Notopala sublineata: An Endangered Snail within the Murray-Darling Basin, NSW.

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A thesis in partial fulfillment of the requirements for the Degree of Masters (Honours)

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2005

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Table of Contents..Page

List of Figures **Page**

Abstract

The introduction of flow regulation to the river systems of the Murray-Darling Basin (MDB) in southeastern Australia has caused significant alterations to the native aquatic invertebrate communities. There has been an almost complete disappearance of the freshwater molluscan diversity, particularly the viviparid snail *Notopala sublineata*. The subspecies *Notopala sublineata sublineata* is assumed to be extinct in the wild and *Notopala sublineata hanleyi* is surviving solely in an irrigation pipeline off the lower Murray River in South Australia. This thesis examines the macroinvertebrate communities of the littoral zone from river sections along the Murray, the Murrumbidgee, the Namoi, the Upper Barwon-Darling and the Lower Darling rivers. The goal of these surveys was to detail the macroinvertebrate assemblages, specifically the molluscan diversity, surviving within the rivers and irrigation structures and ultimately to determine the current distribution and conservation status of *Notopala sublineata sublineata* and *Notopala sublineata hanleyi*. The macroinvertebrates collected during these surveys indicate a shift in the aquatic invertebrate community from taxon found in lotic systems to invertebrates that show a preference to lentic systems. The results also support reports that there has been a severe decline in the molluscan diversity, with a total of only eight species collected, of which only three species occurred within the river channels. The results also indicate a complete loss of both *Notopala sublineata* subspecies from the rivers of the MDB, increasing the possibility that *Notopala sublineata sublineata* is extinct. A living population of *Notopala sublineata hanleyi* was discovered, however, in the Western Murray Irrigation pipeline off the Murray River in NSW. This surviving population now provides an opportunity for breeding and rehabilitation projects in NSW. Although individual attention needs to be paid towards *Notopala sublineata,*

the listing of Endangered Ecological Communities and the establishment of subsequent recovery programs for those communities is the best option for the conservation of the aquatic macroinvertebrates of the MDB.

Declaration

To the best of my knowledge this thesis does not contain material previously published by another person except where due reference or acknowledgement is made and contains no material which has been submitted for the award of any other degree or diploma in any university or institution.

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6/2/2006

Chapter 1 Introduction

Why is it important to conserve biodiversity? Is the loss of a single species or a reduction in species diversity necessarily disturbing as there are millions of species still extant in the wild? Does this mean there is a level of species redundancy within an ecosystem? These philosophical questions beg the broader question of whether mankind has enough knowledge to be able to identify if any species are expendable at all. Most ecologists would answer "No" – this information is not known. Yet, humankind continues to over-utilise natural resources, altering and damaging sensitive ecosystems, in many cases irreversibly. This is a major concern considering that species are continuing to go extinct and the information regarding the role of biodiversity in the maintenance of the systems that human civilization relies upon is lost along with these taxon.

The regulation of the world's rivers has had many impacts on the natural processes of riverine systems, such as increased sediment loads, increased turbidity, alterations to river morphology and substantial modification to temporal and spatial flow variability. This has resulted in major and usually irreversible changes to the biological assemblages that depend on these river systems. It has been suggested that the main impact that has caused the reductions in numbers and diversity of the natural macroinvertebrates has been the reduction in the level of heterogeneity in flow regimes of the aquatic systems (e.g. Harper *et al,* 1999; Cortes *et al,* 2002). This has caused an alteration to food availability, mainly for grazers (e.g. Collier, 2002), and a reduction in the complexity of habitats available for macroinvertebrates (e.g. Aarts *et al,* 2004; Harper *et al,* 1999; Cortes *et al,* 2002;

Usseglio-Polatera and Beisel, 2002). A more complex habitat within a system tends to support a greater taxa diversity (Harper *et al,* 1999; Sheldon and Walker, 1998; Thoms and Sheldon, 2000; Walker *et al,* 1995). In turn, if variability is lost, the level of species diversity is also reduced. This is particularly relevant to Australia's Murray-Darling Basin, which historically had one of the most variable flow regimes in the world (Finlayson and McMahon, 1988; Maheshwari *et al,* 1995; Puckridge *et al,* 1998; Thoms and Sheldon, 2000).

This project aims to highlight the issues involved with the alteration of river ecosystems within Australia's Murray-Darling Basin (MDB), particularly since the time of irrigation development. More specifically, this project aims to identify some of the alterations that have occurred in the macroinvertebrate assemblages within the inland rivers of NSW, using the freshwater river snail, *Notopala sublineata,* as an example of the serious declines in the distribution of aquatic species. Although there is limited information on the natural invertebrate assemblages of the systems in the MDB, there have been reports detailing declines in selected invertebrate groups as well as a greater distribution and abundance in others as a response to the now more lentic aquatic environments (Blanch and Walker, 1998; Sheldon and Walker, 1998; Walker *et al,* 1994; Young, 2001). Crustaceans have shown a marked increase in numbers (Bennison *et al,* 1989; Boulton and Lloyd, 1991; Sheldon and Walker, 1998; Young *et al,* 2001) whereas insects have declined (Bennison *et al,* 1989), along with an almost complete disappearance of the native molluscan diversity (Bennison *et al,* 1989; Boulton and Lloyd, 1991; Evans, 1981; Farnham, 1980; Jenkins, 1991; Lloyd *et al,* 1990; Sheldon and Walker, 1993a,b; Smith, 1978; Thompson, 1986; Walker *et al,* 1992). Molluscs throughout the world have suffered more documented extinctions than any other taxon (IUCN, 2004) and yet continue to be excluded from conservation initiatives (Ponder, 1997).

The study sites for the field surveys undertaken during this project were selected based on the desire to substantiate reports that a viviparid river snail species, *Notopala sublineata*, was virtually extinct within natural habitats of the MDB, but that remnant populations might exist in highly modified irrigation systems (e.g. Fishnote, 2002a; W. Ponder *pers. comm.*; F. Sheldon, *pers. comm.*; Sheldon and Walker, 1997; Sheldon and Walker, 1993a,b; Walker, 1996; Wishart, 1994). It has been hypothesised that the disappearance of *Notopala sublineata* has been caused mainly by the alteration in the composition of the snail's main food source, benthic biofilm. River regulation has created artificial lentic environments that retard bacterial growth and promote algal growth. Algae is a food resource that cannot be utilized by *Notopala sublineata* (Sheldon and Walker, 1997).

This thesis contains general descriptions of the macroinvertebrate communities within sites that were selected primarily with the goal of discovering *Notopala sublineata*'s current distribution. In addition, it aims to test the findings from previous studies that have shown a reduction in the level of protein in biofilm within the rivers of the MDB. The lack of any populations of the snails within the rivers and the generally low molluscan diversity provides the impetus for delving further into the conservation options for *Notopala sublineata* and the macroinvertebrate communities of these aquatic systems.

Invertebrates as a group have a low priority in conservation measures, both within Australia and globally, even though they are the foundation of a functioning ecosystem (Council of Europe, 1987). This is primarily due to the difficulties in creating empathy from the public towards invertebrates, limiting the interest in the political arena to legislate for invertebrate conservation. Even if scientific research has been conducted on an assemblage of invertebrates or a single species to determine whether it is threatened, current legislation in Australia is geared towards the protection of vertebrates, with biological and ecological criteria often inappropriate for invertebrates. The future protection of *Notopala sublineata* highlights these legislative shortcomings and also the issue of threatened species management on private land, especially when the threatened species is considered a pest to industry groups. In this study, the discovery of the first population of *Notopala sublineata hanleyi* found in NSW since 1971 in an irrigation pipeline provides an excellent opportunity for government agencies to begin breeding programs and rehabilitation projects for this subspecies. This is especially so considering past attempts at breeding these snails in the wild has not been successful in creating self-sustainable populations (K. Walker, *pers. comm.*; B. Weir *pers. comm.*). A key focus of this project, therefore, is to determine the conservation status of *Notopala sublineata* in NSW and provide recommendations for the future rehabilitation of *Notopala sublineata* in conjunction with the protection and rehabilitation of the broader macroinvertebrate communities of the lowland rivers of the Murray-Darling Basin.

Chapter 2 The Murray-Darling Basin

2.1 A historical review

The Murray-Darling Basin (MDB) contains one of the largest river systems on the planet. The basin spreads over 4 states - Queensland, New South Wales, Victoria and South Australia, and drains from the Great-Diving Range in south-eastern Australia, covering 1.073×10^6 km^2, 19% of the total landmass of Australia (Walker and Thoms, 1993). The principal rivers, the Murray and the Darling, have a combined length of 5500 km (Walker *et al*, 1992; Walker and Thoms, 1993). The Darling River drains the northern section of the basin and the main tributaries include the Macquarie, Castlereagh, Namoi, Gwydir and MacIntyre rivers (MDBC, 1999). The Murray River, however, drains the lower eastern regions, receiving flows from the Murrumbidgee, Lachlan and Goulburn before the Darling confluence. The Lower Murray consists of the region of the Murray River after the Darling confluence and receives no major tributaries (Maheshwari *et al*, 1995, Walker *et al*, 1992).

Eighty three percent of the basin's rivers have been described as lowland rivers, i.e. "reaches of river below 300m altitude from inland systems and between 40m altitude and the tidal limit for coastal systems" (Harris and Gehrke, 1997; Thoms and Sheldon, 2000). Australian lowland rivers are unique because they do not conform to the "standard" contemporary river models (Lake *et al*, 1987; Thoms and Sheldon, 2000; Williams, 1988), as they show large variability in longitudinal structure and function (Thoms and Walker, 1992; Thoms and Sheldon, 2000).

Not only is the geomorphology of the MDB's lowland rivers variable, but also the flows within the system are considered some of the most variable in the world (Finlayson and McMahon, 1988; Maheshwari *et al*, 1995; Puckridge *et al*, 1998; Thoms and Sheldon, 2000). Although the primary rivers are long, they have a comparatively low combined annual discharge of 10035 gigalitres (Gl) (Walker and Thoms, 1993). Most of the discharge occurs near the source of the Murray with the Darling contributing only 10% (Walker, 1992; Walker and Thoms 1993). The Murray is fed by high catchment precipitation in the winter, whereas the Darling is fed by unreliable summer monsoons (Maheshwari *et al*, 1995; Walker *et al*, 1992). Further, 90% of the basin is described as arid to semiarid land (Maheshwari *et al*, 1995; Thoms and Sheldon, 2000; Walker and Thoms, 1993). The rivers that flow through these lands receive very little run-off and experience large-scale water losses through evaporation, evapotranspiration and groundwater recharge (Thoms and Sheldon, 2000). The combination of these factors have created some of the most spatially and temporally variable flows in the world (Finlayson and McMahon, 1988; Maheshwari *et al*, 1995; Puckridge *et al*, 1998; Thoms and Sheldon, 2000). Even though the water availability in the basin is low and unreliable, the basin supports agricultural and domestic water demands. In the recent past, river impoundments, diversions and storages were installed to answer the ever-increasing demands for water.

2.2 History of river regulation in the MDB

Historically, the growing demand for water for agriculture, particularly from rice irrigators and cotton farmers, pressured river managers into more intense river regulation. These industries began 70-80 yrs ago, and with them the river underwent drastic flow regulation. Between 1920 and 1940, 13 low level, 3m high weirs with lock chambers were installed along the Murray, ten of which were along the Lower Murray River (Maheshwari *et al*, 1995; Walker and Thoms, 1993). The high level weir at Yarrawonga was completed by 1939 (Maheshwari *et al*, 1995) and by 1940 the Murray mouth was fitted with barrages. Dam construction was mainly on the tributaries and this ultimately controlled the water in the main rivers. The Hume Dam was constructed between 1919 to 1931 and its capacities were increased around the 1950s (Close, 1990; Walker and Thoms, 1993) and then again in 1961 in response to growing demands by farmers (Maheshwari *et al*, 1995). The Eildon dam on the Goulburn was built between 1914-1928 and increased between 1951-1956. The Dartmouth Dam on the Mitta Mitta was completed by 1979 (Walker and Thoms, 1993). The Murray and the Murrumbidgee flows were increased by diversions from the Snowy Mountain Hydroelectric Scheme between 1955 and1974 (Maheshwari *et al*, 1995). Finally, the Darling River flows were regulated with the Menindee Lakes Storage construction in 1968. The Lake Victoria storage off the Darling River now transports water from the Darling directly into the Lower Murray River during the irrigation season (Walker and Thoms, 1993).

2.3 The resources of the Murray-Darling Basin

The diversions and impoundments along the rivers were implemented for the supply of water to the surrounding areas. Over 20 major rivers support and supply freshwater for domestic consumption, agricultural production and industry (Blackmore and Connell, 1997). The 1996 Census estimated the Murray-Darling Basin population to be 1,956,765, 10.94 % of the total population of Australia (MDBC, 2004). The Basin supports 1/4 of our nation's cattle production, 1/2 of the sheep industry and 3/4 of the irrigated lands in Australia (Blackmore and Connell, 1997). Indeed the MDB accounts for a huge amount of Australia's income. In 1993-94 the agricultural industry of the MDB, valued at $9.4 bill/yr, provided 40% of the nation's GNP (Blackmore and Connell, 1997). Irrigation alone contributed $3 billion/yr in 1993-94 (Blackmore and Connell, 1997).

Tourism is also a vital industry within Australia and has been steadily growing within the MDB. For example, in 1993-94 the Bureau of Tourism Research estimated the tourism industry of the MDB earnt $3.44 billion, $676 million from tourism in the NSW and Victorian sections of the Murray (BTR, 1994).

However, the rewards for the use of resources from the MDB have not been without costs, many of which have only recently been discovered. The native flora and fauna have borne the cost of such intense utilisation of the water resources. There have been many impacts of flow regulation on the river system and its biodiversity.

2.4 Impacts of flow regulation on the natural variability of flow and flood frequency.

The MDB contains rivers that have highly variable flows, both spatially and temporally. The natural river channel, biodiversity in and surrounding the river system, and river health, are all maintained by this variability. Within semiarid landscapes extreme water losses cause a less predictable temporal and spatial variation, which means the magnitude of flow is especially important (e.g. Beckinsale, 1969; Poff and Ward, 1989; Walker and Thoms, 1993). The level of variability within a river system is often reflected by the complexity of in-stream habitats and biodiversity. Increased flow variability is usually associated with an increase in in-stream biotic complexity (Thoms and Sheldon, 2000; Walker *et al*, 1995).

2.4.1 Temporal variation

Temporal variation, or variation between periods of time, is vital for ecosystem structure and is a key feature in dryland river systems (McMahon *et al*, 1974). Instream ecosystems are often highly adapted and reliant on seasonal and annual flows. Often such flows are cues to initiate reproductive and life cycles of instream biodiversity such as the spawning of native fish species (Cadwaller and Lawrence, 1990; Lloyd and Walker, 1986; Pierce, 1989; Puckridge and Walker, 1990; Walker, 1983; Walker *et al*, 1992). Yet the seasonal demand of water for irrigation has created a regime that has reversed the natural seasonal flow (Maheshwari *et al*, 1995; Walker *et al*, 1992). For example, major flows in the Upper Murray occur during the high precipitation in winter and spring (Walker *et al*, 1992). Dam construction and water diversions now ensure a steady flow of water during the summer season when the natural system would be experiencing low flows or even cessation of flow.

2.4.2 Spatial variation

Spatial variation, or the magnitude of a flow, is the amount of water passing through a particular point in the river system. This is especially important in lowland rivers as there is usually a floodplain associated with the river, dependent on over bank flows to sustain the wetland communities. The Murray River has a floodplain community of wetlands and forests reaching 1-20 km adjacent to the main river channel (Dexter *et al*, 1986; Pressey, 1986; Walker *et al*, 1992). The southern section of the Darling has a 10m channel depth compared with the relatively shallow Murray and a natural discharge too low to sustain a floodplain community (Walker *et al*, 1992). The northern sections of the Darling near Bourke, however, do experience flooding. Flow magnitude is still important in the Darling as water level variability sustains instream habitats such as snags (Thoms *et al*, 1996). Thomson (1992) reviewed the magnitude of natural and regulated flows of the Upper Murray River during 1930-1991. The result of regulation, including an extra 300Gl of annual water diversion in 1991 (Maheshwari *et al*, 1995), led to a marked reduction in the number of midrange flows. The resulting regime was dominated by 'very low' flows that were occasionally punctuated with high flows (Maheshwari *et al*, 1995).

Such alterations were also recorded within the Lower Murray River. Despite enormous impoundments such as weirs and dams along the river, there were still variable flows (Close, 1990; Walker and Thoms, 1993). As with the Upper Murray, major flood events still occur but without the smaller floods. Before regulation, flow sizes of 100-300 Gl would have accounted for 60% of all flows, yet under regulated conditions such flows represent only 13% of all flows (Close, 1990; Walker and Thoms, 1993). Additionally, weir construction along the Lower Murray has resulted in artificial pooling waterbodies, extending 28-92 km upstream of each weir. Weir operations ensure the pools are maintained at a minimum level during winter, which reduces water level variability and prevents natural overbank flows. This process mimics drought conditions, as floodplain communities are isolated from the river channel overflow (Walker and Thoms, 1993). In contrast, during the irrigation season, which is the natural drought season, the water levels in the rivers and weir pools are kept at a maximum. Any considerable precipitation event throughout this period results in an overbank flow inundating surrounding communities. This causes considerable problems for native species that are opportunistic in response to flooding and may not be able to survive the drought conditions once released from a drought resistant stage.

The Darling River also has had many alterations to its natural flood frequencies. Annual floods at Bourke, along the Barwon-Darling River, were reported to have been reduced in frequency by 44% (Thoms *et al*, 1996). Such alterations change the structural complexity of instream communities that rely upon floods for habitat colonisation, e.g. upper photic regions on snags. The reduction of flood frequency has also reduced the inundation of downstream floodplain and wetland inundation by 33% (Thoms *et al*, 1996).

2.5 Impacts of flow regulation on river morphology and sediment transfer

2.5.1 Morphology

Flow variability is also vital for the maintenance of channel morphology. Flow velocity and turbulence are key forces that drive channel morphology. The Murray River has a low gradient, creating instream power typical for carving a meandering river system (Ferguson, 1981; Walker *et al*, 1992). The riverbeds of the Barwon-Darling and Murray historically consisted of a complex series of 'benches'. The benches reflected the adjustment of the riverbed to large floods (Graf, 1987; Thoms and Walker in press b; Walker *et al*, 1992; Walker and Thoms, 1993). The benches also provided an instream structure for organic matter accumulation during periods of low flows. It seems the reduction of natural flow variability has severely degraded these benches. For example, weir construction in the Lower Murray River has created long weir pools that stabilise the water. The lack of flood disturbances has halted the maintenance of the instream riverbed complexity (Walker *et al*, 1992). The result has been an almost complete disappearance of these benches with the deposition of the riverbed sediment behind the weir (Walker *et al*, 1992).

2.5.2 Sediment Transfer

River regulation has significantly impacted sediment load transport (Thoms and Walker in press a; Walker *et al*, 1992), degrading the natural river morphology (Walker, 1985). Some consider that the increase in sediment inputs and resulting turbidity into the rivers of the MDB have had the greatest ecological impacts (Young *et al*, 2001).

