis* set further away from the bank. Approximately 40% vegetation cover existed, with the paper barks occurring no more than 1m back from the water's edge. The pool was moderately open for its width (38m) with some of the banks being almost vertical, showing the effects of erosion and runoff, exposing paper bark roots. The water was turbid and stained, rock and logs were evident, but leaf litter was limited. Stock access (sheep and cattle) was evident on both banks.

Moodiarrup Pool

The site was located roughly 500m above the Moodiarrup Bridge on the Boyup Brook - Arthur Road. Sampling was conducted on an accessible, but wide stretch (over 10 km) of the Arthur River, on the 5th of April within fine but slightly cloudy conditions associated with minimal wind. The riparian vegetation consisted mainly of *Melaleuca sp* and unhealthy *Eucalyptus rudis*, forming a buffer of only 3m to 5m in width and providing on average 15% cover. The vegetation occurred no less than 3m to 5m from the bank, providing no overhanging vegetation and representing a very open pool environment. The river banks were reasonably steep, showing signs of extreme erosion and stock access. The water was very turbid and stained with visibility being limited to less than 50 cm. Leaf litter along the bank was virtually non-existent and rocks were absent, leaving a soft bottom and a few logs to provide marron habitat.

Cherry Tree Pool

The site was located north-east of Kojonup on the Carrolup River and was selected from the study by Morrissy (1978*b*). Sampling was conducted on the 5th of April and was located in the mid section of a reasonably open pool which continued for roughly 1km. The weather was fine, wind was minimal and moonlight present under cloud cover (quarter moon). The riparian buffer was 20m in width and consisted of *Melaleuca sp*(40%), *Eucalyptus rudis*(10%), reeds and grasses (50%). Approximately 50% cover was provided along the bank with the vegetation occurring 1m from the water's edge while only 3% of overhanging vegetation was estimated within the reach. The banks had been degraded by erosion and sheep access, and detrital litter was minimal. A secchi depth of only 50cm reflected the turbid and stained state of the pool, within which rocks were absent, but fallen logs and leaf litter provided marron habitat.

2.2.2.2. Marron Survey

The Marron Sample Data

The results in Table 2.4 compare the current survey results with Morrissy's (1978b) results from the 1973 survey of the Blackwood. As stated earlier, Maranup and

Table 2.4: Results for the marron sample from the thesis study and those obtained during the 1973 study.

Number of marron caught / OCL class / Site / Study

Size Class (O.C.L mm)																		
SITE	**20-30**		**30-40**		**40-50**		**50-60**		**60-70**		**70-80**		**80-90**		**90-100**		**TOTAL**	
Cherry Tree Pool																		
Moodiarrup																		
Condinup*									1								1	*
Winnijup										1						1	-	2
Bridgetown	3		4	14	1	18	2	5		5		3					10	45
Maranup *	9		8		11		7		6		1						42	*
Revelly					1	4		3				1					1	8
TOTAL	12	-	12	14	13	22	9	8	7	6	1	4	-	-	-	1	54	55

*** Sites not sampled within the 1973 survey by Morrissy (1978*b*)**

▒ **Current Study's Data**

☐ **1973 Data by Morrissy (1979*b*)**

Condinup crossing were not sampled in the earlier survey. The results here included marron which were caught and sized during the drop net sample, and those marron identified during the river bank search, which were visually estimated in terms of size class. The microhabitat sample yielded no crayfish for any of the sites within this study. The results for the 1973 study were based on drop net catches only.

On the whole, the results show that marron were not caught in a number and size range representative of a population, until Bridgetown. The catches made above this point (Winnijup and Condinup) identified animals over 60mm in OCL suggesting they were remnants of an earlier population still holding on in the area.

Looking at each sample separately, the 1973 survey had its greatest catchrate (45) at Bridgetown, while the current study had its highest catchrate at Maranup located down river from Bridgetown. This change in maximum catch location down river, may be indicative of a reduction in successful marron populations within the natural distribution. Encouragingly though, the maximum haul for both studies had juvenile representation, but when compared with data from the Warren River (Morrissy, 1978), these results show that even in the most favourable environment remaining within the Middle Blackwood system (Bridgetown to Nannup), the marron stock show reduced survival, or production of juveniles. As indicated by Morrissy (1976), cause for any such marron decline within a farm dam situation is indicative of oxygen deficiency in the bottom water due to too high an input of organic matter.

Other Species

The only other species caught in the drop nets or sighted during the bank search was *Cherax quinquecarinatus*, the "gilgie", of which three were caught at Revelly pool, while eight gilgies were caught and sited at the Bridgetown site.

Marron Health

Overall the marron seemed in good health. All were very active when caught, not sluggish and "dopey" as described when they are in poor health (Morrissy, 1978b). Nine of the total 53 marron caught had an epiphytic cover on the carapace, representing one or more from each site. Temnocephala (flatworms) were found on only four marron caught at Maranup and missing limbs were a common occurrence between pools. According to the drop net sample where marron were caught and sexed, each pool had slightly more males which equates to the findings of Morrissy and Caputi (1981), indicating that males are slightly more catchable than females. Of the females none were berried or carried old egg sacs, but those falling within the 40-60mm OCL and above size class were identified as sexually mature.

Marron Distribution

As indicated in Section 2.1.10.3, the 1973 survey by Morrissy (1978b) identified the upper limit of marron distribution in the Blackwood River Catchment to be at Winnijup according to the sample results and questioning locals living on the river at that time. The results from the current survey as shown in Figure 2.6, confirms that the distribution of marron remains reduced below its natural range, but revises the original upper limit slightly to Boyup Brook according to the sample results, and recent anecdotal information to be outlined in Section 3.1.

2.2.3 Discussion

The shrinking marron distribution identified by Morrissy (1978b) has been confirmed within the survey, along with declining marron stock in terms of productivity. This not only indicates a threat to marron but also to the recreational fishery supported by the Blackwood River. Data from the Fisheries Department confirm the threat to the marron fishery within the Blackwood. Figure 2.7 shows that over the past 20 years the catchrate for legal sized marron has declined considerably.

Even though, as outlined in section 2.1.10, overfishing was disregarded as the main cause for the reduction in marron distribution within the Upper Blackwood Catchment, it is important to note that the current and much smaller marron distribution in the Blackwood now provides less fishable area, setting the scene for potential overfishing in the future.

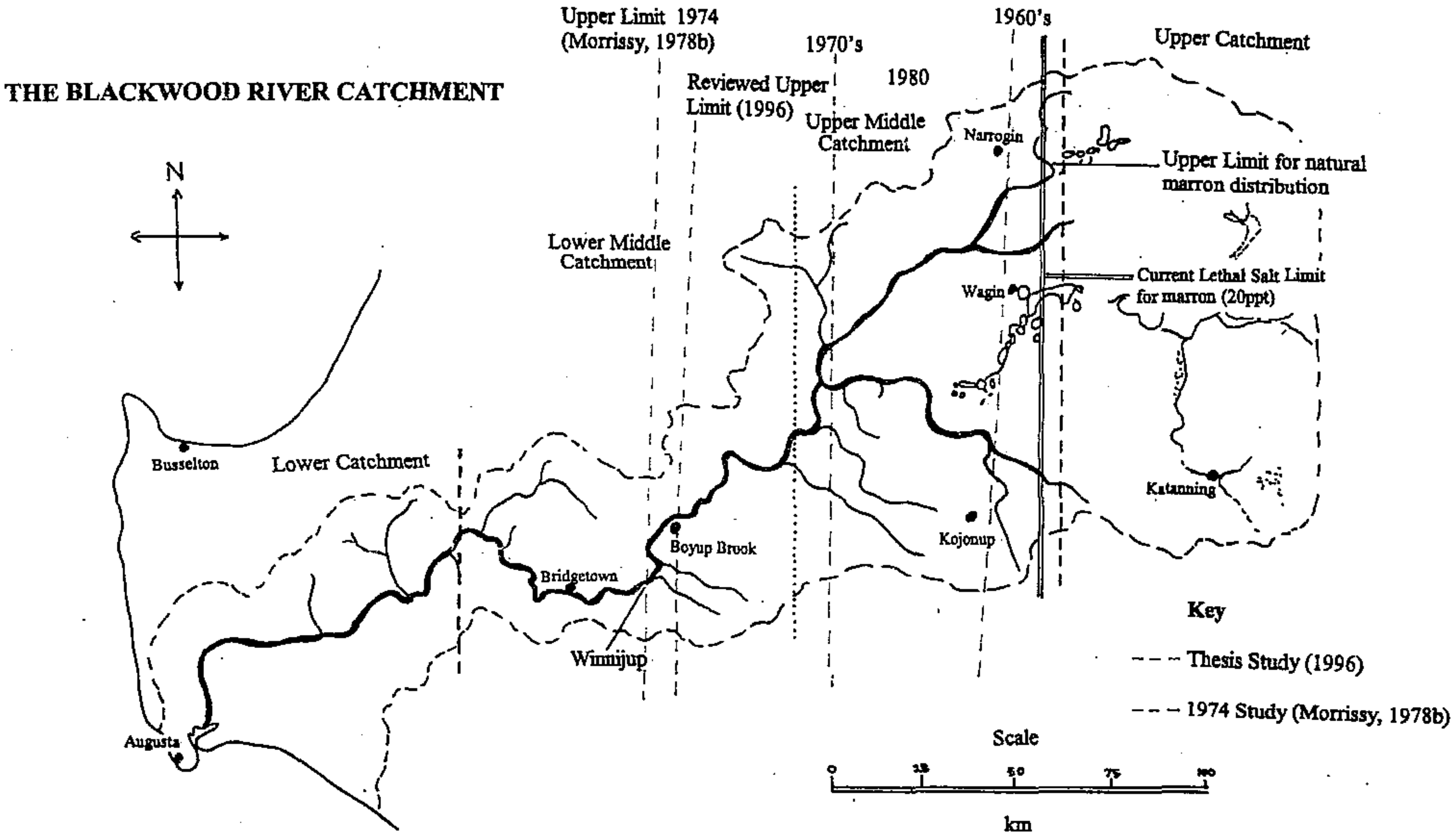


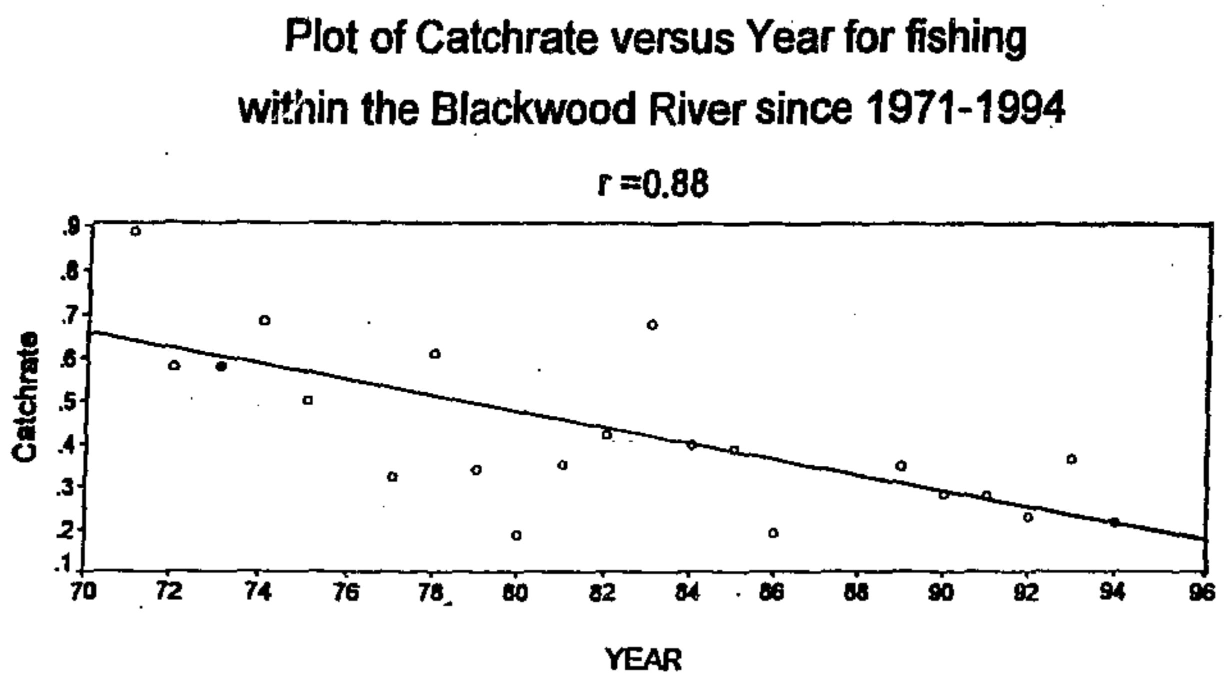
Figure 2.6: Map showing the revised Upper Limit for marron distribution according to the Thesis Study (1996). Thesis findings are compared with the 1974 Study (Morrissy, 1978b)

The river water quality becomes an issues for marron survival during the summer months when the river reverts to numerous large stagnant discontinuous pools. The water quality and habitat availability suitable for marron is degraded by organic loading of the pools, promoting deoxygenation. The impact of this level of degradation compared to that of overfishing on marron stocks can be seen in Figure 2.8 which shows a positive relationship between rainfall and catchrate over the period 1971 to 1994 within the Blackwood.

The plot shows an environmental trend in catchrate. With high winter rainfall the following season's catch is often higher than that following low winter rainfall. These results suggest that the diluting and flushing effect associated with high rainfall improves environmental conditions for marron survival, providing a better catch the following year. This result implies that marron do have the potential for recovery, thus complying with criterion 10 for flagship species selection.

The following section investigates the level of water quality degradation associated with summer pools within the Middle Catchment so as to determine the effect on marron distribution, and to hypothesis as to whether marron can recover from these threats.

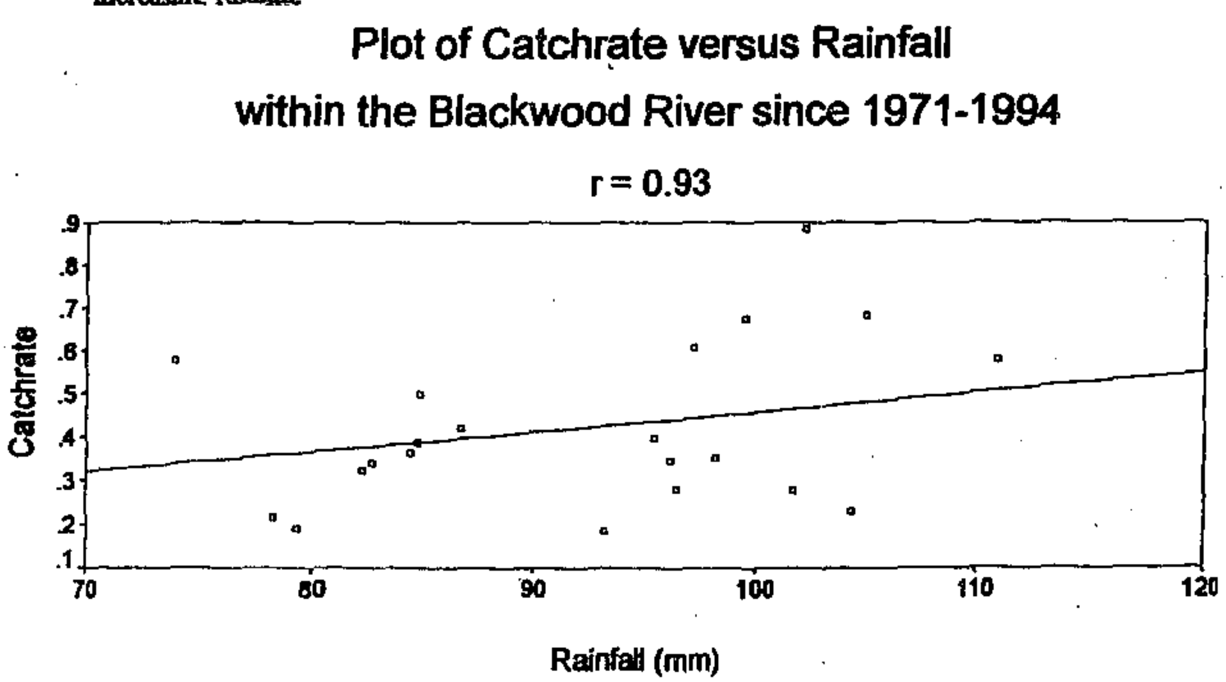
Figure 2.7: Graph showing the steady decline in catchrate for marron over the past 25 years.



catchrate = #legal size marron / drop net / hour fishing / open season

(Fisheries Department WA, unpublished data)

Figure 2.8: Graph showing the environmental trend in catchrate where the catch increases with increasing rainfall.



catchrate = #legal size marron / drop net / hour fishing / open season

Rainfall = % of the longterm south-west mean for the previous winter

(Fisheries Department of WA, unpublished data)

2.3 Summer Pool Water Quality and Habitat Degradation

2.3.1 Introduction

Rivers in the south-west generally consist of a string of deep pools separated by faster-moving shallow riffle zones (Williams, 1992). The Blackwood river is no exception, transforming into visibly isolated pools separated by dry river beds during summer.

The pools within the Blackwood can be quite deep, some exceeding five metres. They were an important component of the catchment's initial settlement, providing a reliable source of water for all purposes (drinking, domestic use, irrigation, stock, and recreation) during the summer months (Christensen et al, 1981). As a result the old homesteads were often located near a pool in the river.

However, river degradation in the form of erosion and silting, increasing salinity, and nutrient enrichment have had a negative impact on the summer pool environment as explained in section 1.2. Consequently, the anthropocentric use of the summer pools has become virtually non-existent, while the ecological well-being of aquatic organisms has been increasingly threatened, especially those dependent on the pools as a refuge during the environmental stresses of the summer months.

In light of the study so far, the objective of this particular section of the research was:

- To qualify the eutrophic condition of the Blackwood River (to determine the summer degradation of the water column by measuring and observing the physical and chemical characteristics of selected summer pools within the Middle Blackwood River Catchment).

- To identify (using the tolerances recognise in section 2.1) threats to marron survival within the summer pool environment of the Blackwood River, and determine the marron's capacity for recovery (flagship criterion 10).

2.3.2 Methodology

2.3.2.1 Study Area

The study area was the Middle Catchment, while the study sites were the same seven pools and sampling time (March 31- April 6) outlined in Section 2.2. This area of the catchment represents a spectrum of river degradation, with water quality improving down river. This diversity of river water quality and habitat degradation encompasses the upper limit of marron distribution as defined in Section 2.1; pool conditions either side of this "limit" may provide information as to the cause of their demise within the river and clues to their potential recovery.

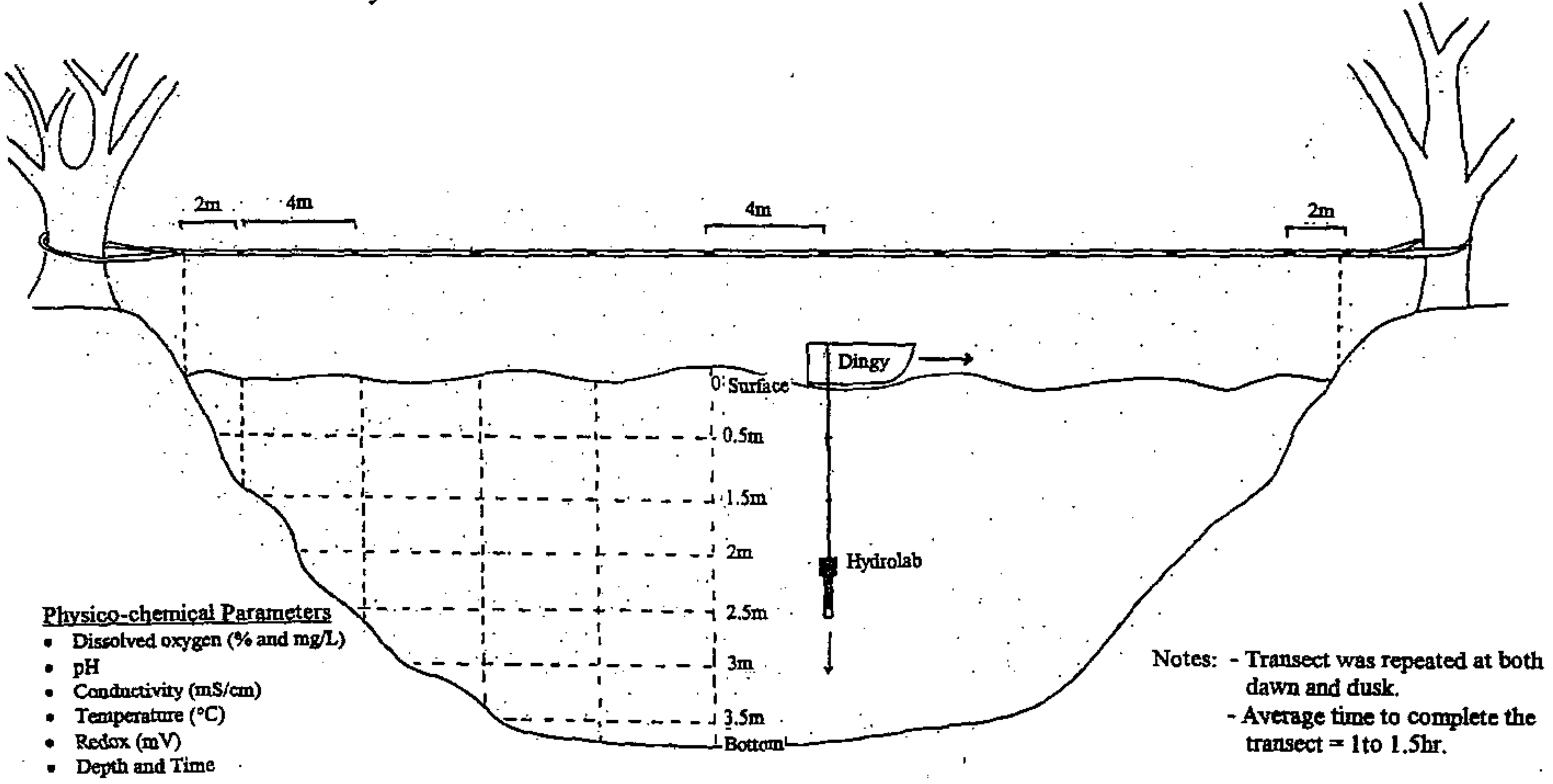
2.3.2.2 Sample Procedure

The methodology undertook vertical profiles of various water quality parameters across each of the seven pools sampled. Initially a randomly selected taut rope transect was placed across the pool's width using a dingy. From this transect, vertical profiles were taken every 4m along the rope as shown in Figure 2.9. Considering the pools ranged in width from 23m to 45m, this increment was seen as the most viable in terms of time.

A Hydrolab (Datasone 3: multiparameter water quality datalogger) was used to take the physico-chemical measurements as outlined in Figure 2.9, all of which are typical water quality monitoring parameters, except redox which was included to provide some measure of the oxidising / reducing potential of the water column and improve detection of possible oxygen depletion near the water sediment interface. The Hydrolab was used to overcome the problems associated with many separate field probes and requirements for sampling over 2m in depth. The Hydrolab was calibrated prior to field work, and then again during the sampling period.

The Hydrolab was lowered from the water's surface (first reading) at each 4m transect point, waiting 1 min at each 50 cm depth increment for the readings to stabilise (Hydrolab readings recorded in a datalogger every 10sec). This stabilising time was established within the laboratory environment since contact with the Hydrolab was not possible once in the boat. For the bottom reading, sediment disturbance was avoided as

Figure 2.9: The cross-sectional profile sample design, showing the vertical profile intervals (4m) and physico-chemical parameters measured using the Hydrolab.



much as possible to prevent contaminating the water column. This process was conducted at both dawn (6am) and just before dusk (5pm), to identify whether the pools were being mixed over night.

The vertical profile of a pool's cross-section took on average 1 hour, therefore with limitations on time and resources (since marron sampling was also to be conducted) only one transect of each pool was conducted. However to obtain at least some measure of within pool variability, four transects were randomly selected at Revelly Pool, during the dawn sample.

Sediment samples were also taken to provide some indication of the organic accumulation and biological oxygen demand in each pool. Sediment samples were taken at the end of the sampling period for each pool so as not to affect water quality readings. The sampling procedure was outlined in section 2.2.1.4.

2.3.2.3 Data Analysis

Profile Data

Initially analysis involved going through the very large data sets generated by the Hydrolab to identify those related to each particular vertical drop. Since the Hydrolab recorded both time (10 sec intervals) and water depth it was possible to remove all recorded values which represented unstabilised readings. The last 10sec reading made for each depth, for each parameter, was used as representative of the water quality at that point within the pool. This selection was based on the assumption that the Hydrolab should have stabilised over the 50 seconds prior to this reading, and could be shown to do so.

This was true for all parameters measured except for dissolved oxygen (DO) which was identified as having a stabilising lag time which exceeded 1 minute (the time the Hydrolab was held at each depth). To overcome this lag time, upward or downward trends were identified in the DO data, intervals between each 10 second reading were examined, and a reading for each depth obtained by selecting the most appropriate value from either the minute held at that depth or the value from the subsequent depth where interval increments were smallest.

The refined data set was used to provide a summary table of each parameter for each pool, various graphs and to map physico-chemical profiles. Only those parameters which varied by more than 1unit (pH> 1 unit, temp> 1°C, conductivity> 1 mS/cm, and DO> 1%) within the vertical profile were mapped. As it so happened this selection criterion related only to temperature and DO for all pools. It was decided that DO would be based on percent saturation only throughout the rest of the study, since it, accounts for temperature and is more representative of the biological changes within the water body.

Sediment Sample Analysis

Analysis followed that used by Mudroch and MacKnight (1991) representing the standard loss on ignition technique applied to determine the organic content of sediments through combustion. The samples (5 replicates for each pool) were initially air dried at 110°C to a constant weight over a weekend, during which time the silt and clay coagulates were ground with a morta and pestle to allow an even distribution of heat within the furnace.

Upon achieving the final dried weight, samples were cooled and weight recorded. Samples were then placed within a furnace at 550°C for 3 hours to ensure a stable weight was achieved. The ash weight was recorded and then subtracted from the dry weight of the sample to provide a weight loss value, representative of the organic content of the sediment. This value was then converted to a percentage for each replicate providing a mean and standard deviation value for each pool, for presentation within a graph.

2.3.3 Results

The following results provide an outline of the findings, often complimented with discussion of the environmental tolerances of marron, referred to within section 2.3.4, the discussion.

2.3.3.1 Hydrolab Summary Table

The results shown in Table 2.5 indicate that all parameters except redox behaved as would be expected within thermally stratified waters. The range shown represents surface to bottom readings taken from the water column. For example temperature, pH, and DO% decline from top to bottom within the vertical profile, while conductivity increases reflective of the higher density of salt water.

Water temperature was lower for the pools sampled lower in the catchment. This is possibly related to the relatively closed nature and the degree of shade associated with these pools. Water temperature was obviously higher during the dusk sample, compared to the dawn, reflecting daytime heating of surface waters.

The pH falls outside the range acceptable for drinking water supplies (6.5 to 8.5) at Winnijup and Condinup (Terry, 1995), but all fall between 6-9 which is generally considered acceptable to most species within an aquatic environment (Abel, 1989). As indicated by Morrissy (1976), marron have an optimal pH range of 7 - 8.5, satisfied by the range shown for the pools (7.5 - 8.9).

The conductivity measurements reflect the reversed longitudinal salinity of the Blackwood River, increasing from 3.5 mS/cm at the lowest pool (Revelly) to 18 mS/cm at the highest pool (Cherry Tree Pool). The results generally show a slightly higher conductivity at dusk, following heating during the day.

Dissolved oxygen is reduced with depth during both the dawn and dusk sample, but is slightly higher at dusk, presumably after photosynthesis by instream aquatic vegetation, providing some replenishment. In general there is a close relationship between aquatic biodiversity and DO of the river, therefore DO is a good indicator of ecosystem health

Table 2.5: Summary of Hydrolab Data showing the range for each parameter measured (top to bottom of profile) during the dawn and dusk samples of each of the seven pools sampled.

SITE	Sample Time	Max Depth	Water Temp	pH	Cond mS/cm	DO %	Redox mV	% Loss on Ignition $\bar{x} \pm$ S.D.
Revelly	Dawn		16.8 - 16.7	7.6 - 7.5	3.48 - 3.57	69 - 50	147 - 137	
	Dusk	2.2m	19.5 - 16.8	7.7 - 7.5	3.40 - 3.59	81 - 46	143 - 161	2.72 ± 0.952
Maranup	Dawn		17.3 - 17.2	8.0 - 7.9	4.04 - 4.05	84 - 74	289 - 281	
	Dusk	1.8m	18.6 - 17.2	8.0 - 7.8	3.91 - 4.06	88 - 73	181 - 158	4.18 ± 1.003
Bridgetown	Dawn		17.8 - 17.6	8.1 - 7.8	5.57 - 5.62	85 - 76	360 - 343	
	Dusk	1.6m	21.9 - 17.9	8.2 - 7.8	5.51 - 5.65	112 - 80	282 - 265	0.9 ± 0.339
Winnijup	Dawn		18.5 - 17.5	8.6 - 7.8	6.49 - 6.61	107 - 67	298 - 344	
	Dusk	2.9m	22.1 - 17.5	8.6 - 7.9	6.46 - 6.59	136 - 78	264 - 298	11.18 ± 2.439
Condinup	Dawn		19.6 - 18.1	8.1 - 7.4	12.02 - 12.15	107 - 34	301 - 330	
	Dusk	2.7m	21.4 - 18.1	8.1 - 7.3	11.93 - 12.07	120 - 31	266 - 284	1.62 ± 0.580
Moodiarrup	Dawn		20.5 - 17.9	8.6 - 8.2	13.66 - 13.83	105 - 23	77 - 279	
	Dusk	4.2m	20.4 - 18.0	8.9 - 8.4	13.56 - 13.93	120 - 17	107 - 210	14.72 ± 1.927
Cherry Tree	Dawn		20.1 - 17.9	8.3 - 8.0	18.00 - 18.53	100 - 41	350 - 320	
	Dusk	2.4m	20.3 - 18.1	8.3 - 8.0	17.90 - 18.50	121 - 58	213 - 219	11.42 ± 5.938

and eutrophication, and a surrogate (cheap) test for high levels of nitrogen and phosphorus (Terry, 1995). The monitoring of macroinvertebrates for many south-west rivers utilises this relationship between aquatic biodiversity and DO level.