(a) Bank erosion

Water levels within the pre-regulated MDB would have been very variable. The sediments of the banks, 12-41% silt and clay along the lower Murray River for example (Walker *et al*, 1992), and riparian vegetation maintained a structurally sound riverbank. The stabilisation of water levels have initiated rapid and large bank falls (Walker *et al*, 1992). It has been suggested that such conditions "undermine the toe of the bank so (*it is*) vulnerable to large falls" (Walker *et al*, 1992). Compounding this problem is the increased clearing of land for agricultural and irrigation development, and animals such as cattle and rabbits destroying riverbanks (Young *et al*, 2001). The result has been rapidly increasing bank erosion and an increased bank slope devoid of riparian or littoral vegetation (Thorne and Tovey, 1980; Walker *et al*, 1992).

Such a marked increase in bank erosion has caused a rapid increase in the amount of sediment being transported within the river. Studies conducted by Wallbrink *et al (1998)* have illustrated that the majority of sediment found in the Murrumbidgee is subsurface material from eroded gullies and stream banks in the middle catchment. This highlights the impacts that land management practices have on the river system.

(b) Turbidity

Erosion throughout the entire basin has caused steady increases in the level of turbidity within the rivers. The Darling River, for example, is naturally laden with fine clay suspensoids (Walker *et al*, 1992; Woodyer, 1978). The Murray is considerably clearer. The Lower River Murray has a considerably higher turbidity level now than in pre-regulated times, primarily due to the water diversions from Lake Victoria off the Darling River, though erosion would be partly responsible. In the past the lower Murray was pumped with a 5:2 mix of Darling and Upper Murray water (Woodyer, 1978), yet over the past 5 years the lower Murray has received an average 4:1 mix of Darling and Upper Murray water during the irrigation season (D. Green *pers. comm.* MDBC, 2005). The result of these diversions has been a drastically increased level of turbidity in the naturally clearer lower Murray (Walker *et al*, 1992).

Channel complexity, flow variability and oscillating water levels have historically maintained in-stream complexity to provide habitats for macroinvertebrates (Pringle *et al*, 1988). The result of alterations to these river characteristics has been a marked impact on the native biodiversity of the MDB.

2.6 Aquatic habitats in the MDB

The main aquatic environments throughout the Murray-Darling Basin include the river channels, the major tributaries and the associated floodplain and billabong systems (Smith, 1978). In the upper reaches of the rivers the flow is high, bed slope gradient steep, higher dissolved oxygen levels and lower turbidity levels (Smith *et al*, 1977; Smith, 1978). In areas such as these, there are usually no aquatic macrophytes and the benthic habitats are found only between stones and within fine sediment (Smith, 1978). As the river slope decreases downstream, the flow velocity decreases, carving a meandering river morphology. Here, the turbidity increases, reducing the depth of light penetration and hence reducing the capacity for aquatic flora to colonise anything other than sections of the river which now have narrower photic zones. The channel width increases in lowland rivers causing periodic flooding of surrounding plains. Snags were typically common in this area as floods wash dead trees into the channels (Lloyd *et al*, 1990; Walker *et al*, 1992), but most snags have since been removed. Following the development of extensive irrigation and crop diversification on surrounding floodplains, such periodic floods cause a decline in water quality due to the leaching of nutrients and salts back into the river systems (Smith, 1978).

These river channel characteristics govern in-stream habitat complexity and the macroinvertebrate assemblages that colonise them. A study on the spatial distributions of littoral invertebrates (Sheldon and Walker, 1998) discovered that different hydrological and geomorphic factors governed habitat structure at three different scales of the river system, i.e. macro-, meso- and micro-scales. Macro-habitats include the 'morphodynamic zones' of the major floodplain rivers and the basin-sized patterns of flow velocity and sedimentation governed these structures (Sheldon and Walker, 1998; Zwolinski, 1992). Meso-habitats include backwaters, billabongs, anabranches, the main channel and the associated floodplain (Boulton and Lloyd, 1991; Lloyd and Walker, 1986; Sheldon and Walker, 1998). Micro-habitats include emergent and submergent vegetation, submerged wood and other substrata (Boulton and Lloyd, 1991; Lloyd and Walker, 1986; Sheldon and Walker, 1998). As with many ecosystems, the structural complexity at the lower scales (i.e. meso- and microscales) is governed by the complexity of the habitat at the macroscale. For example, flow velocity and magnitude at the macroscale determines whether a mesohabitat contains either lentic or lotic aquatic environments. Habitat diversity between these environments varies significantly with a highly diverse lentic mesohabitat and a comparably bare lotic mesohabitat (Sheldon and Walker, 1998). Furthermore, microscale macroinvertebrate assemblage complexity has been found to be proportional to habitat complexity (Boulton and Lloyd 1991; Cyr and Downing 1988; Minshall, 1984; Sheldon and Walker, 1998). A study conducted by O'Connor (1992) discovered that snags with a greater structural complexity contained a more diverse assemblage of macroinvertebrates. Therefore, habitats such as bare littoral zones would be relatively devoid of fauna (Cyr and Downing 1988). Further availability of habitats at the meso- and microscales is dependent on the processes at the macroscale. In turn, any alterations at these larger scales have significant cascading impacts on the smaller scale habitats.

2.7 Impacts of river regulation on aquatic flora and fauna

Since intensive river regulation began over 70 yrs ago there has been a steady decline in the range and abundance of aquatic flora and fauna (Thoms and Walker, 1989; Walker and Thoms, 1993). Aquatic flora and fauna must now cope with environmental modifications such as alienation of wetlands, water level stabilisation, increased turbidity and salinity, pollution and competition from introduced species such as carp (Walker and Thoms, 1993). Habitats have been altered at different scales. At the mesoscale, flow regimes have been altered from a predominantly lotic flow pattern to the now stable lentic environment. At the microscale, regulation has been found to promote some microhabitats at the expense of others (Armitage and Pardo, 1995; Sheldon and Walker, 1998)

2.7.1 Change to littoral habitats

Regulation has promoted the microhabitat of aquatic vegetation. Photographs taken of the Murray River before the weir construction in the 1920s show the river channel bare of vegetation (Walker and Thoms, 1993). The main concentration of biodiversity was found in the littoral zone, i.e. the boundary between the riparian vegetation and the usually sterile channel centre (Walker, 1992; Walker and Thoms, 1993). Historically, high turbidities and strong currents would have limited plant growth, but stable pools have resulted following weir construction. These artificial lentic environments now promote the invasion of the river channel by submergent and emergent vegetation (Blanch and Walker, 1998; Sheldon and Walker, 1998; Walker *et al*, 1994). Such alterations have major implications for the distributions of aquatic fauna. The alteration of food availability has promoted species such as shrimp and prawns that can utilise the invading plants as a food resource (Boulton and Lloyd 1991; Sheldon and Walker, 1998; Young *et al*, 2001). Weir pools have also favoured species that were formerly in floodplain wetlands (Walker and Thoms, 1993). Weir pools also prevent disturbances, limiting the diversity of in-stream aquatic biota and habitat diversity (Humphries and Lake, 2000; Thoms and Sheldon, 2000). Habitats have also been reduced through snag removal, bank slumping, loss of littoral vegetation and changes to the substratum (Young, 2001). Snags in the past were deliberately removed to allow for safe and easier passages for water transportation (Young, 2001). Unfortunately such practices continue today despite being banned or discouraged in most parts of the MDB.

2.7.2 Decline in fish populations

There have been many reports of the severe decline in native fish populations in the MDB (Cadwaller and Lawrence, 1990; Lloyd and Walker, 1986; Pierce, 1989; Puckridge and Walker, 1990; Walker, 1983; Walker and Thoms, 1993). One explanation for the decline is the reduction in flood frequency (Maheshwari *et al*, 1995; Walker and Thoms, 1993). "Major floods promote large scale recruitment among many species which remains the same even under regulated regime" (Maheshwari *et al*, 1995). Smaller floods maintain population numbers with lower levels of recruitment. It is the absence of the smaller flood frequency that could reduce fish numbers to levels that cannot then respond to major floods by increasing their recruitment (Maheshwari *et al*, 1995). Weir construction and water storage limit the dispersal ability of some fish larvae (Maheshwari *et al*, 1995).

2.7.3 Changes in macroinvertebrate communities

Macroinvertebrates within the MDB lowland rivers have shown significant declines in population numbers and abundance. It is unlikely that flow velocity has directly influenced the alteration of the macroinvertebrate communities as the natural velocity of the lowland rivers is low (Young, 2001). It is more likely that the reduced habitat diversity caused by river regulation has initiated the decline (Young, 2001).

It is difficult to quantify these declines due to a lack of historical data. There have been macroinvertebrate surveys conducted on several rivers of the MDB, mainly the Murray. The Darling, however, has had comparatively very little research conducted on its macroinvertebrate communities. Bennison *et al* (1989) surveyed the Murray River from 1980-1985. At the macro-scale, Bennison found different macroinvertebrate communities along the river. From the Hume dam to the Yarrawonga Weir the macroinvertebrates were low in diversity and abundance. From the middle reaches to Lock 9 there was an increase in diversity and abundance of midges and stoneflies, replacing the once dominant mayflies (Young, 2001; Bennison *et al,* 1989). The lower Murray River showed a proportionate decline in the number of insects and an increase in the number of crustaceans. Further, it seems that, with the increase in crustaceans has come the disappearance of many gastropod species. During Bennison's survey there were 6 gastropod species collected: *Glyptophysa cosmeta; Gyraulis meridionalis; Posticobia sp.; P. balonnensis; V. sublineata;* and *Potamopygrus niger.* Yet, collections from Aboriginal shell middens show 15 gastropod species were common within the Lower Murray River before river regulation, all of which are now rare (Smith, 1978; Walker *et* *al*, 1992). Only two gastropod species are still collected but in small numbers: *Ferrissia petterdi* and an introduced snail *Physa acuta*. These two species were found to be common along the Lower Darling (Sheldon and Walker, 1993a). It has been suggested that a possible reason for the survival of the introduced *Physa acuta* is its ability to float, increasing its dispersal capacity in the now lentic environment which has limited the dispersal opportunities for mollusc species such as viviparids which give birth to live young (Walker *et al*, 1992).

One of these declines in gastropod species from the lower MDB has been the near extinction of the river snail *Notopala sublineata*. The plight of this snail is used as a case study within the context of my research. First, I review the information available for *Notopala sublineata* (Chapter 3). Then I present the results of five surveys designed to examine the invertebrate assemblages present in areas where *Notopala sublineata* historically occurred in natural riverine habitats or in irrigation systems where they have been found (in South Australia) in recent times (Chapter 4). Based on my data and other published information, I then consider the framework (Chapter 5) and the techniques (Chapter 6) which are available to conserve this particular species and other endangered aquatic invertebrates.

Chapter 3 *Notopala sublineata*

3.1 Taxonomy and distribution

The genus *Notopala* is part of the family Viviparidae which consists of medium to large prosobranch snails that occur in both lotic and lentic environments (Browne, 1978; Sheldon and Walker, 1993a). *Notopala* is viviparous which limits juvenile dispersal abilities (Smith and Kershaw, 1979). A study on the shell variation of *Notopala* has suggested 4 species in this genus; *Notopala waterhousii, Notopala sublineata, Notopala essingtonensis* and an as yet undescribed "banded" species (Sheldon and Walker, 1993a). *Notopala sublineata* was first described by Cotton (1935a; 1935b) and is endemic to south-eastern Australia (Smith and Kershaw, 1979). Once thought to be all one species, *Notopala sublineata* has since been divided into three subspecies: *Notopala sublineata sublineata, Notopala sublineata hanleyi* and *Notopala sublineata alisoni* (Fishnote, 2002a). There is still uncertainty about the taxonomy and distribution of the subspecies of *N. sublineata* (Sheldon and Walker, 1993a). *Notopala* species are most prevalent in the north of Australia, where *N. waterhousii* inhabits ephemeral waters and *N. essingtonensis* is found in persistent water-bodies in the same region (Walker, 1996). *N. sublineata sublineata* (*N.s.s.*) was formerly found in northern sections of the MDB, primarily the Darling River and its tributaries, but is now thought to be extinct (W. Ponder *pers. comm.*; Fishnote, 2002a; Walker, 1996). *N. sublineata hanleyi* (*N.s.h.*) formerly had a range covering the lower Murray-Darling river systems, yet is now thought to be extinct in the natural environment. Figure 1 displays the past and present distributions of these two subspecies. The species distribution has been calibrated from collections at the Australian Museum. This collection however shows that there has not been a live specimen found in the wild since the early 1970s (Winston Ponder, Australian Museum Data). There was anecdotal evidence collected during this survey that the snails were in the river approximately 30 years ago from local farmers along the Murray. There is, however, now no evidence to suggest that the snails are still remaining within these sections of the rivers. *N. sublineata alisoni* is thought to have a wide distribution in the northern inland and coastal drainages outside NSW (W. Ponder *pers. comm.*; Fishnote, 2002a).

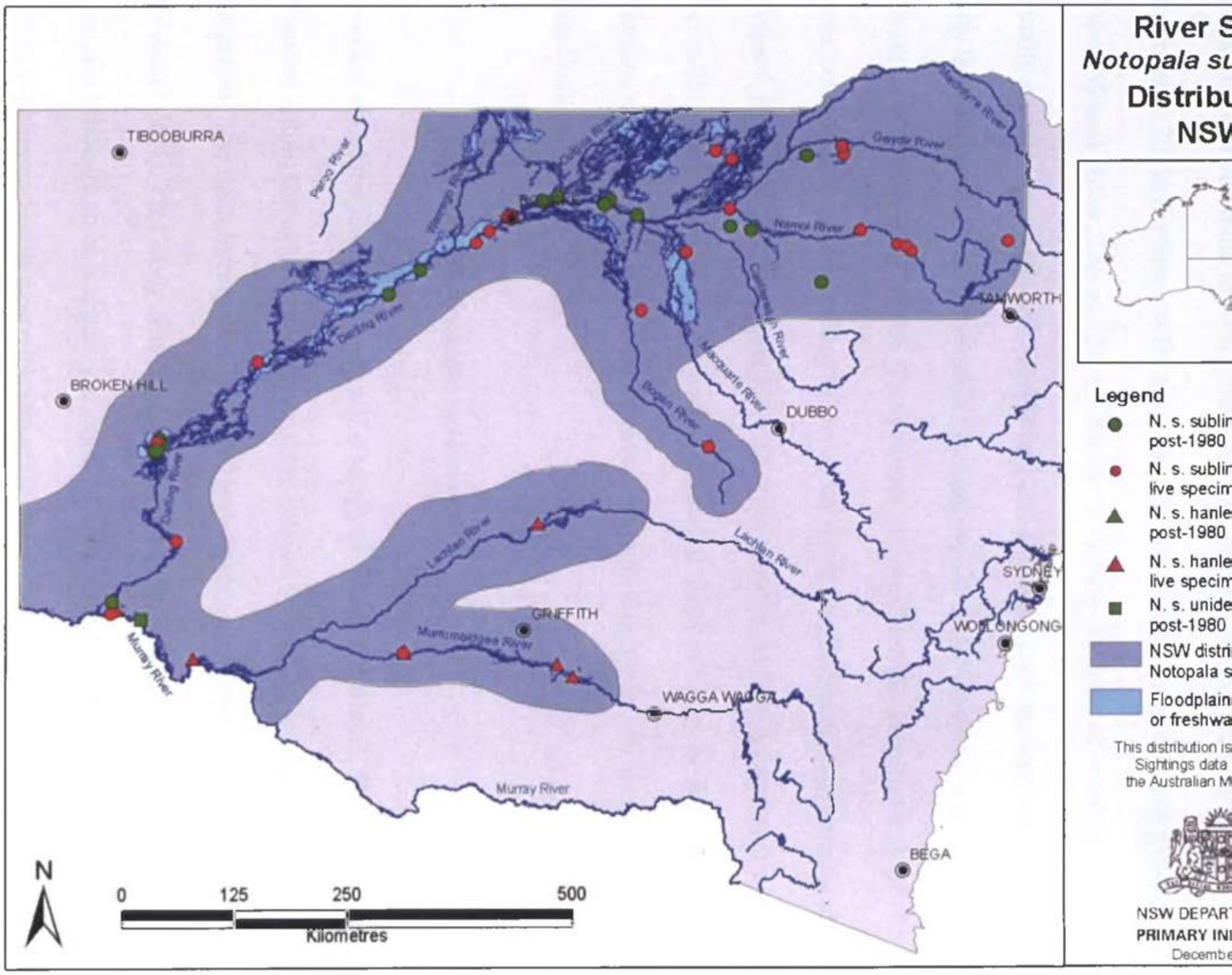


Figure 1 Historical distribution of *Notopala sublineata* (*Notopala sublineata sublineata* and *Notopala sublineata hanleyi*) in NSW

3.2 The Pipeline Discovery

The recent resurgence of interest in this supposed extinct species is due to the surprising discovery of a population of *Notopala sublineata hanleyi* in an irrigation pipeline near Barmera in South Australia in 1992 (Sheldon and Walker, 1993b). The pipes are approximately 2m in diameter, fully enclosed, and fed directly from off-take pipes from the lower Murray River. The accidental discovery by Fran Sheldon of Adelaide University was in response to a request from local irrigators for a mollusc specialist to identify the species that was responsible for clogging the water spray nozzles (Sheldon and Walker, 1993b; Walker, 1996). The pipeline has provided the vast majority of information available on the ecology of the species and its specific habitat requirements. Subsequent work also provided possible ecological reasons for the disappearance of the species within the river systems. As well, it suggested that there may be other remnant populations of these snails within the irrigation systems that are fed by the rivers of the Murray-Darling Basin.

3.3 Biology of *Notopala sublineata*

Little is known of the natural biology and ecology of this snail species. The loss of populations within the natural environment has limited the ability for further investigation. The main information provided is from an unpublished Honours thesis by M. Wishart (1994). This study was conducted on the population *Notopala sublineata hanleyi*, then thought to be a separate species, *Notopala hanleyi*, from the Kingston Irrigation Pipeline in South Australia. Hence, the majority of the information in Wishart's study may not be directly comparable to the biology of *Notopala sublineata* within the natural environment.

3.3.1 Desiccation Tolerance

N. sublineata hanleyi and *N. sublineata sublineata* are prosobranch gastropods and therefore have an operculum which increases their resistance to desiccation. There are many variables involved in an individual snail's ability to resist desiccation. Relative humidity and temperature affect the rate of evaporative loss and desiccation tolerance in freshwater prosobranchs (Skoog, 1976; von Brand *et al,* 1950). Wishart (1994) also states that, though aperture size and shell length may explain resistance difference between species, it does not necessarily explain resistance differences within species. Population variations in desiccation tolerance could be explained by individual physiological or behavioural adaptations (Wishart, 1994).