Redox potential generally falls with depth, in association with lowering pH values and the reducing (low oxygen) potential of the water column. According to Maitland (1990) in the presence of oxygen the redox potential is generally around 500mV. Considering that all but Maranup and Bridgetown pool have an increasing redox potential from top to bottom and a redox value less than 360mV at the surface, it seems the data may have been influenced by a faulty probe or incorrect calibration. This is especially evident when observing the Moodiarrup dawn values.

The sediment sample results showing mean loss on ignition and the standard deviation indicate that there was little variation between the 5 replicates taken from each pool except for Cherry Tree Pool. The values seem to suggest a slight increase in organic content as sampling moved up the river, and as the pools increased in size and depth (see section 2.3.3.5. or further discussion).

2.3.3.2 Temperature and DO% stratification graphs

Figures 2.10a and 2.10b represent the degree of thermal stratification identified at both dawn and dusk, and the consequential depletion of oxygen for each of the seven pools sampled. Stratification for the purpose of this study was said to occur if change in temperature of more than 1°C with any one meter in depth, was identified. Except for Maranup Pool, the figures show that thermal stratification was evident within all pools at either , or both, of the dawn and dusk sample times.

Revelly, Maranup and Bridgetown pool were the shallowest of those selected, with depths ranging from 1.6m to 2.5m. Typical of shallow water bodies these pools showed either no significant variation in the water column (Maranup Pool) or a daily stratification with a thermocline forming by dusk only after heating during the day. This thermocline is then broken down over night with cooling and equalising temperatures.

Fig 2.10a : Graphical representation of the degree of thermal stratification within each pool sampled at dawn and consequential oxygen depletion.

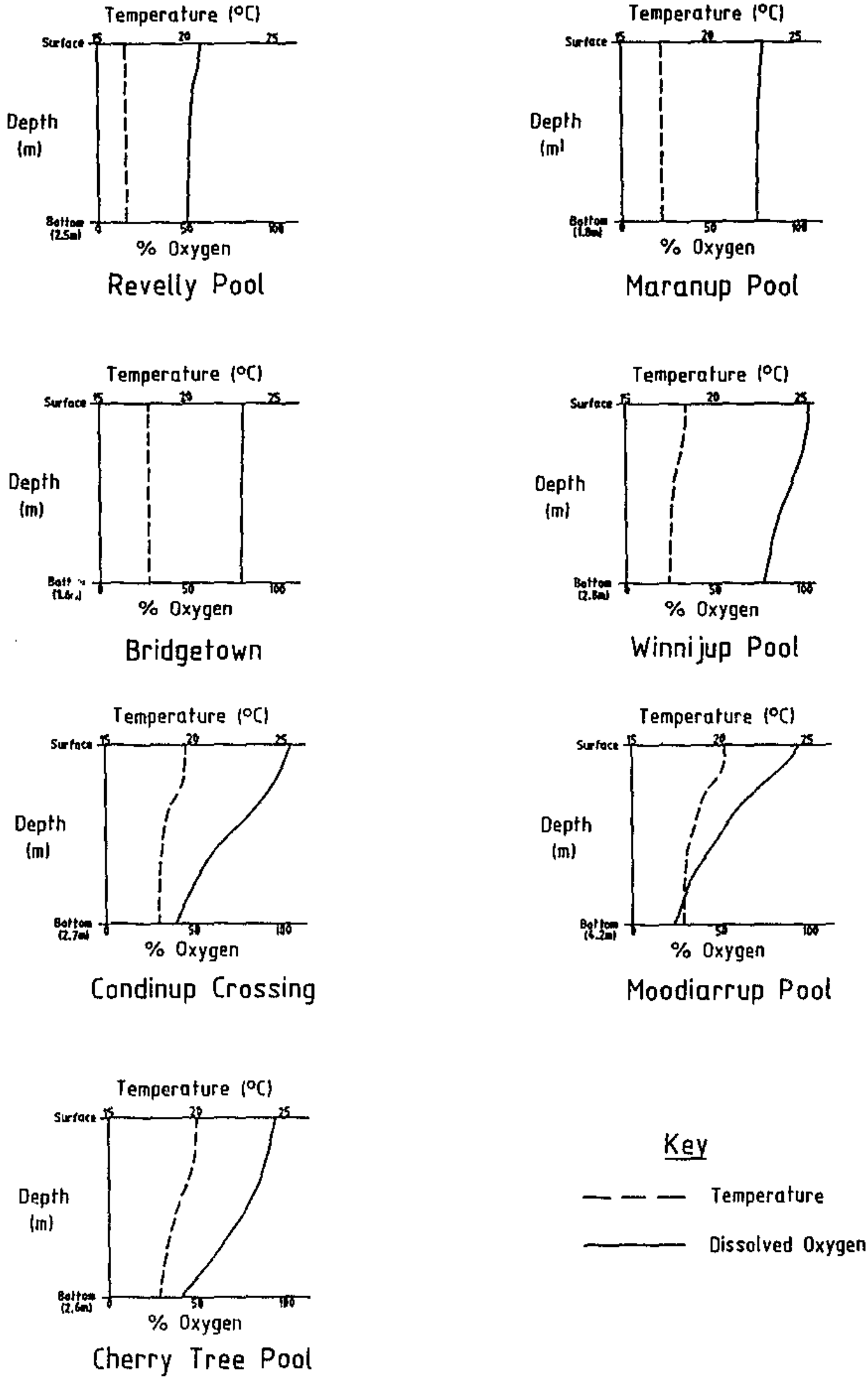
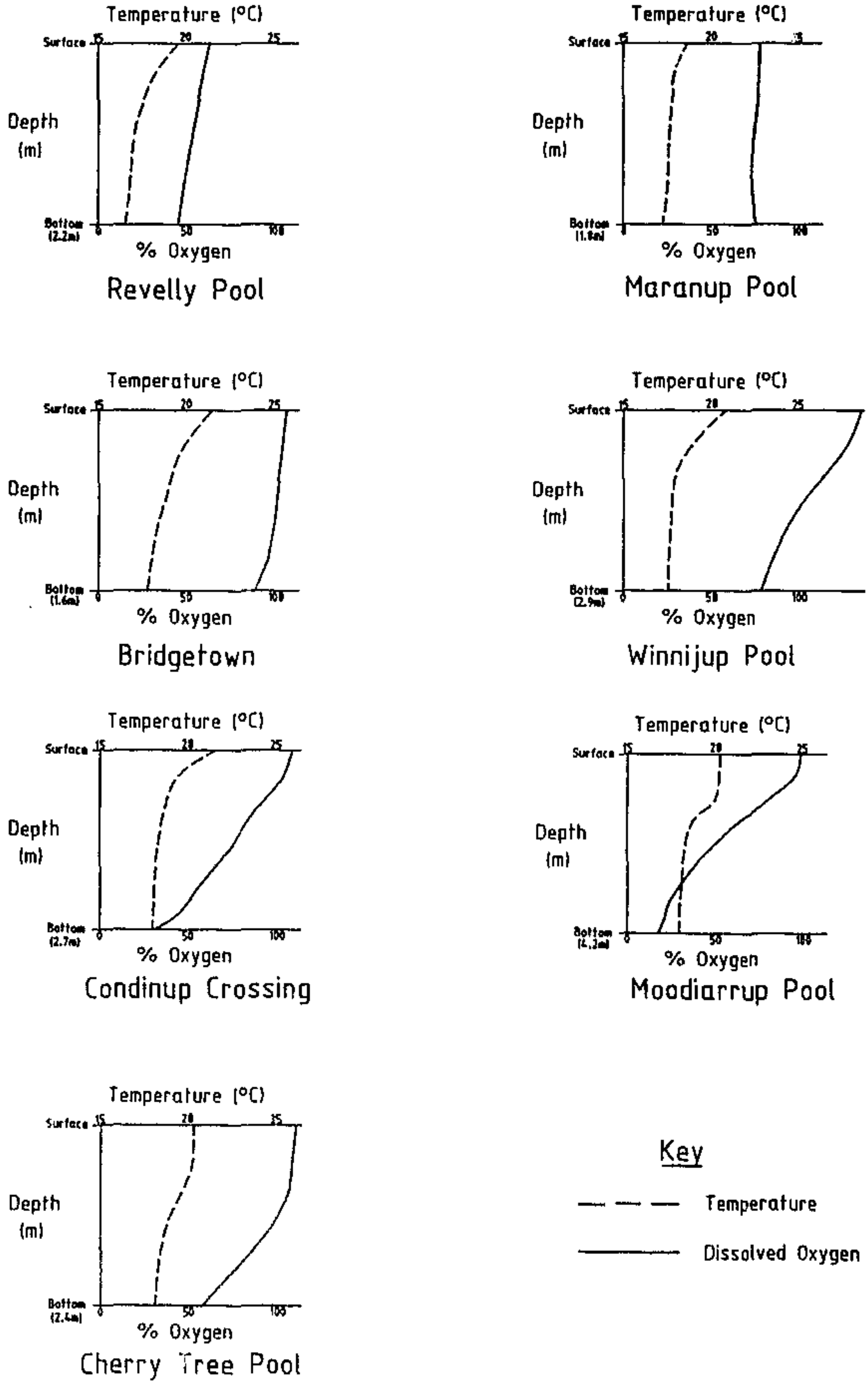


Fig 2.10b : Graphical representation of the degree of thermal stratification within each pool sampled at dusk and consequential oxygen depletion.



The pools above Bridgetown were all over 2.5m deep, and showed a persistent stratification, present for both dawn and dusk. As indicated by Abel (1989), with increasing depth the magnitude of temperature variation within the profile increases and stratification can be maintained. When comparing the degree of stratification for the dawn and dusk sample, each of the upstream pools showed a more pronounced variation from top to bottom, for both temperature and oxygen, during the dusk sample. Even though photosynthesis during the day introduces oxygen and exceeds day time respiration, the biological oxygen demand of the sediments within these pools seems to be a significant factor depleting oxygen in the slightly warmer bottom water during the day. This depletion is particularly evident within the deepest pool , Moodiarrup showing the importance of depth in relation to the degree of stratification possible.

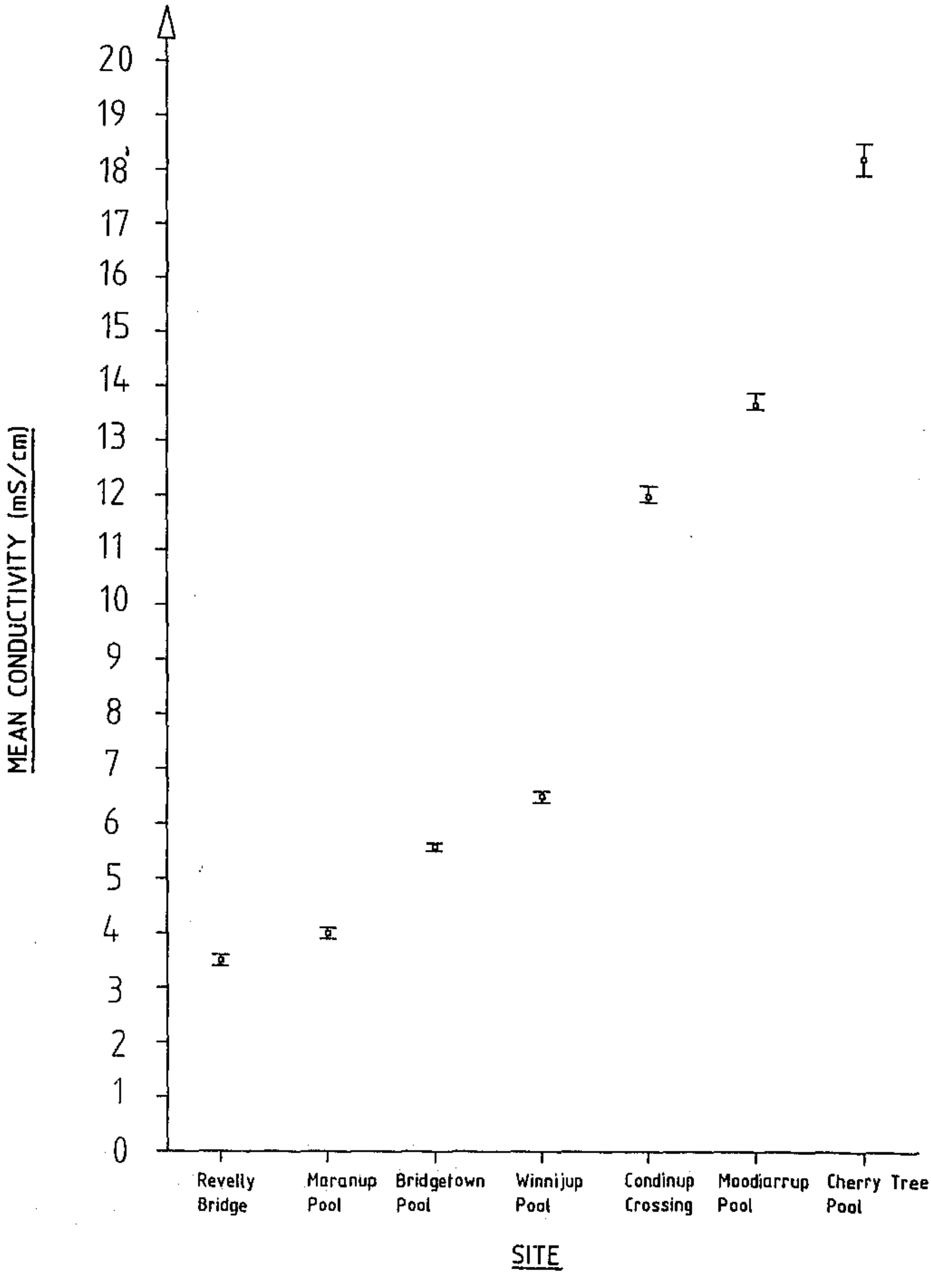
By observing both the dawn and dusk data for each pool, a trend of increasing degradation of the water column (based on the temperature and oxygen data) can be seen as sampling moved up the river. This is more than likely related to the trend in catchment degradation as outlined in section 1.2. For example the pools in the lower portion of the sample area generally had a better riparian zone while those up river were generally open, subject to considerable agricultural runoff, and a lower flush potential during winter, compared to the smaller pools.

2.3.3.3 Conductivity

Figure 2.11 shows the mean and standard error conductivity for each pool sampled. Comparison between pools confirms the unusual reversed longitudinal salinity identified by Morrissy (1974). This phenomenon is characteristic of the longer inland rivers of the south-west (see section 2.1.1 for more details)

For marron the lethal high for salinity has been identified at 33mS/cm (20ppt), which is well above the salinities recorded for the pools sampled. This level of salt only exists in the tributaries of the salt lakes within the upper Blackwood Catchment. Therefore the lack of marron occurrence within the sample area could not be attributed to salinity. However salinity has been identified to limit growth between 9 to 13mS/cm (6 to 8ppt). In reference to this and the salinity recorded for each pool, marron growth would be

Fig 2.11 : Graph showing Mean Conductivity of each pool using both dawn and dusk samples.



limited within the three upper pools sampled above Winnijup. Winnijup defines the transition into environmental conditions more favourable for marron growth and reproduction.

2.3.3.4 Summer Pool Oxygen Profiles

Figure 2.12 (pg 89) shows a cross-sectional view of each pool, mapped with contours of dissolved oxygen saturation for both the dawn and dusk sample. Each pool has been assigned a number corresponding with its location within the catchment, as depicted in Figure 2.4. The purpose of these maps was to clarify degradation of DO saturation within the water column, linked to persistent thermal stratification, and driven by the eutrophic nature of the pools. This information provides an excellent framework for identifying the potential threat to marron within the summer pool environment, because of their intolerance to low DO levels.

When referring to changes in dissolved oxygen which encroach on the tolerance thresholds for marron, it is important to note that the degradation is often temporary, and that marron being relatively mobile organisms, have behavioural characteristics which enable them to move away from unfavourable conditions within their home range. Therefore violation of a tolerance threshold does not necessarily imply that the pool is unsuited for marron survival, but only refers to the particular degraded level within the water column, often lost to marron as a habitat for a particular time of the day or season.

As show in Figure 2.12 all pools exhibit a DO which falls below the optimal saturation (90%) ideal for economic marron growth and fecundity. However this is an aquacultural threshold and unrealistic within a non-flowing natural system like the summer pool of a river.

A dissolved oxygen reading of 70% and below implies that marron surviving within this level of oxygen suffer decreased incremental growth. Figure 2.12 indicates that the pools sampled below Boyup Brook, those lower within the sample area, generally provide marron with DO above this threshold throughout the cross-sectional profile of the pool. Marron were in fact caught within these pools, except at Winnijup Pool (see section 2.2).

However it is necessary to point out the relatively uncharacteristic DO values recorded for Revelly Pool. The low surface DO more than likely relates to the pool's setting, low within a relatively steep sided V-shaped channel, surrounded by tall shading river gums. Therefore light may have been limiting photosynthetic oxygen production, and wind aeration of the surface water was more than likely obstructed by the deep channel. With increasing water temperature during the day the low surface DO was further degraded to 40-50% incompatible for normal marron growth, but not survival as proven by the marron caught from this pool (see section 2.3).

The result for the Winnijup Pool in reference to pools down river and above, suggest a point of transition between the less degraded lower portion of the Middle Catchment and the severely degraded upper section. As indicated by Morrissy (1978b), sampling in 1973 showed that environmental conditions for marron became more favourable below Winnijup Bridge. The results for the present study reflect this improvement.

All pools occurring above Boyup Brook (Condinup - Cherry Tree Pool) exhibited DO levels which threatened marron growth at approximately 1m to 1.5 m depth. Above this depth the DO was favourable (70%-100%). As depth increased within the upper most pools, DO was further degraded to a level below the critical threshold (40%) for marron survival, generally associated with increasing occurrence of death with increasing exposure time. This degree of oxygen deterioration was only associated with the two deeper pools in the upper study area (Condinup and Moodiarrup). Marron, if present within these pools would more than likely be restricted to the first 1-2m of the favourably long, pool bank.

The results suggest that a pool which exhibits persistent stratification, a depth greater than 2.5m and occurs within the more degraded portion of the Middle Catchment has the potential to force marron from the bottom water of the pool in attempt to evading the lethal low DO at certain times of the year (summer) or day (afternoon). During this time marron can be subject to crowding and unfavourably higher water temperatures within the confines of the bank. Effectively marron can be completely locked out of these pools at certain times of the day when they are subject to anoxic conditions and lethal high water temperatures.

NOTES

The physio-chemical parameters outlined for each profile represent values obtained by vertical sampling of the water column from top to bottom.
Physio-chemical units are as follows:
1) Water Temperature (Degrees Celsius)
2) pH (Units)
3) Conductivity (Con) mS/cm.
4) Dissolved Oxygen (DO) %

ORIGINAL DRAWING SIZE	A1	NAMES PRINTED IN FULL	DATE
	DESIGNED	Rachael Nickoll	Sept '96
	DRAWN	Andrew Duffield	Sept '96

Figure 2.12
Cross-sectional profiles of seven pools within the Middle Blackwood Catchment (lower (1) to upper (7)) showing vertical variation in percent saturation of Dissolved Oxygen at dawn and dusk.

Edith Cowan University

DRAWING TYPE	DRAWING NUMBER	AMEND.
	9601-MARRON	

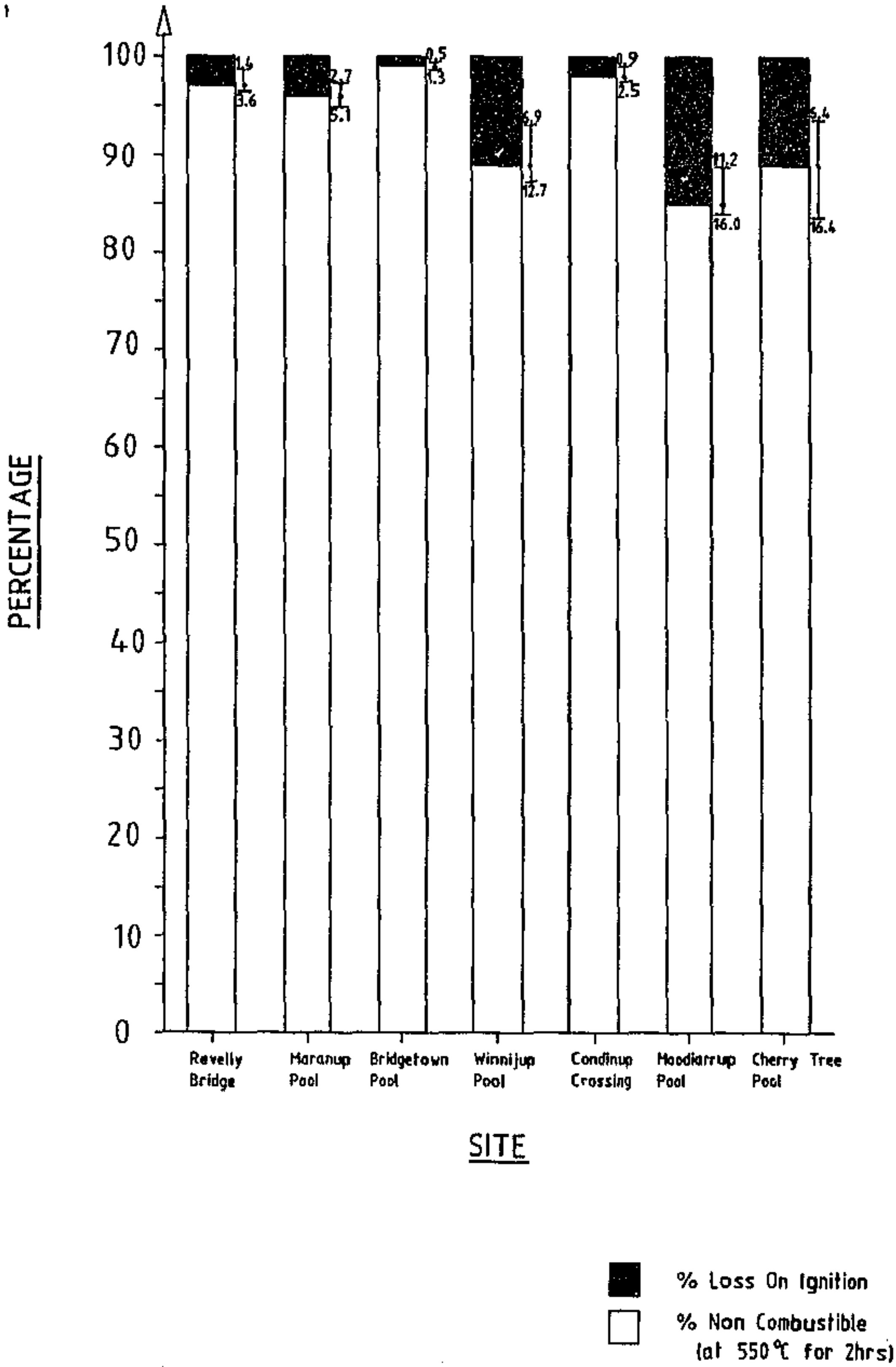
2.3.3.5 Sediment Data

Figure 2.13 shows the mean percentage of organic matter (in terms of weight loss on ignition) for the five replicates taken from each pool sampled within the study. Observations during sampling indicated that the organic content of the grab was generally higher near the middle of the pool. Nevertheless the variations between grabs were small, except for Cherry Tree Pool which had a range of 6.4% to 16.4% organic matter.

Those pools shown to have a higher percentage loss on ignition (e.g. Winnijup, Moodiarrup, and Cherry Tree Pool) were either located higher up in the Middle Catchment (e.g. Moodiarrup and Cherry Tree Pool), and/or were relatively deep and wide compared to the much narrower pools generally found down river (e.g Winnijup to Revelly). The higher organic content of the larger pools more than likely relates to their lower flushing potential during winter flood compared to the smaller shallower pools. The low value obtained for Condinup Crossing pool is indicative of this considering that it was located below a crossing.

The pools identified as having black smelly mud within Table 2.3 are, as would be expected, the pools with the highest mean organic content. As outlined by Morrissy (1978b) there are consequences associated with organically loaded bottom sediment which can threaten marron survival; firstly, by oxygen deficiency in the bottom water, and secondly, by the release of phosphates from the black anaerobic sediments during summer stagnation of the pools, encouraging algal blooms. De-oxygenated conditions have been identified with bottom sediment organic values of 21% - 31% (Morrissy, 1978b). This level of organic composition was not identified within any of the pools sampled (1% to 16.4%). However, within farm dams the organic content of sediment has been known to increase significantly from 10 to 12% after a summer storm, resulting in mass marron mortalities. According to the study's results, those pools with organic sediment content over 10% (Winnijup, Moodiarrup and Cherry Tree Pool) have the potential for a sudden and marked deterioration in pool habitat for marron survival, with heavy summer storm runoff. A scatter plot comparing the lowest bottom DO% against the mean (g) organic content of each pool, indicated a low negative correlation (r = -0.34), but this was not significant.

Fig 2.13: Histogram showing Mean Percentage Loss on Ignition for five replicate sediment grabs taken from each pool sampled.



2.3.4 Discussion

2.3.4.1 Eutrophication

Natural eutrophication occurs over a geological time frame and involves the terrestrialisation of a water body to form a wetland (Bayly etal, 1973), but because eutrophication is caused by the accumulation of plant nutrients and organic matter in the water body, anthropocentric influences have accelerated the process dramatically over the last 50 years (Abel, 1989). Today the term eutrophication is liberally applied to the effects of accelerated (artificial) nutrient supply from the catchment through human activity such as land clearance, agriculture, and urbanisation. This is a far more rapid process of eutrophication which manifests itself in slow or non-flowing water as a decrease in water quality both for humans and aquatic organisms. The endpoint of artificial eutrophication is often expressed through algal blooms, toxins, and de-oxygenation leading to anaerobia (Bayly *et al*, 1973).

The eutrophication of rivers is often overlooked compared to the attention given to lakes and other slow or non-flowing water bodies. This has occurred despite the fact that artificial eutrophication of rivers is a more widespread phenomenon than that of lakes, involving a doubling in the phosphorus and nitrogen content of rivers (Harper, 1992). According to Harper (1992) this oversight is because the biological response of rivers to elevated nutrient levels is less dramatic and visible in rivers. For example few rivers run slow enough to produce phytoplankton blooms, but when they do, small single celled species dominate and generally only turn the water green rather than concentrating into visible floating mats. The self purification process of rivers with flow downstream, often makes the effects of eutrophication relatively unobtrusive compared to that seen in lakes and estuaries (Harper, 1992). Given this scenario, probably the best physical, chemical or biological indicator of eutrophication in riverine pools is depleted dissolved oxygen in the hypolimnion.

Because of seasonal rainfall, the Blackwood River is transformed from a continuous and flowing system during winter into a number of discontinuous temporal pools during summer. The summer pool environment of the Blackwood basically represents a large number of discontinuous lakes with the potential for eutrophication. As outlined by

Negus (1995) and Parker (1994), algal blooms have become sporadic events within these pools during summer, indicative of a eutrophic state. The agricultural land use dominating the catchment has provided the extra nutrients and organic pollutants required to convert the once dystrophic Blackwood River system (dominated by dissolved organic matter staining the water brown) into eutrophic pools during summer.

2.3.4.2 Source of nutrients from the Blackwood Catchment

The symptoms of eutrophication (the proliferation of algae) in freshwater wetlands of the south-west have proven to be associated with the limiting nutrient, phosphorus rather than nitrogen (Hodgkin *et al*, 1993). The biological availability of phosphorus is naturally small in relation to the quantity required for algal growth, so an increase in phosphorus often results in greater productivity. "Phosphatic fertilisers" are the principal source of nutrients within many south-west catchments, together with intensive stock waste (effluent) from paddocks (Hodgkin *et al*, 1993).

The routine application of superphosphate to nutrient deficient soils at relatively high rates (100-250 kg/ha) has led to the accumulation of phosphorus stores in excess of pasture needs (Yeates, 1993). The input of phosphorus into the typically shallow rivers of the south-west occurs through leaching from the poor nutrient-retaining soils associated with the region, and through erosion of topsoil (McComb *et al*, 1993). Streamflow in the south-west is seasonal, reflective of the Mediterranean climate involving hot dry summers and heavy winter rainfall. Farmers tend to spread fertilisers towards the end of the dry season due to difficulties with machinery in the wet soils. The season often breaks with heavy rains which transport alot of this newly applied nutrients to the pools of the river (McComb *et al*, 1993).

The overstocking of paddocks within the Blackwood river catchment has lead to an increase in stock effluent, soil erosion by crumbing the top soil and crop debris, and riparian zone degradation (The Senate Standing Committee, 1993). During the heavy early rains and summer storms the organic pollutants readily have access to the pools, increasing their nutrient load. Figure 2.14 shows the mean monthly rainfall and the heaviest daily rainfall for the shire of Kojonup within the Upper Middle Catchment. It also indicates the incidence of summer thunderstorms over the past 25 years (Morrissy, 1978b).