3.3.2 Feeding Organ

The number of teeth and muscular attachments of the feeding organ of a gastropod can be used to suggest the main food source. *N. sublineata hanleyi* was found to have a taenioglossan radula (Wishart, 1994). Although *N. s. hanleyi* is thought not to actively select its diet, the nature of the radula limits the animal's ability to utilise the food due to the lack of ancillary muscles and a reduced number of teeth leading to a "rake-like structure and movement" (Hawkins *et al*, 1989; Steneck and Watling, 1982; Wishart, 1994). This muscular attachment limits the ability to feed upon tougher food sources such as aquatic macrophytes and filamentous algae. Hence, the shape of *N. s. hanleyi*'s radula suggests grazing is predisposed for softer substrata such as diatoms and microalgae found in detrital material *(Wishart, 1994).*

3.3.3 Population Dynamics

Wishart (1994) observed a sample of the population of snails, removed by the chlorine flushing of the pipeline. The presence of juveniles in females larger than 16mm in length suggested that *Notopala sublineata* is not semelparous, i.e. it reproduces continuously. However, in winter – spring the water use within the pipe was reduced and hypoxia increased, reducing the oxygen availability. Oxygen levels can limit the rate of metabolism and hence the energy available for reproduction is reduced during this period. Wishart (1994) notes a possibility of sampling bias as the pipeline itself was unable to be sampled. Only the individuals of the resulting chlorine flush were used, and there could be active selection of individuals sensitive to chlorine. A more comprehensive study on the population before flushing, and throughout different seasons, is needed before a complete interpretation of the population dynamics of the pipeline population can be determined.

3.3.4 Reproductive Biology

Notopala sublineata has a high energetic cost of reproduction, i.e. viviparity, resulting in more developed but fewer offspring. Fecundity in viviparous snails is usually comparatively low compared to other freshwater gastropods (Browne, 1978; Brown *et al,* 1989; Jokinen *et al,* 1982; Sheldon and Walker, 1997; Taki, 1981). The pipeline population of *N. s. hanleyi* exhibited higher densities along with a higher fecundity compared with other viviparids (Wishart, 1994). In the natural environment, fecundity and density are limited and controlled by various conditions. Fecundity can be determined by food quantity (Brown, 1983) and quality (Eisenberg, 1966, 1970; McMahon *et al,* 1974), population density (Eisenberg, 1970) and physio-chemical variables including water temperature, dissolved oxygen, calcium concentrations and current velocity (McMahon, 1983; Lam and Calow 1989). Population density of viviparids has been suggested to be limited by the prevalence of a food source with a quality high enough to sustain reproduction (Eisenberg, 1970; Stanczykowska *et al*, 1971, 1972 cited in Wishart 1994; Stanczykowska and Magnin, 1973 cited in Wishart 1994; Wishart, 1994).

Some explanations given for the highly fecund and dense pipeline population is that there is no limitation on food quantity or food quality. In other situations, a highly dense population may experience food shortages and alternatively a dioecious population with low numbers may be limited in reproductive capabilities due to the difficulty in finding a mate. The bacterial biofilm within the pipeline potentially provides an extremely high food quality, maintaining high population numbers and increasing an individual's fecundity. In the natural environment, however, it is unlikely that these population numbers and individual fecundity rates would be maintained. Factors including predation and lower food quantity and quality would limit such numbers.

3.4 Decline of *Notopala sublineata*

It was the discovery of the surviving population in the pipeline in SA and the study on the biology of *Notopala sublineata hanleyi* that has highlighted some of the possible causes for the disappearance of the species within the natural environment. The alteration of the major food source for gastropods, biofilm, has been suggested to be the main cause for the declines. How the alteration of biofilm could have caused the massive declines in native snail populations is considered below, and other suggestions as to why *Notopala sublineata sublineata* and *Notopala sublineata hanleyi* no longer exist within the natural environment are also examined.

3.4.1 Biofilm

Biofilms are defined as " a matrix of polysaccharide exudates and detritus of algae, fungi, bacteria and unicellular animals on submerged surfaces" (Burns and Ryder, 2001; Wetzel, 1983). Biofilms have a significant ecological importance as they form the base of food webs, supporting (grazing) crustaceans, insects, molluscs and some fish species (Burns and Ryder, 2001; Lock *et al,* 1984; Rounick and Winterbourn, 1986; Stevenson, 1996). Biofilms have been recently utilised for river management as their short life cycles and good dispersal abilities ensures sensitivity to environmental changes, and are the first to respond and recover from environmental stress (Burns and Ryder, 2001; Lowe and Pan, 1996).

3.4.1.1 Structure and Composition

Biofilm composition is the result of successional development, disturbance and light availability. Succession is controlled by the selective performance of each group of organism within the biofilm in response to resource availability, ecophysiology, life history and disturbance (Burns and Ryder, 2001; Pickett and McDonald, 1989). Biofilms in late succession usually suggest a stable environment and are dominated by autotrophs, i.e. Chlorophyta, Bacillariophyta (diatoms) and Cyanobacteria (Burns and Ryder, 2001; Peterson, 1996). However, physical disturbances such as scouring and substratum loss from flow velocity, water level fluctuations and grazing by macroinvertebrates 'reset' the successional development of biofilm. The prevention of late successional development within a biofilm ensures a heterotrophic, or bacterial dominated biofilm (Burns and Ryder, 2001).

Along with disturbance, light availability is an important factor in the prevalence of either autotrophic or heterotrophic dominated biofilm. Autotrophs persist mainly where light prevails (Burns and Ryder, 2001; Lock *et al*, 1984), yet algae can remain dominant with high nutrient availabilities and low disturbance levels especially where there is pooling (Burns and Ryder, 2001; Peterson *et al*, 1985; Peterson, 1996). Some algae also have been known to survive under low light conditions. It is thought that such survival is species specific and survival length would be limited (Burns and Ryder, 2001; Peterson, 1996). Heterotrophic organisms, however, persist in low light environments and are advantaged by shallow photic zones with variable water levels (Burns and Ryder, 2001; Findlay *et al,* 1986). Also high current flows increase light attenuation through increased turbidity that limits the level of autotrophy (Burns and Ryder, 2001). Sediment depositions on biofilm, however, prevent heterotrophic and autotrophic development (Burns and Ryder, 2001).

3.4.1.2 Impact of Flow Regulation on Biofilm

Biofilm composition has rapidly responded to the alteration of natural disturbance regimes, nutrient availability and light concentration in the MDB to now promote algal based biofilm. Flow regulation has " decreased the magnitude of water level fluctuations" (Burns and Ryder, 2001; Sheldon and Walker, 1997), especially in the weir pools of the lower Murray River (Burns and Ryder, 2001). The stabilisation of the photic zone now favours biofilms dominated by autotrophic algae (Burns and Ryder, 2001; Sheldon and Walker, 1997).

The natural pulse flood regime has shifted to a series of less frequent large disturbances. The natural regime created a heterogenic habitat as a result of multiple and varying disturbance, whereas regulated flows have created a system that promotes homogeneity due to water stagnation between disturbances (Denslow, 1985). Prior to weir construction that commenced in the 1920s, littoral biofilms probably had a bacterial dominated biomass (Sheldon and Walker, 1997). In contrast a study conducted on the River Murray showed that biofilm under regulated conditions, stable waters and deeper light penetration, persisted in a late successional state promoting the growth of filamentous algae *Spirogyra spp* (Sheldon and Walker, 1997). The 1991-92 1000 km toxic blue-green algae bloom in the Darling River (Thoms and Sheldon, 2000) drew attention to the impacts that nutrient enrichment, water storage and flow regulation can have on algal production (EPA, 1997). It is this change in the base food web structure that is particularly concerning to ecologists.

3.4.1.3 Impact of altered biofilm composition on gastropod populations

Biofilm is a major food source for many macroinvertebrates surviving in the MDB. The alteration of biofilm composition results in a major change in food availability for grazers such as gastropods, and freshwater gastropod population declines have paralleled these modifications. In particular, prosobranch gastropods are omnivorous feeders (Burns and Ryder, 2001; Sheldon and Walker, 1997) that display preference for some benthic algal forms (Burns and Ryder, 2001). Around the 1930s huge numbers of specimens of seven different aquatic snail species were collected from the Lower Murray River, including 4677 *N. sublineata hanleyi* specimens and 7592 *T. balonnensis* (Johnston and Beckwith 1945; 1947; Maheshwari *et al*, 1995; Sheldon and Walker, 1993a; Sheldon and Walker, 1993b). This suggests that biofilm within the rivers at this time was supporting reasonably large gastropod populations. All recent surveys have indicated a complete disappearance or severe decline in all of these species (Bennison *et al*, 1989; Boulton and Lloyd, 1991; Evans, 1981; Farnham, 1980; Jenkins, 1991; Lloyd *et al,* 1990; Sheldon and Walker, 1993a;b; Thompson, 1986). Some records do exist of snails found in the 1980s, most likely to be dry collections, but currently only *Ferrissia petterdi* and *Physa acuta* are still regularly collected (Walker, 1992; Sheldon and Walker, 1993a). Snails other than *Notopala* still exist within the Murray River above the Darling confluence, yet it is not known where else these species may be existing within the basin (Bennison *et al*, 1989; Sheldon and Walker 1993b).

3.4.2 Causes for the decline of *Notopala sublineata*

3.4.2.1 Reduction of food quantity and quality

The decline of *N. sublineata sublineata* and *N. sublineata hanleyi* in the natural environment is thought to have many contributing factors as a result of severe alterations to the Darling River, Murray River and their tributaries. A study conducted on the diet of *N. sublineata sublineata* and *N. sublineata hanleyi* discovered that the gut contents and faecal pellets were similar in composition to the biofilm found on snags and leaf litter (Sheldon and Walker, 1997). Such biofilm in lowland rivers would usually be dominated by heterotrophic microbes (Couch and Meyer, 1992; Edwards and Meyer, 1987; Findlay, 1986; Sheldon and Walker, 1997), the softer (bacterial based) food that *Notopala's* radula can remove (Sheldon and Walker, 1997; Walker, 1996; Wishart, 1994). However, more recent stabilisation of water levels have promoted mats of filamentous algae coating submerged surfaces, a food resource *Notopala* is unable to utilise (Dufford *et al*, 1987; Lowe, 1979; Petts, 1984; Sheldon and Walker, 1997; Williams and Minget; 1979).

In a study on the composition of biofilm from Coopers Creek (where a population of *Notopala sublineata alisoni* is surviving in large numbers), the Lower Murray River and from the walls of the Kingston-on-Murray pipeline, it was found that the pipeline biofilm was composed entirely of heterotrophic organisms (Sheldon and Walker, 1997). They suggested that the carbon:nitrogen (C:N) ratio in biofilms can determine the protein content and nutritional quality of the biofilm. High nitrogen content in a biofilm provides a high protein content and therefore a higher quality food source (Sheldon and Walker, 1997). It was discovered that biofilms dominated by heterotrophs had a higher nitrogen content and was therefore an important food source for invertebrates, especially prosobranch snails (Sheldon and Walker, 1997). In gastropods, an alteration in the quantity and quality of food affects the individual's fecundity and reproductive abilities (Calow, 1970; Eisenberg, 1966; El-Eman and Madsen 1982; Hill, 1992; Sheldon and Walker, 1997). A low C:N ratio has been found to enhance the growth and fecundity of aquatic snails (Fenchel and JØrgenson 1977; McMahon *et al*, 1974; Sheldon and Walker, 1993b). As the pipeline was supporting such a large population, the entirely heterotrophic biofilm of the pipeline with a low C:N ratio, could be an explanation. Conversely the lack of heterotrophs (and the discovery of algal dominated biofilms) within the natural rivers could have prevented the ability of the snail to maintain growth and reproduction. The alteration of this food source has serious implications for gastropods which have a poor ability to recover from such alterations.

3.4.2.2 Salinity and Pollution

Another suggestion for the decline of *Notopala* has been the increase of salinity and pollution in the river systems as a by-product of increased agricultural and irrigation practices. It is unlikely, though, that these impacts have caused such a steady decline considering the discovery of *Notopala sublineata hanleyi* was within an irrigation pipeline (Sheldon and Walker, 1993b). The irrigation channels are opened during the summer season when the river's natural salinity levels are at their peaks (Sheldon and Walker, 1997). Although salinity within the Lower Murray River has increased due to dryland agricultural practices, the levels of salinity within the river are still below peak records before regulation (Mackay *et al,* 1988; Sheldon and Walker, 1993b). As well, the pipeline is systematically flushed with chlorine to remove the snails and is still repopulated by the snails, slowly, after the cleaning of the pipelines. This is most likely due to the ability to seal the operculum shut and resist short-term environmental stresses (Smith, 1996), and hence pollution is not thought to be the main cause for the decline.

3.4.2.3 The introduction of Carp (*Cyprinus carpio)*

It has also been suggested that the introduction of the highly destructive carp species, *Cyprinus carpio,* into the lowland rivers, has contributed to *Notopala's* decline (Sheldon and Walker, 1993b). Within NSW, carp are abundant in rivers and tributaries of the Murray-Darling Basin below 700m, after a release suggested to be around the 1970s (Gehrke *et al*, 1995; Harris and Gehrke, 1997). Figure 2 displays the spread of the most common strain of carp, Boolara strain, in 1970, 1977 and 1998. Carp have been present along the Murray-Darling confluence since the estimated time of its introduction. The distribution of the spread of carp overlaps what is thought to be the historical distribution of *Notopala sublineata sublineata* and *Notopala sublineata hanleyi.* Carp could have impacted the snail populations in several ways. Carp may have reduced *Notopala's* population numbers, as they are known to feed upon snails (RMUUC, 2003). A study conducted on the diet of carp by Hume *et al* (1983) on all sizes of carp throughout billabongs, lakes and rivers in Victoria found they fed on a variety of invertebrates (Koehn *et al,* 2000). Though carp can feed upon snails (RMUUC, 2003) the study found molluscs were eaten only when they were in large numbers (Koehn *et al,* 2000). It could be suggested that *Notopala* was never in large enough numbers to contribute significantly to the diet of carp. However, when looking at the third sub-species of *N. sublineata, Notopala sublineata alisoni* in the north of the Murray-Darling Basin, the snails are abundant within the natural environment (W. Ponder *pers. comm.*). As well, in the 1930s huge numbers of *N.s.h.* were collected from the Murray River (Johnston and Beckwith 1945; 1947; Maheshwari *et al*, 1995; Sheldon and Walker, 1993a; Sheldon and Walker, 1993b).

The activity of carp is also known to greatly increase the turbidity of the water, which can smother biofilm (Burns & Ryder, 2001; RMUUC, 2003). Also juvenile carp feed almost entirely on zooplankton and, although macroinvertebrates account for the majority of an adult's diet, they do continue to feed on biofilms (Koehn *et al* 2000). It has been suggested that in areas where carp are abundant the grazing on zooplankton may be too intense for the remaining biofilm to suppress algal growth leading to algal blooms (Gehrke and Harris, 1994). The sensitive gill structures of *Notopala* can also be damaged by the localised increase in turbidity from carp feeding behaviour (Walker, 1996).

3.5 Conclusions

The pipeline in SA was constructed in 1974 (Wishart, 1994), proving that *Notopala sublineata hanleyi* snails were still within the river system at the time of its construction. River regulation was already well established. It was in this period that carp were introduced and were rapidly increasing in numbers. It is possible that altered food availability from river regulation reduced the numbers of the snails drastically. When carp were introduced predation, increased turbidity from carp feeding behaviour and over grazing of periphyton by carp may have reduced the numbers of snails within the system to levels that were too low to maintain populations.

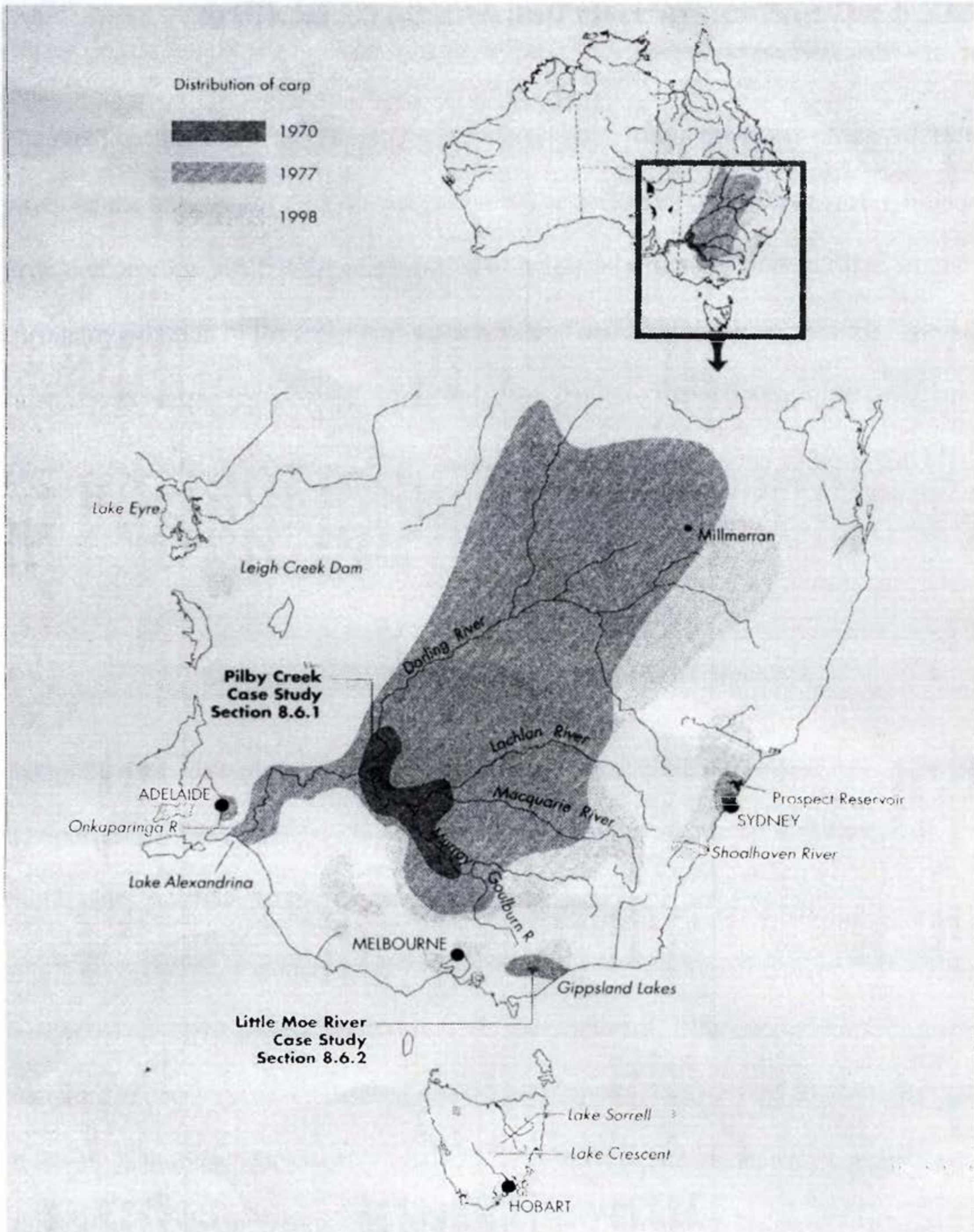


Figure 2 Distribution of all carp strains, predominantly Boolara strain, in 1970, 1977 and 1998. After Koehn *et al* (2000)

Chapter 4 Survey of the invertebrate fauna associated with artificial structures and river systems of the MDB

The rapid decline in the numbers of macroinvertebrates within the rivers of the MDB has provided the impetus for the following survey. The discovery of the river snail within an irrigation pipeline justifies the examination of irrigation structures to determine the current distribution of the river snail in both natural and artificial environments. The sampling technique for the snail within the rivers provides the opportunity to detail the macroinvertebrate communities of the littoral environment within the rivers in the MDB.