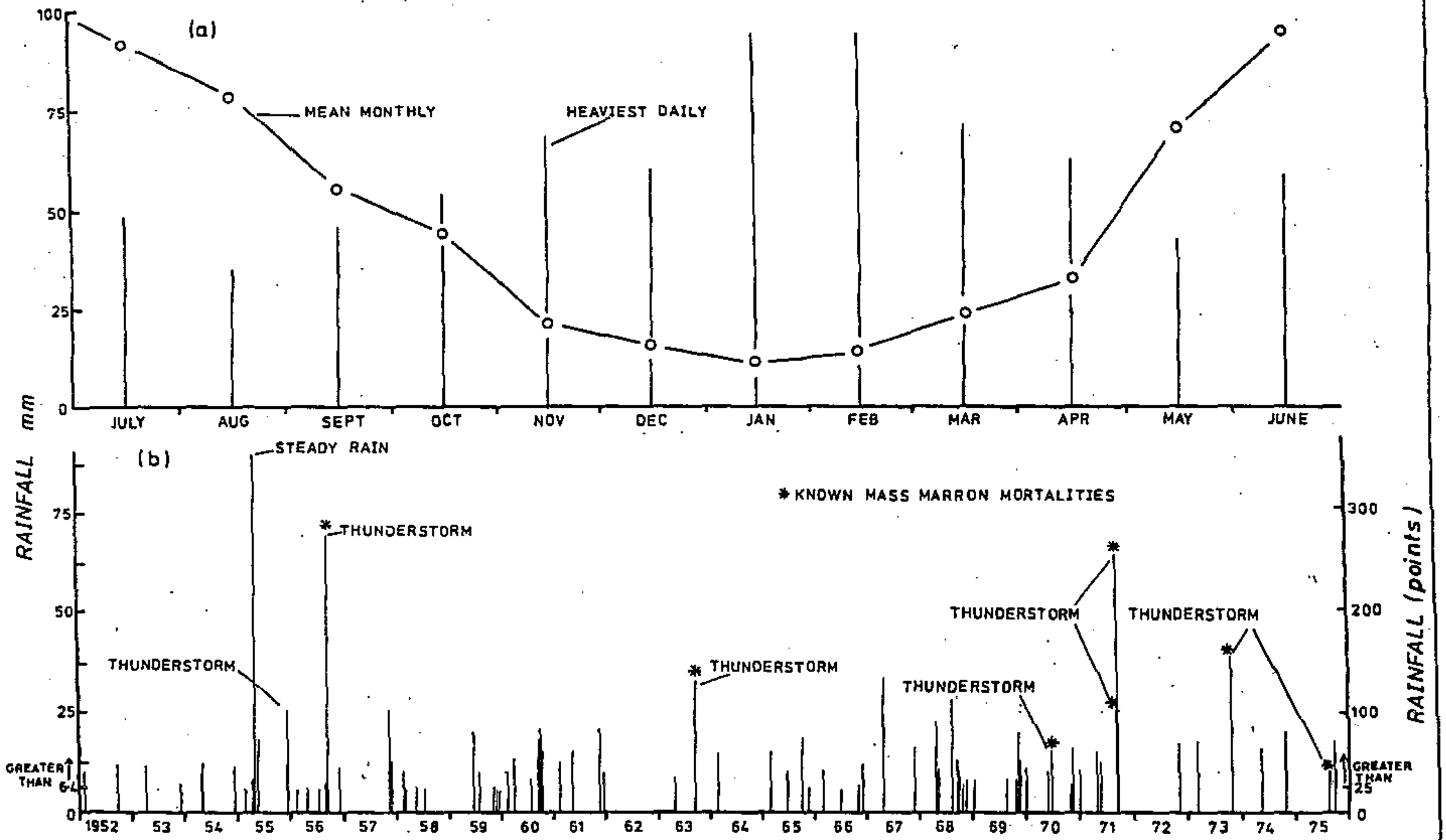


Figure 2.14:-Kojonup rainfall statistics:
(a) Mean monthly rainfall and heaviest daily rainfall.
(b) Incidence of heavy daily rainfalls during the summer period, December to March inclusive, over the past 25 years.

The rate of nutrient input through surface runoff depends not only on the climate, but also the geology of the surrounding catchment. The Middle Catchment, near Bridgetown and Nannup shows an increase in topographical relief which is referred to as the Zone of Rejuvenation. However, as a result of extensive clearing within the high relief areas, erosion and runoff problems have become prevalent.

2.3.4.3 Eutrophication and Thermal Stratification

As indicated by its definition eutrophication is initialised through a high influx of nutrients, in particular nitrogen, phosphorus and organic pollution. An increase in mean biomass and productivity occurs when the nutrients are taken up by algae (epiphytic and planktonic). As part of the sequence of changes associated with eutrophication, this accumulation and eventual decay of plant debris result in a changes in the dissolved oxygen content of the water body, which can have a profound effect on marron survival. As Harper (1992) points out the extent of this variation depends on pool depth and whether the water body has the potential to stratify.

Stratification is initialised by variation in water temperature, commonly occurring when the epilimnion (upper layer) warms during the summer months, making the layer less dense, and a poor conductor of heat to the lower cooler water. The epilimnion thus becomes sharply delineated from the hypolimnion (lower layer). Between them is a narrow zone called the thermocline, within which the temperature drops sharply with only a slight increase in water depth. Little or no vertical mixing can take place as the pool is effectively divided horizontally into two distinct layers separated by the thermocline (Abel, 1989).

Newson (1994) indicates that lakes shallower than 10-15 m do not stratify. As shown in Figure 2.10a and 2.10b, all but one pool (Maranup Pool) showed some degree of stratification over the 24 hour sample period (dawn and dusk) even though the maximum depth only ranged from 1.5m to 4.2m. This strongly implies that something other than temperature has enforced the unlikely stratification on the shallow pools.

Thermal stratification is evident through a rapid falling-off in temperature from top to bottom as summer progresses. A thermocline is considered to exist when temperatures differ by more than 1°C with any 1m depth of water (Maitland, 1990). This scenario was acute within the pools sampled, considering that temperature changed by one degree within only 50cm of water within the stratified pools. Figure 2.10a and 2.10b, clearly depicts the pools showing the extreme variation in temperature, notably Moodiarrup Pool at dusk (20°C - 18°C). Nevertheless, as indicated within the results (Table 2.5) the temperature range of each pool does not breech marron tolerance thresholds. However sampling was conducted at the end of summer and it is likely that water temperatures especially at the surface may have been over 30°C during mid- summer. As indicated by Morrissy (1976) south-west rivers can exhibit a maximum temperature range of 25°-32°C, exceeding the incipient lethal temperature for marron.

The potential for a water body to stratify is also associated with its turbidity, which functions to concentrate heat close to the surface while removing the heating effect from the lower water. Highly turbid waters can exacerbate and prolong stratification until surface temperature drops to promote mixing (Morrissy, 1976). All but two pools sampled were turbid having a secchi depth less than 1m (see Table 2.5). This low level of pool transparency was probably due to the presence of suspended sediments introduced from the catchment, possibly a concentration of planktonic algae within the upper photic zone and the reasonably high gilvin content observed for each pool. Gilvin (staining from dissolved organic matter) is characteristic of many wetlands within the south-west, having ecological importance in nutrient enriched waters by reducing light levels necessary for extensive phytoplankton production, causing algal blooms (Wrigley et al, 1988).

The summer pools of the Blackwood River represent a warm-monomictic pattern of stratification common to Australian waters (Williams, 1983). This pattern involves stratification during the warmest months only, with mixing occurring throughout the other seasons. This is would be expected for the Blackwood River considering the river flows during the wetter months. Within this annual pattern, stratification may vary daily, as in shallower water bodies, or over longer periods, as in deeper waters. The persistence of stratification is generally determined by depth, climate (temperature) and the degree of exposure from the mixing action of the wind (Abel, 1989). Considering that the depth of the seven pools sampled was not stratifiable in theory, their depths should not be able to sustain long periods of stratification.

As indicated in Figure 2.10a and 2.10b, this theory holds true for pools sampled from Bridgetown and below, which either showed no stratification or indicated a daily variation in which the pool was only stratified during the dusk sample. However the remaining pools above Bridgetown were deeper (over 2m) and showed a stratification persisting for both the dusk and dawn sample. This prolonged stratification indicates that factors other than temperature and turbidity are more than likely contributing to stratification.

2.3.4.4 Eutrophication and Chemical Stratification

Following the establishment of thermal stratification, chemical stratification of eutrophic waters consequently follows by creating a chemocline (Bayly et al, 1973). As indicated by Harper (1992), the longer the stratification persists the more chemically and biological distinct the layer becomes, often having a striking biological effect on biota.

Temperature is closely associated with oxygen solubility and consumption (Maitland, 1990). Solubility increases with low temperatures, while respiration (oxygen consumption) increases by 10% with each 1°C rise in temperature (Maitland, 1990). As shown in Figure 2.10a and 2.10b, the shallow nature of the pools allow deeper water to remain warm enough to promote respiration throughout the water column, especially when excessive nutrients are available. The stratifying effect of dissolved oxygen can clearly be seen within Figure 2.10a and 2.10b.

Chemical stratification can be expressed by other water quality parameters subsequently altered by changes in temperature and DO. The results in Table 2.5 show that chemical stratification is associated with all parameters sampled during the study (except redox), showing a gradual change in values recorded for each parameter down the vertical profile (surface to bottom).

Conductivity or salinity changes are reflected in the density relationship occurring during stratification, where the deeper water becomes more saline in the absence of mixing (Bayly et al, 1973). Conductivity within all pools sampled increased gradually with depth, but never varied more than one unit (mS/cm). Therefore oxygen depletion within the hypolimnion has not been caused by a salt wedge or the halocline associated with the longer rivers of the south-west as identified by Morrissy (1979).

Within the hypolimnion the pH is effected by the amount of carbon dioxide and dissolved oxygen in the water column. Low pH is reflective of declining dissolved oxygen and increasing concentration of carbon dioxide which often causes a progressive reduction in bacterial decomposition of organic detritus within eutrophic waters (Abel, 1989). Within the pools sampled pH lowers with depth by less than one pH unit only. The salt concentration within the pools, more than likely maintains this reasonably stable pH (7.5 to 8.9).

The pH also effects the toxicity of free ammonia, an end product of organic decomposition (nitrogenous) and excreta from aquatic organisms. Within low pH conditions (anoxia) ammonia is eventually converted to release elemental hydrogen which readily displaces the less soluble oxygen from the water and contributes further to deoxygenation (Harper, 1992). Alternatively and probably reflective of the pools sampled, a higher pH associated with a reasonably oxygenated hypolimnion, converts ammonia to nitrate which is directly less toxic to aquatic organisms, but generally has undesirable secondary effects on the biota, associated with excess nutrients (nitrogen) (Harper, 1992). As identified within section 2.1 the presence of ammonia can be toxic to marron, giving another reason for the prevention of organic runoff (manure) to ensure the survival of marron.

2.3.4.5 Eutrophication and Deoxygenation within a Stratified Pool

As outlined by Harper (1992), stratification within a eutrophic pool characteristically involves an oxygen saturated epilimnion (100% or over) as a result of diffusion with the atmosphere and the activities of primary producers, the bulk of which are found within the oxygenated, photic zone, along with accelerating numbers of zooplankton. As primary production within the upper layer progresses, nutrients gradually become depleted and the producers and consumers begin to die off. Dead organisms and faeces then sink from the top layer into the hypolimnion, where decomposition by bacteria follows, both in the water column and sediment.

Nutrient depletion of the epilimnion also causes oxygen depletion within the hypolimnion (Harper, 1992). The oxygen demand for aerobic decomposition of the "detrital rain" is high, resulting in a gradual depletion of dissolved oxygen especially in warmer waters within the hypolimnion. The absence of both vertical mixing and photosynthesis in the darker deeper water, prevents re-oxygenation of the hypolimnion. The decline in oxygen concentration with depth can clearly be seen within the profiles outlined for each pool (dawn and dusk) within Figure 2.12.

Respiration of the bacterial biomass in the water column and sediment is the most important factor removing oxygen from the hypolimnion, especially with excessive availability of nutrients and organic detritus (Abel, 1989). The sediment (mud) of a pool is ultimately the sink for the detritus produced in the illuminated layers, together with inorganic silt load and organics and nutrients from the catchment. The bottom sediment is the principle site for decomposition, containing a large number of bacteria, breaking down organic molecules into inorganic components (Burgis et al, 1987). This process of decomposition requires oxygen, often becoming depleted in the sediment to be substituted by oxygen from the overlying hypolimnetic water (Burgis et al, 1987). This process has serious implications for shallow stratified pools with a small hypolimnion, becoming progressively deoxygenated over summer.

Once oxygen becomes absent from the hypolimnion of a stratified pool, decomposition is maintained by anaerobic bacteria. The products of anaerobic decomposition include acetic acid, hydrogen sulphide and methane in addition to the ammonia, CO_2 and water, characteristic of aerobic decomposition (Mason, 1981). As indicated by Harper (1992), the anaerobic process of denitrification of ammonia to nitrogen gas, and the production of methane often occurs within the mud prior to the deoxygenation of the hypolimnion, due to a poor rate of diffusion and rapid up take of oxygen in the sediment.

The resulting black mud consequently has a characteristic "rotten eggs" smell and can be toxic to aquatic organisms. This process is natural in many small organic rich lakes, but the noxious gases are usually a sign that conditions are deteriorating (Burgis etal, 1987).

Black organic sediment under stratified conditions also has the potential to release nutrients in association with low pH and redox potential existing near the mud / water interface. In the absence of reliable redox data and fully defined DO readings, conformation of this process is not possible for the pools sampled. However, according to the description of sediment samples taken from each pool (see section 2.3), black noxious smelly mud was present at Winnijup, Moodiarrup and Cherry Tree Pools, all of which showed prolonged stratification for both dawn and dusk. Therefore in association with the possibility of deoxygenated bottom water (if readings were left to stabilise for over 2 min, as indicated by the data lag time) it seems likely that these pools have the ability to release nutrients from the sediment, thus further prolonging eutrophication beyond the periodic organic inputs from the surrounding catchment.

Therefore a balance between the organic and inorganic constituents of the mud, and the intensity of aerobic and anaerobic bacterial activity is very important to the health of the riverine pool ecosystem. Considering that marron are benthic dwelling organisms it seems obvious that they will suffer within the presence of sediment with a high organic content, not only due to oxygen depletion, but the release of toxic gases such as CH_4 + H_2S. Loss on ignition values (a surrogate for organic content) were generally higher for the larger pools, of the upper middle catchment, suggesting that this process may have been existing for some time.

2.3.4.6 Eutrophication, the Threat to Marron and their Survival

As an overview of the changes already described, associated with the summer pools and eutrophication, Ryding *et al* (1989) verifies that:

- stratification,
- an increase in temperature and conductivity,
- a decline in hypolimnetic oxygen concentration and transparency,
- low pH and redox potential near the sediments,
- and black anoxic mud

are all symptomatic of eutophication.

The summer pool eutrophication confirms that marron are threatened, as first implied by Morrissy (1978*b*) in riverine pools of the Blackwood Middle Catchment.

To survive an organism must live within an environment which meets its needs, providing a suitable physical habitat including space, shelter, and a sufficient supply of food, oxygen and other metabolic requirements, and which is not subject to extremes of temperature and other physical variables outside the animal's tolerance range. The process of eutrophication can make a number of these requirements limiting, preventing an organism's survival within the water body.

The adaptation of marron to a habitat of open water and high oxygen levels has made marron susceptible to low DO. This predictable susceptibility, suggests they are excellent indicators for degrading water quality, particularly associated with eutrophication (Morrissy *et al*, 1984). The results here indicate that marron survival is threatened in all pools at certain depths (>2m) more so at a particular time of the day (dusk).

Oxygen values presented in Figure 2.12 show that complete deoxygenation of the hypolimnion never eventuated within any of the pools during sampling. However, as a side effect of the sampling procedure used, the bottom DO values recorded for each pool may in fact be an underestimation. As indicated within the data analysis (section 2.3.2.3) a 2 min lag time was associated with the DO readings from the Hydrolab, therefore stabilisation probably never occurred for the bottom DO reading for each pool. If stabilisation had been achieved then DO readings for the deeper pools exhibiting black anoxic sediment, in particular Moodiarrup may have dropped below 7.5%, the lethal low for marron, thus eliminating them from the deepest, coolest section of the pool.

These factors have important implications for continued marron survival within the diversity of pools making up the Blackwood River during summer. They also highlight the fact that the process of water column recovery from persistent stratification can be daily with mixing occurring over night or seasonally with the flushing effect of winter rainfall. This natural process of water quality improvement has obvious implications for marron recovery, as already indicated in Figure 2.8.

The potential exists to accelerate these natural recovery processes through restoration, targeting those pools which do not benefit from seasonal flushing and mechanical mixing of the wind. This research finds that these pools are generally found above the current upper limit of marron distribution making them a focus for riverine restoration, and marron recovery.

Chapter 3

RESTORATION, FLAGSHIPS AND THE BLACKWOOD RIVER COMMUNITY

3.1 Oral History

3.1.1 Introduction

The Blackwood River has suffered enormous changes owing to the land degradation outlined in Section 1.2.5, but the history of this deterioration remains largely in the unrecorded memories of the now older, long-time residents still living within the catchment. Sanders (1991) recognised that this valuable source of historical information would be lost to future generations if not documented. Consequently, some oral history memoirs documenting environmental changes in wheatbelt wetlands have been transcribed and published for wetlands within the Avon and Blackwood Catchment. The oral history research conducted here has also been aimed at identifying environmental changes specific to the Blackwood Catchment, but interviews the respondent in terms of their opinions, attitudes and values towards restoration, marron, and the flagship concept.

The rationale for this research has been based on the assumption that the perspectives' of others are meaningful, knowable, and able to be made explicit (de Vaus, 1995). The interviews were aimed at obtaining data complimentary to the research question, and providing a medium to identify community attitudes towards river restoration and their value and association with marron within the Blackwood River Catchment.

The oral history component of the interview provided a valuable account of the environmental changes observed for the land, river, vegetation, and animals over the last 80 years, in particular marron disappearance and reasons identified for this. These data along with anecdotal information from Sanders (1981), and the marron survey outlined in section 2.2 have provided a review of marron distribution since last recorded in 1973 (Morrissy, 1978b).

The participants' attitudes and opinions on restoration, marron and the flagship concepts were used to gain an insight into the concerns, and ways of thinking associated with the Blackwood River Catchment community. This was crucial for the development of a framework for the study's community questionnaire, outlined in section 3.2. The interview, nested within the oral history, established "informants" from the sample community, providing useful clues about meaningful questions and clarifying concepts and wording (common vernacular) to be explored within the questionnaire (e.g. restoration, endpoint).

3.1.2 Methods

3.1.2.1 Respondent Selection

The names and background of 18 people were nominated by the BCCG, according to their historical knowledge of the catchment and strong affiliation with the Blackwood River community. They were identified by the BCCG as representative of a cross-section of the community. From the initial 18 potential interviewees six were selected, each of whom had a farming background, was aged over 40 years and had lived in the catchment all their life. Their current status within the community ranged from retiree, farmer, politician, to conservationist.

The participants were also selected on the basis of providing a continuum of historical information down the length of the river, according to their property location within the Middle Catchment. In most cases there were two people present during the interview (husband and wife), but generally one dominant informer while the other helped to recall dates and name etc.

Since time limited the number of respondents to six, the research was restricted in its ability to cross reference dates and events for greater accuracy when collating information. Nevertheless the number of interviewees was adjusted to nine as other names were suggested during the course of the oral history. The additional interviewees were identified as well known "keen marroners" within the community. They were sampled informally during spare time available between the original six pre-arranged oral history.

The original interviewees were contacted by phone during which the purpose of the interview was outlined. This was followed by setting a date and time for the interview, subsequent to their agreement to participate. Ideally the next step should have been a preliminary visit, but time and the cost of travelling to the Blackwood Catchment could not justify this approach.

The statement of consent (Appendix 2) was designed according to the ethical consideration required by Edith Cowan University. Initially it functioned to outlined the purpose of the study, its aims and the topics intended to be addressed during the interview. As the name suggests, it also ensured consent was sought before tape-recording the interview, and was used to confirm whether the respondent preferred to remain anonymous within the study.

The interview time ranged from 1.5 to 2 hours. An interview duration of no more than 2 hours was set so as to avoid fatigue for both parties and to allow all six interviews to be conducted within the 2 days allocated, especially since the first and last interviews were just under 260km apart.

3.1.2.2 The Interview Procedure

The interview technique used, was the "guided approach", involving an outline (Table 3.1) designed prior to the interview, containing a set of questions or issues which were intended to be explored with each respondent (Glassner and Moreno, 1989). In practice the guide was used passively as a check list during conversation to ensure all topics were covered so that the purpose of the interview was achieved. Flexibility was necessary since topics were often not covered in any sequence. As indicated by the outline the interview was based on open-ended experience/ behaviour, opinion/ value, background/ demographic, and knowledge questions (Glassner *et al*, 1989).

For the interview of the 3 "keen marroners" attention was focused only on issues relating to marron fishing, including the interviewee's:

- history as a marroner of the Blackwood River;
- past and present fishing location; and
- opinion on the disappearance of marron.

Table 3.1: Interview Outline used to guide the Oral Histories and to ensure all points intended were covered

Brief Biography of interviewee

- Name
- Postal Address
- Home Address
- Contact Number
- Occupation and role in the community.
- How long have you lived in the catchment?

Significant environmental changes noticed since living in the catchment

- Clearing
- Salinity
- Erosion
- Floods
- River water quality
- Summer pools
- Pests (plant / animal)
- Disappearance of species (plant / animal)

Knowledge on marron occurrence in the Blackwood Catchment

- First sighted - decline
- "Marroning"- size, catch, bait.
- Why do you fish for marron?
- Why has the marron distribution been reduced - "threat" ?

What is the most significant environmental problem faced by the Blackwood Catchment today?

What are your views on current land conservation practices and "restoration" efforts within the catchment?

- Fencing "remnant" vegetation.
- Tree planting and agro-forestry
- "Riparian" zone restoration.
- Drainage and contour trenches
- Community attitudes - change?
- What improvement is needed?
- What are your solutions to the catchment's environmental problems?

What do you consider an appropriate "endpoint" to restoration?

- Is restoration possible?
- What would you like to see in the catchment in 50 years time?

What is your opinion on using marron as a "flagship" for restoration of the Blackwood River?

- Are marron appealing?
- Does the community care or value marron enough.

NOTE: All words identified by (" ") were investigated as to their appropriate use within the general community.

The role of the interviewer was to provide an environment within which the respondent could respond comfortably, accurately and honestly to questions. As suggested by Glassner et al (1989) the interviewer was responsive and facilitated conservation so that the respondents could express their own personal perspective in their own words. In reference to the outline constructed the interviewer explored, probed and asked questions which elucidated a particular subject and maintained some control so as to minimise long-winded responses, irrelevant remarks and digression from the interview's purpose. Therefore unlike an informal conversational approach to interviewing, the guide method introduces some bias into the conversation, but which is necessary to obtain relevant data (the outline) within a specified time frame.

3.1.2.3 The Transcribing Process

The most time-consuming stage within the study was the process of transcribing the recorded interview to word processor, with each 10 minutes of interview taking 20 to 30 minutes to transcribe. The interviews were transcribed into third person notes, restating what was considered most relevant to the main topics investigated by the study, with only minor editorial changes.

The quality of the tape-recorder and tapes were not the best, therefore at times it was difficult to identify what was stated. However, in association with the ethics involved in documenting an individual's knowledge, this limitation was overcome, by sending a draft copy of the transcript to the interviewee for editing. This was performed for the six pre-arranged interviews but was not executed for the brief, less detailed "keen marroner" interviews.

The edited version was return by each interviewer for changes and additions to be incorporated into the final transcripts. All six final transcripts of the interviews, along with the unedited marroner interviews are lodged in the Oral History collection at the Battye Library.

Oral history interviews typically involve photo albums, postcards, newspaper clippings and letters, along with scones and ginger nut biscuits! This study was no exception, with the interviewer concluding on a full stomach and privileged with a swag of priceless anecdotal hard copy, which can also be found at the Battye Library.

Table 3.2 is the respondent profile which indicates the interviewee's name, the shire in which they live, and their area of knowledge, which often related to the respondents location within the shire.

Table 3.2: Profile of respondents participating in the Oral Histories.

Name	Shire	Area of Knowledge
Mr Beeck	Kojonup	Carrolup River
Mr Cusack	Boyup Book	Arthur River and Moodiarrup area
Mr & Mrs Trigwell	Boyup Brook	Trigwell Bridge area
Mr Ritson	Boyup Brook	Boyup Brook
Mr Purse	Boyup Brook	Boyup Brook
"Keen Marroners"	Boyup Brook	Marron fishing within the catchment.
Mr Reid	Bridgetown-Greenbushes	Maranup Ford

3.1.3 Summary of Transcript Data

3.1.3.1 Significant Environmental Changes noticed since Living in the Catchment

The oral histories describe many changes to the catchment environment, both river and the landscape. These changes, mainly associated with clearing and agriculture, included salinisation, erosion, and changes in biota.

Clearing

Clearing was identified as the most significant change by all involved. In the 1890's the early settlers initiated clearing within the catchment using axes and burning. However the introduction of machinery advanced the clearing without thought for shade trees for stock.

Even though the better land within the Middle Catchment was cleared late last century, most was cleared within the last 40-50 years. Economics has apparently played a major part in forcing many farmers to continue to clear land and over stock paddocks. Land which had been cleared less than 25 years ago by one interviewee, was already being replanted to combat rising water table problems.

It was pointed out that alot of this cleared land was inappropriately used, for instance, steep and stony properties west of Bridgetown had been transformed due to sheep and cattle grazing, which promoted erosion.

Salinity

The connection between clearing and the problem of salinity was made by all participants. For instance one property owner, on the Carrolup River had 200 acres of land affected by salt, one quarter of which was unproductive and the remainder, only suitable for light grazing situations. It was stated that salinity has seriously threatened farming within the Upper Middle and Upper Catchment in a similar way.

Salinity was more an issue for those with low lying property, such as the flatter land found within the Upper Catchment, from the Beaufort River and up. Rising water tables and the associated salinisation of the soil were seen as a the major threat to land within the catchment

Erosion

Erosion, especially water erosion is one of the problems which has developed over time in association with clearing and the hilly country found on many farms around Boyup Brook and below. Erosion was not identified as a significant problem within the low lying properties of the Upper Middle Catchment.

According to one interviewee, erosion was not a problem until bulldozers arrived after the 2nd World War and has gradually become more serious in the Boyup Brook area since. Not only is water erosion a problem when the early heavy rains come, but wind erosion has become evident on the bare hill tops where sheep tend to camp at night. The frustration associated with erosion within the Lower Middle catchment can be identified in the following statement made by an interviewee: "There are never enough contours in a paddock to try to stop the problem".

The River Environment and Water Quality

During the 1930's the settlers drank water from the Carrolup River located in the Upper Middle Catchment. Apparently, the water was still excellent for stock even during summer. By 1940's the river was not drinkable even in winter, but remained good stock water until prevented by increasing salinity. Bulrushes, once dominated the river bank, but today the paper barks which remain do so by mere accident since settlers were not required to leave the riparian vegetation.

The Blackwood River was once used to irrigate the orchards around Bridgetown in the early 1950's. Since then the water quality of the river has deteriorated, not only as a result of increasing salinity, but runoff too. One interviewee stated that with continued clearing in the catchment, the runoff has reduced the river to the status of an open sewer. A black sludge has gradually built up over time, gradually getting worse.

Organic runoff was identified as the main problem faced between the Lower Arthur River and Bridgetown area. Runoff had not only led to river pollution, but also the loss of important nutrients and top soil from the paddocks. An interviewee divided the catchment's problems, into that most threatening to the land: rising water tables and salinity, and that most threatening to the river: sediment, manure, fertilisers and crop debris which runs off into the river from the bare and over stocked paddocks.

Floods

Flood events were considered a disaster within the catchment, The two most noted occurring in 1955 and 1982, both of which were the result of summer cyclones from the north. The floods damaged river frontage, caused sand wash-outs, leached all of the "goodness" out of the ground, burst dams often filling them with manure, while the river became "filthy", however according to one interviewee the aquatic biota managed to survive. According to the interviewees, the only winter flood recorded, occurred in 1964.

Summer Pools

Most of the early settlers built their homes near the main pools along the river. The obvious importance of the pools for aquatic organisms, and their value to the settlers as stock water was indicated during an interview.

In reference to the summer pools today, opinions were that the pools differed in water quality, not necessarily getting worst as you move up river. It was highlight that the pools were in fact becoming shallower as a result of erosion, and reference was made to the increasing occurrence of algal blooms in the pools, often described as "the colour of sulphur".

3.1.3.2 Changes in Biota within the Catchment

Pests

All participants indicated that the rabbit was once in plague proportions, prompting farmers to fumigate until trapping improved and the myxomatosis virus was introduced to keep numbers down. An interviewee indicated that one of man's worst actions would have to be the introduction of the rabbit and fox into Australia.

All respondents identified the 28-parrot as a pest, becoming a problem due to the environment created by farming. Today the 28-parrot threatens regrowth, fruit trees and grass tree (blackboy) populations. Similarly, kangaroos have increased in number in association with cropping practices. An increase in the occurrence of "turtles" (it seems that the tortoise is commonly referred to as a turtle) in the catchment was reported. Blackberry was identified as one of the major pests impacting on the river environment, especially near Nannup.

Species which have Disappeared

Respondents reported the disappearance of a number of native mammals once common to the catchment, these included the possum, chuditch, numbat, bilby and tammar. Table 3.3 displays the aquatic animals identified by participants to have disappeared from parts of the Blackwood River.

Table 3.3: Date when species were observed to have disappeared from parts of the Blackwood River (According to those interviewed within this study only).

PARTICIPANT	1920 to 1930	1930 to 1940	1940 to 1950	1950 to 1960	1960 to 1970	1970 to 1980	1980 to 1990	1990 to 1996
Mr Beeck			marron		perch			
Mr Cusack				mussel	marron			
Mr & Mrs Trigwell			mussel	leeches	perch marron			
Mr Ritson						leeches	cobbler	
Mr Purse								marron
Mr Reid								

Where possible the approximate time of disappearance is outlined within the table, based on the date given by the participant within this study only. As indicated by one respondent, mussels used to occur in handfuls along the river in the 1950's, while perch (~2 pound) could always be caught. It was also reported that during the 1950's, leeches were so common they were a problem when people went swimming.

As indicated, sandalwood was once prevalent in the Upper Middle Catchment, but disappeared after the industry wiped the species out after the 1900's. Similarly, the occurrence of mallet also declined because of its value as a hard wood. In relation to this, the disappearance of "bushland birds" with the clearing of remnant vegetation was recounted

Marron

According to one interviewee marron were first sighted on the Carrolup River around 1903-1904. Up until 1939 it was common to catch 3 to 4 good sized marron (~35cm) using a rabbit head as bait, but by 1940 marron had disappeared from this area of the catchment.

Lower down the Blackwood system, near Moodiarrup, marron of all different sizes (~30cm to 1inch) could easily be caught during the early 1950's, but as outlined by one respondent the numbers began to decline by the end of the 1950's towards a noticeable disappearance in the early 1960's. However, a participant indicated that people were still catching a few marron from the Arthur River after 1968. Supporting this, he spoke of a fire near Duranillin in 1968 which forced marron to walk out of the river, due to ash changing the water chemistry of the pools.

Marron started to disappear from the Trigwell Bridge area, along with the redfin perch, in the 1960's. However the participants reporting this were informed of marron being caught at the Bridge by tourists in 1994, but the validity of this was raised within the interview.

According to participants living near Boyup Brook, there are still plenty of marron around the Boyup Brook area, supported by the many observations of marron "walking out of the river in the thousands" after a summer flood. During the 1982 flood, an interviewee recalled that people were scooping marron up into bags around the Boyup Brook area. Similarly, a March flood in 1994 caused many marron of various sizes (the largest being ~10 to 20cm) to walk out of the river between Boyup Brook and Winnijup.

It was indicated that the farm dam is now more popular for marron fishing than the river because the water quality is better, the marron taste good, and a catch is almost guaranteed.

A respondent recalled that marroning in the Blackwood below Bridgetown was a popular activity during the 1940's and 1950's, where marron were plentiful enough to make them easy to catch. It gradually became more difficult to catch a good feed of marron in the early 1960's in this area, however it was pointed out that marron had not disappeared.

Comments from the "Keen Marroners"

It was indicated that marron could be caught anywhere along the Blackwood River in the 1940's, but marron were seen to be "definitely less abundant in the river today". This was related to the increasing salinity of the river. The disappearance of marron between Trigwell Bridge and Balingup in the 1960's was confirmed by one of the experience marroner, who also recognised the effect of summer runoff on the oxygen content of the river, "forcing marron to walk out of the river".

All three experienced marroners agreed that "a few marron" still exist in the Boyup Brook area, as observed after a flood. However the decline in catchrate in this area has forced most people to fish below Boyup Brook, around Bridgetown and Nannup. Consequently, as noticed by one participant, catches made below Boyup Brook (at Sunnyside) have generally been less than the legal quota since the 1980's. This suggests a gradual decline in the marron populations in this area too, potentially due to increasing fishing pressure.

The experienced marroners called for more restrictions on marron fishing which included reducing the use of drop nets and another closure of the marron season. According to these respondents, the closure in 1988 and 1989 improved marron fishing the following year, which once again indicates the marrons potential for recovery.

Factors which have Contributed to the Decline in Marron Number and Occurrence
It was indicated that along the Carrolup River the most likely cause for the disappearance of marron was salinity, but nutrients were also identified as a contributing factor, with the increasing use of fertilisers and herbicides by farmers in the area.

Near Moodiarrup it was suggested that salinity may have had a slight impact but, that salt levels were not significantly high during the 1960-1970's, whilst marron were disappearing. Instead, it was identified that the input of sheep manure and fertilisers were the significant contributing factor. An interviewee stated that the farm dams are a good indication of what was happening in the river: "marron are often seen walking out of the dam as oxygen levels drop" following pollution after summer rains.

Overall it was generally agreed that the input of manure and fertilisers into the river after heavy rain, were the main contributing factor to marron disappearance.

3.1.3.3 Views on Current Restoration Efforts within the Catchment

The common response was that current restoration efforts within the catchment were too little and adhoc, but a step in the right direction nevertheless. It was noted that there seemed to be alot of focus on the symptoms rather than the causes, with many farmers apparently continuing to think in the short term.

A number of interviewees highlighted that the problem of salinity and nutrient input into the rivers had been advanced due to the economic situation of many farmers. This was compounded by the fact that financial advisers are known to instruct farmers to over stock paddocks and buy more machinery, rather than restore the land.

It was indicated, that to date there has been no real direction in recent restoration efforts, with farmers working on an individual basis in regards to restoration on their property. This lack of direction was attributed to a poor understanding of what needs to be done, and "economics". All participants indicated that the lack of money was the main reason stifling efforts. For example the low returns received by farmers for wool, have had serious impacts on the amount of revegetation work on properties.

It seems that those affected less by the degradation, are less appreciative of the problem, promoting a number of interviewees to state that education is lacking in terms of current restoration efforts. Nevertheless, one respondent highlighted the changing attitudes toward trees, explaining that an increasing number of farmers were involved in planting on their properties. Similarly, the efforts of the BCCG and the LCDC's were identified as a good start in the right direction, in terms of restoring the river.

Finally, it was indicated that it seemed no-one is apparently responsible for the management of the river reserves. The local council at present has no obligations to the local environment, which according to one interviewee, was hampering river recovery efforts.

3.1.3.4 Improvements Needed for Restoration Efforts in the Catchment

The most common response to this question was the need to fence off more remnant vegetation, complimented by the exclusion of stock. A reduction in stock loading on paddocks was also suggested along with tree planting. Even though the planting of natives was obviously desirable, it was indicated that plants which do the job quickest, should be used instead for a quick resolution to the problem.

As suggested by most, there was a need for increased awareness and education, promoting the desire to nurture, and a compromise between farming and nature conservation. One respondent identified that people living within the cities required greater awareness of the problems faced within the catchment.

It was recognised that attention needed to be directed towards the Upper Catchment before efforts could be successful lower in the catchment. In response to the salt problem in the Upper Middle Catchment, a respondent indicated that efforts needed to be directed towards the drainage of salt affected areas in attempt to lower salt levels in soil.

All participants conferred that government funding and incentives (e.g. taxes), "with less red tape" were required to encourage farmers to sustainably manage their land. It was identified that better access to resources (including the scientists) was required along with an improvement in cooperation between the BCCG, the experts (scientist) and the State and Federal Governments (the muscles).

An interviewee argued strongly for the involvement of local authorities in the management of the river environment within their boundaries, and identified that an improvement should be made on the current grouping of responsibility for government departments such as CALM (whales) and the Fisheries (marron), based on the appropriateness of their responsibilities.

3.1.3.5 Endpoints to Restoration

The most desirable endpoint according to an interviewee was a return to the original state of the river, but considering this was seen as impossible, the protection of remaining remnant vegetation, an arrested salt problem, and a halt to water quality degradation and eutrophication, were instead identified as an acceptable and realistic endpoint to restoration.

According to another respondent, a reasonable combination of farming and nature conservation involving corridors of vegetation linking up with the riparian zone, represented an acceptable endpoint along with a greater diversity in native vegetation within the landscape.

An endpoint to restoration was also associated with the return of species which had gradually disappeared from the catchment.

One participant indicated that an endpoint to restoration would involve limited loss of soil from farm land, allowing clean water to leave the farm and enter the river, while another respondent quantified his vision of an endpoint as the return of at least 30% of cleared property back into trees.

3.1.3.6 Opinions on the use of Marron as a Flagship Species for River Restoration

Using marron as a flagship was viewed by one respondent as something which could "tug on the sentimental heart strings of the average Aussie bloke", thus indicating that people could relate to marron no matter what role an they had in the community.

According to another interviewee, marron used in this way would get people to think about what was happening to the river, functioning to increasing public awareness. By promoting marron as a flagship, public awareness would increase when marron are observed crawling out of the river after a summer storm. Interestingly, it was point out that the flagship concept needed to be complemented with a water quality measurement, for the community to make a connection between marron and the condition of the river.

It was recognised, that with such a high profile, marron have the potential to compete for media attention within the busy community. The cultural value of marron was also confirmed, with an interviewee indicating that marroning was a social event involving family and neighbours.

The main concern raised in regards to the flagship concept, was the increasing popularity of marron fishing in dams and the influence this may have on promoting marron as a flagship for river restoration. It was indicated that people were not marroning or using the river as much any more, and that it would be difficult to get people not living near the river, or within the catchment, to support the concept considering they were generally unaware of the river's predicament.

3.1.4 Conclusion

The oral history was initiated to gain some insight into the environmental change within the catchment. The results indicated that widespread clearing associated with agriculture landuse was recognised as the major change. This was linked to the progressive loss of remnant vegetation, along with salinisation, erosion and organic pollution, all identified as the major threats faced by the Blackwood Catchment. Anecdotal information on marron occurrence within the Blackwood, advised that the disappearance of marron was associated with the process of salinisation and the input of nutrients into the river following summer storm events, forcing marron at times to literally walk out of the river. Such phenomenal observations in recent years (1994) suggests that the upper limit of the marron distribution within the Blackwood is around the Boyup Brook area.

In terms of sampling general attitudes and opinions towards restoration, the interviewees generally indicated that current restoration efforts lack direction, understanding and finance, but are a good start nevertheless. The suggested improvements included an increase in public awareness and understanding of the problems, increased government funding and direct involvement of local government in managing the local environment.

The restoration endpoints identified generally shied away from restoration to the original river environment, but instead implied an integration of farming and conservation.

A positive response was conveyed by all interviewees for the flagship concept and the appropriate use of marron. It was generally agreed that marron are a high profile species within the community, thus having the ability to increase public awareness of the river environment and its threats. However valid concern was raised in regards to the potential conflict between the concept of using marron as a flagship for river restoration, and the increasing popularity of dam fishing for marron. This suggests that the connection between marron and the river may be difficult for members of the community to relate to, posing a problem for the issue of river restoration.

3.1.4.1 Framework of the Community Questionnaire

The oral history provided crucial information for the construction of various response categories for questions used within the questionnaire (Section 3.2). These include the major environmental problems associated with the catchment and a number of processes identified as potentially threatening towards marron (e.g. salinity, fertilisers, erosion). The Oral History was utilised as a pilot study for the questionnaire.

A list of species familiar to the community were derived from the interviews, providing a number of responses categories and enabling the questionnaire to test for other potential flagship species, as well as marron.

The oral history indicated that degradation of the catchment's land and waterways was clearly evident to those interviewed from the general community, suggesting that the issues of degradation and restoration would more than likely be understood by the broader community, when tested within the questionnaire.

The oral history established a community definition of restoration by recording individual visions of a restoration endpoint, and by adapting the major concerns and perceived threats to the river environment. These endpoints to restoration were tested within the questionnaire and included for example, the eradication of feral animals, the return of native animals which have disappeared, and fencing of all remaining remnant vegetation.

The oral history clarified that the term "marroning" is in fact a common word used within the community to refer to marron fishing. Therefore it was used within the questionnaire to ensure smooth communication between respondent and interviewer. In reference to the list of species complied for the questionnaire, it was noticed that the long neck tortoise was commonly referred to as a "turtle" and referred to as such within the questionnaire.

The concern identified within the interviews, relating to the conflict between dam and river marron fishing was tested within the questionnaire, along with the level of concern and community awareness of marron disappearance and river degradation.

Overall the results suggest that community understanding of restoration has been significantly affected by the short time in which degradation has manifest itself within the catchment. A lack of understanding can be attributed to the fact that the generation involved with clearing is the same generation now being asked to plant trees. The concern shown and positive response directed towards marron within these interviews suggests that the flagship concept may in fact have the potential to instil this understanding of restoration through awareness.

3.2 The Questionnaire

3.2.1 Introduction

The impetus for the questionnaire was to establish whether a relationship already exists between the restoration process and high profile species. The aims were:

1. To determine the community's value and awareness of, and preferred future for the river environment, within the Middle Blackwood Catchment.
2. To identify the community's perception of river restoration, its endpoint, and level of support for a restoration programme.
3. To identify potential flagship species for the restoration of the Blackwood River.
4. To test marron against the flagship selection criteria 11 to 15, associated with community values and attitudes towards marron, viz:
    - evoke public sympathy,
    - identifiable to the public,
    - evoke community pride,
    - aesthetically appealing,
    - popular.

These criteria are crucial for community understanding and commitment to restoration. Alone, the essential role marron plays in the aquatic ecosystem (selection criterion 1 to 9), is not going to initiate widespread community support for restoration. Marron must have some impact on the community, some human centred value. The questionnaire aims to determine whether marron have more than economic and cultural value, to identify if a closer more personal connection exists between the Blackwood Community and marron.

The questionnaire is descriptive research which attempts to gain a detailed understanding of the attitudes, beliefs and reported behaviours of a cross-section of the community (Middle Blackwood Catchment).

3.2.2 The Study Area

The questionnaire was conducted within the Middle Catchment Zone, approximately one-third of the entire Catchment, an area encompassing the shires of Bridgetown-Greenbushes, Boyup Brook (Lower Middle Catchment) and Kojonup (Upper Middle Catchment). As indicated in Figure 3.1, these shires connect across the length of the Middle Catchment, providing a belt along the length of the river, which may capture longitudinal variation in attitudes and opinions within the broader Middle Catchment Community.

Over the last 40 years this area has gradually incurred similar environmental problems once characteristic of only the Upper Catchment, and new environmental predicaments perculiar to the region. Therefore the study area supports a community confronted with recent environmental change. This change has severely degraded the water quality in the Upper Catchment and now threatens the anthropocentric values associated with the river in the Middle Catchment (Negus, 1995).

Attitudes in the study area have previously been investigated by government departments and community groups such as CSIRO, Agriculture WA and the BCCG, thus providing comparative descriptive background data for the current survey's findings.

3.2.3 Previous Study: Butterworth and Carr (1996)

Members of the Blackwood River community have been exposed to issues of river condition, value, current and future use and management in a number of earlier independent surveys. As indicated by the coordinator for BCCG (S. Masterson, personal communication, March 1996) research within the catchment must avoid over-questioning the community on the same issues. Current data should be added to and integrated into new research to stimulate progressive research into catchment management.

In attempt to provide progressive research information for the BCCG and build on existing data, and as a means of reducing the scope of the questionnaire, the results obtained from a survey conducted by Butterworth and Carr (1996) were used as base line information for this research. Their survey entitled: "Riparian Zone Management in the Middle Catchment: A Baseline Study of Landholders' Views" provides up to date information relevant to the study area and aims of this questionnaire.

The title conveys the major objective of the study which aimed to assess attitudes, beliefs, reported behaviours and the level of information/ knowledge relating to riparian zone management, Landcare, Integrated Catchment Management (ICM) and the BCCG within the Middle Catchment. The landholder's general view of past and present conditions and the preferred future of the river environment were also explored. Considering that landholders make up a majority, approximately 5000 out of 8900 adults living within the questionnaire's sample area (Shire Office of Bridgetown-Greenbushes, Boyup Brook and Kojonup, personal communication, August 1996), it seemed justifiable to utilise the Butterworth and Carr (1996) data to cover the first aim of the questionnaire, and to provide background information for the questionnaire's second aim.

The Butterworth and Carr (1996) study not only provided information contributing to the questionnaire's aims, but also provided relevant terms, wording and response categories which were familiar to the thesis sample population and useable within the questionnaire. This was supported by the fact that a workshop was conducted prior to the construction of the Butterworth and Carr questionnaire enabling community input into the questions and issues which needed to be addressed, functioning similar to the Oral History within this study (section 3.1).

3.2.4 Questionnaire Construction

The Questionnaire was designed in reference to the aims outlined above. All questions were constructed based on the descriptive information required to fulfil these aims and the minimum level of analysis necessary to provide this data, so as to avoid obscuring the question's initial purpose. As outlined by de Vaus (1995), the wording and response categories designed for each question influence the level of information and power of analysis used to obtain the data.

Thus careful attention was given to question wording and category construction, not only to establish an outline of the analysis procedure prior to the sampling , but also and more importantly to ensure reliability and validity of the questions, and to enhance respondent understanding and interpretation. A reliable question (questionnaire) implies that the same response is give on repeated occasions, whereas validity refers to the question's ability to measure what was intended (Deschamp and Tognolini, 1983). These both relate to the wording and the level of information given to the respondent.

The aims of the questionnaire required questions which tested *behaviour* (e.g. Do you fish for marron?), *beliefs* (e.g. are marron endemic to the south-west?), *attitudes* (e.g. How would you like to see the river in 50 yrs time), and *attributes* (demographic information and level of awareness for issues).

A closed question format was used throughout the questionnaire to sample the above information types. This involved a number of alternative answers provided for each question from which the respondent could select only one. This method was used because the questions were made quick and easy to answer, and easier to analyse at a later date. Open questions on the other hand involve the problem of researcher misinterpretation when analysing what people meant. It was considered that the oral history compensated in part for not allowing respondents to have their own say within the questionnaire.

However as indicated above the problem of false opinions, and that of giving "acceptable" answers had to be taken into account when using the closed question format. Therefore all questions involved a "don't know" response to ensure reliability of data. The questions were worded using simple and familiar language identified within the oral history (section 3.1) for example the terms "marroning" and "turtle". Care was taken that no double-barrelled, leading questions and biasing questions were asked. This was especially so when it came to testing marron as a flagship species.

Visual aids were incorporated into the questionnaire, considering sampling was not self administered by the respondent (filling out the questionnaire), but interview based (verbal). Therefore the visual aids were designed to clarify to the respondents what was required of them, and to enhance the rate and reliability of response. Figure 3.2 is an example of one of the seven visual aids used.

Figure 3.2: Likert-style rating scale used to provide a number of alternative responses and to rate the individuals' response

Scale One

1	2	3	4	5	6
not at all or none	not very	moderately	quite	very	don't know

As indicated by Figure 3.2, scales were used as one of the main forced choice responses within the questionnaire. This scale represents a Likert-style rating scale, functioning both to provide a number of alternative responses and to rating the individual's choice (de Vaus, 1995). The same scale was used within the Butterworth and Carr (1996) study without any problems
(J. Butterworth, personal communication, April 1996). This type of scale was used throughout the questionnaire making it familiar to the respondent as questioning progressed.

Similar to that outlined in de Vaus (1995) "semantic differential" type questions were used within the questionnaire which provided two extremes of a continuum asking for responses within the extremes. Question 36 is an example of this (refer to the questionnaire is located at the end of this section, Figure 3.3, pg 128).

Lists were also used within the questionnaire from which the respondent was asked to choose. This technique provides the greatest variety of responses within a closed question format. Question 19 is a good example of this.

Response measures were either *nominal* such as that associated with gender (male / female) and resident type (farm / town), *ordinal* where the response categories could be ranked but the difference between them could not be quantified numerically, such as seen within the main scale used (figure 3.2), or *interval* where it is possible to quantify the precise differences between categories, an example being age, and question 16 which asks the respondent how long it would take to achieve successful restoration. The response measure functioned to define the analytical technique to be used, but this will be discussed further in Section 3.2.8.

The questions involved both impersonal questions asking the respondent to speak on behalf of the community, and personal questions which sort to identify how they felt. Questions were used to test the respondent's knowledge on issues such as marron occurrence and river management issues, therefore it was deemed important to make the respondent feel comfortable regardless of the response they gave, this was especially so for question 27.

Figure 3.3: The Sample Questionnaire

A Questionnaire on the Blackwood River and its Community

1) Do you live within the Blackwood River Catchment?

yes no don't know (show map)

--- Thankyou for your time, unfortunately this questionnaire is applicable only to those living within the catchment!

2) How long have you lived in the catchment? ________________

3) Which shire do you live in? (**show map if necessary**)

____

4) Do you live in a town or on a farm? town / farm / elsewhere

5) Does your property or house occur within 1km from a river or stream of the Blackwood River system?

yes no don't know

6) Do you use any of the rivers and streams within the Blackwood River catchment?

yes no don't know other (lakes etc)

Answering the following from the scale given to you.

1	2	3	4	5	6
none	not very	moderately	quite	very	don't know

7) How would you describe your <u>awareness</u> of river management issues?	1	2	3	4	5	6
8) How <u>interested</u> in river management issues are you?	1	2	3	4	5	6
9) How <u>important</u> is the river environment to you?	1	2	3	4	5	6
10) How <u>important</u> to you is native vegetation on the river and stream banks?	1	2	3	4	5	6

11) 25 years ago do you think the water quality in the river was better / worse/ same as it is now?

1-better 2-worse 3-same 4-don't know

12) **Looking at the list provided** (Back of scale sheet!) ..... which one of the following factors do you consider most threatening to the health of the Blackwood River?

1- algae blooms.
2- sheep and cattle access to the river.
3- salinity.
4- paddock runoff.
5- loss of river and stream bank vegetation.

13) Do you think the river needs restoring to some kind of acceptable level?

yes no don't know

14) There are a number of possibilities for river use in the future. Indicate using yes / no, or don't know, which of the following you would like to see in the future?

	YES	NO	don't know
a) more canoeing and swimming.			
b) more farming use.			
c) more tourism.			
d) more domestic / household use.			
e) more fishing and marroning.			
f) more restrictions on river use.			
g) used the same as it is now.			

15) Using the scale, how necessary do you think the following statements are, for river restoration to be declared successfully completed?

* For **restoration** to be **declared completed** is it **necessary** that......

1	2	3	4	5	6
not at all	not very	moderately	quite	very	don't know

a) all rubbish and litter is removed from the river bank.	1	2	3	4	5	6
b) the river water is drinkable.	1	2	3	4	5	6
*c) crops can be irrigated using river water.	1	2	3	4	5	6
d) river animals once common, but disappeared, have returned naturally.	1	2	3	4	5	6
e) the community is educated and aware about the river environment.	1	2	3	4	5	6
*f) feral animals are eradicated.	1	2	3	4	5	6
g) stock can drink the river water.	1	2	3	4	5	6
h) the entire length of river and stream bank is revegetated.	1	2	3	4	5	6
*i) children can safely swim in the river during summer.	1	2	3	4	5	6
j) the river water is suitable for household domestic use.	1	2	3	4	5	6
k) the entire length of river and stream is fenced.	1	2	3	4	5	6
*l) the river is exactly as it was before major clearing.	1	2	3	4	5	6
m) algae blooms are a rare event.	1	2	3	4	5	6

16) How many years do you think it will take to achieve successful restoration?

Numbers of years_____________ or Never or Don't Know

17) Name up to 3 animals which to your knowledge have disappeared from parts of the Blackwood river?

1___________ 2____________ 3__________ or don't know

18) **Using the scale,** to what degree does this concern you.

1	2	3	4	5	6
not at all	not very	moderately	quite	very	don't know

19) If we are looking for a symbol for the Blackwood River which **three** would you consider most appropriate from this list, or you may choose your own?

- water rat	- river gum	- paper bark	- turtle
- water lily	- cobbler	- cormorant	- leech
- freshwater mussel	- marron	- gilgie	- duck
- minnow	- perch	- frog	- koonac

OR

don't know   none   other: 1________________

2________________

3________________

20) Out of your 3 choices which do you consider most appealing?

________________ / none / all / don't know

21) Out of your 3 choices which do you feel most proud to know they live in your community? ____________________/ none / all / don't know

22) Do you Agree / Disagree or Don't Know about the following statements?

a) Marron occur in the Blackwood River.

agree **or** (disagree **or** don't know)----Go to Qu **27**

b) Marron used to occur in the rivers and streams of the upper Blackwood. (such as the Balgarup, Arthur, and the Carlecatup)?

agree **or** disagree **or** don't know

c) Marron only occur naturally in south-west rivers of W.A.

agree **or** disagree **or** don't know

23) Which of the following do you agree with: Over the last 40 years the number of marron in the Blackwood River has:

1	2	3	4	5	6
increased dramaticall	increased slightly	remained the same	declined slightly	declined dramatically	don't know

24) Indicate which one of the following you think would be the major threat to marron.

a) increase in salinity.

b) fertiliser input into river.

c) over fishing.

d) summer storms

e) other: ____________ or don't know

Using the scale answer the following questions.

1	2	3	4	5	6
not at all	not very	moderately	quite	very	don't know

25)How important to you is it to have marron in the Blackwood River?	1	2	3	4	5	6
26)To protect marron in the Blackwood how well would you support.. a) Reduction in fertiliser use on farms.	1	2	3	4	5	6
b) Closure of the marron season for 2 years.	1	2	3	4	5	6
c) Fencing to remove stock from river banks.	1	2	3	4	5	6
e) Promotion of marron as an emblem of south-west rivers.	1	2	3	4	5	6
d) Revegetating streams and river banks.	1	2	3	4	5	6

27) Without guessing, which of the following 4 pictures would you associate with a marron?

1	2	3	4	5
picture 2	a picture other than 2	all of the pictures	don't know	none

28) **Using the scale**, please answer the following:

1	2	3	4	5	6
not at all	not very	moderately	quite	very	don't know

a) How well do you think the communities general knowledge is about marron?

1 2 3 4 5 6

b) How popular has marron fishing been in the community...

(i) during the last 5 years? 1 2 3 4 5 6

(ii) 25 years ago? 1 2 3 4 5 6

29) In the last 25 years have you or your family fished for marron?

YES (no OR don't know)__ **Go to Qu 36**

30) Using the following, how often:

1 - every season.

2 - occasionally.

3 - more so now than in the past.

4 - not any more, but used to in the past

31) Have you marroned in the Blackwood River ?

YES (no OR don't know) ____**Go to Qu 33**

32) Using the following, indicate where you normally fish:

1 - upstream of Boyup Brook

2 - between Boyup Brook & Bridgetown

3 - between Bridgetown & Nannup

4 - down stream of Nannup

33) Have you marroned in other rivers?

yes no don't know

34) Do you fish for marron in dams?

YES (no OR don't know) ________ **Go to Qu 36**

35) Compared to rivers, how often do you marron in dams?

1 - more in dams.

2 - about the same.

3 - less in dams.

4 - don't know

36) Where would you place marron in the following scales?

a)	ugly	1	2	3	4	5 beautiful
b)	boring	1	2	3	4	5 interesting

c) If the Koala has high public appeal and the Spider has low public appeal, where would you place marron within this scale?

Spider	1	2	3	4	5 Koala

VERY IMPORTANT :

- Sex: F / M

- ~ Age: 20 to 30yrs / 30 to 40yrs / 40 to 60yrs / > 60yrs

3.2.5 Pilot test

Prior to administering the questionnaire a pilot test was conducted on randomly selected people present on campus. Limitation of time and funding did not allow pilot testing within the intended sample area (Middle Blackwood Catchment). It was considered that the oral history had provided a specialist review of the questionnaire (representatives of the subjects to eventually be questioned).

The pilot study was conducted with the intention of testing respondent interpretation, the meaning implied by the questions, the adequacy of alternative response categories, timing, and the display of visual aids. The pilot test respondent was asked to provide feed back, so that problem areas could be amended before final administration.

3.2.6 Question Rationale and Design

The questionnaire was divided into two parts. Part A was focused on satisfying aims 1 and 2 of the questionnaire relating to the river and its restoration, and establishing the demographic information on the sample population. Part B focused on aims 3 and 4, associated with substantiating potential flagship species and testing marron against the flagship selection criteria.

The following briefly outlines the rationale behind each question. It is recommended that the sample questionnaire provided prior to this section (Figure 3.3) be reviewed during the following.

3.2.6.1 Part A: Community perception of the river environment and restoration

Questions 1 to 6 were used to obtain basic demographic information on the respondents and to filter out non-members of the community. This information was used to create sub-groups (variables) within the sample to facilitate comparative analysis of results (eg, resident time, shire, and resident type). The age and sex of the respondent was ascertained by the interviewer after questioning. Particular care had to be taken with the definitions associated with questions 5 and 6. For example, living "near" the river in question 5 was defined within the question as living within 1km of the river, while the definition of "river use" in question 6, was described by the interviewer as any use of the river environment (active or passive).

To legitimately use the results and conclusions drawn by Butterworth and Carr (1996) as base line information on the attitudes and opinions of the landholder within the Middle Blackwood Catchment community, a link was established between both studies. Questions 7 to 11 were all taken directly (with permission) from the Butterworth and Carr study to allow t-test analysis to determine whether both studies were representative of the same population (the Middle Blackwood Catchment Community), thus legitimising the integration of results.

However, if this was not the case the questions were still applicable to the aims of the current research, with questions 7 to 11 exploring community awareness and interest in river management issues; the importance placed on the river environment and riparian vegetation; and the sample's general opinion on changes in the river water quality over the last 25 years.

Question 12 involved a list of threats to the river environment. These were commonly identified within the Oral History and the Butterworth and Carr (1996) study. The question was designed to identify the area/ issue most threatening to the respondent, thus providing some insight on where the participant was most likely to direct their support for restoration efforts.

Compared to earlier questions, 13 to 16 focused directly on the second aim of the questionnaire which relates to community perception of restoration. Question 13 was based on the understanding that before the respondents could define river restoration they must first agree that the river needed restoring. Question 14 was based on the assumption that how an individual desired to use the river governed his / her definition of restoration, which relates to the public perceived restoration to "usefulness" as identified by Cairns *et al* (1977) in section 1.3.1. The future river use activities selected as response categories for this question were derived from the Butterworth and Carr (1996) survey and the Oral History.

The future activity denoting "more fishing and marroning" was taken directly from Butterworth and Carr (1996), providing valuable information complimenting the third aim of the questionnaire. The possibility of biasing following questions, was raised during the questionnaire construction. However it was concluded that the phase simply expressed a popular past-time within the community, the basis for its initial use by Butterworth and Carr, thus not affecting later questions specific to "marroning" in the questionnaire.

Question 15 attempted to determine whether members of the community identify a restoration endpoint for the Blackwood River. The thirteen statements making up the question were derived from the Oral Histories and the Butterworth and Carr (1996) survey. Each statement was assigned a place within the scale by the respondent, measuring its importance in enabling restoration to be declared successfully completed.

The question was designed based on the knowledge that by identifying the general perception of a restoration endpoint from a cross-section of the community, whether it be returning the river to a condition found prior to major clearing, or to one which allows children to swim safely in the river during summer, specific objectives can be set to enhance and provide a direction for the restoration process (see section 1.3).

Question 16 quantifies restoration by asking the individual to state how long it would take to be successfully achieved. The question functions to further verify whether the respondent has some image of a restoration endpoint, and whether this is achievable.

3.2.6.2 Part B: Flagship Species and Marron

Part B question design was based on the understanding that a flagship species, similar to restoration, is a community-based concept, therefore each criterion as identified in Section 1.5 must be systematically evaluated through community responses.

Questions 17 to 21 were designed firstly to coax the sample population into identifying potential flagship species appropriate for the Blackwood River Catchment, and secondly to test how marron faired in comparison. The fact that marron was primarily under investigation within Part B of the questionnaire was not revealed to the respondent until Question 22, when questions began to specialise. It was rationalised that if marron were well represented (over 20%) within the results then it could be assumed that a reasonable association exists between marron, the Blackwood River and the participant of the questionnaire (a cross-section of the community).

A flagship species must be able to evoke public sympathy, therefore questions 17 and 18 aimed to find out whether the community were aware of the gradual disappearance of marron and how the loss of species concerned them. Question 17 also functioned to measure the respondents general knowledge and interest in the Blackwood River considering they were asked to identify 3 species of their own which had disappeared. A generally poor response to the question would suggest that there was a lack of awareness or interest in the river's past ecology.