4.1 Field Methods

4.1.1 Sampling difficulties for rare and endangered molluscs

Sampling methods were evaluated to determine the most effective way of recording the composition of the macroinvertebrate assemblage while maximizing the chances of finding rare mollusc species. Mesh net sweeping, such as the one conducted by Sheldon and Walker (1998), is a standardized method for macroinvertebrate sampling. A study conducted on a rare and endangered mussel (Kovaluk *et al*, 1986) suggested that quadrat sampling to detect presence/absence was the most appropriate method for sampling for an endangered mollusc when there is insufficient information available on the population densities or habitat utilisation. The only information available on the snail's habitat requirements is a preference by the snails for biofilm found on snags and leaf litter (Sheldon and Walker, 1997). Anecdotal evidence has noted that the snails burrow into the sediment hence sampling requirements for the snail could be comparable to those suggested for an endangered bivalve. This study has focused on littoral zones that contain snags and leaf litter when such environments were available within selected river stretches.

There are some disadvantages in using the mesh net sweeping technique along with quadrat sampling only along riverbanks. The sweep net method collects approximately 10cm deep of sediment along riverbanks to a depth of water of over 1m. Also, when the stretches of river were passable, areas were sampled which were closer to the centre of the river channel. Finally it is considered unlikely that snails would be found in the centre of the river channel if they were not also present on the banks.

Macroinvertebrates were sampled to determine the richness of littoral invertebrates within the river systems of the MDB. The results of this survey may help identify where within the systems there is the greatest macroinvertebrate richness. The discovery of any environmentally sensitive macroinvertebrates could potentially signify areas where there has been less alteration to the environment and hence could provide areas where introductions of these snails may be more successful.

4.1.2 River Selection

Rivers were chosen on the basis of past *Notopala* specimen collections and on the presence of industries supported by irrigation from the rivers. These rivers were the Namoi, Lower Darling, Upper Barwon-Darling, the Murray (from Echuca to Mildura), and the Lower Murrumbidgee (See Figure 3). For individual site locations see Appendix 1.

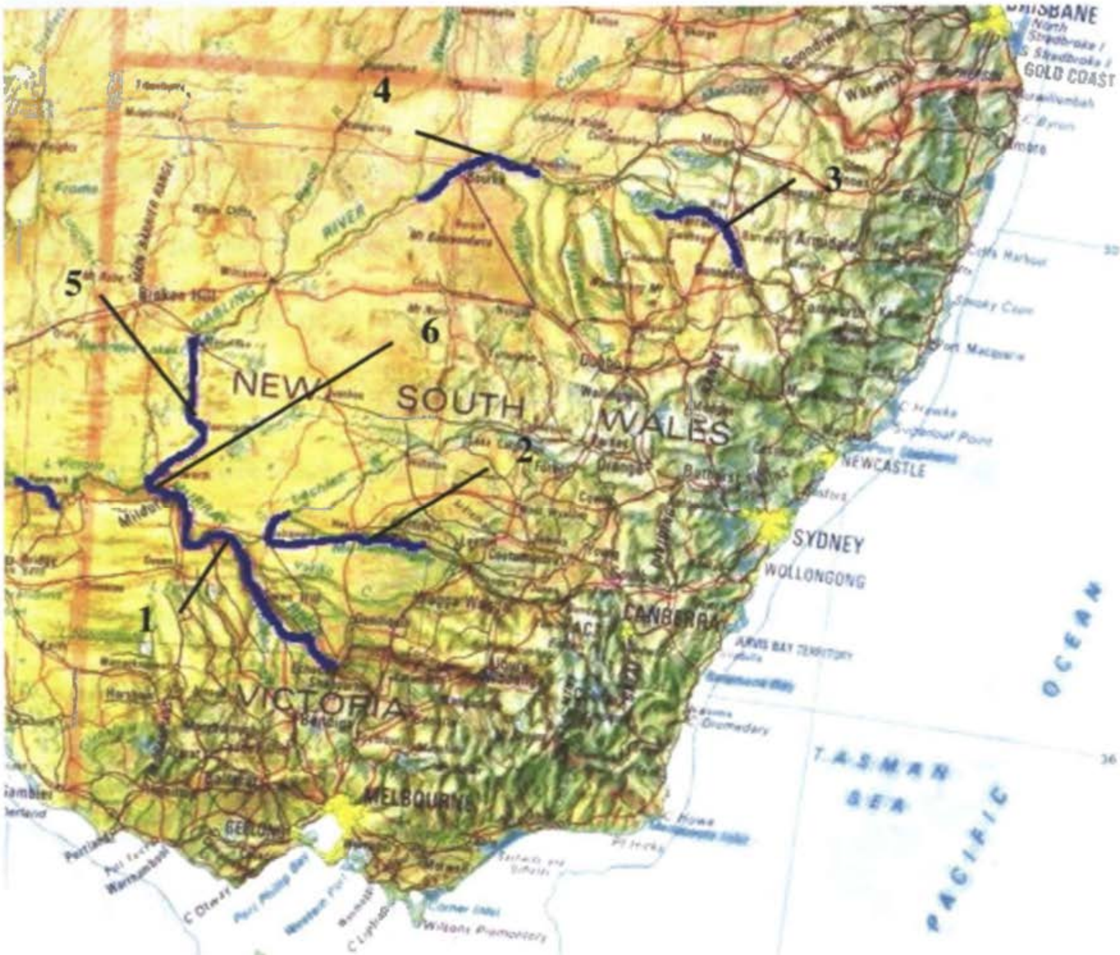


Figure 3 River systems sampled within NSW

1 Murray River
2 Murrumbidgee River
3 Namoi River
4 Upper-Darling River
5 Lower-Darling River
6 Western Murray Irrigation

(For site locations see Appendix 1)

4.1.3 Sampling sites within the river

The surrounding environment, appearance of river and accessibility to the river, determined the sites for macroinvertebrate sampling. Large stretches of river often were inaccessible due to extreme bank erosion as well as the dangerous conditions along clay banks after rain. Areas that had obvious algal blooms were avoided along with areas damaged by the presence of sheep and cattle. Prior to surveys of the rivers, the presence of snags and riparian vegetation was also a criteria for site selection. Sampling was focused on instream habitats such as snags and leaf litter when such habitats were available; often they were not. Sampling sites were often chosen opportunistically as river access was mainly within private properties and hence my sampling was limited to areas where authority for access had been given. Sampling was conducted within the rivers during different seasons (Table 1).

River	Date of Sampling	Sites per River
Murray	June 2004	10
Murrumbidgee	September 2004	8
Namoi	October 2004	5
Upper Darling	August 2003	5
Lower Darling	May 2004	9

Table 1 Date of sampling and number of sample sites per river.

4.1.4 Macroinvertebrate sampling techniques

Macroinvertebrate sampling was conducted within the littoral zones of the rivers. One quadrat was sampled at each site, but there were different numbers of sites per river.

Quadrats consisted of approximately 10m in width and these were sampled to a water depth of approximately 1.3m. The littoral zones were swept for approximately 3 minutes. The content of the net, including the sediment, was emptied onto a sorting tray. The invertebrates were sorted out of the sediment and placed directly into 70% ethanol solution. Any dry shells of specimens along the banks were also collected.

4.1.5 Biofilm sampling techniques

Biofilm was sampled at each of the sites where macroinvertebrates were sampled. Sampling consisted of the removal of biofilm from instream substrates such as leaf litter, sticks, branches and bark. The substrate was taken from within the quadrat. The biofilm was removed from the substrate by scrubbing with a toothbrush into distilled water (Sheldon and Walker, 1997). The toothbrush was sterilized between samples. One sample was taken per site. The sample was allowed to settle and the supernatant was poured off. The remaining biofilm was then placed into a cryovial and stored in liquid nitrogen for later analysis.

4.1.6 Artificial structures sampling techniques

There were many different irrigation structures encountered in this survey; open irrigation channels that were constantly filled with water, open irrigation channels that are periodically flooded with water and closed pipelines fed directly from the river. The sampling technique for each of these structures was as follows.

- Open Concrete Channels permanently filled (Plate 4).

These open channels consisted of environments similar to river channels and hence were sampled using the same methods as described above (Section 4.1.4).

- Open Dry Soil/Temporary Channels (Plate 1)

Sampling on these structures consisted of manual handpicking of shells of dead molluscs; if other invertebrates were present (e.g. crustaceans) their presence was noted (See Appendix 3)

- Closed pipeline and water tanks (Plate 2)

Sampling within these pipes was often not possible as many were only approximately 5cm in width and were underground. They went underground for kilometres and had exit points ending in water troughs or tanks along the property.

The filter system was often the sample point (Plate 3). The filter tray was removed and any mollusc specimens found were removed and placed in ethanol. Any other invertebrates were also collected. Most pipelines also had points where the water could be flushed out. The hose was opened and if any organisms were released then they were collected. The holding tanks for water at the exit points of the irrigation pipeline were also sampled. These included water tanks fed directly from the river feeding the property house, holding dams and water troughs. These were sampled via handpicking or visually making note of molluscan specimens where the collection was not possible. Irrigation structures on properties that did not have river access were still surveyed.

4.1.7 Water Quality Measurements

Water quality was measured using a Horibu U-10 kit. The water parameters measured were dissolved oxygen, pH, salinity, turbidity, conductivity and temperature.

Plate 1	Temporary Irrigation Channel: Fed from the Namoi River

Plate 2	Closed pipelines: Fed from the Murray River

Plate 3 Closed PVC piping with filter plate: Fed from the Lower Darling River

Plate 4 Permanent irrigation channel: Moira Irrigation Channel

4.2 Laboratory Methods

4.2.1 Biofilm Analysis

Biofilm analysis was conducted at Macquarie University in the Department of Biological Sciences. An oven was heated to 48°C. This temperature was appropriate for drying biofilm whilst limiting nitrogen loss (B. Atwell, *pers. comm.*). Biofilm was removed from liquid nitrogen and placed into glass petri dishes and left to thaw. The excess water was removed using a pipette once the sample had thawed. The biofilm was then placed into the oven for approximately 3 hours, or until the contents were dry. The petri dishes were taken out of the oven and each biofilm sample was removed and individually placed into a mortar and pestle. The contents were homogenized and 2-4mg were measured out using a Heckel-Meiner balance. Samples were analysed using a CHN-900 machine (LECO Australia Pty Ltd) for carbon and nitrogen content.

4.2.2 Macroinvertebrate Identification

Macroinvertebrates were sampled throughout the system to determine the level of richness at the family level. Macroinvertebrates were sorted to family where possible but some could only be sorted to Order, Class or Sub-Class due to identification difficulties and time restrictions. The molluscs, however, were identified to species. Non-molluscan invertebrates were identified using Gooderham and Tsyrlin (2002) as an identification guide. Mollusc species were identified using Smith and Kershaw (1979) and with the assistance of staff at the Australian Museum.

4.2.3 Macroinvertebrate Diversity and Equitability Indexes

Macroinvertebrate data were analysed using the Simpson's Diversity and Equitability Indices (Begon *et al*, 1986).

Diversity Index: $D = 1 / \sum Pi^2$

Equitability Index: $E = D/S$

Where S is the number of taxon found within a river.

4.3 Results

4.3.1 Macroinvertebrate Results

Live invertebrates were found in all river channels, but some were also found in permanent irrigation channels. A total of 27 families, 6 orders, 2 classes and one sub-class were found throughout the system (Appendix 2). Appendix 3 displays the families, orders and classes that were found throughout the systems and highlights those that were found only in the rivers, only in the irrigation channel and those that were in both habitats.

Figure 4 shows the average number of taxa collected per site for each of the rivers sampled, and Figure 5 shows the average macroinvertebrate abundance at each site for each of the rivers. The Upper Darling contained the greatest richness. The Murray River has the highest numbers of macroinvertebrates, but this is due to the large numbers of waterboatmen, Corixidae (2063 collected) which accounted for 82.7% of all the invertebrates collected in the Murray River. The Corixids made up 65.6% of all invertebrates collected throughout the basin. Figure 6 displays the abundance of the three most common families found in all rivers sampled throughout the basin. The Murray, Murrumbidgee, Upper Darling and Namoi Rivers all contained ≥12 taxon in total. The Murrumbidgee contained the lowest numbers of specimens but still contained a reasonably high richness.

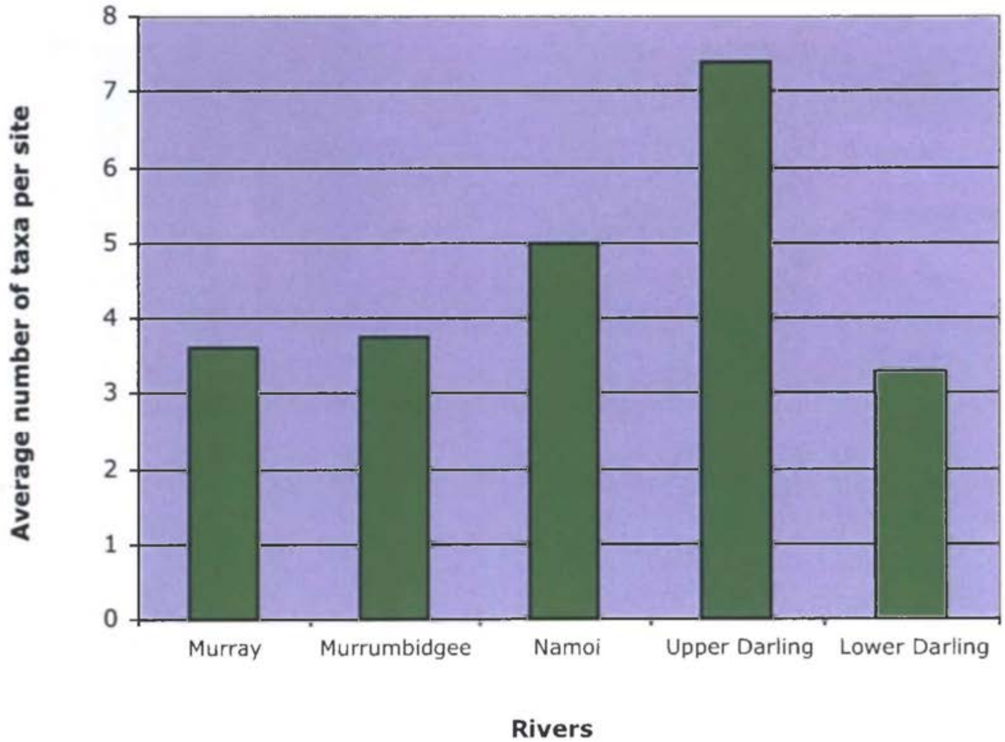


Figure 4 Average numbers of taxa collected per site

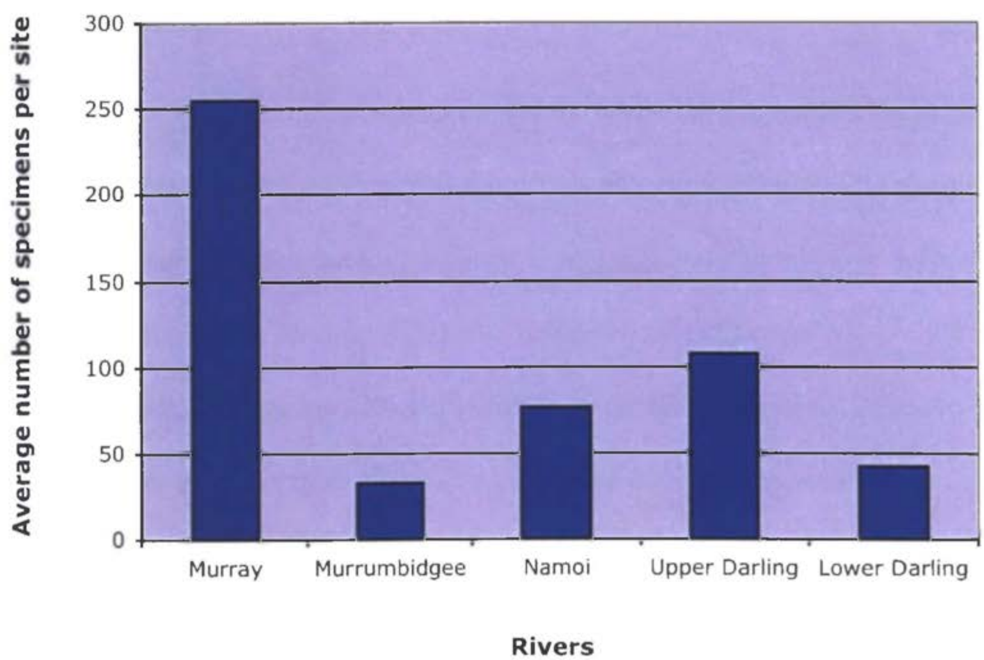


Figure 5 Average number of specimens collected per site

Figure 6 Total abundances of Atiydae, Corixidae and Palaemonidae in the rivers sampled throughout the MDB.

The Lower Darling, however, contained the lowest macroinvertebrate richness. It should be noted that there were only 5 families of invertebrates (including molluscs) found in the river channel. Other invertebrates were found in an irrigation channel (see Appendix 3) that is associated with the Darling River and hence should not be included in the river's diversity. The lack of diversity within this river is most likely the result of a one-off accidental release of water from Menindee Lakes that occurred two months prior to this sampling. The area surrounding the Lower Darling experienced an extremely hot summer in 2003/2004, so much so that sections of the Darling dried during January/February (Whyte *pers. comm.*). During this period the average temperature during the day was approximately 40°C (Whyte *pers. comm.*). Water was released from Menindee Lakes Storage Facility and when the water reached the dried sections of the river, small amounts flowed over hot sand, creating a boiling toxic sludge that entered the large pools of the Darling. At this time cattle and sheep that were drinking from the river were killed along with large numbers of big Murray Cod (Plate 5). This type of environmental pressure could explain the lack of diversity in the lower Darling at the time of this survey. This type of problem also highlights how water management impacts directly on the instream communities of the river systems.

Simpson's Diversity Index was initially applied to the macroinvertebrate data to determine the diversity of the river systems, but due to the unequal abundance of families within the rivers the Diversity Index was misleading, as to which rivers were more diverse than others (Begon *et al*, 1986). Instead, equitability, how equal the abundance of each taxon is within a river, was calculated (Table 2) using Simpson's equitability index.

River	Species Richness	Diversity	Equitability
Murray	17	1.4	0.0824
Murrumbidgee	14	1.948	0.139
Namoi	12	3.433	0.2861
Upper Darling	18	4.711	0.2617
Lower Darling	5	2.223	0.4447

Table 2 Macroinvertebrate Equitability in 5 rivers of the MDB sampled in 2003/2004

These results show that although the lower Darling had the lowest taxa richness it has the greatest equitability between taxa. Conversely, the Murray River had a high richness that was extremely unequal due to the enormous abundance of the Corixid family.