Question 19 required the respondent to select 3 appropriate symbols for the Blackwood River, from a list of plant and animal species constructed from Oral History data and the literature review on the Blackwood Catchment (Section 1.2). Question 20 and 21 were based on the three symbols chosen, where the respondent was asked to select the one which they considered most appealing and one which evoked most pride.

Question 19 was used to test whether marron was *identifiable* to the general community, while questions 20 and 21 tested the marron's *public appeal* and ability to *evoke pride*, respectively.

From question 22 onwards, marron became the focus of the questionnaire. Question 22 tested what was identified within the Oral History as common knowledge about marron within the Blackwood community. The question was designed to identify respondents without the basic knowledge and to test the community's awareness of the flagship criterion associated with *endemism*. Similarly questions 23 and 24 both attempted to determine the level of community awareness of the threat to marron within the Blackwood, and whether this awareness related to the respondent's location in respect to the Upper Catchment. The response categories for question 24 were derived from the Oral Histories.

Question 25 functioned to determine the respondent's willingness to support efforts to protect marron in the Blackwood River. Without introducing bias to the respondent's answer, the question was broken down into different measures of marron protection.

The degree of support indicated was to reflect the respondent's concern (*sympathy*) and the importance (*pride*) placed on marron as being part of the Blackwood River environment.

Question 26 tested the identifiability of marron within the Blackwood River community. The question was worded carefully to avoid offending the respondent and to avoid the potential for guessing. Extensive knowledge of marron physiology was not necessary to identify the marron. Basic knowledge of specific features such as dark colouration and pincer like claws could be used to distinguish the marron from the three other freshwater crayfish displayed on the visual sheet provided. It must be noted that such features are not good identifiers for taxonomic surety, but ones familiar to the general public.

Question 27 explored the popularity of marron through impersonal questions directed firstly, towards the community's general knowledge of marron and secondly, the prevalence (popularity) of marron fishing over time (past and present). The latter question was used to confirm the declining popularity of marron fishing within the Blackwood River as identified by Morrissy (1978*b*) (see section 2.2)

Question 28 to 32 focused specifically on the marron fishing habits of the study's sample population. They were designed to provide basic statistics on the number of marroners within the sample, where they fished in the Blackwood and whether they fished in other rivers and dams. Question 32 was established to verify the warnings given within the Oral Histories as to the issue of river versus dam marron fishing and its potential to conflict with the flagship concept. It was envisaged that statistical analysis would provide background information on the type of people in the local community who fish for marron.

A flagship species must have aesthetic appeal. The fact that books have been written on the subject of aesthetics does not make it any easier to define for the respondent. Research revealed the term's abstract and subjective nature, often defined as pleasing to the eye, beautiful, interesting, and delightful. Consequently three "semantic differential scales" (as defined earlier) were designed to determine where the sample population would place marron in relation to the adjectives beautiful and interesting, and in reference to the high public appeal of the Koala.

3.2.7 Sampling Procedure

The aim of the research was to explore the attitudes and opinions of the Middle Catchment Community, therefore requiring the sample population for the questionnaire to be representative of the community. As outlined by de Vaus (1995) the only way of ensuring a high degree of representation is to sample randomly, providing equal probability of selection.

The 71 people sampled within the questionnaire were members of the community living within the Middle Blackwood Catchment. Each subject either lived in town or on a property (including special rural block) within the shire of Bridgetown-Greenbushes, Boyup Brook or Kojonup.

In accordance with the ethical considerations required for the research, no minors, mentally ill or dependent individuals were questioned. The subjects were active, coherent, intelligible adults (over the age of about 20).

To obtain the best representation of the community in light of the large sample area (125 km in length), and constraints of time and labour, a once off sample was conducted within each town. This occurred during a time and day, in which a cross-section of the community including landholders and townsfolk, had an equal likelihood of being present. Information gained from the unstructured interviews and consultation with town residents prior to sampling, indicated that either the Friday afternoon banking or Saturday morning shopping period from 8:30am to 12 noon were the best times to sample the community. The latter suggestion was incorporated into the sampling procedure as it provided a longer time frame to increase the sample number, with which representation improves.

A total of nine interviewers (volunteers) were involved, five of whom lived and worked within the sample area, thus they were experienced in dealing with the community. Two had conducted surveys in the catchment in the past. An intensive briefing period the day prior to sampling, was conducted by myself, developing the volunteer interviewers' personal skills to conduct an objective interview and ensuring all were comfortable with the questions, scales and visual aids. All interviewers were informed that the fabrication of results was unacceptable. The closed question format eliminated as much as possible, interviewer interpretation and opinion within the results. Interviewers were reminded that sampling was to be random rather than selective.

Through consultation with locals, three areas common to each town were designated for interviewers to sample. These sites were selected on the basis of popularity and representation of the community, and included:

- the main street in each town;
- the major shopping center (Charlie Carters and Foodlands);
- outside the local co-op for agricultural supplies.

An interviewer was assigned to each site and remained there during the sampling period between 8:30 am and 12 noon. No further sampling was conducted after this time. This was followed by a debriefing period so the interviewers could convey uncertainties occurring during the sampling process, which were taken into account during analysis. An active face-to-face approach was used to solicit subjects, where every adult (fitting the subject criteria) passing the interviewer was approached whilst a subject was not being questioned. The face to face interview technique is commonly considered the best method in terms of obtaining a good response rate, representation of the general public, control over who completes the questionnaire and administering a long questionnaire (de Vaus, 1995). However it is less effective at obtaining accurate answers, prone to socially desirable responses and is often associated with administration difficulties related to poor interviewer training (de Vaus, 1995).

The introduction used by each interviewer was selected on the basis that it had proven successful in past surveys within the study area. The respondent was asked to spare 10 to 15 minutes of their time to participate in a questionnaire to gain information on the Blackwood River environment to help better manage the catchment. Respondents were free to refuse participation and remained anonymous throught the interview process. Interviewers were made aware of biasing the response by discussing the questions prior to questioning, therefore all informal discussion with the participant was kept to the end of the interview.

3.2.8 Analysis of Data

As indicated by Jolliffe (1986), how the responses are analysed depends on the information wanted from the question. In light of this both univariate and bivariate techniques were used, describing single characteristic (variables) of the sample (e.g. age or awareness), or two variables simultaneously. The significance of these descriptions was tested through a number of inferential statistics, all of which were conducted on the statistical package SPSS-for-Windows, Version 6.0.

Univariate descriptive frequency distribution analyses were conducted on all questions, providing information on the number of people who provided an answer and the percentage of people who gave that particular response. This generally included the non response, "don't know" answer. A mean value was obtained for response categories in interval measures (e.g. age, resident time, and the scale response e.g. awareness).

Bivariate analyses followed on from the descriptive data, identifying associations between variables. As outlined by de Vaus (1995) an association between variables exists when sub-groups differ in opinion on another variable. For example male and female are subgroups of the variable gender (sex) and require separation when they differ in opinion on the importance of marron.

The main bivariate analysis used within the study was crosstabulation which was used to detect an association between variables, allowing an explanation to be theorised / hypothesised only (Jolliffe, 1986). The variables selected for crosstab analysis were chosen on the basis of experience and prediction of expected association. Generally the variables used within such analyses included: age, gender, resident type, river use, resident time, shire, living near the river, interest in river management issues and importance placed on the river environment. Only those indicating a strong but non-significant trend were outlined within the results, followed by some inferences about the relationship. The significance of the crosstab relationship was established through chi-square analyses.

Chi-square analyses requires that no more than one-fifth of the expected values remain below a threshold value of 5 (Fowler and Cohen, 1990). Chi-square analyses involving the scale response (utilised as either nominal or interval) often indicated a significant relationship with another variable, but violated the above requirement. According to Fowler and Cohen (1990), this outcome is indicative of either a high number of subgroups (response categories), a small sample size, or a combination of both, and may be overcome by aggregating respective response categories. For example the original 5 categories making up the scale used through-out the questionnaire was often folded into three:

1. not at all - not very
2. moderate - quite
3. very

Irrespective of the above changes an unacceptable number of expected values often still remained below five. These results were identified as non-significant and only supporting inferences were made on the crosstabulation data. When less than one-fifth of the expected values were below the value 5 then a significant difference in the variables was accepted.

When bivariate analysis was conducted on two interval variables typically associated with a scale such as interest and awareness in river management issues, Spearman's rank correlation analysis was used to identify an association. Only significant relationships ($p<0.05$) were recorded within the results.

As indicated above t-test analyses was conducted on questions 7 to 10, to determine whether the current study and that of Butterworth and Carr (1996), sampled the same population. As defined by Fowler and Cohen (1990) a t-test was used to test differences between the means of independent samples. Likert scales such as that used within questions 7 to 10 are traditionally treated as equal interval scales, therefore meeting the requirements of a parametric t-test where the dependent variable must be on a interval scale, while the independent variables must be nominal (e.g. study 1 and study 2) (Blackmore, 1994).

Another requirement for t-test analysis is the normal distribution of data, therefore frequency distributions were graphed for both study's results to visualise the distribution. Only question 7 conformed, however the distributions of responses to questions 8 to 10 were skewed in the same direction for both studies.

The purpose of testing for normality prior to a t-test, is to ensure that the distribution of both samples does not effect the mean test (Fowler and Cohen, 1990). The skew of two data sets in the same direction represent a comparison of mean similar to that of two normal data sets, therefore not impacting on the t-test results, and avoiding the need for data transformation (pers comm Elaine Pasco, 1996).

If both studies sampled the same population, then it is expected that the mean opinion expressed by each study should be very similar. If $p<0.05$ then a significant difference has been identified and it must be concluded that both studies sampled different populations for the particular question concerned. A t-test could not be used to compare the response give by both studies in question 11 since both variables were nominal, therefore a chi-square analyses was used (Blackmore, 1994).

3.2.9 Results

The following results section distinguishes between both Parts (A and B) within the questionnaire with a summary of the results at the end of each. The results for each question will have the following format:

- frequency distribution information
- crosstab association and trends identified
- chi-square significance of association
- other inferential statistics if used (t-test and Spearman Rank Correlation).

3.2.9.1 Part A: Results

Basic demographic information.

Table 3.4: Frequency distribution of age and gender of the questionnaire sample (N=71).

Gender	N	Percent	Age	N	Percent
Female	26	37	20 - 30	13	18
Male	45	63	30 -40	26	37
			40 - 60	20	28
			> 60	12	17
			mean = 30-40yrs		
TOTAL	71	100%	TOTAL	71	100%

Males represented 63% of the sample population. This was a surprising outcome considering sampling was conducted during a Saturday morning shopping period where more females were initially expected. Each age category was represented by more than 10 individuals, with the strongest representation (37%) falling into 30 to 40 year category.

Q2) How long have you lived in the catchment?

Table 3.5 Distribution of resident time in the catchment within the sample (N=71).

Years	N	Percent
< 5	19	27
6-10	10	14
11-30	25	34
31-70	17	24
mean =	17.5yrs	
TOTAL	71	100%

The number of years lived within the catchment ranged from less than one to seventy years, with an average of 17.5 years. The relatively high number (34%) of respondents living within the catchment for 11 to 30 year is probably related to the average age of the sample population (30 to 40 years), represented by individuals who have grown up in the catchment, and those who settled in the area in their early twenty's.

Q3) Which shire do you live in?

Table 3.6: The number of participants sampled within each shire (N=71).

Shire - resident of	N	Percent	Shire - sampled in	N
Bridgetown - Greenbushes	33	46	Bridgetown - Greenbushes	31
Boyup Brook	17	24	Boyup Brook	19
Kojonup	21	30	Kojonup	21
TOTAL	71	100%		71

Seventy-one people were sampled from within the study area, of which almost half (46%) lived within the shire of Bridgetown-Greenbushes.

Table 3.6 also shows that a number of respondents were not sampled within the shire they lived. This shows why it was important to sample the three shires as a cross-section of the community, since they are all linked not only geographically but as a functioning community with movement and communication across shires.

Q4) Do you live in a town or on a farm?

Table 3.7a : Distribution of each resident type within the sample (N=71).

Response	N	Percent
Town	47	66
Farm	24	34
TOTAL	71	100%

Two-thirds of participants stated that they lived in town. Sampling was conducted on a Saturday morning to reduce a bias sample of respondents only living in town. According to the project's Oral History, people living on farms often came to town to restock supplies for the following week during the Saturday morning shopping hours, the reasoning behind sampling at the local co-op in each town.

Most rural residents approached (identified through their response and the goods they were carrying) did not have the time to respond to the questionnaire. The response " I've been on the tractor all morning and don't fancy answering any questions" is indicative of the cropping season during which the sampling was conducted, and the lower response rate from farmers seen in the results. The number of refusals were not recorded.

Table 3.7b: Percent of respondents living in on a farm and in town within each shire.

	Bt-Gb	BB	Koj
	%	%	%
Town	73	47	71
Farm	27	53	29
TOTAL	100%	100%	100%

Results show that a majority from the shire of Bridgetown-Greenbushes (Bt-Gb) and Kojonup (Koj) lived in town, 73% and 71% respectively, while over half (53%) from the shire of Boyup Brook lived on a farm. The definition of "farm" also included special rural properties within this survey.

Q5) Does your property or house occur within 1km from a river or stream of the Blackwood River system?

Table 3.8: Frequency of people living near a tributary of the Blackwood River (N=71).

Response	N	Percent
Yes	56	79
No	14	20
Don't know	1	1
TOTAL	71	100%

Over three-quarters of participants stated that their house or property occurred within 1km of a tributary of the Blackwood River system. This can be related to the fact that each town sampled was bisected by a river or stream. Bridgetown and Boyup Brook were located on the banks of the Blackwood River, while Kojonup Brook flows through the town of Kojonup, feeding the Balgarup River.

Of the 56 people who lived near a river or stream within the Middle Catchment, seventeen lived on a farm and thirty-nine lived in town. This represents over half, 83% and 71% from each resident type, "town" and "farm" respectively.

Q6) Do you use any of the rivers and streams within the Blackwood River catchment?

Table 3.9a: Frequency of people using the tributaries within the Blackwood Catchment (N=71).

Response	N	Percent
Yes	44	62
No	27	38
TOTAL	71	100%

Nearly two-thirds of participants stated that they used the rivers and streams of the Blackwood River catchment. These results closely reflect Butterworth and Carr's findings, where 64 % of the sample population indicated they used the river.

There was little difference between resident type (town and farm) river use, with approximately 60% representation from both.

Table 3.9b: Comparing shires and their respective river use

Shire		Yes	No	Total
Bridgetown-Greenbushes	row%	82	18	100
	column%	61	22	
Boyup Brook	row%	47	53	100
	column%	18	33	
Kojonup	row%	43	57	100
	column%	21	44	
Total	%	100	100	

Analysis indicates that there was a very significant difference (**p< 0.01**) in river use between the three shires sampled (Table 3.9b). Of those who use the rivers and streams a majority (61%) lived in the shire of Bridgetown-Greenbushes while 18% and 21% came from Boyup Brook and Kojonup respectively.

Looking at the shires individually (row%) the results indicate that 82 % of respondents from Bridgetown-Greenbushes used the river, while over half of the participants from Boyup Brook (53%) and Kojonup(57%) did not use the rivers and streams within the Blackwood River Catchment.

The reason for such a significant difference in river use between the shire of Bridgetown-Greenbushes and the other shires sampled may reflect the fact that water quality within the Blackwood River has deteriorated to the extent that the Upper Middle Catchment is now becoming progressively worst, but still maintains some anthropocentric value, as suggested by Negus (1995). Thus the results in Table 8b suggest that the community's perception of water quality may relate to its scientific assessment, with river use declining as sampling progressed up the catchment.

The following results refer to Table 3.10 which presents the current study's data for question 7 to 10, and those from the Butterworth and Carr (1996) study. The results for both studies are shown and compared for each question within the table, for reasons explained within Section 3.2.6.1. Questions 7 to 10 all use the scale shown in Figure 3.2, providing response categories. The crosstab, chi-square and correlation results within the following only relate to the thesis data.

Q7) How would you describe your <u>awareness</u> of river management issues?
A seen in Table 3.10 the mean score for question 7 (awareness) indicates that there is on average, a moderate awareness (3.1) of river management issues within the thesis sample population. However this is slightly lower than that observed for Butterworth and Carr's (1995) sample population (3.5).

Based on crosstab analysis, a number of speculations can be made on what may influence an individual's awareness of river management issues. These inferences are outlined below and provided some insight on how to improve the level of awareness indicated by both studies.

- Respondents living near the river had a higher proportion (73%) placing their awareness within the "moderate" to "very" aware range, compared to those who lived further away from the Blackwood and its tributaries (50%).
- Respondents who considered themselves to be "moderately " to "very" aware (over 60%) of river management issues tended to be those who used the rivers and streams of the Blackwood.
- Almost half (48%) of the participants indicating a low levels of awareness ("not at all - not very") did not use the rivers.

Table 3.10: Frequency Data for Questions 7 to 10 comparing the Thesis and Butterworth and Carr (1996) results, showing the Mean and Standard Deviation.

		Question 7 Awareness %		**Question 8** Interest %		**Question 9** River Important %		**Question 10** Veg Important %	
Response	**Scale Rating**	**Thesis**	**B&C**	**Thesis**	**B&C**	**Thesis**	**B&C**	**Thesis**	**B&C**
not at all	1	8	2	3	0	0	0	1	0
not very	2	21	13	11	6	4	2	3	9
moderately	3	38	40	14	23	11	11	6	11
quite	4	16	24	27	34	16	34	8	23
very	5	16	21	45	38	69	53	82	57
don't know	-	1	0	0	0	0	0	0	0
TOTAL	-	100%	100%	100%	100%	100%	100%	100%	100%
	Mean	3.1	3.5	4.0	4.0	4.5	4.4	4.7	4.3
	Standard Dev.	1.16	1.03	1.13	0.92	0.86	0.76	0.70	1.00

- A trend was noticed in the general awareness of each shire as sampling moved up the catchment. The shire of Bridgetown-Greenbushes had a slightly higher awareness than those from Boyup Brook and Kojonup with an average ranging from "not very to moderately" aware.

Spearman rank correlations indicated that there was a significant relationship between an individual's level of awareness and the importance they placed on the river environment ($r = 0.26$, $df = 70$, $p = 0.032$), and a very significant relationship between a respondents awareness and their interest in river management issues ($r = 0.37$, $df = 70$, $p = 0.002$).

These results suggest that respondents indicating high awareness of river management issues, also have high interest in river management issues and a high opinion of the river environment, compared to those less aware.

The t-test results indicated that a significant difference ($t = 2.04$, $df = 121$, $p = 0.044$) existed between the mean identified for each independent study: thesis (3.1) and B&C (3.5), hence samples were drawn from different populations.

Reasons of the significant difference may be due to the fact that the Butterworth and Carr sample was landholder based, while the current study attempted to sample a cross-section of the community (landholders and townsfolk). The slightly higher level of awareness indicated by landholders may possibly be related, one would hope, to the necessity of integrating an awareness of river management issues with landuse practices on the properties sampled; all of which were either located along the river or no more than 5km away.

Q8) How <u>interested</u> in river management issues are you?

Referring to Table 3.10, the mean result for question 8 indicates that there is "quite" (mean = 4) a high level of interest in river management issues within the thesis sample population, exactly that found within Butterworth and Carr's sample population. Therefore samples were taken from the same population.

Based on crosstab and chi-square analyses of the thesis data only, the following trends were identified:

- Crosstab data indicated that a higher percentage (82%) of people living on farms had "quite" to "very" high levels of interest in river management issues, compared to people living in "town"(66%). This possibly reflects the fact that those farming the land have greater contact with catchment process, thus promoting an interest in river management issues.
- A significant difference ($x^2 = 15.09$, df = 8, p = 0.013) seems to suggest that interest in river management issues seems to be dependent an individual's locality in relation to the river. Participants who considered themselves "moderate" to "very" interested in river management issues tended to live near the rivers and streams, while those "not at all - not very" interested generally did not.

Q9) How <u>important</u> is the river environment to you?

As shown within Table 3.10, the mean score indicates most participants placed the importance of the river towards the top end of the scale within both studies. In fact no more than three people (~ 5 %) put the river below a "moderate" level of importance.

Crosstab analyses indicated that a higher proportion of people living on farms (96%) considered the river slightly more important than respondents living in town (79%).

- Living near a river or stream within the Blackwood Catchment indicated a greater sense of importance towards the river environment, with a significance of $x^2 = 13.9$, df = 6, p = 0.02. For example almost all (98%) who lived near the river considered the river environment to be "quite - very" important.
- Spearman rank correlation indicated that a highly significant relationship (r = 0.62, df = 70, p< 0.001) existed between the importance placed on the river environment and that of riparian vegetation. Respondents placing a low level of importance on the river environment did so for riparian vegetation as well. This is consequential for restoration of the river environment.

The t-test indicated that there was no significant difference between the means of the two studies, confirming the Ho: both samples were obtained from the sample population.

Q10) How important to you is native vegetation on the river and stream banks?
Within Table 3.10 the native vegetation was rated as "very" important by the majority of interviewees (82 %) for the thesis study, having a slightly higher mean than the Butterworth and Carr sample (4.3).

Chi-square analyses stated that those who use the river had a significantly ($x^2 = 6.8$, df = 3, p = 0.007) higher opinion on the importance of riparian vegetation than those not using the river. For example, 73% of the participants not using the river considered the riparian vegetation to be "not very to moderately" important to them.

The t-test indicated a very significant (t = 2.92, df = 121, p = 0.004) difference between the means of both studies, confirming the Ha: that the two studies sampled different populations.

Similar to that outlined for question 9 this may be attributable to differences in sample procedure used for both studies. Butterworth and Carr's sample population included only landholders, suggesting that the significant difference between the means, could in fact be reflecting the difference in opinion identified within this study so far, between those living on farms and in town.

Q11) 25 years ago do you think the water quality in the river was better / worse/ same as it is now?

Table 3.11: Frequency distribution of the thesis data (N=71) and that of Butterworth and Carr (1996) (N=53), for Q11.

Response	N	Percent	Response B&C(1996)	N	Percent
Better	53	75	Better	37	70
Worse	4	6	Worse	0	0
Same	4	6	Same	8	15
Don't know	10	14	Don't know	8	15
TOTAL	71	100%%	TOTAL	53	100

The bulk of those interviewed in both questionnaires, believed that the water quality in the river had deteriorated over the last 25 years. Unlike Butterworth and Carr's results, four participants in the thesis survey indicated that the water quality was worse 25 years ago. This suggests that the question may not have been interpreted correctly by the four respondents, considering the strong majority of the sample (75%) indicating otherwise.

Analysis highlighted the following trends associated with the thesis study:

- New residents of the catchment (less than 5 years) generally stated that they did not know what the water quality was like 25 years ago.
- Those living near or using the Blackwood River tended to have a greater proportion of responses indicating the water quality in the river was better 25 years ago.
- None of the respondents who had lived in the catchment for over 30 years perceived the water quality to be anything other than "better" (100%) 25 years ago.
- Opinions became more unified as sampling moved up the catchment. For example all participants from Kojonup indicated that the water quality was "better" 25 years ago. The shire of Bridgetown-Greenbushes had a broader range of responses with most stating the water quality was "better", but four and two people indicated it was the "same" and "worse" respectively.
- Chi-square analysis substantiated a non-significant difference ($p>0.05$) between the responses given in both the thesis and Butterworth and Carr (1996) study, suggesting the samples were probably from the same population.

Q12) Which <u>one</u> of the following factors do you consider most threatening to the health of the Blackwood River?

Table 3.12: Frequency distribution data for Question 12 showing the proportion of respondents indicating each threatening process (N=71).

Response	**N**	**Percent**
Algae blooms	7	10
Stock access	3	4
Salinity	36	51
Paddock runoff	15	21
Vegetation loss	10	14
TOTAL	71	100%

Half of the participants considered the increase in the salinity most threatening to the river's health. Paddock runoff was identified by 21% of respondents, while loss of vegetation was the main threat to river health according to 14% of those involved.

Crosstab analyses showed that almost half of the respondents living in the shire of Kojonup indicated that salinity was the main threatening process. This may well relate to their close contact with the effects of salinity compared to the other shires. Participants from the shire of Bridgetown-Greenbushes generally had a broader range of response to the question and a lower proportion indicating salinity as the main threat.

Females generally had a broader range of opinion with the strongest response (31%) being associated with both "salinity" and "runoff". Males tended to consider "salinity" (over 60%) as most threatening to the health of the Blackwood River.

Q13) Does the river need restoring to some kind of acceptable level?

Table 3.13: Showing the distribution of response to question 13 (N=71).

Response	N	Percent
Yes	67	94
No	0	0
Don't know	4	6
TOTAL	71	100%

Clearly, most of those interviewed believed that the river needed restoring to some kind of acceptable level. No one stated that the river did not require restoring and only four out of the seventy-one respondents stated that they did not know.

This relates to the 80% of respondents in the Butterworth and Carr (1996) questionnaire, who stated that there would be a further decline and degradation if no action was taken to address the river's condition.

Q14) There are a number of possibilities for river use in the future. Indicate using yes / no, or don't know, which of the following you would like to see in the future?

Table 3.14: Distribution of response for the various possibilities tested for future river use.

Response	YES		NO		Don't know	
	N	%	N	%	N	%
a) more canoeing and swimming.	66	93	2	3	3	4
b) more farming use.	17	24	50	70	4	6
c) more tourism.	57	80	7	10	7	10
d) more domestic / household use.	24	34	44	62	3	4
e) more fishing and marroning.	63	88	6	8	2	3
f) more restrictions on river use.	39	55	20	28	12	17
g) used the same as it is now.	19	27	45	63	7	10

Each future river use category was represented by an over 50% majority as indicated by the shaded cells. Recreational and tourist activities received responses of over 80%, implying that all but a few participants wanted to see more of this in the future. Activities which may have been viewed as detrimental to the river environment, such as more farming and domestic use of the river, had a majority "no" response of over 60%. This supports the majority preference (55%) to see more restrictions on future river use, and changes to current use of the river environment (63%)

The data were further explored using crosstab and chi-squared analysis to identify background information on respondents advocating the different future river uses activities:

- Respondents who use the river gave an almost unanimous support (98%) for more swimming and canoeing in the future (higher than that indicated by those not using the river (85%)).
- A very significant difference ($x^2 = 10.37$, $df = 2$, $p = 0.005$) was identified between shires in respect to their opinion on future farming use of rivers and streams within the Blackwood Catchment. Of respondents stating "yes" they wanted more farming use, almost 60% lived in the shire of Boyup Brook. For the shire of Bridgetown-Greenbushes and Kojonup, respondents clearly indicated that they did not desire future farm use of the river, represented by a "no" response of 73 % and 95 % respectively.

A possible reasoning behind Boyup Brook's alternate response may relate to the fact that the eastern part of the middle catchment between Darkin and Boyup Brook occurs within the "sheep belt", having one of the highest stocking rates in W.A. As highlighted by Negus (1995) the rivers and streams in this zone are subject to grazing pressure from stock. Therefore it seems that the general support for future farm use of the river by Boyup Brook residents, may in fact reflect the economics associated with high stocking rates and low water and fodder availability in this area, especially during summer. This assumption is further supported by the fact that over half of the participants from Boyup Brook (53%) lived on a farm, unlike the less than 30% representation by farmers in the other shires sampled.

- Those living in the catchment for over 10 years tended to be more accepting of future farming use of the river, which may reflect a conditioning to such land use practices over time. This is supported by almost half (42%) of those over the age of 60 years.
- Those living near the river were more likely to indicate that farming use and domestic household use of the rivers was not acceptable in the future (over 70%), compared to those who did not live near the river (57%).
- Of the twenty-four participants wanting domestic-household use made of the rivers and streams in the future, 64% came from the shire of Boyup Brook. This differs significantly
  ($x^2 = 4.39$, df = 4, p = 0.02) from the shire of Bridgetown-Greenbushes and Kojonup who generally did <u>not</u> consider this an acceptable river use for the future (68% and 80% respectively). Similar to the farming use response, Boyup Brook once again responded positively to what may be considered by the other shires as a detrimental river use.
- All resident time categories had over 90 % representation for more fishing and marroning in the future, except those living in the catchment for 30 to 70 years. The slightly lower response (79%) may reflect the older and less mobile/active fisherperson, or possibly a greater recognition through a good history of local knowledge, that marron and perch have become scarce with the popularity of fishing.
- With respect to more restrictions on river use in the future, participants from Boyup Brook considered this unacceptable. This was reflected in their strong support for maintaining river use the same in the future.

- Participants responding with "don't know" within Table 3.14, tended to be those who either did not use or lived away (more than 1km) from a river or tributary of the Blackwood

Q15) Using the scale, how necessary do you think the following statements are, for river restoration to be declared successfully completed? (See Table 3.15)

Question 15 asks the respondent to indicate how necessary each event is, for restoration to be considered successfully completed. The shaded results in Table 3.15 highlight those which represent over 50 % of the sample population, all of which occur in the top end of the scale.

In terms of the mean scores obtained, the statements tested in Table 3.15 can be placed in order of those considered most to least necessary for river restoration to be identified as successfully completed :

Quite-Very necessary / important for river restoration to be achieved.

1. River animals once common, but disappeared, have returned naturally.
2. The community is educated and aware of the river environment.
3. Algal blooms are a rare event.
4. Feral animals are eradicated from the catchment.
5. Children can safely swim in the river during summer.
6. The entire length of river and stream bank is revegetated.
7. All rubbish and litter is removed from the river bank.

Moderately necessary / important for river restoration to be achieved.

8. The river is used exactly as it was before major clearing.
9. Stock can drink the river water.
10. The river is drinkable.
11. The river water is suitable for household domestic use.
12. Crops can be irrigated using river water.

Not very necessary / important for river restoration to be achieved.

13. The entire length of river and stream is fenced.

Analysis has identified a number of significant differences and non-significant trends between sub-samples, providing background information on the respondents and their opinions expressed in Table 3.15.

Table 3.15: Frequency distribution data showing the range of opinions associated with each restoration endpoint statement tested within the thesis questionnaire.

	Scale Response												
	not at all 1		**not very 2**		**moderately 3**		**quite 4**		**very 5**		**don't know**		**Mean scores**
Restoration Activity	N	%	N	%	N	%	N	%	N	%	N	%	
a) Litter removed	0	0	11	15.5	11	15.5	12	16.9	37	52.1	0	0	4.06
b) River drinkable.	8	11.3	10	14.1	16	22.5	12	16.9	24	33.8	1	1.4	3.48
c) Crops irrigated.	12	16.9	9	12.7	18	25.4	15	21.1	16	22.5	1	1.4	3.20
d) River animals returned	0	0	2	2.8	4	5.6	7	9.9	56	78.9	2	2.8	4.69
e) Community educated	0	0	3	4.2	5	7	12	16.9	51	71.8	0	0	4.56
f) Feral eradicated.	0	0	4	5.6	6	8.5	8	11.3	53	74.6	0	0	4.55
g) Stock can drink.	7	9.9	6	8.5	15	21.1	15	21.1	28	39.4	0	0	3.72
h) River revegetated.	0	0	1	1.4	9	12.7	18	25.4	39	54.9	4	5.6	4.42
i) Children can swim.	0	0	5	7	9	12.7	7	9.9	50	70.4	0	0	4.44
j) Household use.	11	15.5	12	16.9	11	15.5	12	16.9	24	33.8	1	1.4	3.37
k) Entire river fenced.	11	15.5	29	40.8	11	15.5	7	9.9	11	15.5	2	2.8	2.68
l) River before clearing.	4	5.6	9	12.7	11	15.5	12	16.9	35	49.7	0	0	3.92
m) Algae blooms rare	2	2.8	0	0	7	9.9	8	11.3	50	70.4	4	5.6	4.55

People who tended to consider drinkable river water to be "not at all" to "not very" necessary for achieving river restoration were those who:

- lived on a farm
- considered the river environment to be very important.

In regards to restoring the river for crop irrigation, a significant difference ($x^2 = 15.90$, df = 5,

p= 0.026) was identified between those who do and do not use the river environment. For example a majority of those using the river indicated that the irrigation of crops was "not at all to not very" necessary for restoration, while over 50% of those not using the river indicated that it was "quite to very" necessary for restoration to be achieved.

Before restoration can be successfully completed, it is "very" important that the river animals once common, return naturally to the river. This statement was strongly supported proportionately by participants who:

- were female;
- lived near a river or tributary within the Blackwood River Catchment;
- used the rivers and streams within the catchment;
- lived in town.

Participants who were stronger in their conviction towards the necessity for community education and awareness about the environment, were those who:

- were over the age of 60;
- lived in the shire of Kojonup (86%), with the shire of Boyup Brook having a lower representation of only 59%.

Proportionately, participants indicating that the revegetation of all river banks is "very" important for successful completion of river restoration, were those who:

- lived in the shire of Kojonup;
- lived on a farm.

Proportionately, respondents more resolute in their opinion that before restoration can be successfully completed children must be able to safely swim in the river during summer, were those who:

- were over the age of 60 years;
- had lived in the catchment for longer (over 30 years);
- lived in the shire of Bridgetown-Greenbushes;
- identified algal blooms as the major threat to the river;
- lived in town.

Participants more disposed to indicating that fencing of the entire length of the river was "very" necessary for achieving restoration were those who:

- lived in the shire of Kojonup;
- used the rivers and streams within the Blackwood River Catchment.
- lived on farms.

Participants who tended to indicate that a reduction in algae blooms is "very" important for achieving restoration were those who:

- indicated that algal blooms were the major threat to the river;
- lived in the shire of Bridgetown-Greenbushes (90%).
- lived near and use the river.

Finally within the above analysis it was generally noted that people less interested in river management issues tended have an opinion lower in the scales than those more interested participants.

Q16) How many years do you think it will take to achieve successful restoration?

Table 3.16: Frequency data showing how long respondents considered successful restoration would take to achieve (N=71).

Response	N	Percent
5 - 20 yrs	20	28
20 - 50 yrs	26	37
80 - 100 yrs	7	10
250 yrs	1	1
Don't know	13	18
Never	4	6
TOTAL	71	100%

Given that the word restoration was not qualified, 75% of the sample population indicated that it would take under 100 years to achieve successful restoration of the Blackwood River. Within this response range most indicated that restoration would be achieved within 10 to 30 years (44%). A total of four individuals stated that restoration would never occur, and 13 indicated that they did not know.

Butterworth and Carr questioned respondents as to whether their future image of the river was achievable over a 25 to 50 year time frame. A total of 83 percent stated that "yes" it was possible, and many supported this by adding that anything was possible if people put their minds to it and were given the right incentives. Three respondents stated that restoration was not possible and 6 indicated that they were "not sure".

Through further statistical analysis the following background information was obtained:

- People with a lower level of awareness of river management issues tended to indicate that either restoration would take only 5-20 years or it was never achievable; and were a majority of those responding with "don't know".
- Results suggest that those living on farms tended to consider that restoration would take longer than that indicated by those living in town. Of those indicating it would take 80-250 years, 75% were farmers.
- The shire of Bridgetown-Greenbushes was more cohesive in their response with over half indicating that restoration would take 5-20 years.

3.2.9.1.1 Summary of Results for Part A with reference to Aim 1 and 2 of the study (see pg 121)

Aim 1: To determine the community's value and awareness of, and preferred future for the river environment.

- Over three-quarters of participants lived within 1km of the Blackwood River or its tributaries.
- Nearly two-thirds of participants indicated they used the rivers and streams of the Blackwood River Catchment.
- There was a significant difference in river use between shires, where river use declined as sampling moved up river from Bridgetown-Greenbushes towards Kojonup.

- The study's sample population conveyed a moderate level of awareness and quite a high level of interest in river management issues within the catchment.
- The importance placed on the river environment was high.
- Those living near the river had a significantly higher opinion of, and interest in the river environment.
- Participant placing great importance on riparian vegetation, often those who used the river, placed significantly higher importance on the river environment in general.

- Analysis indicated that the general opinion indicated by the thesis study and that of Butterworth and Carr (1996) was significantly different in terms of, level of awareness in river management issues, and the importance placed on riparian vegetation. This difference was attributed to the fact that the Butterworth and Carr (1996) study was landholder based, while the thesis study sampled a cross-section of the community (landholders and townsfolk). These results suggest that there is a significant difference in the opinion held by landholders and that of the general community.

- In terms of possible/ preferable river use in the future, there was a strong positive response for more recreational and tourism use, while activities viewed as detrimental to the river environment generally evoked a negative response.
- Significantly more people living in the shire of Boyup Brook indicated they desired more farming and domestic household use of the river in the future, compared to those sampled from Kojonup and Bridgetown-Greenbushes.

Aim 2: To identify the community's perception of river restoration, its endpoint, and level of support for a restoration programme.

- Over 70% of respondents from both studies indicated that the water quality of the river had deteriorated over the last 25 years, with responses becoming more consistent as sampling moved up the river towards Kojonup.
- Half of the respondents sampled within the thesis study, indicated that salinity was most threatening to the health of the river, followed by 21% identifying paddock runoff.
- Most of those sampled believed that the river needed restoring to some acceptable level, indicating that the community desired action to address the river's condition.

- The following represents the community's perception of river restoration and its endpoints. The statements have been placed in order of those considered most to least necessary for river restoration to be defined as successfully completed:

Quite-Very necessary / important for river restoration to be achieved.

1. River animals once common, but disappeared, have returned naturally.
2. The community is educated and aware of the river environment.
3. Algal blooms are a rare event.
4. Feral animals are eradicated from the catchment.
5. Children can safely swim in the river during summer.
6. The entire length of river and stream bank is revegetated.
7. All rubbish and litter is removed from the river bank.

Moderately necessary / important for river restoration to be achieved.

8. The river is used exactly as it was before major clearing.
9. Stock can drink the river water.
10. The river is drinkable.
11. The river water is suitable for household domestic use.
12. Crops can be irrigated using river water.

Not very necessary / important for river restoration to be achieved.

13. The entire length of river and stream is fenced.

- Three-quarters of the population indicated that it would take less than 100 years to achieve successful restoration of the Blackwood River. Only four participants indicated that restoration would never occur.

3.2.9.2 Part B: Results

Q17) Name up to 3 animals which to your knowledge have disappeared from parts of the Blackwood river? (see table 3.17)

Out of a total 213 (71x3) possible responses only 84 responses were made, which identified a total of 25 animals. Of the 59 respondents who could not name three animals: 35 could provide no examples, while 12 people could only identify one or two animals. The percentages outlined in table 14 and 15 were based on the number of participants within the sample (71) not the number of responses for each question.

The animals identified varied from those specifically associated with the Blackwood River (such as the marron), to native bushland animals found within the catchment (including the chuditch). Only animals named by over 5% of the population are displayed (Table 3.17) and discussed below. The other animals named were only identified by 1 to 3 people (<5%) and are outlined in Appendix 3.

Table 3.17: Showing those animals identified by over 5% of the population as one of 3 which have disappeared from parts of the Blackwood River

Response	N(84)	Percent
Marron	21	30
Native Fish	11	15
Perch	5	7
Chuditch	5	7
Possum	4	6
Total	46/84	N/71

The highest single response was marron, identified by 30 % of participants. This was followed by one-quarter of the sample identifying native fish and 7%, the perch. All three were identified by people with similar characteristics. Most were male; aged between 30-60 years; had lived in the catchment for over 10 years; near the river and generally in town. Almost all fished for marron; and indicated that both marron and the river environment were very important to them. Just under 60% of those who selected marron, and all of those who identified perch, came from the shire of Kojonup. Almost half of those who chose native fish came from the shire of Bridgetown-Greenbushes.

Q18) Using the scale how does this concern you?

Each respondent was asked how the disappearance of the animals identified concerned them (using the scale). Those who didn't identify an animal were asked a similar question "if animals had disappeared from parts of the Blackwood river how would this concern you? "

Within the scale from one to five, ranging from "not at all" to "very" concerned, most (69%) respondents considered the disappearance of riverine animals from parts of the Blackwood River to be "quite"(4) to "very"(5) concerning. Only six people placed their concern below the scale's mid-point.

Q19) If we are looking for a symbol for the Blackwood River which three would you consider most appropriate from this list, or you may choose your own?

Table 3.18: Showing those species identified by over 20% of the respondents, as an appropriate symbol for the Blackwood River.

Response	Percent
Marron	72
River gum	60
Paper bark	28
Frog	22
Turtle	20
Total	N/71

Using a list provided every respondent was able to make 3 choices on the most appropriate symbol for the Blackwood River (not ranked). Results showed that all species on the list were selected by one or more individuals, but as indicated in Appendix 4 most were only represented by less than 20% of the sample population' making them inappropriate for analysis, representing less popular symbols.

Table 3.18 identifies the top five responses, representing over 20% of the sample population.

The most commonly identified symbol was the marron, expressed by nearly three-quarters (72%) of all participants. The second most popular symbol for the Blackwood River was the river gum (60%), followed by a much lower 28%, selecting the paper bark.

Questions 20 and 21 required each respondent to identify out of their three symbols, one which they considered to be most appealing (question 16), and one which makes them most proud to know it lives within the catchment (question 17). Table 3.19 displays the frequencies for both questions.

Table 3.19: Responses given for questions 20 and 21 (N=71).

Most Appealing (Qu 20)			**Most Community Pride** (Qu 21)		
Response	**N**	**Percent**	**Response**	**N**	**Percent**
Marron	27	38	Marron	34	48
River gum	20	28	River gum	15	21
Frog	6	8	Turtle	4	6
Paper bark	3	4.2	Frog	3	4.2
Water lily	3	4.2	Water Rat	2	2.8
Turtle	3	4.2	Cobbler	2	2.8
Water Rat	2	2.8	Paper bark	1	1.4
Cobbler	1	1.4	Water lily	1	1.4
Cormorant	1	1.4	Cormorant	1	1.4
Gilgie	1	1.4	Gilgie	1	1.4
Koonac	1	1.4	Koonac	1	1.4
Duck	1	1.4	Duck	1	1.4
Phascogale	1	1.4	Don't know	5	7
Don't know	1	1.4			
TOTAL	71	100%	TOTAL	71	100%

Over one-third of the sample population identified the marron as most appealing from among their three choices in question 19. Twenty respondents chose the river gum, while the frog was the next most appealing symbol selected by only 6 people. As the results suggest, 66% of the sample population selected either the marron or river gum as most appealing.

It is clearly evident which symbols evoke most community pride. The marron was identified by nearly 50% of those sampled, having over double the response for river gum. Both the marron and the river gum have a response rate over three times that of all other symbols identified as promoting respondent pride.

Crosstab analysis provided the following characteristics for those people selecting marron and river gum within questions 16 and 17.

<u>For those selecting Marron:</u>

- most were male (78%);
- ninety percent considered marron to be "very to quite" important to them;
- had a lower proportion of people placing riparian vegetation at a high level of importance,
- seventy percent had lived in the catchment for over 10 years;
- Of those selecting marron a proportionately higher number lived in the shire of Kojonup compared to the shires lower in the catchment.

For those selecting the River Gum:
- over half were female (60%);
- lower importance was placed on marron, ranging from "very" to "moderately" important;
- just under 90% indicated that riparian vegetation was "very" important;
- fifty percent had lived in the catchment for less than 5 years only;
- had the strongest response from those living in Bridgetown-Greenbushes, with the lowest representation from those living in the shire of Kojonup.

Q22a) Marron occur in the Blackwood River! Agree / Disagree

Apart from eight participants all (89 %) had no hesitation in affirming that marron do occur in the Blackwood River system. Due to the high representation the characteristics of these participants generally reflect the demographics of the general sample population. No one disagreed with the statement and only eight stated that they did not know.

A majority of those who "don't know" were over the age of 60 years and had lived in the catchment for less than five years. Six were female and seven of the eight lived in town.

Table 3.20: Showing response to question 22 part a, b, and c.

	Frequency Data for Question 22		
Response	**Question 22a (%)**	**Question 22b (%)**	**Question 22c (%)**
Agree	89	54	61
Disagree	0	3	8
Don't know	11	43	31
TOTAL	100%	100%	100%

Q22b) Marron use to occur in the rivers and streams of the upper Blackwood. (such as the Balgarup, Arthur, and the Carlecatup). Agree / Disagree

Just over half of the participants agreed that marron use to occur in the tributaries of the upper Blackwood. Only two individuals disagreed with the statement, while just under half indicated that they did not know whether or not this was true.

Of those who did not know most were either representative of the youngest (20-30yrs) or oldest (over 60yrs) age categories within the questionnaire. An above average proportion were females (60%) who had lived in the catchment for less than 10 years and placed their interest in river management issues at the lower end of the scale. In contrast to this, participants who agreed with the statement were generally aged between 30-60 years, were male (60%), had lived in the catchment for over 10 years, used the river (66%) and generally indicated that they were quite to very interested in river management issues.

Both male respondents who disagreed that marron use to occur in the upper Blackwood did not use the river, lived in the shire of Bridgetown-Greenbushes and indicated a low level of interest in river management issues.

After the disagree response (outlier) was removed from the data, a significant difference ($p<0.05$) was identified between the shires in response to whether marron used to occur in the upper Blackwood. The results related to the proximity of each shire to the upper Blackwood. Over half of the respondents living in the shire of Bridgetown-Greenbushes located within the lower part of the middle catchment responded with "don't know" to the question. A similar proportion of people from Boyup Brook had the same response, while those from Kojonup (81%) shire, located in the upper catchment, agreed with the statement.

Q22c) Marron only occur naturally in south-west rivers of W.A. Agree / Disagree

Just under two-thirds of the respondents agreed that marron were endemic to south-west rivers of Western Australia, while approximately one-third of participants did not make a committed response. Of those who did not know, none lived in the shire of Kojonup.

A majority of those agreeing with the statement were male (72%) and over 50% of those with low levels of interest in river management issues responded with "don't know" to this question.

Q23) Which of the following do you agree with: Over the last 40 years the number of marron in the Blackwood River has:

Table 3.21: Showing the range in opinion on changes in marron numbers within the Blackwood over the last 40 years, (N=71).

Response	Rating	N	Percent
Increased dramatically	1	0	0
Increased slightly	2	0	0
Remained the same	3	0	0
Declined slightly	4	9	13
Declined dramatically	5	45	63
Don't know	-	17	24
TOTAL	Mean= 4.8	71	100%

One-quarter of the participants did not know whether the number of marron had gone up or down over the last 40 years. All of the remaining responses were recorded within the range identifying some degree of marron decline. Nearly two-thirds stated that marron numbers had declined dramatically.

Of those who did not know, most had lived in the catchment for less than five years; were generally "not very" interested in river management issues, and most were female.

Q24) Indicate which one of the following you think would be the major threat to marron?

Table 3. 22: Distribution of responses within the sample population on the main threat to marron, (N=71).

Response	N	Percent
Increase in salinity	25	35
Fertiliser input into the river	24	34
Over fishing	12	17
Summer storms	0	0
Don't know	10	14
TOTAL	71	100%

One-third of the sample population indicated that increased salinity and fertiliser input into the river were both the major threat to marron. This accounts for 69.0 percent of all responses to the question. Twelve people identified over fishing as the main threat, while no one perceived summer storms to have any impact on marron unlike the recognition expressed with the Oral Histories.

Q25) How important to you is it to have marron in the Blackwood River?

Table 3.23: Level of importance placed on marron within the community, (N=71).

Response	Rating	N	Percent
Not at all	1	0	0
Not very	2	1	1
Moderately	3	3	4
Quite	4	11	16
Very	5	48	68
Don't know	-	8	11
TOTAL	mean= 4.6	71	100%

As the frequencies and mean score indicate, most participants (83%) responded at the top end of the scale, including over two-thirds of those sampled. Crosstab analysis indicated that there was a positive association between a respondents interest in river management issues and the importance placed on marron, and those who fished for marron.

In relation to question 26, the mean scores shown in Figure 3.24, indicate that there was a "moderate to quite" high level of support for the following, to protect marron in the Blackwood River.

- the reduction in fertiliser use on farms,
- fencing to remove stock from the river, and
- promotion of marron as an emblem for the Blackwood River.

The results indicate quite to very high support for a two year closure of the marron season and the revegetation of river banks along the Blackwood River, in an attempt to protect the native marron. A distinction was observed between the response given by each resident type category. Those living in town had a higher level of support for the reduction of fertiliser than people living on farms. For example 50% of those living in town indicated a "very" high level of support, while only 23% of farmers were of the same opinion.

Q26) To protect marron in the Blackwood how well would you support...

Response	not at all		not very		moderate		quite		very		don't know		mean score
		%	N	%	N	%	N	%	N	%	N	%	
Reduce fertiliser	5	7	7	10	10	14	11	16	26	37	12	17	3.78
Closure of marron season	5	7	7	10	6	8	8	11	35	49	10	14	4.00
Fencing to remove stock	6	8	10	14	12	17	5	7	29	41	9	13	3.66
Promote marron as an emblem	6	8	2	3	10	14	21	30	24	34	8	11	3.87
Revegetating river banks.	0	0	1	1	7	10	7	10	48	68	8	11	4.62

Table 3.24: Distribution of responses given for each statement of marron protection.

In contrast farmers indicated a stronger support for the closure of the marron season and fencing to remove stock, compared to those living in towns, nevertheless these differences were not significant.

27) Without guessing, which of the following 4 pictures would you associate with a marron?

Table 3.25: Showing the distribution of results on the how well the sample population identified marron within question 27, (N=71).

Response	N	Percent
Correct picture	45	63
Incorrect picture	12	17
All pictures	0	0
Don't know	14	20
TOTAL	71	100%

Just under two-thirds of the participants (63.4 percent) selected the correct picture, depicting a marron. Only twelve respondents selected incorrectly, and 19.7 percent indicated that they did not have the knowledge to identify a marron from the other freshwater crayfish on display. Those responding with "don't know" were mostly female. The results suggested that the longer a respondent had lived in the catchment, the more likely they were to select the correct picture.

Of those participants who agreed that marron do occur in the Blackwood River (question 18), 80% selected the correct picture, but interestingly all those who didn't know selected the incorrect picture. A difference was also identified between shire in respect to selecting the correct picture, where identification seemed to improve as sampling moved up the catchment. For example those from Bridgetown-Greenbushes had the lowest number of correct responses (58%), compared to 89% of people living in the shire of Kojonup with the correct response.

Q28a) How good do you think the communities general knowledge is about marron?

Descriptive analysis states that most participants (70%) consider the community's general knowledge of marron, to be at, or just below a moderate level of knowledge, with a mean score of 2.95 within the standard scale used.

Qu 28b) How popular has marron fishing been in the community... (past / present) (see Table 3.26)

Question 28b required each respondent to suggest a level of popularity for marron fishing during (i) recent years, and (ii) in the past. As shown in Table 3.26, the mean result (3.5) for marroning in recent years suggests that marroning was "moderate to quite" popular within the Blackwood. Popularity in the past was higher with a mean of 4.3, reflective of the 65% of participants placing their response high in the scale (quite to very).

Table 3.26 : The samples opinion on the popularity of marroning in the present and in the past, (N=71).

Popularity at Present Qu 28b (i)				**Popularity in the Past** Qu 28b (ii)			
Response	**Rating**	**N**	**Percent**	**Response**	**Rating**	**N**	**Percent**
Not at all	1	2	3	Not at all	1	0	0
Not very	2	12	17	Not very	2	2	3
Moderately	3	18	25	Moderately	3	7	10
Quite	4	15	21	Quite	4	16	22
Very	5	17	24	Very	5	30	43
Don't know	-	7	10	Don't know	-	16	22
	mean=3.5	N=71	100%		mean=4.34	N=71	100%

The crosstab analysis indicates that those individuals living in the catchment for longer generally (>60%) considered marron fishing to be more popular in the past than at present. The newer residents tended (60%) to indicate that marron fishing is more popular today than in the past.

Q29) In the last 25 years have you or your family fished for marron?

Table 3. 27: Number of respondents who fish (or family fish) for marron, (N=71).

Response	**N**	**Percent**
Yes	60	84
No	11	16
TOTAL	71	100%

Of those sampled randomly from the study area, over three-quarters indicated that they or their families had fished for marron in the last 25 years.

The following trends were determined:

- The shire in which marron fishing seemed most popular was Kojonup (90%).
- A majority of those who responded with "yes" were male (68%). Even so, over three-quarters of the females sampled responded with "yes" to the question.
- Over 70% of those who fished for marron indicated that marron was very important to them while less than 50% of those not fishing, were of the same opinion.

Q30) Using the following, how often do you fish for marron?

Table 3. 28: Distribution of responses in relation to the regularity of marron fishing within the sample, (N=60).

Response	N	Percent
Every season	13	22
Occasionally	20	33
More so now than in the past	1	2
Not any more, but use to	26	43
TOTAL	60	100%

Of the sixty people who indicated that they fished for marron, over one-third declared that they had fished in the past, but not recently, while 20 people fished "occasionally". Less than a quarter of those sampled fished regularly, with only one individual declaring that they had been fishing more now than in the past.

These results reflect the difference in the popularity of marron fishing over the last 25 years, as indicated in questions 28b. The number of people fishing occasionally and more so in the past (46) is considerably greater than those fishing more so now and seasonally (14).

Of the 21 people who indicated they did not use the river (question 6), only three did not fish for marron. This implies that 86% of people who said they did not use the river, did not consider marron fishing as a river use. This may be associated with how the question was interpreted, or that 86% of the 21 who don't use the rivers actually fish for marron in dams.

Q31) Have you marroned in the Blackwood River ?

Table 3.29: Number of participants who fish within the Blackwood River and its tributaries, (N=60).

Response	N	Percent
Yes	39	65
No	21	35
TOTAL	60	100%

Of the sixty people who indicated that they or their family fished for marron, 39 announced that they fished within the Blackwood River, representing over half of the sample population. Analysis has highlighted the following background information for those who do and don't fish for marron in the Blackwood River.

- All people who considered marron to be "not very" or "moderately" important to them, did not fish for marron in the Blackwood, while a good majority of those who placed marron at a high level of importance did.
- Participants living in the catchment for less than 10 years were more likely to not fish for marron in the Blackwood, than those living in the area for over 10 years. This difference was significant with $p = 0.04$, $df = 7$.
- A trend was identified, suggesting that as sampling moved up the catchment the number of people who fished in the Blackwood River decreased. For example approximately 60% of people from the shires of Bridgetown-Greenbushes and Boyup Brook fished in the Blackwood, while in contrast over half of those from Kojonup did not.
- Most (61%) of those using the river, fished for marron in the Blackwood. Interestingly, the results show that 44% of those who stated they did not use the river (question 6) do in fact fish for marron in the Blackwood.

  This suggests low reliability of results, certainly for question 6. However the problem may be and is more likely attributed to question 29. The problem may have arise from the fact that question 29 allows the individual sampled to answer "no" to river use in question 6, but to answer yes to marron fishing, speaking on behalf of members in their family who fish for marron. This is further supported by the fact that all respondent sampled fished both in rivers and dams, therefore a "no" response to question 6 doesn't suggest they fished in dams only.

Q32) Using the following, indicate where you normally fish in the Blackwood River?

Table 3.30: Shows the distribution of marroning within the study's sample area, (N=39).

Response	**N**	**Percent**
Above Boyup Brook	6	15
Between Boyup Brook & Bridgetown	15	38
Between Bridgetown & Nannup	12	32
Below Nannup	6	15
TOTAL	39	100%

When asked, where they normally fish in the Blackwood, six people identified the stretch of river above Boyup Brook; fifteen normally fished between Boyup Brook and Bridgetown; and twelve fished between Bridgetown and Nannup. The results indicate that the majority of those sampled, fished within the project's sample area, as only six people fished below Nannup.

For each particular area:

- Above Boyup Brook - of the n = 6, 5 had lived in the area for 30-70 years and were over 60 years of age. Four lived in the shire of Kojonup and 2 in Boyup Brook (the upper part of the sample area).
- Between Boyup Brook and Bridgetown - a majority had lived in the catchment for over 10 years and all but two came from the shire of Bridgetown-Greenbushes and Boyup Brook. Most participants who lived on a farm and fished for marron in the Blackwood, fished in this area.
- Between Bridgetown and Nannup - this category generally included those who had lived in the catchment for less than 30 years, with an overwhelming majority (92%) living in the town of Bridgetown.
- Below Nannup - three of the n = 6 had lived in the catchment for 30-70 years. Most lived in town with 50% living in the shire of Bridgetown-Greenbushes, followed by 33% and 17% from Kojonup and Boyup Brook respectively.

The location selected was often closest to the shire which the individual lived in. For example, the most popular area to fish for people from Bridgetown-Greenbushes was between Bridgetown and Nannup; those from Boyup Brook fished between Boyup Brook and Bridgetown and most of those who fished in the river and came from Kojonup, fished above Boyup Brook. Correlation analysis indicates, however that the relationship was not significant.

Q33) Have you marroned in other rivers?

Table 3.31: Popularity of other rivers for marron fishing, (N=60).

Response	N	Percent
Yes	28	47
No	32	53
TOTAL	60	100%

Of the 60 people who indicated that they or their families had fished for marron in the last 25 years, 47% indicated they had fished in other south-west rivers for marron. Of these people over 90% considered the Blackwood River to be "very" important to them and knew that marron occurred in the Blackwood River.

Q34) Do you fish for marron in dams?

Table 3.32: Testing the popularity of dam marroning within the sample population, (N=60).

Response	N	Percent
Yes	39	65
No	21	35
TOTAL	60	100%

Ironically, the same number of people who fish in the Blackwood River (39), fished in dams. Therefore those who fished in dams represented almost two-thirds of the sample indicating that they had fished for marron in the last 25 years.

The following generalisations have been derived through comparative analysis of both response categories (yes & no).

- Over 60% from both categories considered marron to be "very" important to them.

- Those who did not marron in dams tended to live in the catchment for less than 10 years, while those who fished in dams were generally older residents within the catchment.
- A slightly higher percentage of those who marroned in dams lived on farms, while most of those who did not marron lived in town.
- Ninety-five percent of those who fished in dams knew marron occurred in the Blackwood River.
- Those who did not fish in dams had a higher proportion of people (84%) who indicated that the river environment was "very" important to them, compared to those who fished the dams (56%).
- Over half of the respondents from Bridgetown-Greenbushes and Boyup Brook did not fish in dams, while 76% of those from Kojonup did. This difference was almost significant.

Q35) Compared to rivers, how often do you marron in dams?

Table 3.33: Showing the degree of preference for dam fishing over river marron fishing, (N=39).

Response	N	Percent
More in dams	34	87
About the same	2	5
Less in dams	3	8
Not at all in dams	0	0
TOTAL	39	100%

The results show that of those who fish in dams, also marron in rivers. Of the thirty-nine individuals who fish in dams 87% fished more in dams than rivers. Only two people indicated that they fished about the same in both environments, and three suggested that they participated in dam fishing less than in the rivers.

Results show that:

- of those who fished more in dams than river, a majority lived in the shire of Kojonup.
- all farmers who fished in dams indicated they did so more than in rivers.
- all three people who indicated they fished for marron more in rivers than dams, indicated that they also fished in other rivers of the south-west.

Q36) Where would you place marron in the following scales?

Table 3.34: Test of the aesthetic and public appeal of marron within the sample population.

Question 36a		**Question 36b**		**Question 36c**	
Response	**Percent**	**Response**	**Percent**	**Response**	**Percent**
Ugly	7	Boring	3	Spider	2.8
2	8	2	6	2	11.3
3	37	3	11	3	46.5
4	18	4	34	4	22.5
Beautiful	30	Interesting	46	Koala	16.9
mean = 3.54		mean = 4.15		mean = 3.4	
TOTAL	100%	TOTAL	100	TOTAL	100%

Question 36 was designed to identify the level of appeal associated with marron, within the Blackwood River community.

Question 36a measures the aesthetic appeal of marron, where the respondents were presented with a five point scale with "ugly" and "beautiful" at each extreme. As the mean score (3.54) indicates, marron was generally considered moderately to quite beautiful, and nearly one-third of respondents considered the marron to be a beautiful creature.

- Results for each shire suggests that as sampling moved up the catchment the proportion of people indicating that marron are "beautiful" increased slightly. This is reflected in the fact that nobody from Kojonup inferred that marron were "ugly"; most of those who came from the shire of Bridgetown-Greenbushes; had lived in the catchment for less than 5 years and were female.