The rivers with the greatest species richness - the Upper Darling, the Murray and Murrumbidgee - also contained invertebrates which are considered to be environmentally significant, i.e. they are sensitive to environmental change and are sometimes used as indicators of river 'health' (Gooderham and Tsyrlin, 2002). The season when sampled and number of sites within each of the rivers, however, could explain their presence. These key taxon included the Scorpian Fly nymphs (Mecoptera) and Toebiters (Megaloptera) from the Murray River, the Stonefly nymphs (Gipopteryidae) from the Murrumbidgee and the Freshwater Mites (Acarina) and Caddisfly larvae (Leptoceridae and Philopteridae) from the Upper Darling. Their presence could indicate a habitat that may be less altered than others but their absence within a river does not necessarily represent a degraded environment.

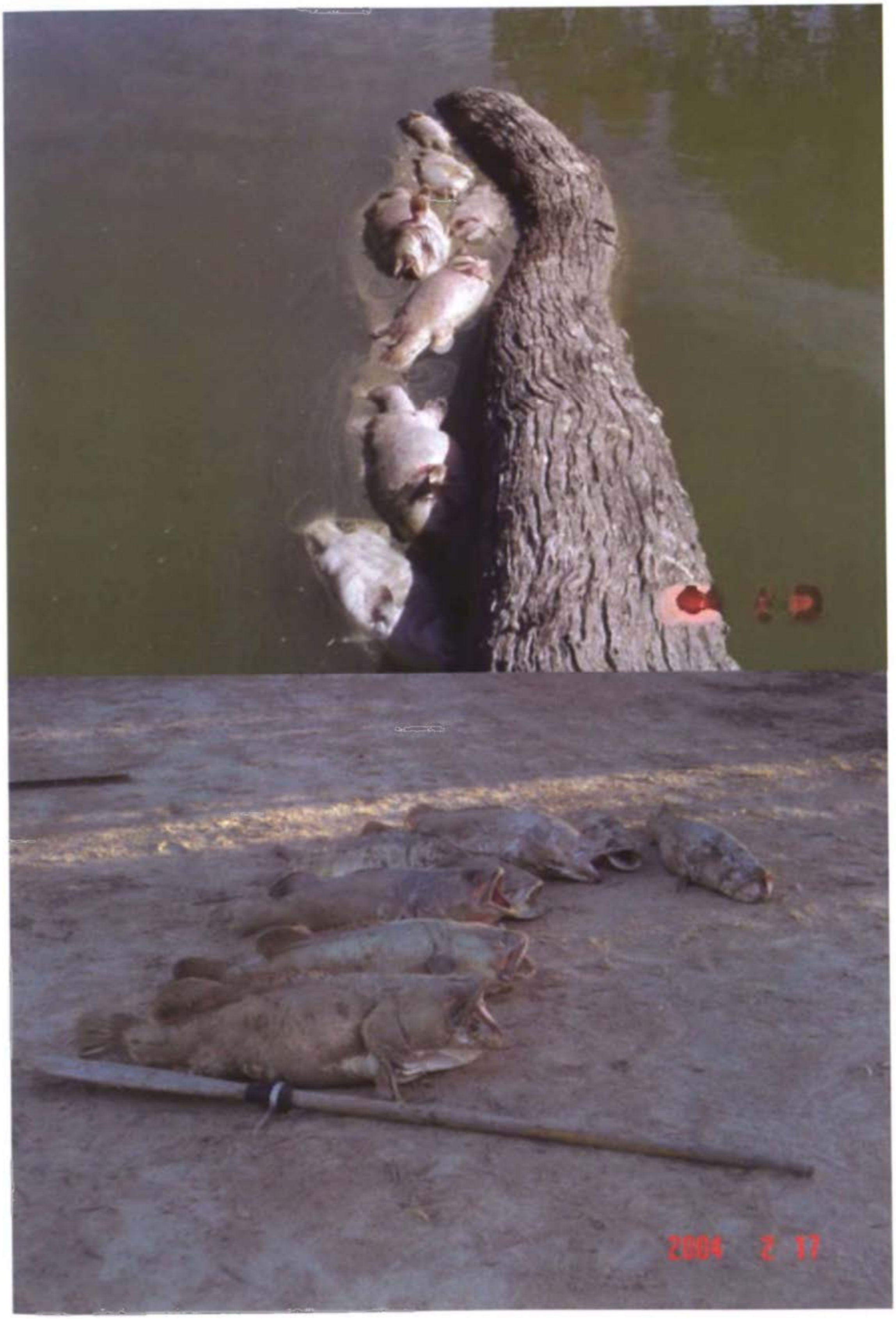


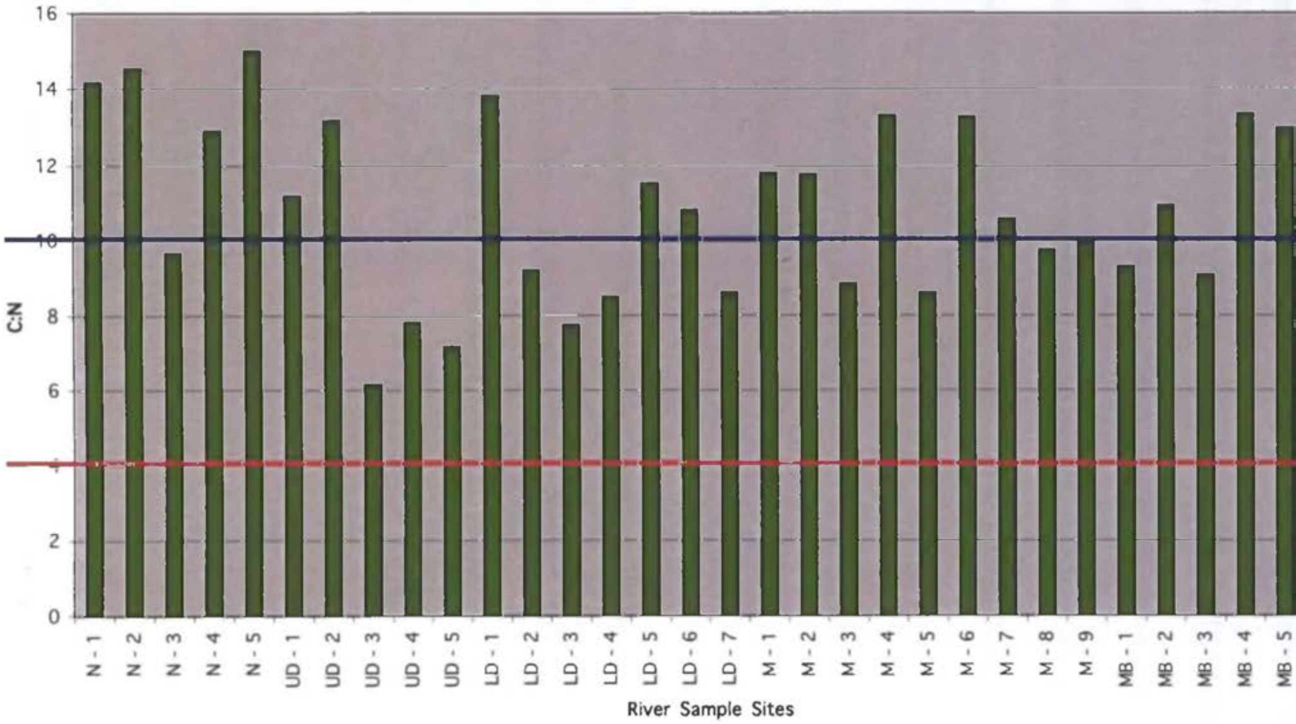
Plate 5 Dead Murray cod from the Darling River – Photographs courtesy of Allan Whyte

4.3.1.1 Conclusions

At the time of sampling the Upper Darling river appears to have had the greatest taxa richness of macroinvertebrates. The season when sampling was conducted is, of course, a factor in calculating the number and richness of macroinvertebrates collected. The lack of richness in the Lower Darling, however, highlights how water management impacts instream communities. The greatest abundance for all rivers combined was the freshwater shrimp and prawns and the water boatmen. It has been suggested that the abundance of the shrimp and prawns are due to their ability to utilize invading plants as a food source. The presence of these exotic plants has been the result of altered hydrology promoting lentic environments (Boulton and Lloyd, 1991; Sheldon and Walker, 1998; Young *et al*, 2001). As well Corixids (water boatmen) are found to be prevalent in temporary billabongs, a more lentic type of environment (Sheldon and Walker, 1998). Corixids are most often found among aquatic vegetation which they also use as a food source (Gooderham and Tsyrlin, 2002). The result of the macroinvertebrate collection, specifically the abundance of these three families, highlights the alterations that have occurred as a result of river regulation within the MDB.

4.3.2 Biofilm Results

Biofilm was collected to determine the level of protein and food availability for the snail within the river systems and in other structures that are supported by the river systems. Biofilm was collected where possible. In many instances within the river systems there were no instream structures available to sample the biofilm from. In these environments the substrate was usually clay/silt bank that was highly damaged by the presence of cattle and sheep, even though such areas were avoided as much as possible. The biofilm that was collected was analysed for the C:N ratio as it is a measure of protein content or food quality. Figure 7 displays the values calculated for the biofilm samples. The results show a C:N ratio throughout the system ranging from 7.184 to 14.993. Sample UD-3 was considered an outlier because it was collected from a filter pump along the Upper Darling where a large population of *Physa acuta*, the introduced snail, was found. An explanation for the lower C:N value could be due to the reduced light availability within the pump that would promote bacterial growth over algal growth, given that bacteria have a higher nitrogen content. The Upper Darling contained the samples with the lowest ratio. The lower Darling also contained some samples with lower ratios. This could potentially highlight the impact of disturbance (such as the water release from the Menindee Lakes mentioned earlier) on the biofilm composition. The results from the biofilm analysis demonstrate that there is a large range of food quality within habitats and between rivers.



C:N content of regulated Murray River (Sheldon and Walker, 1997)

C:N content of Loveday Irrigation pipeline (Sheldon and Walker, 1997)

Figure 7 C:N content of biofilms collected throughout the MDB

4.3.2.1 Conclusions

To maintain active cell growth animals require protein levels (or a carbon:nitrogen ratio) in their food source to be <17:1 (Russell-Hunter, 1970; Wishart, 1994). The study by Sheldon and Walker (1997) found the C:N ratio in regulated Murray River was approximately 10:1 compared to the Loveday irrigation pipeline that was approximately 4:1. This represents a significant decrease of food quality from unregulated river biofilm (4:1) to now regulated river biofilm (10:1). The results from this current survey do represent a basin-wide reduction in food quality, if indeed the nitrogen content in biofilm content was much greater in pre-regulated rivers. It is unlikely that the natural nitrogen content in the biofilms of the rivers would have been as high the nitrogen in the pipeline biofilms. Habitat parameters in the pipeline, particularly the very low light levels, would not be readily found in the natural environment.

The level of food quality in this survey, however, could be much lower due to the greater concentration of suspended sediments (SSC) (Wishart, 1994). An increase in the level of SSC may reduce the level of ingestible material, further reducing the food quality or food availability for aquatic invertebrates including *Notopala* (Wishart, 1994). As well, an increase in SSC has the potential to clog the molluscan radula and increase the level of sediment in the mucus. More energy is exerted in order to obtain similar or smaller quantities of food (Wishart, 1994). It is unlikely, however, that the reduction of nitrogen within biofilm content has been the only cause, if in fact a cause at all, for the demise of *Notopala,* and possibly other invertebrates, within the river systems. The Kingston pipeline was opened in the early 1970s when river regulation was already well established within the Basin. The snails were still surviving within the system at this time, if in small numbers, and hence were able to exist in the rivers even with the reduced food quantity and quality.

4.3.3 Molluscan Diversity Results

4.3.3.1 *Notopala sublineata sublineata and Notopala sublineata hanleyi*

In December 2004, snails from a pipeline off the Murray River (see Figure 3), owned by the Western Murray Irrigation Corporation (WMI), were posted to me. These snails, 7 in total, collected as live specimens along with shells of *Plotiopsis* and *Corbiculina,* were positively identified as *Notopala sublineata hanleyi* (Plate 6). This is the first recorded live population of *N. s. hanleyi* found in NSW since 1971, when live specimens were found along the Lachlan River (AM data, 2004). This research project has identified a surviving population of snails that otherwise would have gone unnoticed. Had the importance and environmental significance of these snails not been made public to irrigators it is likely that this population of snails would not have been discovered and would have most likely been removed from the pipeline. Unfortunately due to the time when this population was discovered (i.e. at the end of my project) I was not able to detail the habitat of the pipeline in which the snails were found. Further research on this population is vital for the recovery of the snail.

Plate 6 *Notopala sublineata hanleyi* collected from Western Murray Irrigation pipeline. Approximately 28mm in aperture length.

Other than the snails sent to me from the Western Murray Irrigation system, no other live specimens were found of either of the sub-species throughout the basin sampled in NSW. This included the natural river systems and the irrigation systems. Shells of *Notopala sublineata sublineata* were, however, discovered in a water tank in northern NSW along the Upper Barwon-Darling. Shells were found around the tank that had been cleaned earlier in February 2003. This tank was approximately 40 years old and had not been cleaned for approximately 15-20 years. At the time of sampling the property was acquired by National Parks and Wildlife Service. Subsequently, the tank was destroyed due to safety issues and there were no live specimens or shells remaining in the tank. Shells of *N. sublineata* can last decades and therefore cannot be dated (F. Sheldon, *pers. comm.*). Some shell fragments were found near Walgett and Bourke and also near Menindee in the floodplain alongside the Darling. In the sections where these were found there were no live specimens found in the river and there were no significant irrigation systems associated with these particular stretches of river.

Fresh shells (still containing their operculums) were found by Winston Ponder (Australian Museum, Malacology) in the culverts in Menindee lakes and in the Walgett town supply pipe approximately 10 years ago (W. Ponder *pers. comm.*), yet during my survey no extant populations or shells were discovered in areas near these structures suggesting further declines in the snail's distribution during the last decade.

4.3.3.2 Irrigation infrastructure in NSW.

It is unlikely that a remnant population of *Notopala sublineata sublineata* is present within an artificial structure in the northern sections of the Murray-Darling Basin. The irrigation infrastructure in this part of the MDB consists of private single systems compared with the much larger and more complex irrigation districts found in SA and along the Murray River. Individual properties contain closed PVC-piping that feeds water through a filter plate and transports it throughout the property. The filter plate prevents the colonization of invertebrates within the pipeline. The size of these pipes, approximately 5cm in diameter, would significantly reduce the possibility of an extant population of *Notopala* living within the pipes. In areas such as the Namoi River where there are large irrigation structures supporting cotton farms, these mainly consist of open temporary channels that would not support snail populations.

4.3.3.3 Molluscan diversity within the natural rivers

Only three species of mollusc were found in the natural river systems - the little basket shells, *Corbiculina australis,* and the freshwater mussels, *Velesunio ambiguus* and

Alathyria jacksoni. Table 3 displays the areas where these species were found. Only *Corbiculina australis* was discovered as a wet specimen, the rest were dry shells. Mussel shells were found along the Murray River, Murrumbidgee River, Lower Darling and the Bohema Creek (Namoi tributary) but live *Corbiculina australis* were only found along the Murray.

Mollusc Species	*V. ambiguus*		*A. jacksoni*		*C. australis*	
	Live	Dead	Live	Dead	Live	Dead
Murray		1		2	1	
Murrumbidgee				1		1
Namoi				1		
Upper Darling						
Lower Darling		1				

Table 3 Numbers of molluscan species collected as Live or Dead specimens within river systems sampled in the MDB.

4.3.3.4 Molluscan diversity within artificial structures.

There was a much higher diversity and abundance of molluscs in the artificial structures that are supported by the rivers of the MDB. A total of 8 species were found in artificial structures. Table 4 shows the species that were collected and the structures they were collected from. *Glyptophysa spp* were found in areas that replicated lentic environments – i.e. holding dams, water tanks and garden ponds that had the water fed from the river. *Physa acuta*, the introduced snail was found in large numbers in filter containers, along siphons in open irrigation channels and within water tanks. Freshwater mussels, *Alathyria jacksoni* and *Velesunio ambiguus,* were found in unused and used concrete water tanks and open permanent irrigation channels. Little basket shells, *Corbiculina australis,* and the ornate snail, *Plotiopsis balonnensis,* were found in large numbers in enclosed pipelines along the Murray and open irrigation channels (permanent) and unused water tanks throughout the basin. Due to the sampling difficulties for these pipelines it is unclear how many individuals there are surviving within these systems. Thousands were collected from vortex filters, and *Isidorella newcombi* was found in large numbers in concrete water tanks and also in dried dams at the ends of small irrigation pipelines.

River	Molluscan Species	Common Name	Sites
Upper Darling	*Notopala sublineata sublineata*	River Snail	Water tank
	Physa acuta	Introduced Snail	Filter pump
	Glytophysa spp	Native freshwater snail	Holding Dam
Lower Darling	*Isidorella newcombi*	Native Freshwater Snail	Concrete water s
	Corbiculina australis	Freshwater Little Basket Shells	Water tank
	Plotiopsis balonnensis	Sculptured Snails	
	Velesunio ambiguus	Freshwater Mussel	Irrigation Channel
Namoi	*Corbiculina australis*	Freshwater Little Basket Shells	Irrigation Channel
	Plotiopsis balonnensis	Sculptured Snails	
	Physa acuta	Introduced Snail	Irrigation Siphons
	Alathyria jacksoni	Freshwater Mussel	River Channel
Murray	*Velesunio ambiguus*	Freshwater Mussel	River Channel
	Alathyria jacksoni	Freshwater Mussel	
	Alathyria jacksoni	Freshwater Mussel	Water tank
	Plotiopsis balonnensis	Sculptured Snails	Irrigation Channel
	Corbiculina australis	Freshwater Little Basket Shells	
	Glytophysa spp	Native freshwater snail	Garden Pond
	Corbiculina australis	Freshwater Little Basket Shells	Irrigation Pipeline
	Notopala sublineata hanleyi	River Snail	
	Plotiopsis balonnensis	Sculptured Snails	
Murrumbidgee	*Corbiculina australis*	Freshwater Little Basket Shells	Irrigation Channel
	Physa acuta	Introduced Snail	Water tank
	Alathyria jacksoni	Freshwater Mussel	River Channel
	Glytophysa spp	Native freshwater snail	Pond
	Isidorella newcombi	Native Freshwater Snail	Floodplain
	Physa acuta	Introduced Snail	Irrigation Siphons

Table 4 Mollusc species collected throughout the MDB

4.3.3.5 Conclusions: Molluscan diversity

There is debate over the number of mollusc species that previously occurred in the basin due to problems in early collections and taxonomic confusion (Sheldon and Walker, 1993). More data are available on the Murray River than the northern rivers such as the Barwon-Darling. Smith (1978) recorded 15 native aquatic molluscs distributed throughout the streams and irrigation channels of the Murray-Darling river systems. Sheldon and Walker (1993), however, noted historical records of 18 gastropod taxon along the Lower Murray River. Bennison *et al* (1989) recorded 20 molluscan taxon collected by an Artificial Substrate Sampler during a survey on the Murray river between 1980 –1985. Yet the more recent surveys have shown a continuing loss of molluscan diversity. Surveys by Sheldon and Walker (1998) in 1990 on the Darling and Murray Rivers found 4 molluscan species along the Darling and three along the Murray, with *Physa acuta* the only species common to both systems. A recent project conducted along the Darling River and Menindee Lakes recorded only one mollusc species (ESD, 2002). Indeed, the universal lack of molluscs within the river system sampled adds to the growing data on the loss of molluscan diversity throughout the basin. The inability to discover any live populations of *Notopala sublineata* in the wild during my survey supports previous assumptions that these sub species may be extinct in the wild. It is ironic that the vast majority of the molluscs collected within this survey are now reliant upon the irrigation structures that, due to their construction, reduced the prevalence of molluscs within the rivers.