Question 36b tested whether marron had the potential to promote public interest. A five point scale was used, with "boring" and "interesting" at each extreme (question 36b). On average (4.15) the community identified the marron as quite to very interesting, with the highest response rate (46%) falling within the interesting category. Only 9 people had an opinion below the scales mid point "3".

Finally, to test the public appeal of marron (question 36c), a five point scale was created, weighted with an example of a creature which generally has low public appeal (spider) and one which is often associated with high public appeal (koala). As the mean score

(3.4) indicates, marron, in terms of its appeal in the general community, was considered to have "moderate to quite" high appeal.

Crosstab analyses indicates the following differences in general opinion between various people within the sample:

- People who had fished for marron in the last 25 years had a higher representation in the upper end of the scale, than those who did not fish.

  Respondents who had lived in the catchment for longer (over 30 years) had a greater proportion of people indicating that marron was very appealing (koala). Similarly those over the age of 60 years had a greater number of people placing marron in the upper end of the scale compared to other age groups sampled.
- Males considered marron to have more public appeal than what was generally indicated by female respondents, with 20% of males compared to 11% of females placing marron equal to the koala within the scale.
- Even though the highest single response from each shire place marron at "3" within the scale, a difference can be noted between the general response from each. People living in the shire of Bridgetown-Greenbushes generally had a moderate to low opinion of the marron's public appeal, while participants from Boyup Brook indicated moderate(3) to quite (4) high appeal. Residents from Kojonup had the most positive opinion with 30% indicating that marron were as appealing as the koala and none placing it below the scales mid-point.

Correlation analysis was conducted to identify if a significant relationship existed between the general response given for each scale.

- The results stated that there was a highly significant ($r = 0.5$, $df = 70$, $p < 0.001$) positive relationship between an individuals opinion of marron's aesthetic appeal and the public interest it promotes. For instance, all of the participants who considered marron to be "boring " creatures also indicated that they were "ugly".

- A significant relationship ($r = 0.3$, $df = 70$, $p = 0.014$) was identified between a participants response to marron's public appeal and the level of interest marron inspired. Those placing marron between "moderate and very" interesting also considered marron to be "moderately to very" appealing (koala).

3.2.9.2.1 Summary of Results for Part B, with reference to Aims 3 and 4 of the study

Aim 3: To identify potential flagship species for the restoration of the Blackwood River.

- Almost three-quarters of participants selected marron as a most appropriate symbol for the Blackwood River, closely followed by the River Gum.
- Marron had the strongest response for the most appealing symbol and the species which evoked the greatest sense of community pride. Once again this was followed by a lower number of people selecting the River Gum.

Aim 4: To test marron against the flagship selection criteria 11 to 15, associated with community values and attitudes towards marron.

Evoke Public Sympathy

- Marron was the most popular species selected to have disappeared from parts of the Blackwood River, promoting many respondents to indicate a high level of concern over the disappearance.
- All respondents indicated that marron numbers had declined over the last 40 years, except for the 17 who indicated they did not know.
- Both, increased salinity and fertiliser input into the river were identified as the major threat to marron.

Identifiable to the Public

- Apart from eight participants, all agreed that marron occur in the Blackwood River, however a lower 61% and 54% agreed that marron were endemic to the south-west and use to occur in the Upper Blackwood, respectively.
- A significant difference was identified between the shire response to whether marron use to occur in the Upper Blackwood. Those living lower in the catchment tended not to know.
- Just under two-thirds of the participants could correctly identify a marron. Those less successful tended to be either female, had lived in the catchment for a short period, or lived near Bridgetown-Greenbushes.
- Identification of marron tended to improve as sampling moved up the catchment.

Evoke Community Pride

- All but five respondents indicated that it was "quite to very" important to them, to have marron within the Blackwood River.
- To protect marron a majority were willing to support the reduction of fertiliser use (particularly townsfolk), closure of the marron season (particularly farmers), fence and revegetate river banks and promote marron as an emblem of the river.

Aesthetically Appealing

- On average marron were considered quite beautiful creatures by the sample population.
- Almost half (46%) of the sample indicated marron were interesting rather than boring.

- In terms of public appeal the sample generally considered marron to have moderate to quite high appeal, similar to that of a koala, rather than a spider.
- The results indicated that respondents who indicated marron were "boring" creature were significantly likely to state marron were "ugly" too.

Popular

- On average the general knowledge of marron was rated as moderate.
- The sampling indicated that marron fishing was more popular in the past than today.
- However 84% of those sampled indicated that they or their family had fished for marron in the last 25 years, with 43% indicating that they don't fish any more, while the remainder fish seasonally or occasionally.
- Of those who fish, most lived in the shire of Kojonup, were male, and indicated that marron were very important to them.
- Over half of the sample population indicated that they fished within the Blackwood River. Most of which had lived in the catchment for over 10 years, and / or lived lower in the catchment, as the number of people decreased as sampling moved up the river towards Kojonup.
- Most of the fishing was conducted between Boyup Brook and Nannup.
- The same number of people who indicated they fished in dams also fished in the Blackwood.
- Those who fished in dams often lived on farms and / or came from the shire of Kojonup.
- Eight-seven percent of those who fished for marron, indicated that they do so more from dams.

3.2.10 Conclusion

The questionnaire attempted to sample a cross-section of the community, therefore random selection was conducted within each town on a certain day and time, where equal probability of selecting all different sectors of the community was possible. The representativeness of the sample was tested by observing the number of farmers and townsfolk sampled from each shire and comparing this with shire office estimates. Table 3.35 below, shows the percentage of town and farm residents identified within the study and by the shire offices (personal communication, August 1996).

Table 3.35: The percentage of town and farm residents sampled within the study and compared to estimates provided by the shire offices.

Shire	Bridgetown-Greenbushes		Boyup Brook		Kojonup	
	Study%	Actual%	Study%	Actual%	Study%	Actual%
Town	73	57	47	33	71	36
Farm	27	43	53	67	29	64

Briefly, the results showed that the random sample made within the shires of Boyup Brook and Bridgetown-Greenbushes were similar to the actual proportions identified by the shire offices, especially Boyup Brook. However the study results for Kojonup indicated virtually the reverse of the actual estimates.

In light of these results it seems that the representativeness of the study lacks response from the rural sector of the community, the landholder. Some reasoning as to why this occurred can be related to the large area covered by the shires, as shown in Figure 3.1, and the relatively low number of landholders over this area (Kojonup has the most - 2300). It is likely that sampling was conducted during a period when farmers were most active, with the task of putting crops in with the coming rain. As explained, many farmers declined participation in the questionnaire, which unfortunately was not recorded as part of the sampling procedure, a limitation of this study, but a recommendation for future surveys in the area.

However, the sample was more representative of the Middle Catchment Community than the Butterworth and Carr (1996) survey, which focused on the landholder exclusively. This was evident with t-test analysis on the sample mean for questions 7 and 10. The result suggested that the thesis study succeed firstly in, significantly incorporating the opinions of the landholder, and secondly in sampling a cross-section of the community. These results clarify the importance of sampling a cross-section of the community rather than those who represent a majority (the landholder), as it was made evident, that their opinions do not always represent that of the whole community.

Comparing both studies showed that landholders have a slightly higher awareness of river management issues and placed less importance on riparian vegetation. Similarly, within the thesis study, differences were identified between those living on farms and in town. For example those living on properties had a higher level of value and interest in the river environment and management issues than those living in town. Respondents living on farms also tended to consider that restoration would take longer.

In light of the low landholder representation within the thesis questionnaire, it is valuable to compliment the finding of this study with that of Butterworth and Carr (1996), providing a more illustrative picture of community opinion, attitude and behaviour towards the river environment.

The first aim of the questionnaire (Section 3.2.1) endeavoured to determine community values, awareness and the preferred future for the river environment. Questions 7 to 10 all indicated that the sample population for both studies had on average a moderate to quite high level of awareness and interest in river management issues and placed quite to very high importance on the river environment and its associated native vegetation.

This level of value and awareness was significantly related to a respondent's level of contact with the river environment. In terms of river use, over 60% of participants from both studies indicated they use the Blackwood River and its tributaries. These people generally had a higher level of awareness of river management issues and significantly placed greater importance on the river environment.

Results indicated that an individuals interest in, and the importance they placed on the river environment was significantly related or dependent on the individual's locality in relation to the river. Respondents living near the river showed greater value for the river environment.

Respondents living near and / or using the Blackwood River also tended to have a greater proportion indicating that the river water quality was better 25 years ago. As depicted in Table 3.7b, a significant association existed between river use, the perceived water quality of the river, and the different shires sampled. A significant trend of declining river use was identified as sampling moved up the river from Bridgetown-Greenbushes to Kojonup. This reflects the trend of deteriorating water quality from the Lower to the Upper Blackwood Catchment identified within Section 1.2.4.

In terms of the main threat to river health, both the Butterworth and Carr (1996) and thesis studies had a majority identify salinity followed by paddock runoff as the main threat to the Blackwood River.

The idea of a healthy river played an important role in the response given towards the various future river use activities tested in question 14. The results showed that those activities deemed detrimental to the river environment, such as farming and domestic / household use of the river, were generally rejected as a future river use. Recreational and tourist activities were strongly favoured as future river use, with primary contact activities such as swimming and fishing having the highest response.

The Butterworth and Carr (1996) study asked a similar, but open question, requiring respondents to indicate "what they thought they would do" in the future (rather than "would like to do"). Results from this question supported the conclusion drawn by Nancarrow, Jorgensen and Syme (1995), who identified that past experience and perceived water quality impact on future primary contact activities. According to these findings, future river use activities such as swimming and fishing should have a low representation, given current perceptions on the water quality of the river.

Alternatively, the thesis question was based on a vision of preferred future river use which, according to the responses given, was obviously associated with a desired improvement in water quality, this still in agreement with both Butterworth and Carr (1996) and Nancarrow et al's (1995) conclusions.

Results from question 14 indicated that a preferred future for the river involved some level of restoration to river water quality. This relates well to the second aim of the questionnaire which attempted to investigate the community's perception of river restoration and its endpoints, and potential level of support for the restoration programme.

Complimentary to the aim, question 13 prompted all but four people (94%) to indicate that the river required restoration to some acceptable level. This relates to the 80% of respondents within the Butterworth and Carr (1996) survey who stated that their would be further decline and degradation if no action was taken to address the river's condition.

Conclusions drawn from the Butterworth and Carr (1996) survey, indicate that essential foundations do exist for successful restoration of the Blackwood River. For example, results showed that there was a positive attitude towards the BCCG, LCDC's and Landcare and a strong support for protection of the riparian zone. Over two-thirds of participants believed tree planting and fencing had a positive influence on the river's condition, and most believed they were able to help improve the river environment. This last result is crucial for restoration and should have been tested within the thesis questionnaire also.

However the questionnaire did succeed in displaying a definition of restoration according to a cross-section of the Middle Catchment community, and their perception of a restoration endpoint.

- Fencing the entire length of the river was not regarded by the community as very important to achieve restoration of the Blackwood River.

- Drinkable river water (for both stock and humans) and a river condition similar to that experienced prior to clearing, was considered only moderately necessary for river restoration to be achieved, along with irrigation and domestic use.

- Community education and awareness; controls on feral animals and litter; and the revegetation of river banks, was considered quite important before restoration could be achieved. The sample also identified that water quality must improve enough for algae blooms to become rare and so children can safely swim in the river.

- According to almost 80% of those sampled, it was deemed most important that river species once common to the Blackwood return naturally to the successfully restored river environment.

The final statement represents the sample community's most accepted endpoint to restoration. It would be fair to say that the scientific community would tend to agree that the return of native species, to survive and reproduce within original habitats, is a most acceptable and rewarding endpoint, which at the same time has the potential to provide direction for such a difficult task. According to the those sampled, such a task is achievable within a time frame of 100 years.

The desired return of riverine species once naturally common to the Blackwood River, is the crux to the success of the Flagship Species concept proposed within this research. Aims 3 and 4 of the questionnaire test the appropriateness of marron as a Flagship Species, the results from which compliment the thesis Research Aim and Research Question, as outlined on page 33.

Marron was by far the most popular image recalled by the sample, in terms of the most appealing species, most appropriate symbol for the Blackwood River, and the species which evoked the greatest sense of pride. Marron was also the most recognised species to have disappeared from parts of the Blackwood River. All of these results compliment the marrons recruitment as a flagship species for the Blackwood.

Other potential flagship species identified, were the River Gum, Frog, Tortoise and Paper Bark. Interestingly, descriptive analysis indicated that individuals most likely to select marron generally had the following characteristics, were male, lived in the shire of Kojonup, lived in the catchment over 10 years, and considered marron to be very important to them, while riparian vegetation was less important. Interestingly those most likely to select the River Gum (the second most popular response) were often female, placed lower importance on marron, but indicated that riparian vegetation was very important to them, had lived in the catchment for less than 5 years, and generally lived in the shire of Bridgetown-Greenbushes.

As indicated above, variations in opinion and attitudes between shires, gender, and those individuals who fished for marron, were often reflected in the responses given for questions relating to marron.

Females within the sample generally showed a lower level of knowledge and appreciation for marron, compared to males. This was evident in the fact that females made up the majority responding with "don't know" for the following questions:

- marron occur in the Blackwood River?
- marron use to occur in the Upper Blackwood ?
- which of the following pictures would you associate with a marron.

Participants from shires in the Lower Middle Catchment (Bridgetown-Greenbushes and Boyup Brook) showed a lower sense of value for marron compared to those sampled from Kojonup, who displayed greater general knowledge and popularity for the species. Results indicated that as sampling moved up the river from Bridgetown-Greenbushes to Kojonup more people agreed that marron use to occur in the Upper Blackwood, were endemic to the south-west, and could select the correct picture of a marron. People living in Kojonup had a majority indicate that marron were "beautiful" creatures and had high public appeal. More people in Kojonup fished for marron, but marroned less in the Blackwood River and more in dams.

The above discussion highlights that the potential conflict indentified within the Oral Histories concerning the increasing popularity of dam marroning compared to the river, is of little concern. Those who fished more from dams, also had a majority indicate that marron were a most appropriate symbol for the Blackwood River.

Similarly, respondents who fished for marron (dam or river) tended to place greater importance on marron in the Blackwood than those who did not fish. Interestingly, as mentioned earlier, river use such as marroning, has a significant influence on a individuals level of awareness and value for the river environment. Therefore it can be said that the act of marron fishing promotes a high level of value for the species and the river environment. This link, is the structural foundations for using marron as a flagship for restoration of the Blackwood River.

However in light of these differences in attitudes and opinions, if marron is to be raised to the status of "Flagship" then efforts need to be directed towards educating those who are less aware of marron as a species, its history and place within the Blackwood River environment. Therefore efforts should be directed towards females, those living lower in the Middle Catchment near Bridgetown-Greenbushes, and people who do not participate in the recreation of marron fishing.

Overall the results justify that marron have the potential to fulfil flagship selection criteria 11 to 15, which pertain to the species identifiability, popularity and appeal within the community, and its ability to evoke public sympathy and a sense of community pride. All of which is compelling data for the pertinent role of marron as an icon for River Restoration.

Chapter 4

DISCUSSION

4.1 Introduction

The thesis aimed to establish whether the use of a high profile riverine species could be effective in providing the community with a clear understanding of the restoration process and its objectives, by acting as a flagship, and as a key indicator for change as the restoration becomes effective. The thesis research was based on the idea that marron was this charismatic icon and that the Blackwood River was in need of, and in fact had, the community framework essential for successful restoration.

The major objective of the research was to determine whether marron (*Cherax tenuimanus*) fulfilled the requirements of a flagship species as defined by New (1995) and Yen et al (1996). A list of selection criteria was established within Section 1.4 to critique the marron's performance as a flagship species. The following table outlines each criterion and basic conclusions drawn from the critique.

Table 4.1: Flagship criteria adapted from New (1995) and Yen et al (1996) and thesis conclusion on marron's fulfilment of each.

Chpt	Criteria	Thesis Conclusion
II	1. diverse and widespread grouping;	Yes
	2. known taxonomy;	Yes, but not at the population level
	3. localised endemism;	Yes
	4. functionally important - (keystone species);	Yes
	5. biology sufficiently known to define habitats;	Yes, but relatively poor
	6. relatively sedentary	Yes
	7. aesthetic and cultural value;	Yes
	8. economic value;	Yes
	9. indicator of habitat change: (indicator species).	Yes, but aquaculture derived data
	10. recover from a threatening process.	Yes
III	11. evoke public sympathy	Yes
	12. identifiable to the public	Yes
	13. evoke community pride	Yes
	14. aesthetic appeal	Yes
	15. popular	Yes

4.2 Scientific knowledge and ecological, cultural and economic value of marron.

As indicated within Table 4.1 and Section 2.1 of the thesis, marron belong to a relatively diverse and widespread family and genus, but as a species they are endemic to the south-west of Western Australia. This is an important feature not only to monitor provincial ecosystem health (since they are adapted to local and intrinsic physical conditions) and complimented by their sedentary nature, but also to foster local community pride.

The taxonomy of marron was identified as satisfactory to species level but in terms of wild populations further research is required similar to that conducted by Austin (1986).

Austin defined the presence of a sub-species within the distribution of wild populations. Hence, there exists the potential that other genetic differentiation exists in rivers of the south-west. This knowledge is essential if restoration requires reintroduction of marron, avoiding the genuine threat of genetic pollution as indicated in section 2.1.10.1.

Marron satisfies the role of a keystone species by representing a central component of the food web within south-west rivers. It maintains the greatest biomass within the aquatic system, feeding on a variety of habitats (omnivore, detritivore and cannibalistic), ensuring a maximum energy source to preserve the relatively large biomass. This biomass provides an abundant food source for a variety of fauna, notably cormorants, perch and humans. As a keystone species the marron functions as a host and habitat for a wide diversity of symbiotic biota. Consequently it has been identified as an important organism for conserving the biodiversity of invertebrates and their habitats (Cannon et al, 1994).

Basic biological research indicates that marron are benthic dwellers, tending to occupy broad and deep permanent water bodies. They are one of a few non-burrowing freshwater crayfish, dependent on the provision of shelter (logs, rocks and leaf litter) and permanent water, restricting them to river pools in summer, during which spawning occurs and young are left to survive in the harshest time of the year in terms of water quality. This basic biological data is primarily a product of aquacultural research, with little based on wild population structure and function. Of those studies based on wild population dynamics most are not formally published and are generally left to circulate within the academic circle.

Similar to the knowledge available on marron biology, the environmental tolerances of marron as identified within section 2.1.9 are commonly associated with aquacultural research. Nevertheless toxicological tests indicates that marron are potential indicator species for a number of key physical and chemical parameters related to natural water bodies, making a significant contribution to limited information on marron biology and their requirements for survival in the wild. The most applicable of these to wild population within the Blackwood River are salinity, organic pollutants, temperature and dissolved oxygen levels (see section 2.1.9 detailed information).

As indicated within the within Table 1.4 the thesis concludes that marron have cultural and economic value. An ideal flagship has direct significance to human affairs and the economic development of the communities. Marron support a world class amateur fishery, a leisure activity typically south-west Australian of which people from all over the world come to participate in, bring with them the tourist dollar supporting many local communities within the south-west. The marron is arguably the most easily identified aquatic animal within south-west rivers with a popularity which could rightly make it the State's aquatic emblem. In fact it was on the original logo for the Department of Fisheries and Wildlife (now Fisheries Department of WA) along with the numbat and kangaroo paw.

Aquacultural production makes up the bulk of the economic value associated with the marron. As demand continues to exceed supply the return price for a kilo of marron on the market begins at $25. This economic incentive has raised the number of prospective marron farmers and prompted concerted government, university and industrial based aquacultural research, focused on improving marron farming technologies. Admittedly, this level of value could proceed without the natural habitat of marron, but at the cost of forfeiting viable wild populations which would undoubtedly be recognised as a benefit to the future of the marron growing industry. The possibility for industry participation in the welfare of wild marron populations, provides a means of return, for the use of all genetic material available in this freshwater crayfish species.

4.3 Threats to marron survival

Before marron can recover from a threatening process as a flagship species (criterion 10), it must be established if, in fact the species is threatened. The study by Morrissy (1978b) showed a significant deterioration in the original distribution of marron down river from the Upper Catchment since 1950-60's. These results were confirmed within the marron survey (section 2.2) and reflect similar patterns of decline observed for other freshwater crayfish in Australia, such as the Murray Crayfish, now extinct from the lower reaches of the Murray River.

The study defined three processes threatening to marron, originally identified by Horwitz (1990, 1995c): the threat of genetic pollution, overfishing, and habitat and water quality degradation. However, as related by Morrissy (1978b), the latter was the most important to wild marron stocks within the Blackwood River, particularly oxygen deficiency in the bottom water of summer pools due to excessive input of organic matter from surrounding agricultural land. This accounts for the mass mortalities witnessed and attested to within anecdotal information, a local marron population limited to adults, and evidence of breeding failure originally attributed to over fishing.

The thesis confirms the presence of water column degradation within the summer pools of the Blackwood. Research and complimentary results have indicated that excessive input of nutrients and the resultant eutrophication of the naturally nutrient poor waters of the Blackwood has in fact exacerbated the natural process of diurnal stratification during summer, creating a greater chemical distinction between the pool layers in terms of temperature and oxygen availability.

During summer the deeper and more eutrophic pools become heated and thermally stratify, aggravated by turbid waters. Increasing water temperature and associated biological and chemical process, limit oxygen availability within the water column. With warm summer nights typical of the south-west the deeper eutrophic pools remain uncharacteristically stratified contributing to further deoxygenation of the hypolimnion in the absence of daylight photosynthesis.

It is this persistence which most threatens marron survival with oxygen depletion being driven by nutrient availability and a flourishing bacterial biomass in the sediment and water column increasing the biological oxygen demand of the pool. Without replenishment DO will drop below that for marron survival as indicated in section 2.3. The physiological adaptation of marron to a habitat of high oxygen availability has made them susceptible to low DO and enabled them to become an excellent indicator of degraded water quality.

The behavioural response of marron subject to such adverse environmental conditions would be to move up the bank avoiding the oxygen depleted bottom water, but as stated previously the shallower surface waters can approach temperatures exceeding 30°C the upper limit for marron survival. As identified by Morrissy (1976) the maximum surface water temperatures of 33°C-36°C occur briefly during mid-afternoon in unshaded ponds, with little inflow of water, wind and air temperature exceeding 40°C. Marron must therefore compromise between overheating and anoxia, effectively being locked out of the pool on certain days (summer) and certain times (afternoon). Extreme cases of this situation are expressed with the mass mortalities observed after summer storms (see Figure 2.14).

4.4 The potential for marron recovery

However, as aquaculture research shows this process can be reversed with a simple cool front providing lower air temperatures cooling the water body and wind for the process of holomixis. This process of water column and marron recovery can be daily with mixing occurring over night or seasonally with the flushing effect of winter rainfall. As shown in Figure 2.14 marron recovery is clearly evident following a season of high rainfall, expressed as improved catch rates. Survivors of the last bout of water column deterioration reproduce and grow during optimal environmental conditions following the flushing winter rains. The greater the rainfall during winter the better the survival the following summer. Hence, marron do have the ability to recover from a threatening process fulfilling the requirement for a flagship species (criterion 10).

The fact that marron recovery depends on the restoration of river water quality, reinforces its role as an indicator for river restoration. This restoration should be directed towards reducing the persistence of the stratification within the river pool environment. The persistence of stratification depends on the degree of shelter, shade, quantity and nature of organic input, pool depth, and a long hot summer. Encouragingly, all but the latter can be altered through positive human intervention to enhance the rate of natural recovery, to restore the water body chemically (dissolved oxygen and nutrient availability), physically (temperature) and biologically (marron).

Lessons in marron recovery for the summer pools can be learnt from the aquacultural solution to stratification and oxygen depletion within production dams. Mixing of the water column and aeration of the bottom water within the dam is ensured by using an artificial aerator, often a floating electric paddle wheel. Aeration is only required when the water temperatures are high in the late afternoon and early morning if algae is present (Marron Growers Association, 1987). Within strategic areas of the river where marron stocks are holding on (between Boyup Brook and Bridgetown) it seems reasonable to suggest the use of the relatively in-expensive aerators as a means of mixing pools when necessary.

The effect of heavy summer rainfall and organic runoff into marron farm dams has been prevented by the aquaculturalists using mesh fences or earthen banks across the front of the pool trapping organic debris during summer, but remaining open during winter to allow normal winter runoff to flush the water body. Within the Blackwood Catchment, contour banks already exist on a number of properties where the landholder has recognised the polluting effect of farm runoff. Such land management practice should be made compulsory and coordinated to ensure effectiveness, especially in the hilly areas of the catchment (Boyup Brook to Nannup).

The filtering effect of riparian vegetation is a more aesthetic means of diverting organic runoff and improving river water quality. As indicated in section 1.3.5, restoration of the riparian zone has numerous other benefits on the terrestrial and riverine systems. More importantly for marron it provides shade, regulating water temperature and light availability for algal blooms, provides instream habitat crucial for maintaining marron populations, and prevents erosion and sedimentation.

Structural restoration of the summer pools to a level suitable for marron survival could involve the mechanical removal of the black organic rich sediment, symptomatic of deoxygenated conditions. This would only be required for the deeper broader pools in the Middle Catchment since the narrower channel pools are generally flushed out when the river begins to flow during winter. The results from the section 2.3 indicate that this flushing effect is not happening to the broader deeper pools which continue to accumulate organics until the next major flood.

Following the reduction in nutrient and organic input as described above, it would be possible to control the impact of temperature on marron by dredging the pools to increase depth and habitat availability. This restoration technique could establish annual flow of the river which would sanction the self purification process typical of flowing rivers. However, in light of the temporal flow regime of the Blackwood River, typical of the longer river in the south-west and seasonal rainfall, it is preferred to avoid this level of intervention into the natural cycle of the river system since these are the conditions to which aquatic biota have adapted. The negative effects of river training has recently been observed in the Avon River.

4.5 Restoration, Flagship species and the Community perception of marron.

Restoration of the river environment for marron survival will not occur unless the community desire an improvement in the natural function of their river. It has become clear through the thesis questionnaire and oral histories that the desire exists for the original qualities of the river environment including:

- a reduction in both salinity and the occurrence of algal blooms.
- promoting a healthier river environment for primary contact activities such as swimming and fishing.
- the return of native riparian vegetation, and more importantly for marron recovery, the return of species which have disappeared from parts of the Blackwood.

Contact between an individual and the river environment via river use (e.g. marroning) or living near the river, has a significant influence on the individual's level of awareness and value for the river environment. Those who fished for marron placed greater importance on marron in the Blackwood River than those who did not. These results are the foundation for using marron as a flagship for river restoration.

The popularity of marron, its identifiability, community appeal and ability to evoke community pride was best represented within questions 19 to 21 of the questionnaire. Marron was identified as the most appropriate symbol for the Blackwood River by a majority of the sample, likewise for the most appealing and the species which evoked a sense of pride.

Considering that 84% of those sampled in the questionnaire, fished for marron (or their family) and 65% could correctly identify the species amongst other native freshwater crayfish, marron can be deemed identifiable and popular within the local community. This is all compelling data for the appropriate role of marron as an icon for river restoration, fulfilling criteria 12 to 15.

However if marron is to be raised to this status then efforts should be directed towards educating the minority within the local community who were unaware of the endemic nature of marron and the extent of their decline. This study shows that efforts should be directed towards females within the community who generally showed a lower general knowledge and appreciation for marron, compared males. It may be beneficial to link the flagship role of marron with that shown for the river gum identified within the questionnaire, of which females were most in favour of. Efforts should also be directed towards the shires in the Lower Middle Catchment since the participants from the shire of Kojonup had greater general knowledge and level of value for marron than those sampled in Boyup Brook and Bridgetown.

The thesis research confirmed the conflict identified by the oral histories, that marron fishing in dams was now more popular than the river within the Blackwood River Catchment (see table 31, section 3.2). Nevertheless this was mainly representative of respondents from Kojonup, who as outlined above had a great knowledge and value for marron as part of the river environment. The results suggest that those within the Lower Middle Catchment may in fact take for granted their ability to catch marron within the river, while residents higher up the river have had their value tested. They have lost marron from their local tributaries, which has forced them to compensate by seeding farm dams, so they can enjoy the favourite south-west Australian past-time of marron fishing without travelling for miles.

4.6 Conclusion

This research finds that marron are an appropriate flagship for the restoration of the Blackwood River, fulfilling criteria for flagship selection. In line with the thesis aim it represents a high profile riverine species, is an appealing icon for community understanding of the restoration process, returning marron to the Upper Middle catchment is the goal or endpoint of the restoration process, while improving river water quality, riparian zone function and the implementation of conservative landuse practices are the objectives. Secondly marron is a biological indicator for low dissolved oxygen levels indicative of water quality degradation. It can be used not only as an icon for the restoration process, but also to monitor for change as restoration becomes effective. Therefore it has the potential to provide a tangible direction for restoration action, and milestone for a restoration programme for all stakeholders within the Blackwood Catchment.

4.7 Recommendations

In light of the study's findings it is recommended that the pools which make up the Blackwood River during summer be mapped and monitored in terms of water quality and changes in depth.

As originally intended, time was not available during the research to conduct another marron survey and water quality profile sample in August after the river was flushed. This is a recommendation for future since it would provided an excellent comparison to the data presented on marron recovery, and confirm the degradation of the water column over summer within each pool sampled.

Research needs to be conducted on the frequency of high surface water temperatures and the presence of thermoclines with their associated conditions, which function to lock marron out of the river. In association with the profile samples it was originally intended that the biological oxygen demand (BOD) of each pool would be measured, but as investigation into the procedure progressed, the logistics of taking a representative samples with the crude equipment available has made it a recommendation for future research on oxygen depletion in summer pools.

Those pools identified within the capacity for prolonged stratification should be subject to immediate riparian rehabilitation work which endeavours to restore the natural function of the riparian zone. It was beyond the scope of this study to design a restoration program based on using marron as a flagship for the process, but this would seem the next most logical step and a recommendation for further research.

In terms of using marron as a flagship for restoration, research needs to be devoted to existing wild populations. The Fisheries Department of Western Australia needs to divert some attention away from creating the bigger, better aquacultural product, to providing baseline data on the population structure, feeding biology, reproductive and life history of marron in the wild. The knowledge on wild stock is shamefully poor considering marron has been officially recognised as important in Western Australia for over 30 years. Similarly the marron aquaculture industry must adopt part ownership in the welfare of marron, in return for the genetic material they benefit from. It is recommended that the industry promote marron and become involved in the recovery of marron populations by supplying ecological information and lobbying for effective funding.