Chapter 5 Invertebrate Conservation

The results from this survey throughout the MDB in NSW indicate a significant need for measures to be taken towards the conservation of molluscs, and particularly *Notopala sublineata.* As *Notopala* is a snail there will be debate in the public and political arenas over whether its conservation is necessary, a common reaction to any invertebrate conservation initiative. The justifications for and issues associated with invertebrate conservation will be discussed accordingly, as well as the measures that can be taken for *Notopala's* protection, including practical rehabilitation and legal protective measures.

5.1 Invertebrate Conservation

5.1.1 Invertebrates. Is there a quantitative number?

There is continued debate over how many invertebrate species there are on the planet. In reality there will never be an exact number known. In 1992 there were 1.7 million species named (Groombridge, 1992). Vertebrates consisted of 2.7% of the total species count and that number is thought to cover over 95% of all extant vertebrates (Ponder, 1992). There is thought to be some 40000-50000 species of vertebrates contrasting with the staggering count of 1.4 million *named* invertebrate species (Fitter, 1986; Council of Europe 1987 cited in Yen and Butcher 1997). This could be merely 3-20% of the total invertebrate diversity (Ponder, 1992). Each year 15000-20000 new species of invertebrates are named illustrating how little we know about the total numbers of animal life (CONCOM 1989 cited in Yen and Butcher, 1997). The total number of species could be between 5-30 million (Yen and Butcher, 1997; Groombridge, 1992). Our lack of data on organisms that are not as obvious as the vertebrates could mean that current estimates on species diversity could be out by orders of magnitude (Ponder, 1992).

In view of the limited amount of knowledge we currently have on invertebrate species diversity it is highly likely that species will go (and have gone) extinct before they are discovered. A common attitude towards invertebrates is that they are plentiful and under no immediate threat of extinction, but this couldn't be further from the truth. There have been approximately 500 animal and 600 plant extinctions recorded globally since 1600 (Burgman and Lindenmayer, 1998), yet molluscs, for example, have had more documented extinctions than any other group of organism (Ponder, 1992). For a species to be considered extinct it must be named, recorded and had surveys conducted with no finds for several decades (Burgman and Lindenmayer, 1998). Data from early collecting and documenting of invertebrate species is generally not available thus limiting the ability to determine extinct or severely declining species (Ponder, 1997). This is a significant problem especially considering invertebrates are highly susceptible to environmental change.

5.1.2 Why Should we conserve invertebrates?

As we continue to alter the surrounding environment we continue to lose the invertebrate diversity about which we know very little. Invertebrates are steadily declining particularly due to habitat loss, habitat fragmentation, altered hydrology and introduction of exotic species (Horne *et al,* 1995). Should we be making a concerted effort to conserve our invertebrate species? This question needs to be asked due to the lack of recognition of the value and importance of our invertebrate fauna compared with the relatively dedicated interest in our larger vertebrates such as the Koala. Why is it more people are concerned with a panda becoming extinct than a snail? In many instances vertebrates are in no way vital for the maintenance and retention of an ecosystem (Ponder, 1992). Koalas are not necessarily protected because of their role in a habitat; instead they are protected because we value the appearance of the species, as it is an icon for our country's environment. Similarly the diversity of invertebrates' form, colour and uniqueness should be justification enough for their retention (Williams, 1989). The word "invertebrate" generally conjures up the images of pest species and those that cause disease for humans and livestock (Horne *et al,* 1995; Ponder, 1992). In reality those species represent a minute proportion of all invertebrates (Ponder, 1992). As well it is difficult to create a sense of value for invertebrates when there is very little political interest in their conservation. Politicians promoting environmental protection generally want to be seen patting a kangaroo instead of holding a leech (Lunney, 1999). With such a reputation more utilitarian based justifications may be more successful if resources are to be allocated for invertebrate conservation. Yen and Butcher (1997) completed a review of invertebrate conservation in Australia in *An overview of the conservation of Non-Marine Invertebrates in Australia*, where the following justifications for invertebrate conservation were given.

- Invertebrates contribute both directly and indirectly to an ecosystem and are essential to maintaining a balanced biosphere (Council of Europe, 1987).

Some of these include pollination, soil fertility, decomposition, herbivory, predation and parasitism.

- Invertebrates play an important role in scientific research and there is great potential for invertebrates to contribute to new medical advances and products. The lifecycles of invertebrates also enable scientists to study fields that would be difficult with other animals, and also to be used as bio-indicators of environmental change.
- Invertebrates contribute significantly to the economy through the utilisation of species as well as their role in ecosystem functioning such as soil fertility (Council of Europe, 1989). In addition invertebrates play an important role in local economies of developing countries through the sale of invertebrates and more recent tourism attractions such as insect zoos and butterfly houses (Pyle *et al*, 1981).
- Invertebrates are utilized for medicinal purposes. For example the endangered leech, *Hirudo medicinalis,* is used for anticoagulant hirudin (Collins and Wells, 1983; Fitter 1986, cited in Yen and Butcher, 1997). Many of the medicinal values of invertebrates are yet to be discovered.
- Invertebrates are a highly underutilised education tool for our youth regarding the interaction of fauna with our environment, including our urban environments (Yen, 1993; Yen and Butcher, 1997).
- Invertebrates can also be utilized for their aesthetic values i.e. their beauty and individuality. As well invertebrates are photographed, collected and observed for recreational enjoyment.

- Invertebrates ultimately have a right to existence. The current generations have a moral obligation to preserve species and environments for their use by future generations (Greenslade, 1985) or "intergenerational equity": (Burgman and Lindenmayer, 1998) where future generations have a right to experience nature that is surviving at present.

5.2 Molluscan Conservation

5.2.1 The status of molluscs across the globe.

At present the IUCN has listed specifically the Class Gastropoda with more extinct species than any other animal group. This includes the combined extinctions of all Mammalia, Amphibia, Reptilia and Aves. Table 5 compares the number of extinctions listed under the IUCN (2004) worldwide. This highlights the significant worldwide conservation concern for gastropods. Due to this there has been a Specialist Group founded in the IUCN to deal specifically with the conservation of molluscs (New, 1994). Achievements of this group include the release of several issues of a molluscan conservation newsletter 'Tentacle' (New, 1994). More extinctions are known for the molluscan fauna than other fauna potentially because we known more about molluscs. Yet the observed numbers of extinctions for molluscs in the last 400 years are higher by orders of magnitude than the expected numbers of extinctions if the rates were to equal the background rates of extinctions in geological time (Burgman and Lindenmayer, 1998).

Class	Gastropoda	Bivalva	Mammalia	Aves	Reptilia	Amphibia
Extinction No	260	31	74	139	21	7

Table 5 Worldwide extinctions listed under IUCN 2004 (IUCN, 2004)

Australia does not contain a diverse range of freshwater molluscs. There are very few large freshwater molluscan families. The Family Hyriidae contains 18 species; Corbiculidae contains 2 species, Viviparidae 6 species and Thiaridae 9 species (Ponder, 1997). There are 9 families of small molluscs (Ponder, 1997). Although the molluscs aren't so diverse they have an extremely high level of endemicity – 98.6% endemic (Ponder, 1997; Yen and Butcher, 1994). Data aren't available on the historical distributions of molluscs in the now rural and urban environments, even though there is more data on molluscs than other non-marine invertebrates (Ponder, 1997). As well there is relatively very little information on recorded declines of molluscs, making it very difficult to calculate the rate of decline.

Australia does not have a good conservation record with the second greatest number of extinctions in the world (the highest being the United States of America) (IUCN, 2004). The IUCN (2004) has recognized 175 molluscs that are either Critically Endangered, Endangered or Vulnerable within Australia. Yet NSW, Victoria and South Australia together have only listed 5 molluscan taxon. In contrast, Western Australia has 33 listed molluscan taxon. The problem is further accentuated with the complete lack of recovery plans implemented for the listed taxon. If a species is not listed under legislation as a threatened taxa then it is even more difficult to begin the recovery of the species. Without significant action taken for the rehabilitation of the species (or its habitat), the listing process is useless for the conservation of the species.

5.3 Legislation

The results from this current survey indicate a need for better protection for freshwater molluscs like *Notopala sublineata*, as there has been a loss of species across the entire MDB. The listing of a species under legislation ensures the scientific credibility of the conservation status of the taxa not just anecdotal evidence. The following section highlights the advantages and disadvantages for listing of a species and also the problems involved with the listing of an invertebrate, specifically *Notopala.*

5.3.1 Legislative advantages and disadvantages

Protection of a species is most effectively achieved through legislation. This could be through international protection laws, federal legislation or state legislation. Justifications for the use of legislation to protect invertebrates were outlined in Yen and Butcher (1997). These include

- legal protection to prevent the collection or killing of a potentially endangered species,
- the use of flagship species drawing attention to an otherwise invisible species,
- increasing the level of knowledge on invertebrate diversity and,
- the ethical right for invertebrates to have the same legal protection as vertebrates.

Listing of a species can be an excellent education tool. Landholders who are given the opportunity to manage an " Endangered species" are often more diligent in their protection than other authorities such as National Parks, even if the species is an invertebrate (Horne *et al*, 1995; Kitching, 1999).

There are still disadvantages to the listing of a species under legislation and indeed the listing of a species does not necessarily prevent a species from becoming extinct. The prevention of extinction, or the reduction of the risk of extinction, does depend on the social and political will of the country to alleviate the threatening processes and to increase the protection of the habitat of the taxa (Kitching, 1999; Yen and Butcher, 1997). Also the listing of a species can potentially increase the level of black market trade in rare and endangered invertebrates – which are harder to patrol as they are easily transportable (Yen and Butcher, 1997). Listing deters amateur collectors – a valuable resource for biological information collection (Yen and Butcher, 1997). Finally there is the potential to create huge lists of protected invertebrates that practically cannot be protected and will be difficult to justify politically (Yen and Butcher, 1997). This is especially so considering the fundamental limitation of funding for faunal conservation, especially invertebrates.

5.3.2 Legislation available within Australia relevant to the protection of threatened Fauna

Legislative goals for the protection of native wildlife differ between states and between countries. Table 6 details the legislation that is available within Australia at both the federal and state levels. Also it details what taxon are recognized and able to be listed under the corresponding legislation.

5.3.2.1 IUCN Listing

As well a taxa can be listed under the IUCN Red List. This list is scientifically credible but has no legal standing in Australia. As well the listing of a taxa under the IUCN Red List does not entitle states or the federal government to also list this taxa.

Legislative protection is indeed, at present, the best option for the protection of a taxa. Yet even with legislation available it does not seem to be effective for the protection of invertebrates, especially those that are found only on private land.

	Legislation	Recognized Taxon
Commonwealth	*Environmental Protection and Biodiversity Conservation Act 1999*	All taxon, excluding humans
New South Wales	1. *Threatened Species Conservation Act 1995*	. Vertebrates (excluding humans) and invertebrates, vascular and non vascular plants, excluding fish and marine vegetation.
	2. *Fisheries Management Act, 1994*	.. All fish, including oysters, aquatic molluscs, crustaceans, echinoderms, beachworms and other polycheates
Australian Capital Territory	*Nature Conservation Act, 1980*	Vertebrates (excluding humans), invertebrates and plants
Victoria	*Flora and Fauna Guarantee Act, 1988*	Any animal life, both vertebrate and invertebrate including fish, excluding humans. Any plant life, both vascular and non vascular
Tasmania	*Threatened Species Protection Act, 1995*	Any taxon of fauna, both vertebrate and invertebrate, excluding humans. Any taxon of plant, both vascular and non vascular
South Australia	*National Parks and Wildlife Act, 1972*	All mammals (excluding humans), birds, reptiles, amphibians and all plants.
Western Australia	*Wildlife Conservation Act, 1950*	All indigenous animals (non human) and flora
Northern Territory	*Territory Parks and Wildlife Conservation Act, 2000*	All vertebrates, invertebrates, protistans including algae, lichen, prokaryotes and viruses.

Table 6 Legislation in Australia

5.3.3 Is legislation successful in protecting the invertebrate fauna of Australia?

Australia has a huge diversity of invertebrate fauna and yet there is a significant imbalance in the number of invertebrates protected through legislation. The IUCN Red List contains many Australian invertebrates, but these are not protected under the corresponding state or federal legislation. South Australia does not have a single invertebrate protected under either the *National Parks and Wildlife Act 1972* or the *Fisheries Act, 1982*. Invertebrates within South Australia are considered to be "effectively conserved through ecological community approach" (P. Copley, *pers. comm.*). There is an assumption that enough information is known on the ecosystem to retain invertebrate species without any specific information on the invertebrates themselves. Caution should be taken when assuming the role of taxon within an ecosystem. The website for threatened species in South Australia does, however, recognize the importance of invertebrates in an ecosystem, perhaps a sign of changing times. Victoria, under the *Flora and Fauna Guarantee Act 1988*, has 59 invertebrate taxon listed, 10 of which have an Action Statement released but not implemented. In NSW there are 10 listed invertebrates under the *Threatened Species Conservation Act, 1995* and 4 species listed under the *Fisheries Management Act 1994*. The ACT has only 3 invertebrates listed under the *Nature Conservation Act 1980*. Tasmania currently has 55 invertebrates protected under the *Threatened Species Conservation Act, 1995*. The N.T. has 188 invertebrates listed yet this includes IUCN criteria such as Data Deficient, Least Concern and Near Threatened. Western Australia has the most detailed legislative capabilities in terms of invertebrate protection. They have separated major groups of invertebrates – a recognition that no other legislation has adopted, including federal legislation. Under this legislation there are 84 invertebrates protected.

Figure 8 compares the numbers of invertebrates listed under Australian federal legislation compared with other fauna protected. In this context the imbalance towards vertebrate conservation is blatantly obvious. This highlights the lack of early detection of invertebrate declines and hence limits the *prevention* of species reaching critical levels where human intervention is necessary. The scarcity of listed invertebrates is not a representation of the number of threatened invertebrates, instead merely the lack of political will or interest to protect invertebrates. There are many reasons why invertebrates have been neglected in legislative protection.

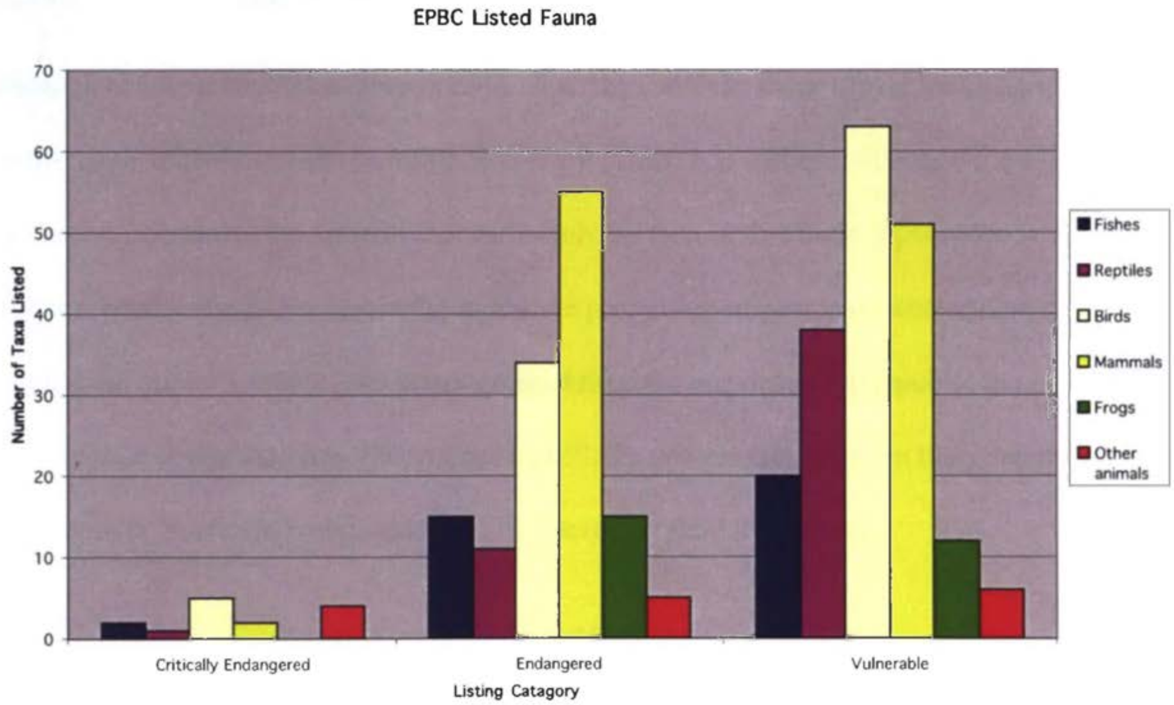


Figure 8 EPBC listed fauna

5.3.4 Reasons for lack of legislative protection for invertebrates.

5.3.4.1 Invertebrate Data

The amount of information available to support the listing of a species is limited in the invertebrate field due to the lack of historical research in invertebrate taxonomy, biology, ecology, distribution, population dynamics etc. In the past vertebrates were the only fauna considered for research, primarily due to the lack of funding available to support invertebrate research and funding constraints continues to limit invertebrate biological research (Lunney 1999).

5.3.4.2 Lack of public and political interest.

Biological conservation has always been biased towards the more visual fauna and flora ie the large animals and the beautiful flowering plants. It is difficult to create a sense of pride and/or concern for animals that can barely be seen or that their appearance is not so conventionally attractive. Again the miniscule proportion of pest invertebrates have tainted the public's view of the entire group. Often the response by the public to invertebrate conservation is "What does it do?". To answer this question there needs to be considerable research, which needs public interest to fund the projects.

5.3.4.3 Threatened Species listing criteria

Probably the most significant problem in listing invertebrates under legislation is the criteria for each of the categories. Most federal and state criteria are loosely based on the IUCN (2001) criteria. The problem lies in the use of these criteria for invertebrates. The IUCN was initiated with the main goal of preserving vertebrate species and vascular plants. The majority of the quantitative criteria is inappropriate for invertebrate taxon due to the significant differences in biology and ecology to vertebrate taxon (Kitching, 1999). For example, one of the IUCN criteria for the listing of a "Critically Endangered" taxon is "Population size estimated to number fewer than 250 mature individuals" (IUCN, 2001). This would be sufficient for the listing of a large mammalian species that has a naturally small population number. This, however, is not applicable for a species of ant, for example, that has an estimated population size reaching into the millions in a single nest. Many of the criteria also rely on detailed records of decline rates in population size and geographic distribution, which for the vast majority of invertebrates is not available

(Ponder, 1992; Yen and New, 1995). As well the level of genetic information on invertebrates is extremely limited. This decreases the ability to prove the level of significance of populations. Legislation listing criteria do recognize that there are gaps in biological information though even with this recognition it is difficult to prove the conservation status of a taxa.

5.4 Conservation of *Notopala sublineata sublineata* and *Notopala sublineata hanleyi.*

From the results of this survey the two populations of *Notopala sublineata hanleyi* in the irrigation pipeline in SA and in NSW are the only known populations in Australia. Measures need to be introduced swiftly to protect this species. The results also suggest that with more intensive surveys there may be more populations discovered in other irrigation districts. The problems involved with the protection of invertebrates and the ability of legislation to effectively protect are highlighted in the conservation initiatives that have already been applied for *Notopala sublineata.*

5.4.1 Problems associated with snails in pipelines

The protection of *Notopala* is difficult due to the location of the final populations and the nature of those populations. The Kingston-on-Murray pipeline feeds the Kingston-on-Murray winery and 25 private irrigators (Wishart, 1994). The juvenile *Notopala* snails, along with *Plotiopsis balonnensis* and *Corbiculina australis,* cause blockages to the sprinkler irrigators, causing the heads to be shut down. The filters need constant cleaning, with significant financial expenses to the irrigators (Wishart, 1994). When the pipelines are inactive (winter-spring) the snails die due to hypoxic conditions, fouling the water supply and causing water quality problems. At present the control method for the reduction of the snails in the pipelines has been to dose the pipe with higher than necessary concentrations of chlorine. This is a relatively effective method, where a single chlorination event has been effective for several years (Wishart, 1994). The chlorination of the pipeline has the potential to wipe out the sub-species in a single event, increasing the snail's extinction risk.

Unfortunately, after the discovery of the species in 1992, the approach by local environmentalists towards farmers caused alienation between these two groups, very much to the detriment of the species (B. Weir, *pers. comm.*). Local irrigators were (and still are) concerned with the loss of water availability and limitations to their control methods for these snails. Environmentalists however are concerned with the highly possible extinction of *N.s.hanleyi*. There exists a stalemate. Local irrigators do not want environmentalists to have access to the pipe in fear of restrictions, and environmentalists want to breed up snails to prevent the reliance on the pipeline environment but are not able to collect live specimens.

The new discovery of the population in NSW needs to be treated with a greater sensitivity towards the irrigators than was used when the SA population was discovered. The WMI pipeline is experiencing similar problems with the snails.

5.4.2 Listing of *Notopala sublineata*

At present the snail is reliant on the seasonality of the supply of water to the pipeline. Ironically this system has protected the snail from extinction. Legislative protection of this species would ensure the continuation of this water cycle, not reduce the water supply as may have been assumed by farmers. Subsequent recovery planning for the snails would ensure that scientists take samples of this population so that the future of the snails is not reliant on these two pipelines. The adaptability of legislation to alter the conservation status of species listed ensures that once the threat of extinction is significantly reduced then the species will be "demoted" to a less endangered criterion. Measures could then be taken to reduced the pressure these "endangered pests" (Walker, 1996) are having on irrigators. This is an excellent opportunity for the irrigation community to be involved with a conservation project, to increase their environmental image and to create a working relationship with local and government environmental groups.

5.4.3 Current Status of *Notopala sublineata hanleyi* and *Notopala sublineata sublineata*

Notopala sublineata sublineata and *Notopala sublineata hanleyi* are currently listed as Endangered under the *NSW Fisheries Management Act 1994* and endangered under the *Flora and Fauna Guarantee Act 1988* in Victoria. As well it is recognized as Endangered by the IUCN (Ponder, 1996). In both states it is presumed that both subspecies are extinct in the wild. Until this discovery of the NSW pipeline population, no live snails have been found in NSW in the wild or in any artificial structures since 1971. The only population known was that in South Australia where it could not be legally protected. The discovery of the NSW population ensures a population is protected under legislation (*NSW Fisheries Management Act 1994*). However, the irrigation district's pipelines are privately owned, and without the cooperation of these districts the protection of this snail may be difficult.

It would be beneficial to have both populations protected under legislation. Without significant alteration to the current SA legislation the Kingston-on-Murray population will not be able to be protected. Another option is to have both subspecies listed under the federal legislation, the EPBC. The listing of *Notopala* under EPBC has already been attempted (EPBC, 2005). A nomination was put forth for the listing of the species as Critically Endangered (CE). The rejection of this nomination highlights the inadequacies in the criteria used for listing and the listing process.

5.4.4 Listing of *Notopala sublineata* under the EPBC

For a species to be listed under the EPBC it is recommended that each of the criteria be addressed yet only one criterion need be met for the taxa to be eligible. In the recent nomination no information was provided for the potential listing under Criterion 1, 3, 4 and 5 (EPBC, 2004). Even though quantitative data is difficult for *Notopala* it is still available. The next section details the justifications why *Notopala* should be listed as CE under the EPBC Act and the problems associated with the criteria in relation to *Notopala's* situation with direct reference to the reasons for the rejection.

5.4.4.1 Criterion 1 Population declines (EPBC, 2004; IUCN, 2000)

A (2).

An observed, estimated, inferred or suspected population size reduction of >80% over the last 10years, or 3 generations, whichever is longer (up to a maximum of 100 years in the future), based on and specifying any of (a) to (e) under A1.

It has been suggested that for invertebrates a more practical way to determine a reduction in population size is to " express in terms of the reduction of its area of occurrence in conjunction with spatial structure of meta-population and ecological attributes of the species" (Hitchings and Ponder, 1999). Historical records and current assessments are unable to determine whether *Notopala sublineata sublineata* and *Notopala sublineata hanleyi* contained genetically distinct populations throughout their range within the basin. As a result, it could be suspected that the population size of both of these subspecies was the size of their distribution within the basin. Hence the population size in terms of area of occupancy for *N.s.s.* would encompass the Darling River and its tributaries and for *N.s.h.* would encompass the Murray River and its tributaries. Recent and past surveys have found no live specimens of either of the subspecies over the past 10-15 years in their natural environment (Bennison et al, 1989; Sheldon and Walker, 1993a,b; 1997; Walker et al 1992; Walker 1996; Ponder, 1997; Ponder *pers. data*, Australian Museum Data 2004; Ponder *pers. comm.*; ESD, 2004). This current report has also found no specimens in the natural environment of the MDB. The only known populations now are the

Kingston-on-Murray pipeline and the recently discovered Western Murray Irrigation Pipeline, where *Notopala sublineata hanleyi* is surviving.

Based on this information it can be estimated that the population of *Notopala sublineata sublineata* has been reduced from an area of occupancy, according to DPI Fisheries (Fishnote, 2002a), of the Darling River (2640 km) (Ponder, Australian Museum Data) to no known surviving populations. That is a 100% reduction in the subspecies population size, an assumed extinction of *Notopala sublineata sublineata.*

For *Notopala sublineata hanleyi* however there are two known populations. The area of occupancy of the population consists of a 4 km pipeline in SA and an estimated 8 km pipeline in NSW. The historical distribution of *N.s.hanleyi* is found approximately halfway along the Murray (a length of approximately 1250 km), along the Murrumbidgee before Wagga Wagga (approximately 400 km) and along the Lachlan (approximately 400 km) (Ponder, Australian Museum Data). This gives a combined population coverage of approximately 2050 km. There has been a complete disappearance of the snail within the natural environment and now the population is reduced to a combined pipeline length of 12 km. Hence the percentage decline in population size can be calculated as:

12 km (pipeline) / 2050 km (historical population coverage) × 100 / 1

= 99.41 % decline in population size.

(Frankham *et al*, 2004)

This extent of decline clearly establishes the eligibility of a listing for the snail as Critically Endangered.

The causes for the reduction of these populations have also not ceased based on A.1.c) (EPBC, 2004). The habitat quality of the snail is primarily based on the availability of a bacterial biofilm. The alteration of biofilm and the subsequent reduction of the snail's food quality and quantity have been suggested as one of the main cause for the disappearance of the snail. Prior to river regulation there would have been a greater nitrogen content, and therefore a higher quality food source, within the biofilm. This report has shown a much lower level of nitrogen within the composition of the biofilm that was collected throughout the basin maintaining an inappropriate level of food quality for the survival of the snail (see Figure 7).

As well the introduction of carp has been suggested as a cause for the decline of the species (see section 3.2.3). There have been no successful carp eradication projects and carp remain abundant throughout the system, retaining the threat to *Notopala* (Koehn *et al*, 2000).

5.4.4.2 Criterion 2. Geographic Distribution (EPBC, 2004)

(TSSC Guidelines)

Its geographic distribution is precarious for the survival of the species and is very restricted.

In their recent nomination of *Notopala*, the snail was found to be eligible under this criterion yet the nomination was still rejected. It was accepted that *N. s. hanleyi* was known to be surviving in one pipeline. This was before the discovery of the WMI pipeline population. However there was significant uncertainty about the extent of the species in both the natural and artificial environments. There was also uncertainty over the conservation outcome from the listing of the species.

(a) Extent of Occurrence in Artificial Structures

This survey has shown a universal lack of *Notopala sublineata* populations within artificial structures and this survey consisted of the irrigation systems supported by the Murray, Murrumbidgee, Namoi, Upper and Lower Darling Rivers. The irrigation systems within the northern sections of NSW sections of the basin, and the upper sections of the Murray, differ in their habitat availability to the systems that support the populations of *Notopala sublineata hanleyi* in SA and in NSW along the lower sections of the Murray. The two pipelines that support the snail are old, under ground, and completely enclosed. The irrigation systems in NSW consist of open irrigation channels and closed small piping. The irrigation channels, that promote algal growth, are only filled with water during the irrigation season, which means some of the channels are only filled for a week at a time and then let to desiccate. The small underground pipelines (approximately 5cm in diameter) have filter plates at the point of access from the water and are too small to allow for the passage of the snails, including the juveniles. These pipes are also only approximately 20 years old so if there were populations surviving in the past pipes they were removed when the new pipelines were introduced. There is no evidence to suggest that there are surviving populations of either subspecies within the irrigation structures of the MDB, other than the Kingston-on-Murray pipeline and the Western Murray Irrigation Pipeline supporting *N.s.hanleyi*.

(b) Conservation outcome for the listing of the species

The listing of this species would significantly increase the chances of the snail's survival, as it would be protecting the known populations and be an incentive for the local irrigators to allow for collection of specimens from the pipelines. It would also ensure a basin-wide approach to the snail's recovery. A recent success of a breeding program of the snail by Bookmark Biosphere in SA (see Section 6.2) suggests that the appropriate action taken by the recovery plan determined under the EPBC has the potential to increase the likelihood of the survival of *N. s. hanleyi* within the river systems of the MDB. This in itself justifies the listing of the snail under the EPBC.

5.4.4.3 Criterion 3 and Criterion 4

Criterion 3 C1. Population size estimated to number fewer than 250 mature individuals

Criterion 4. D. Population size estimated to number fewer than 50 mature individuals.

Criterion 3 and 4 highlight the problems with population size, or mature individual count within a population when looking at endangered and threatened invertebrates. The numerical values of 250 and 50 individuals, initiated from vertebrate population numbers, are in no way relevant to an isolated invertebrate species whose individual numbers could be thousands (Kitching, 1999).

5.4.4.4 Criterion 5. Probability of extinction

E. Quantitative analysis showing the probability of extinction in the wild is at least 50% within 10years.

It has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in it past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form.

The previous range of *Notopala sublineata hanleyi* is the southern section of the Murray-Darling Basin i.e. the Murray River and its tributaries. The most recent discovery of a live specimen of this subspecies found in the wild was in 1971 along the Lachlan River (Ponder, AM Data). Since then there has been no live discoveries in the natural environment. There is a cultivated population off a tributary of the Murray maintained by the Australian Landscape Trust. It is thought that the population is successfully self-sustaining in these artificial habitats. This is a positive sign that with human intervention and significant efforts for rehabilitation that the snail may escape complete extinction and be reintroduce into the natural environment, where they are currently assumed extinct. Individual listing for *N. sublineata* is important considering the potential for extinction. Yet recently a more ecosystem-based approach to conservation has been attempted for the aquatic biota of the MDB.

5.5 Listing of Ecological Communities

As well as being listed as Endangered as individual taxa, *N.s.s.* and *N.s.h.* are part of ecological communities that have been listed as Endangered under the *NSW Fisheries Management Act* (FMA). These communities cover the 'Lower Murray River Catchment' (Fishnote, 2002b) and the 'Lowland Catchment of the Darling River' (Fishfacts, 2003). The areas where these Endangered Ecological Communities (EECs) have been identified overlap the historical distribution of both subspecies. The listing of 'Ecological Communities' is a mechanism now being used to protect whole assemblages and *Notopala sublineata* is the only invertebrate taxa within the assemblage that has been individually listed.

When an ecological community is listed a Recovery Plan is drafted, as for an individual taxa, as part of the obligation under the FMA. Recovery plans for EECs ultimately aim to maximize or maintain a level of biodiversity that have been recognized and those that are yet to be identified, primarily through the prevention or control of threats to that EEC, as well as the rehabilitation and maintenance of the processes and habitats that support the community (Fishnote, 2002b; Fishfacts, 2003).

The threats to the ecological community that have been identified by the Fisheries Scientific Committee are similar for both of these EECs (Fishnote, 2002b; Fishfacts, 2003). These include:

- Modification of natural river flows as a result of river regulation (dams, weirs etc), leading to reduced habitat quality, loss of spawning cues, and reduced opportunities for dispersal and migration
- Spawning failures resulting from cold water releases from dams
- Predation and competition from introduced fish species such as carp, goldfish, redfin perch, gambusia, weatherloach and tench
- Degradation of the riparian zone through clearing of native vegetation and stock access, leading to loss of shelter and increased sedimentation.
- Removal of snags, which are an important habitat component and territory marker for many fish and invertebrates.
- Agricultural practices such as irrigation, clearing, grazing and the use of fertilizers and pesticides, which have affected water quality
- Over-fishing has probably contributed to past declines in populations of some species. Illegal fishing, together with hooking injuries in accidentally caught fish, still pose a threat to some threatened species.

The recognition of the main threats to the EECs is important, yet without the implementation of threat abatement plans and/or recovery plans the listing of an Ecological Community does not benefit the community. Recovery actions have, however, already begun for the Lower Murray River Catchment (Fishnote, 2002b). These include:

- Managing environmental water flows in regulated rivers to restore natural seasonal flow patterns, and to reduce the impact of cold water originating from large dams.

- Conserving and where possible restoring habitats through the protection of aquatic and riparian (riverside) vegetation and encouraging the use of effective siltation control measures.
- Developing and implementing control programs for introduced species.
- Re-snagging waterways, where appropriate.
- Sustainably managing fishing activities.

There is, however, no recovery plan implemented specifically for the Lower Darling Ecological Community (Fishfacts, 2003). The recovery plan will be linked with the threat abatement plans for each of the Key Threatening Processes (KTP's) that have been listed under *Fisheries Management Act* (see Chapter 6) (Fishfacts, 2003).

The Department of Primary Industries (DPI), in the recommendation for the listing of these communities, acknowledges that much of the data on the specific taxon within these communities is not yet known (Fishnote, 2002b; Fishfacts, 2003). The protection of an ecological community focuses on the whole assemblage and creates more of an ecosystem-based approach to conservation rather than focusing on a niche habitat of a single threatened species. Protection of EECs under legislation recognises the importance of faunal interactions within an ecosystem. In terms of preserving invertebrate diversity within the rivers of the MDB the listing of EECs is more practical than identifying and listing individual taxon that appear to be declining. More importantly, however, the threats that have been identified for these EECs are broad issues that effect the entire aquatic environment e.g. the construction of instream structures. Hence threat abatement plans and recovery plans for these EECs will benefit the entire system, including maintaining populations of taxon that are not yet threatened and therefore *preventing* species loss.

For *Notopala sublineata* an individual breeding project is still needed due to the lack of populations within the river systems. It is still important that *Notopala sublineata* be individually listed. The known populations are within artificial pipelines, which are excluded from the range of the EECs and therefore the legislative protection. Yet the implementation of the recovery initiatives for the ecological communities of the Lower Murray River and the Darling River would be fundamental to the success of any recovery plan for *Notopala sublineata* as the EECs listed are the communities that *Notopala sublineata* is included in. There is never only one species in an environment and dealing with the issues affecting the entire system is potentially the only way to create a successful rehabilitation project for a community, and within that community a single species.

5.6 Conclusions

Legislation is at present the best option for the conservation of a taxa, and assemblages of taxon. This is primarily due to the obligation by the governing body to implement a recovery plan. It also allows for the consideration of declaration of 'critical habitat' for the species. In the case of *Notopala* it is clear that both subspecies are eligible for listing under the EPBC as Critically Endangered. The rejection of a re-nomination for the listing with the additional information from this survey would indeed have no scientific basis behind that choice. Collaboration with the recovery programs initiated for the EECs would be extremely beneficial for both *Notopala sublineata* and for the ecological communities of those systems.

Chapter 6 Recovery Planning For the Conservation of *Notopala sublineata hanleyi* and *Notopala sublineata sublineata*

6.1 Recovery Planning in NSW

Recovery planning is an essential element if the listing of a threatened species will result in successful conservation of that species or community. Without significant efforts to alleviate the threatening processes and/or rehabilitate the natural environment of the species, the listing of a species or community is redundant. During the period in which this survey was conducted, NSW Fisheries, now part of the Department of Primary Industries (DPI), drafted a recovery plan for the rehabilitation of *Notopala sublineata* in NSW as part of the obligation of listing *Notopala sublineata* as Endangered under the *NSW Fisheries Management Act 1994*. One of the main issues highlighted was the lack of any known extant populations in NSW. The discovery of the population in the WMI pipeline provides an opportunity for a breeding program and subsequent reintroduction in NSW. This is an excellent chance for NSW Fisheries and WMI to prevent the extinction of this snail. The goal of any recovery project for *Notopala* is the successful reintroduction of *Notopala* into the natural environment, the prevention of a species' extinction, and the removal of an "endangered pest" (Walker, 1996) from the pipeline.

DPI has recognized that the recovery program will have to work with other threat abatement plans if the reintroduction is to be successful. There have been Key

Threatening Processes (KTP's) listed which are relevant to the disappearance of the snail. These include:

- Degradation of the Riparian vegetation along NSW water courses,
- Installation and operation of instream structures and other mechanisms that alter, natural flow regimes of rivers and streams,
- Introduction of fish to waters within a river catchment outside their natural range and,
- Removal of large woody debris from New South Wales rivers and streams.

Along with the Threat Abatement Plans for the KTP's, the recovery project for *N. sublineata* will work in collaboration with the Recovery Plans for the 'Endangered Ecological Communities' of the Lower Murray Catchment and Darling Catchment. Hence recovery planning specifically for *Notopala* needs to focus on details of rehabilitation projects that have already been attempted for the conservation of the snail to determine the effectiveness of alternative methods.