Finally it is suggested that the Water and River Commission and Tourist Bureau of Western Australia promote the large handsome and quintessentially south-west Australian marron as the aquatic emblem of south-west rivers, whilst at the same time elevating it to a status of a flagship for the riverine conservation and restoration, most notably, for the Blackwood River.

REFERENCES

Abel, P.D.(1989). *Water pollution biology.* Ellis Horwood Limited. England.

Anon. (1988). *Sport Fishing for Marron in Western Australia: Management for the Future.* Fisheries Management Paper No. 19. W.A. Fisheries Department. April 1988. pp 1-20.

Austin, C.M. (1986). *Electrophorectic and Morphological Systematic Studies of the Genus Cherax (Decapoda: Parastacidae) in Australia.* Unpublished Ph D Thesis, The University of Western Australia.

Austin, C.M. and Knott, B. (1996). Systematics of the freshwater crayfish genus Cherax (Decapoda: Parastacidae) in Southwestern Australia: Electrophoretic; Morphological and Habitat variation. In *Australian Journal of Zoology.*

Bayly, I.A.E. and Williams, W.D. (1973). *Inland Waters and Their Ecology.* Melbourne: Longman Cheshire.

Berger, J.J (1990). *Environmental Restoration: Science and Strategies for restoring the Earth.* Island Press United States of America.

Bunn, S., and Horwitz, P. (1980). *The oxygen consumption of Cherax tenuimanus and Cherax destrustor-albidus (DECAPOCA : PARASTACIDAE) in response to temperature, salinity and oxygen concentration.* Unpublished honours thesis, University of Western Australia, Perth, Western Australia.

Burgis, M.J. and Morris, P. (1987). *The Natural History of Lakes.* Cambridge: Cambridge University Press. pp. 24-43.

Butterworth, J.E. and Carr, A.J.L. (1996). Riparian zone managementin the Middle Blackwood Catchment: A baseline study of landholders' views. Division of Water Resources Consultancy Report No 96. Australia: CSIRO.

Cairns, J., Dickenson, K.L., and Herricks, E.E. (1977). A Challenge for Action: Symposium Analysis. In: *Proceedings of the International Symposium on the Recovery and Restoration of Damaged Ecosystems.* pp 522-531. Charlottesville. University Press of Virginia.

Cannon, L.R.G. and Sewell, K.B. (1994). Symbionts and Biodiversity. *Memoirs of the Qeensland Museum.* **36** (1): 33-40. Brisbane.

Chambers, M.G. (1994). The effects of acute cadmium toxicity on marron, (*Cherax tenuimanus*). *Freshwater Crayfish 10: 209-220.*

Chapman, J. D. (1992). *Controlling Pollution in the Derwent Estuary*, Tasmania. Unpublished thesis. University of Tasmania. Hobart.

Christensen, P., Pentony, K., and Schmidt. (1981). *The Blackwood: A valley in transition.* Western Australia. Forests Department of Western Australia.

Constantine, C. (1988). *Cherax tenuimanus. Ammonia toxicity of marron.* Unpublished Honours Thesis. University of Western Australia.

Cooke, G.D.; Welch, B.B; Peterson, S.A. and Newroth, P.R. (1993). *Restoration and Management of Lakes and Reservoirs.* 2nd Ed. Lewis Publishers United States of America.

Cribb, A.(1989). The Last of the Wild Marron. *Landscope* (summer 1988-89). pp 4-8. CALM. Western Australia.

CSIRO (1992). Towards Healthy Rivers - Seeking Solutions. A report to Hon. Ros Kelly, Minister for Arts, Sport, the Environment and Territories. Consultancy Report No. 92/44.

Dept of Fisheries Western Australia. (1993). *Identifying freshwater crayfish in Western Australia.* Fisheries Department of Western Australia, Perth.

Dept of Fisheries Western Australia. (1995). *Aquaculture W.A. No2: Marron*. Fisheries Department of Western Australia, Perth.

Deschamp, P and Tognolini, J.(1983). *Questionnaire Design and Analysis*. Educational Department of Western Australia.

de Vaus, D.A. (1991). *Surveys in Social Research* (3rd Ed). Allen and Unwin. London.

de Vaus, D.A. (1995). Surveys in Social Research: 4th Edition. Australia. Allen & Unwin.

Endangered Species Advisory Committee, (1992). *An Australian national strategy for the conservation of Australian species and communities threatened with extinction*. Canberra. Australian National Parks and Wildlife Service.

Evans, L.H. and Fotedar, R.F (1996). Current status of marron farming in Western Australia. In *The marron Growers Association of Western Australia: Open Seminar, May 1996*. Aquatic science research unit. Curtin University, WA.

Fast, A. W. (1977).Artificial Aeration and Oxygenation of Lakes as a Restoration Technique. In: Cairns, J., Dickenson, K.L., and Herricks, E.E. (1977). In: *Proceedings of the International Symposium on the Recovery and Restoration of Damaged Ecosystems*. Charlottesville. University Press of Virginia.

Fisheries Department of Western Australia, (1995). *Aquaculture Western Australia*, Fisheries Bulletin No 2. Fisheries Department of Western Australia.

Geddes, M. C., Musgrove,R. J. and Campbell, N. J. H., (1993). The feasibility of re-establishing the River Murray Crayfish *Euastacus armatus*, in the lower River Murray. In: *Freshwater Crayfish* **9**: 368-79.

George, R. (1995, October 30) Bleeding landscape needs revegetation. In: *The Western Australian: Earth 2000*.

Glassner, B. and Moreno, J.D (1989). *The Qualitative - Quantitative distinction in the Social Sciences*. Kluwer Academic Publishers. Netherlands.

Golden Lion Tamarin Conservation Project (gltcp). "Golden Lion Tamarin Conservation Project." [http://www.life.umd.edu/nsc/glt.html]. June 1995.

Gore, J.A. (1985). *The Restoration of Rivers and Streams: Theories and Experiences.* United States. Butterworth, Stoneham and Mass Publishers.

Grein, S.B. (1995). *Remnant Vegetation and Natural Resources of the Blackwood River Catchment: An Atlas*. Agriculture Western Australia.

Growns, I.O. (1993). *A survey of the giant freshwater crayfish, Astacopisis gouldi Clark, to identify processes potentially threatening its populations in the Gog Range, Northern Tasmania: Final report to the Endangered Species* Unit, Australian Nature Conservation Agency. Australia. Australian Nature Conservation Agency.

Harper, D. (1992). *Eutrophication of Freshwaters: Principles, problems, and restoration*. London: Chapman and Hall.

Hey, R.D. (1996). Environmentally sensitive river engineering. In: Petts, G. and Calow, P. *River Restoration: selected extracts from the rivers handbook.* pp 80-106. London. Oxford. Blackwell Science Publishers.

Hodgkin, E.P., (1978). *Blackwood River Estuary. Report No 1*, Department of Conservation and Environment. Government Printer: Western Australia.

Hodgkin, E.P., and B.H. (1993). Fertilisers and eutrophication in in southwestern Australia: Setting the scene. In Hodgkin, E.P., and Yeates, J.S. (Ed.), *Fertiliser Research*. **36**: 95-105. Netherlands: Kluwer Academic Publishers.

Horwitz, P. (1990). *The conservation status of Australian Freshwater Crustacea.* Australian National Parks and Wildlife Services Report Series 14, 121 pp. Canberra, Australia.

Horwitz, P. (1994). An environmental critique of some freshwáter captive breeding and reintroduction programmes in Australia. In: *Reintroduction Biology of Australasian Fauna.* Surrey Beatty and Son.

Horwitz, P. (1995*a*). *A preliminary key to the species of Decapoda (Crustacea: Malacostraca) found in Australian Inland Waters: Identification Guide No 5.* Published by Cooperative Research Centre for Freshwater Ecology, Albury, New South Wales.

Horwitz, P. (1995*b*).Recreational Fishing and Translocated Species. In: *The Greener Times, (February Ed).* Published by the Conservation Council of Western Australia.

Horwitz, P. (1995*c*). The Conservation Status of Australian Freshwater Crayfish: Review and Update. *Freshwater Crayfish,* **10***:*70-80. International Association of Asteocology. Australia.

Horwitz, P. and Knott, B. (1995). The distribution and spread of the yabby *Cherax destructor* complex in Australia: speculations, hypotheses and the need for research. *Freshwater Crayfish.* **10***:* 81-91.

Horwitz, P., and Nickoll, R. (1996). Marron as a Flagship for River restoration in South-Western Australia and the role of Marron-Growing Industries. In: *Marron Growers Association: Open Seminar.* Aquatic science Research Unit, Curtin University. W.A.

JB care for the rare. "Care for the Rare - Elephant." [http://www.jandb.co.uk/care-ftr/html/elephant.htm]. 1995.

Jolliffe, F.R.(1986). *Survey Design and Analysis.* Ellis Horwood Limited. England.

Jones, C. (1996). The Redclaw Experience: Lessons for marron aquaculture. In *The marron Growers Association of Western Australia: Open Seminar, May 1996.* Aquatic science research unit. Curtin University, WA.

Kingsford, R. T., and Halse, S.A. (1996) Waterbirds as the flagship for the conservation of arid zone wetlands?. In Proceedings of the fifth Intercol: International Conference on Wetland (in press). Perth. Western Australia.

Knott, B. (1996). Parastacid Research at the Department of Zoology, The University of Western Australia. In *The marron Growers Association of Western Australia: Open Seminar, May 1996.* Aquatic science research unit. Curtin University, WA.

Lake, P.S.(1990). Streams - Ecological Structure, Degradation and Restoration. In: *Wetlands, their ecology, function, restoration and management,* by Diez, S, Wildlife Reserves, La Trobe University. Victoria.

Large, A.R.G., and Petts, G.E. (1996). Rehabilitation in River Margins. In: Petts, G. and Calow, P. *River Restoration: selected extracts from the rivers handbook.* pp106-124. London. Oxford. Blackwell Science Publishers.

Maitland, P.S. (1990). *Biology of freshwater: 2nd Edition.* USA: Chapman and Hall.

Malanson, G.P.(1993). *Riparian Landscapes.* Cambridge University Press: Great Britian.

Manes, C. (1990). *Green Rage: Radical environmentalism and the unmaking of civilisation.* Canada. Little, Brown and Company.

Marron Growers Association. (1986). The Marron Growers Association. In *Austasia Aquaculture Magazine.* Vol. 1 No5 Dec. 1986.

Marron Growers Association (1987). Marron Culture. *Austasia Aquaculture.* **6**: 12-13.

Mason, C.F. (1981). *Biology of freshwater pollution.* New York: Longman Publishications.

Masterson, S. (Vol 2, Summer Ed.1996). Historic Millions for Blackwood. In: *The Blackwood Catchment News.*

McComb, A.J., and Davis, J.A. (1993). Eutrophic waters of southwestern Australia. In Hodgkin, E.P., and Yeates, J.S. (Ed.), *Fertiliser Research.* **36**: 105-115. Netherlands: Kluwer Academic Publishers.

Miller, G.T. (1992). *An introduction to environmental science: living in the environment.* Belmont, California. Wadsworth Publishing Company.

Mills, B.J. (1989). *Australian Freshwater Crayfish: Handbook of Aquaculture.* Published by Freshwater Crayfish Aquaculture Research and Management, Tasmania. Australia.

Milner, A.M. (1996). System Recovery. In : Petts, G. and Calow, P. *River Restoration: selected extracts from the rivers handbook.* pp 205-227. London. Oxford. Blackwell Science Publishers.

Morey, J.G. (1988). *Freshwater Crayfish Survey: La Trobe River System,* Central Gippsland Region, Department of Conservation, Forest and Lands.

Morrissy, N. (1970). *Spawning of Marron, Cherax tenuimanus, Smith (Decapoda: Darastacidae), in Western Australia. Fisherises Bullitin, No 10.* Dept of Fisheries and Fauna. Western Australia.

Morrissy, N. (1974*a*). Reversed Longitudinal Salinity Profile of a major river in the South-West of Western Australia. *Australian Journal of Marine and Freshwater Research.* **25**: 327-35.

Morrissy, N. M. (1974*b*). Reversed Longitudinal Salinity Profile of a Major River in the South-west of Western Australia. In: Aust. J. mar. Freshwat. Res., **25**, 327-35.

Morrissy, N.M. (1974*c*). The ecology of marron *Cherax tenuimanus* (Smith) introduced into some farm dams near Boscabel in the Great Southern Area of the Wheatbelt Region of Western Australia. *Fish. Bull. West. Aust.*, **12,** 1-55.

Morrissy, N. (1975). The Influence of Sampling Intensity on the Catchibility of Marron, Cherax tenimanus. *Australian Journal of Marine and Freshwater Research,* **26**: 47-73.

Morrissy, N. (1976*a*). Aquaculture of Marron, Cherax tenuimanus (Smith), Part 1: Sight selection and the potential of marron for Aquaculture. *Fisheries Research Bulletin of Western Australia.* **17**(1): 1-27.

Morrissy, N.M. (1976*b*). Aquaculture of Marron, *Cherax tenuimanus* (Smith) Part 2. Breeding and Early Rearing. *Fisheries Research Bulletin of Western Australia* (W.A. Dept of Fisheries and Wildlife). **17**(1): 1-27.

Morrissy, N (1978). The Past and Present Distribution of Marron Cherax tenuimanus in Western Australia. *Fisheries Research Bulletin of Western Australia. No 22 .* Department of Fisheries and Wildlife. Western Australia.

Morrissy, N. (1979*a*). Inland (Non-estuarine) Halocline Formation in a Western Australian River. In: *Australian Journal of Marine and Freshwater Research,* **30**: 343-53.

Morrissy, N.M. (1979*b*). Experimental pond production of marron. *Cherax tenuimanus* (Smith) (Decapoda: Parasticidae). In *Aquaculture* **16**(4): 319-344.

Morrissy, N.M (1980). Production of marron in Western Australian wheatbelt dams. *Western Australian Research Laboratories Fisheries Research Bulletin* **24**:1-79.

Morrissy, N.M. (1989). *Specification of a minimum net mesh size for the recreational marron fishery.* Fisheries Research Bulletin Western Australia. **28,** 1-17.

Morrissy, N.M. (1992*a*). *A Guide to Marron Farming*. Fisheries Department of Western Australia.

Morrissy, N.M. (1992*b*). *An introduction to Marron and other Freshwater Crayfish Farming in Western Australia*. Fisheries Department of Western Australia.

Morrissy, N.M. and Caputi, N. (1981). *Use of catchability equations for population estimation of marron, Cherax tenuimanus* (Smith) (Pasastacidae). Aust. J. Mar. Freshwater Res. **32**: 213-25.

Morrissy, N.M., Caputi, N., and House, R.R. (1984). Tolerance of Marron (Cherax tenuimanus) to Hypoxia in relation to aquaculture. In Aquaculture. **41**, 61-74. Elsevier Science Publishers.

Morrissy, N. M. and Cassells, G. (1992). Spread of the introduced yabby *Cherax albidus* Clark, 1936 on Western Australia: Fisheries Research Report No 92. Fisheries department of W.A. Perth.

Morrissy, N.M., Evans, L.H., and Huner, J.V. (1990). Australian freshwater crayfish: aquaculture species. In *World Aquaculture* **21** (2): 113-122.

Morrissy, N.M., and Fellows, C.J. (1990). *The recreational marron fishery in Western Australia, summarised research statistics, 1971-1987*. Report No 87. Fisheries Department of Western Australia. Perth Western Australia.

Mulcahy, M. J. (1973). Land forms and soils of south-western Australia. *Journal of Royal Society Western Australia*. **56**: 16-22.

Murdoch, A., and Mac Knight, S.D. (1991). *Handbook of Techniques for Aquatic Sediments Sampling*. CRC Press. United States.

Nabbin, T. (1993). Introduction to River and Foreshore Management Workshops. In: *Proceedings of the Blackwood Catchment River and Foreshore Management Workshop*. Department of Agriculture Western Australia.

Nancarrow, B.E., Jorgensen, B.S. and Syme, G.J. (1995). *Stromwater management in Australia: Community perceptions, attitudes and knowledge.* Urban Water Research Association of Australia. Research report No 95, August.

National Research Council, (1992). *Restoration of Aquatic Ecosystems*. National Academy Press, Washington. D.C. United States.

Negus, T. (1995). *Blackwood Catchment - Regional Land Conservation Strategy.* Blackwood River Catchment.

New, T.R. (1995). *Introduction to Invertebrate Conservation Biology.* Oxford University Press, New York.

Newbry, R. (1993). River Rehabilitation with soft Engineering. In: *Ecology and Management of Riparian Zones in Australia*, pp 89-99. Land and Water Resources Research and Development Corporation, Canberra.

Newson, M. (1994). Hydrology and the river environment. Oxford: Oxford University Press.

O'Brien, B. (1984). *Population Characteristics and Ecological Significance of Marron - Cherax tenuimanus*. Metropolitan Water Authority Catchment Management Internal Report. Metropolitan Water Authority.

O'Brien, B. (1996). Strategies for marron culture: Single and multi-cohort populations. In *The marron Growers Association of Western Australia: Open Seminar, May 1996.* Aquatic science research unit. Curtin University, WA.

Olsen, G. and Skitmore, E. (1991). *State of the Rivers of the South West Drainage Division.* Western Australia Water Resources Council.

Parker, I. (1994). *Report on Water Quality in the Blackwood River.* Unpublished Report. Water and Rivers Commission, Perth, Western Australia.

Pen, L.J. (1993*a*). *Fringing Vegetation of the Collie and Brunswick Rivers*. Waterways Commission Report No 37.

Pen, L.J. (1993*b*). *Fringing Vegetation of the Canning, Southern and Wungong Rivers.* Swan River Trust Report No 7.

Pen, L. (1993*c*). Living streams: A guide to bringing watercourses back to life in south-west Australia. In: *Proceedings of the Blackwood river catchment River and Foreshore Management Workshop.* Western Australia. Department of Agriculture.

Pen, L.J. (1994). *Conditions of the Kalgcn River Foreshores.* Waterways Commission Report.

Pen, L.J, and Majer, K. (1993). Living Streams: A guide to bringing water courses back to life in South Western Australia. *Waterways Information, Bulletin No 7,* Waterways Commission, Western Australia.

Pen, L.J. and Potter, I.C. (1992). Seasonal and size-related changes in the diet of perch, *Perca fluviatilis*, in the shallows of an Australian river, and their impliactions for the conservation of indigenous teleosts. *Aquatic Conservation: Marin and Freshwater Ecosystems.* **2**: 243-253. John Wiley & Sons.

Petts, G. and Calow, P. (1996). The Nature of Rivers. In: *River Restoration: selected extracts from the rivers handbook.* pp. 1-7. Oxford. Blackwell Science Publishers. London.

Platt, R.B. (1977). Conference Summary. In: Cairns, J., Dickenson, K.L., and Herricks, E.E. (1977). *Proceedings of the International Symposium on the Recovery and Restoration of Damaged Ecosystems.* Charlottesville. University Press of Virginia.

Richardson, A. (unpublished). *Threatened Wildlife of Tasmania: Freshwater Crayfish: monsters and miners.* Dept. of Zoology, University of Tasmania.

Riek, E.F. (1967). The Freshwater Crayfish of Western Australia (Decapoda: Parastacidae*). Australian Journal of Zoology.* **15**: 103-21.

Ring, Ed. "Flagships of the Forest." [http://www.ecoworld. com/ adflgfor.htlm]. May 1995

Roberts, B. (1995). *The Quest for Sustainable Agriculture and Land Use.*

Ryding, S.O., and Rast, W. (1989). *The Control of Eutrophication of Lakes and Reservoirs.* Unesco, New Jersy. Paris and The Parthenon Publishing Group. pp. 37-64.

S. A Department of Fisheries. (1988). *Marron and Marron Farming in South Australia.*

Sanders, A. (1981). *Oral Histories Documenting Changes In Wheatbelt Wetlands.* Occasional Paper 2/91. Department of Conservation and Land management. Western Australia.

Saw Swee-Hock, (1990). *A Guide to Conducting Surveys.* Times Edition: Singapore.

Schorer, A. (1968), *A History of the Upper Blackwood.* South West Printing and Publishing Company. Bunbury.

Suter, P.J., and Richardson, A. M. (1977). The biology of two species of Engaeus (Decapoda: Parastacidae) in Tasmania. III. Habitat, food, associated fauna and distribution. *Aust. J. Mar. Freshw. Res.* **27**, 95-103.

Syme, G.J., Butterworth, J.E., and Nancarrow, B.E. (1993). *National Whole Catchment Management: A review and analysis of processes.* Australian Research Centre for Water in Society. CSIRO. Australia.

Terry, J.P. (1995). *National Pollutant Inventory: current water quality monitoring in the south-west high rainfall region of Western Australia.* Agriculture Western Australia.

The Senate Standing Committee, (1993). *Water Resources: Toxic algae.* Canberra: Senate Printing Unit.

Walker, K.F. (1982). The plight of the Murray Crayfish in South Australia. In *Redgum,* **6**(1),2-6.

Wallis, R. (1993). An overview of the Blackwood River: the issues, uses and importance. In *Proceedings of the Blackwood Catchment River and Foreshore Management Workshop.* Department of Agriculture Western Australia.

Western Australian Water Resources Council (1994). *River Management in Western Australia.* Western Australian Water Resources Council. Perth. Western Australia.

Wetzel, R.G. (1983). *Limnology,* (2nd Ed). Saunders College Publishing United States.

Williams, W.D. (1983). *Life in Inland Waters.* Australia: Blackwell Scientific Publications.

Williams, P. (1992). *The State of the Rivers in the South West.* Western Australian Waters Resources Council.

Wood, K. (1989). Community involvement in wetlands : The Victorian wetland trust. In: *Wetlands and their ecology, function, restoration, and management: proceedings of the Applied Ecology and Conservation Seminars Series.* Wildlife Reserves. La Trobe University. Victoria. Australia.

Wrigley, T.J., Chambers, J.M. and McComb, A.J. (1988). Nutrient and gilvin levels in waters of the coastal plain wetlands in an agricultural area of Western Australia. *Australian Journal of Marine and Freshwater Research.* **39**: 685-94.

Yeates, J.S. (1993). Soils and fertiliser use in southwester Australia. In Hodgkin, E.P., and Yeates, J.S. (Ed.), *Fertiliser Research*. **36**: 123-127 . Netherlands: Kluwer Academic Publishers.

Yen, A.L., and Butcher, R. J. (1996). *An overview of the conservation status on non-marine invertebrates in Australia.* Report to the Endangered Species Unit, Australian Nature Conservation Agency.

Appendix 1 CHARACTERISTICS OF HEALTHY RIVERS (CSIRO, 1992)

Healthy rivers:

- are unpolluted by wastes such as oils, litter and dyes, suds and foam etc and unpolluted by human faecal coliforms and other enteric bacteria and viruses.
- receive toxicants such as pesticides, metals and organic compounds, in concentrations such that there is no discernible effect on the biota;
- flow saline only during low flow, as a result of evaporation and groundwater input;
- receive and store sub-critical amounts of nutrients (especially P and N) to minimize phytoplankton and aquatic plant growth;,
- receive sufficient organic matter at the right time(s) of the year for ecosystem functioning and to minimize biochemical oxygen demand, and the death of fish and invertebrates.
- carry the minimum amount of suspended sediment to limit particulate-transported nutrients, and so phytoplankton growth (especially toxin and odour producing cyanobacteria); and limit riverbed sedimentation, in upland gravel and sandbed reaches where benthic fauna are threatened by silt and clay, and in lowland reaches where nutrients can be stored in bed deposits to be released under appropriate flow and chemical conditions;
- in humid areas are shaded by overhanging trees, contain snags, have deep pools and intervening riffles and bars, and support emergent and submerged macrophytes in mosaics: in the arid zone are fringed by vigorous vegetation;
- should contain a minimum of exotic species, both from non-Australian locations and from other Australian catchments; if present at all they should be a minor component of the ecosystem;
- receive waters from reservoirs that are not depleted in oxygen and are not rich in sulfide and manganese, and are neither too cold nor too hot for the season;
- if dammed, then only by the minimum number of structures necessary to regulate flow for human needs but retain ecologically essential elements of flow, like seasonal variability;
- if dammed, then only by structures with appropriate fishways, managed to supply flows that allow fish migration;
- are not over exploited so that populations of animals at the top of the food chain (eg fish) are viable;
- have vigorous and visually appealing vegetated riparian zones of adequate width to provide organic matter, shade and bank stability, and in which exotic species are a minor component;
- contain viable populations and communities of primary and secondary consumers that are distributed in continuous gradients along rivers;
- have floodplains and channels coupled appropriately by overbank flows which flood nutrients and sediment into wetlands, provide water to the 'dryland' floodplain vegetation, allow fish spawning and bird breeding, and are not obstructed by built structures on the floodplain.
- carry minimal sediment loads (both suspended and bedload) so that channel slope and stream power per unit area of bed are minimised;
- have well-vegetated banks to reduce sediment and nutrient supply to the river, where erosion is limited to that consistent with lateral migration and large floods
- are not constrained by artificial means from attaining new equilibria following a man-made change of flow and/or sediment regime, or from recovering after a large flood;
- do not experience excessive instream mining of sand and gravel, and so can recover quickly from mining-induced changes to their beds;
- are coupled with catchments that are managed to limit the delivery of sediment, nutrients and other contaminants;

- are not channelised;
- in humid areas contain sufficient water of an appropriate quality for both passive and active recreation, where this is an appropriate use; and for drinking;
- are managed to ensure their contribution to overall landscape beauty;
- are subject to appropriate monitoring of their health, like the regular examination recommended for humans;
- are the objects of well-conceived and targeted scientific and social research to refine our views of both the most important processes and conditions that need to be maintained, and the most appropriate ways of monitoring and improving their condition;
- are valued by those responsible for their health as rivers supporting a healthy biota, rather than drains or water supply canals.

This list should be carefully used, applying it selectively to: upland and lowland reaches; energetic gravel-bed streams; sluggish suspended load channels; streams that lose most of their water to human consumption; streams that flow free to the sea. Some of the listed characteristics of healthy streams are contradictory, and so the desirable characteristics of particular rivers or reaches of rivers need to be identified to suit the region and the intended use. It must be emphasised that healthy rivers have many features, and should be managed to maintain their diversity of physical and biological components.

Appendix 2

STATEMENT OF DISCLOSURE AND INFORMED CONSENT

Informal Interview / Oral Histories

Dear Community Member,

Thankyou for agreeing to provide time for this informal interview, which is required to complete my Honours degree within a Bachelor of Science - Environmental Management, in association with the Edith Cowan University.

Within an informal discussion environment I would like to determine your attitude and opinion (as a representative of the community), on a number of issues related to the environmental changes you have observed since becoming a member of the Blackwood River community. The following topics intend to be addressed:

- Present and historical occurrence of marron.
- Significant environmental events/changes which have occurred to the river and catchment.
- Environmental issues of concern to you.
- Your attitude towards current restoration and the potential use of marron in this process.
- Your opinion on what would be an acceptable endpoint to restoration of the river.

This will provide you, as a prominent member of the Blackwood River Catchment with an avenue to express your valid concerns to the rest of the community, and impart your knowledge which is a valuable resource to the local and scientific community.

I intend to tape the interview with your approval, so that the information you provide will be recorded effectively and enable myself to participate fully in the conversation. You will not be asked to disclose any information that you are uncomfortable with, and may remain anonymous within in the study if you request. The recorded interview will be transcribed by myself into categories of information to be used within the study. This information will be sent to you in the week following the interview for your approval.

Under no circumstance will information other than the above be used within the study. The original tape will be erased and confidentiality of information will be maintained by myself and the protocol covering thesis preservation within Edith Cowan University.

I will be more than willing to answer any questions you have in regards to the interview and the project itself:

Any questions concerning the project entitled, **"An investigation into the use of Marron (Cherax tenuimanus) as a Flagship for the Restoration of rivers in the south-west of Western Australia"** can be directed to Rachael Nickoll of the Department of Environmental Management - Edith Cowan University (Joondalup) on
'09) 400 5058 or
(09) 405 3286 (home).

Signed Agreement

I ____________________(participant) have read the information above and any questions I have asked have been answered to my satisfaction. I agree to participate in this interview, realising I may withdraw at any time.

____

Participant Date

I agree that the research data gathered for this study may be published provided
(I) I am not tape recorded ______________________________
(ii) I may be tape recorded ______________________________
(iii) I am not identifiable ______________________________
(iv) I may be identified ______________________________
Participant Signature

____

Investigator Date

Thankyou for you cooperation.

Appendix 3

Table listing the animals which were identified to have disappeared from parts of the Blackwood River, and the number and percentage of respondents to identify each in response to question 17.

Q17) Name up to 3 animals which to your knowledge have disappeared from parts of the Blackwood River?

Response	N(71)	Percent
Marron	21	30
Native Fish	11	15
Perch	5	7
Chuditch	5	7
Possum	4	6
Water rat	3	4
Freshwater mussel	3	4
Frog	3	4
Phascogale	3	4
Cobbler	3	4
Kangaroo	3	4
Gilgie	2	3
Trout	2	3
Wallaby	2	3
Turtle	2	3
Duck	2	3
Koonac	2	3
Numbat	1	1
Blue wren	1	1
Aquatic invertebrates	1	1
Swan	1	1
Lizard	1	1
Brim	1	1
Tammar	1	1
Boodie	1	1
TOTAL	84	100
Don't know / No response	129 / 213	60

Appendix 4

Table showing the species identified as appropriate symbols for the Blackwood River, and the number and percentage of participants who selected each in response to question 19.

Q19) If we are looking for a symbol for the Blackwood River which three would you consider most appropriate from this list, or you may choose your own?

Response	N(71)	Percent
Marron	51	72
River gum	43	60
Paper bark	20	28
Frog	16	22
Turtle	14	20
Cobbler	10	14
Duck	9	13
Koonac	8	11
Water lily	8	11
Gilgie	6	8
Freshwater mussel	5	7
Water rat	5	7
Perch	5	7
Cormorant	5	7
Minnow	2	3
Phascogale	1	1
Leech	1	1
Don't know	4	6
TOTAL	213	N/71