6.2 Current Rehabilitation Projects.

Notopala has created a lot of interest in developing techniques for its protection and significant efforts have been made to create more stable populations since the discovery of the population in Kingston-on-Murray pipeline. Two efforts have been made to reintroduce the snails into alternative environments to their natural lotic river systems. These are the Loveday Wetland and the Banrock Wetlands.

6.2.1 Loveday Wetlands

Loveday wetlands are situated off the Lower River Murray in South Australia. The land is owned by Centra Irrigation Trust (CIT) but leased by a local bird-hunting group, Barmera/Moorook Field and Game (BMFG). As part of BMFG's interest to preserve the local wetland bird diversity the BMFG began an initiative to breed *Notopala sublineata hanleyi*. The snails were stocked from the population in the Kingston Pipeline.

The Loveday Wetlands contain one permanent wetland and one wetland that is periodically dried. The wet/dry function of the wetland is maintained by the Department of Environment and Conservation in SA. The process of setting up the wetting and drying regime was based on the Canadian Ducks Unlimited Model (B. Weir *pers. comm.*). Most of the design of the box culvert flow regulators, carp screens and breeding pipelines was conducted through BMFG with Peter Schramm and Assoc. Prof. Keith Walker from Adelaide University.

The artificial structure for supporting the breeding snails consisted of an underground pipeline joining the two wetlands that were approximately 300m apart. Periodically along the pipeline PVC-pipes were attached. The PVC-piping consisted of a pipe with holes throughout to allow for juvenile dispersal. One end of the PVC-pipes were submerged in the sediment and the other end of the pipe extended to ground level. Adults and juveniles were placed in the piping hoping for dispersal into the wetland. Unfortunately, the introduction of the snails has been unsuccessful, as of November 2004, with no self-sustaining populations eventuating. There are many factors to why this could be so. The accumulation of the bacterial biofilm is yet to be achieved, therefore still displaying the problems with the snails in the natural environment. As well there are still carp present in the wetland which could have a significant impact via either predation or increased siltation/turbidity. As well, due to the drought in the area, the wetting/drying regime can only be maintained when the Murray River receives a significant amount of flow. Finally, the dispersal ability of *Notopala* is poor especially due to its viviparity and this may mean the snails are unable to colonise the wetlands.

6.2.2 Banrock Wetlands

Banrock Wetlands is located on a 4200 acre property in SA – 3600 acres are rehabilitated wetlands. At present these wetlands have been listed as a Ramsar Wetland Site. In February 2001, as a conservation initiative, *Notopala sublineata hanleyi* was introduced into the Banrock Wetlands in PVC pipes identical to those in the Loveday Wetlands. At present the reintroduction project has been unsuccessful as the population within the pipe is not self sustainable and needs constant restocking from the Kingston-on-Murray pipeline. As well, the presence of carp within the wetland may be preventing a successful dispersal of juveniles into the wetlands. It is unclear whether biofilm necessary for the snail's survival and reproduction has been recreated.

6.2.3 Captive Populations

A successful captive population was set up for *Notopala sublineata hanleyi* as a component of an Honours Thesis by M. Wishart to determine the energetic cost of viviparity. The specimens were provided from the pipeline population and maintained in a circulating aquaria (K Walker *pers. comm.*). The difficulty in this project was the development of artificial food containing bacteria but it provides an opportunity to create breeding populations in captivity.

6.2.4 Bookmark Biosphere

The most recent effort in the rehabilitation of *Notopala sublineata hanleyi* has been conducted by Bookmark Biosphere in collaboration with the Australian Landscape Trust (ALT). The ALT manages the properties Calperum Station and Tayorville – both pastoral leases in South Australia owned by the Australian government (Bookmark, 2004). Calperum Station is a large area of land set aside for conservation under the UNESCO mandate and Biosphere Scheme (Bookmark, 2004). Biosphere reserves, recognized by the United Nations, are areas that are biologically significant (Bookmark, 2004). Local communities are highly involved in the management and protection of these areas specifically in the land protection, wildlife management, scientific research and monitoring and the development of policies to protect the land (Bookmark, 2004).

The snail breeding project has been funded by Chicago Zoological Society (C. Hedger *pers. comm.).* At present the ALT has maintained three populations of snails in individual tanks and five populations in holding tanks. Three populations in artificial habitats, PVC piping, are being maintained in a creek off the Murray River. The piping containers have holes to allow for water flow but at present are not large enough to allow for juvenile dispersal as there has been no active carp control within the creek. All of these colonies are on Calperum Station and each colony ranges from approximately 25-40 snails (C. Hedger *pers. comm.)*. The snails were transferred directly from the pipeline on Kingston-on-Murray to the containers before the biofilm had generated on the substrate. To compensate for this, biofilm was placed directly from water filters in the irrigation district to the containers. After two months the biofilm became visible, but to speed up the biofilm accumulation, debris was added to the containers (C. Hedger *pers. comm.)*. As yet it is not known what type of biofilm is surviving in the containers but it appears that the snail populations are self-sustaining. This is a significant outcome as it suggests that biofilm of enough quality is still capable of supporting *Notopala* (however reduced in population size) in the natural environment. It also suggests that the presence of carp may be the primary cause for the *complete* disappearance of the snail. However, significant additional research needs to be conducted before such conclusions can be made. The Bookmark Biosphere project aims to create a structure that can be relatively easy to reproduce therefore creating local interest in the rehabilitation (C. Hedger *pers. comm.)*.

Chapter 7 General Discussion

7.1 Recommendations for the future conservation efforts for the recovery of *Notopala sublineata sublineata* and *Notopala sublineata hanleyi* in NSW.

7.1.1 *Notopala sublineata sublineata*

The results of my survey indicate an absence of this subspecies in the river reaches sampled. This finding is consistent with other recent surveys and reviews which suggest that *Notopala sublineata sublineata* has disappeared throughout NSW rivers and irrigation structures. There is no evidence to suggest that a remnant population will still be surviving and the nature of the NSW irrigation systems supports this assumption. It is extremely likely that *Notopala sublineata sublineata* is extinct. Further surveys need to be conducted near Walgett and the Menindee Lakes to verify if the location of the shells found a decade ago (Ponder, *pers. comm.*) may be an area supporting an extant population. Aside from these surveys no further efforts should be utilised specifically on this taxa, as it seems to be a fruitless use of limited resources. This, however, is a sad reminder to the irreversibility of the many impacts that past and present practices have had in the MDB. If indeed no live specimens or fresh shells are discovered in these localities it is my suggestion that processes begin for the listing of *Notopala sublineata sublineata* as an extinct taxa.

7.1.2 *Notopala sublineata hanleyi.*

(a) Breeding Program

With the discovery of some *Notopala sublineata hanleyi* in NSW in the Western Murray Irrigation pipeline, it seems that there are at least two populations of this subspecies surviving, both in artificial structures. There were no live specimens or shells found in any of the river systems sampled during this survey. Due to the limitations of this project and the nature of the irrigation systems supported by the Murray, there is a possibility that this subspecies may have other remnant populations. In fact, this is quite likely. Yet this does not alter the status of this snail as being under serious threat of extinction. This project surveyed a few districts along the Murray and found no evidence of other populations. More intensive surveys are now needed to document the extent of any remaining populations in the Lower Murray irrigation districts. The discovery, however, provides an excellent opportunity for an environmental project to protect remaining *Notopala sublineata hanleyi* populations in NSW. A cooperative relationship between conservation organizations and the irrigation community needs to be initiated if there is any chance of a successful conservation effort and recovery of the snail. The most important aspect of this recovery plan is the need for a breeding program to be initiated *before* the next flushing of the WMI pipeline, which will be during September 2005. This is fundamental to the success of the recovery program as the next chlorination or flushing event could potentially destroy this population (assuming it is still there). Areas of potential reintroduction must be located within the natural systems. Information should to be collated on the habitat type that was chosen for the PVC-pipe introduction into the tributary off the lower Murray in the Bookmark Biosphere reintroduction effort in South Australia. This information can then be used to find similar habitats in NSW rivers. The rivers chosen for the snail's recovery should begin with the Murray River and its tributaries and then in the future, depending on the success of the initial recovery program, look at possible reintroductions into the northern rivers of NSW. Based on the unsuccessful reintroduction of snails into the wetlands along the lower Murray River, no further efforts should be made to reintroduce the snails into lentic environments; suitable lotic environments need to be identified as a matter of urgency.

A captive breeding facility needs to be available before the snail's reintroduction into the wild so a population is maintained throughout the project in case of failures in the reintroduction efforts. Again this needs to be initiated before September 2005. Any recovery plan in NSW needs to focus on the methods used by the Bookmark Biosphere breeding program. Constant monitoring of these populations will determine whether the methods are successful and whether alternative procedures need to be implemented.

(b) Biofilm

Biofilm also needs to be collected and placed within the PVC piping and containers. For the captive population studied by M. Wishart, details of the artificial food composition needed to maintain the populations are given. The Bookmark group translocated biofilm directly from irrigation filter plates and the inside of the Kingston pipeline into the PVC piping and tanks where the snails were relocated. Debris was added to help with the accumulation of biofilm. As the food quality and quantity was initially thought to be the main cause for the decline in the snails within the rivers – and also an explanation to the large population numbers in the Kingston pipeline - then an examination of the biofilm is fundamental to this project. The success of the Bookmark group's project in the Murray tributary suggests that the biofilm within the river is still able to maintain populations, though probably with a reduced population density. A detailed examination of the composition (species composition and chemical composition) may provide valuable information on food quantity and quality thresholds in which the snail populations can still be maintained in the wild. This, in turn, could lead to further sections within the MDB river systems that may support the reintroduction of the snail.

There have been problems with biofilm accumulation in past recovery efforts, i.e. at the Loveday and Banrock Wetland. The biofilm accumulation for the Bookmark effort was noticeable after approximately 2 months. Therefore, if the PVC-piping does not contain significant biofilm after the translocation from the WMI pipeline following a 2 month accumulation period, then direct translocation of biofilm from the Kingston pipeline could be another option. This then of course requires collaborative working relationships with Kingston-on-Murray farmers.

(c) Carp

Carp appear to be a significant factor associated with the complete disappearance of the snail in the rivers. Any recovery plan for the snail must also be in collaboration with an active effort for the eradication or control, if that is all that is possible, of carp from within the rivers where *Notopala sublineata hanleyi* could potentially be reestablished. This has already been recognized in the NSW Fisheries draft Recovery Plan. Once active carp control was implemented in the rivers and the snails found to be successfully reproducing in the PVC piping, introduction of the snails directly into the natural environment could be trialed to determine whether certain sized snails were able to be maintained within the rivers. This could determine whether there was a level of carp control needed to allow for *Notopala's* survival in the natural environment. Initially, however, any type of breeding program should resemble the Bookmark methods, specifically, the use of PVC piping that contains holes only large enough for water flow, preventing any interaction with carp.

(d) Further Research

The discovery of the WMI population does suggest that there could be more populations with the irrigation structures in the Lower Murray Catchment in NSW, Victoria and South Australia. Government agencies need to work closely and cooperatively with industry groups such as WMI and with conservation groups to explore ways of conserving the species.

7.2 The future for other mollusc species in the MDB

The molluscan diversity of the lowland rivers of the MDB has declined significantly in response to altered hydrology throughout the basin over the past century (Bennison *et al*, 1989; Boulton and Lloyd, 1991; Evans, 1981; Farnham, 1980; Jenkins, 1991; Lloyd *et al*, 1990; Sheldon and Walker, 1993a,b; Smith, 1978; Thompson, 1986; Walker *et al*, 1992). *Notopala sublineata* is the only mollusc listed as Endangered in NSW rivers. However, Table 7 displays the molluscan taxon that are part of the protected Ecological Communities of the Lower Murray River Catchment and the Lowland Catchment of the

Darling River. The list for the Lower Murray catchment is thought to be relatively comprehensive for macro-molluscs (FSC, as of November 2002). Considering that shell middens show 15 gastropods common within the Lower Murray prior to river regulation (Smith, 1978; Walker *et al* 1992) the need for protection of these communities is justified. The list of molluscs in the ecological community of the Lowland Catchment of the Darling River, however, is thought to be incomplete (FSC, as of July 2003). None of the known molluscan species are regularly identified in the field. Some of this apparent rarity may be due to naturally low population numbers and hence unsuitable sampling methods (Ponder *pers. comm.*), but densities may be critically low due to severe declines in their population numbers. Only 4 species were collected in the rivers during this survey. Historical records do show a greater molluscan diversity presence within the rivers, with very large numbers for some of the taxon (Johnston and Beckwith, 1945; 1947; Maheshwari *et al*, 1995; Sheldon and Walker, 1993a; Sheldon and Walker, 1993b). A comprehensive historical distribution map should be prepared for all known freshwater molluscs throughout the basin to detail the locations and dates of collections for specific taxa (Ponder *pers. comm.*). Further research is needed in both drainages (the Murray and the Darling) to detail the *current* distribution and status of the molluscan species. At one level, it is concerning that the majority of molluscs are now only collected from irrigation channels and pipelines. This is particularly so considering they are a negative presence for local industries within these artificial structures. On another level, however, it is comforting that there is at least some apparent refuge habitat for these species.

Lowland Catchment of the Darling River	Lower Murray River Catchment
Alathyria condola (mussel)	*Alathyria condola* (mussel)
Alathyria jacksoni (mussel)	*Alathyria jacksoni* (mussel)
Velesunio ambiguus (mussel)	*Corbiculina australis* (bivalve)
Austropeplea lessoni (snail)	*Sphaerium problematicum* (bivalve)
Austropeplea tomentosa (snail)	*Sphaerium tasmanicum* (bivalve)
Bayardella cosmeta (snail)	*Velesunio ambiguus* (mussel)
Bithynia affinis australis (snail)	*Austropeplea lessoni* (snail)
Ferrissia tasmanica (snail)	*Glytophysa gibbosa* (snail)
Glacidorbis hedleyi (snail)	*Notopala sublineata hanleyi* (snail)
Glytophysa aliciae (snail)	*Thiara balonnensis* (snail)
Glyptophysa gibbosa (snail)	
Gyraulus gilberti (snail)	
Gyraulus scottianus (snail)	
Isidorella newcombi (snail)	
Notopala sublineata (snail)	
Notopala suprafasciata (snail)	
Posticobia brazieri (snail)	
Thiara balonnensis (snail)	
Corbicula australis (clam)	
Musculium problematicum (clam)	
Musculium quirindi (clam)	
Pisidium carum (clam)	
Pisidium hallae (clam)	
Pisidium ponderi (clam)	
Ferrissia petterdi (clam)	

Table 7 Molluscan Taxon listed as part of the Endangered Ecological Communities in the MDB

As no other mollusc is listed as threatened under the FMA the best option for molluscan protection is to initiate the recovery plan for the two EECs. The EECs recovery plans will hopefully create an umbrella for those species that need protection. As part of the recovery plans, detailed surveys should be conducted to determine that the proper conservation priorities are given to declining taxa. It is highly possible that many of the other molluscan taxon are experiencing similar situations to the restricted occupancy of *Notopala sublineata.* More detailed analysis of the diversity within the systems may prove some of the molluscan taxon are being supporting solely by irrigation structures.

Entire communities in these structures could be translocated back into the wild systems as part of the recovery plan for the EECs.

7.3 Protecting aquatic invertebrate assemblages in the MDB

7.3.1 Research

The invertebrate assemblages of the MDB are vital for the maintenance of water quality, fish populations and the overall biodiversity of the system (Yen and Butcher, 1997). Little information is known on the historical invertebrate assemblages of the MDB prior to river regulation and hence alterations in those communities are difficult to detail. There have been few comprehensive surveys of macroinvertebrates post river regulation which limits the ability for organizations to affectively create management strategies for the protection of threatened communities or taxa. Hence a vital aspect for invertebrate conservation in the MDB is continued monitoring, surveillance and taxonomic identification of the aquatic fauna within these river systems.

7.3.2 Legislation

Threatened species or community protection begins with the listing under legislation. It is important that invertebrates be recognized as taxa that are able to be protected under legislation. This is a significant issue in the South Australian legislation. At present invertebrates can be protected in a similar strategy to the listing of Endangered Ecological Communities such as the ones listed in NSW. Individual taxa listing, however, is vital for not only the recovery of such threatened invertebrates but also as a recognition of the individual importance of invertebrates within a system.

In NSW there have been 257 taxon (including fish) listed under the EEC Lowland Catchment of the Darling River (FSC, 2005), and 140 taxon (including fish) listed under the EEC Lower Murray River Catchment (FSC, 2005), with the recognition by the Fisheries Scientific Committee that many more taxon are part of these communities but not as yet described. The listing of these EECs is an excellent opportunity for not only the protection of these assemblages but also the potential for the recovery of the unknown invertebrate fauna within these systems, increasing our level of knowledge on the river's biota. It is not possible, or practical, because of the size of the EECs and the number of invertebrates within the system to document the individual decline or alteration of each of the taxa. The overall protection of these systems, particularly through threat abatement plans, has the potential to greatly increase, or maintain the invertebrate diversity of these two drainages.

Many listings are put forth for endangered taxon and yet nothing is done once the listing is successful. It seems that the issues of river health degradation, fish stock declines and the loss of aquatic biodiversity within the Murray River are sufficiently serious to have already initiated some of the actions listed in the two recovery plans under the FMA. Hopefully, enough interest can be generated for the commencement of a further recovery plan (or plans) specifically for the upper reaches of the Darling Catchment, so as to create a basin-wide approach to invertebrate diversity protection.

Acknowledgements

I would like to thank Winston Ponder of the Australian Museum for the identification of the molluscs and for his words of wisdom about the world of molluscs. I would like to thank Sylvia Zukowski, Bruce Weir. Allan Amos, Chris Hedger and Allan Whyte for all their help and advice. Thank you to James Hooker of Macquarie University for the Biofilm analysis. Thank you to Dr Lesley Hughes for your advice and encouragement. I would like to thank Glenco, Western Murray Irrigation, especially Jim Andrews, Murrumbidgee Horticulture and Murrumbidgee Irrigation. Special thanks to all of the farmers that allowed me to sample along their properties and showed me such hospitality. I was accepted with open arms and for that I am so grateful.

I would like to thank Dr Bob Creese for his supervision and for your excellent advice when critiquing my work and I thankyou. I would also like to mention Antonia Creese, Gabrielle Holder and Samantha Hessey for their help throughout this project.

To Dr Jim Kohen. Captain Planet of the FEW Research team. A man who has the most incredible time management of anyone I have met. You were always there to help me with my work and always gave me constructive advice when critiquing my papers and I have appreciated everything that you have helped me with so thankyou.

I would like to thank all of my friends in the department at uni and especially the FEW Research Group. To Nat and Jack. With you two wonderful friends I won't ever stop smiling and laughing.

To my beautiful family. Mum (Sally), Dad (John), Briony and Clare. I am so lucky to be part of this family. Thank you for putting up with me and for always being there.

And finally to that little snail.
Here's hoping you one day again thrive in that watery wonderland.

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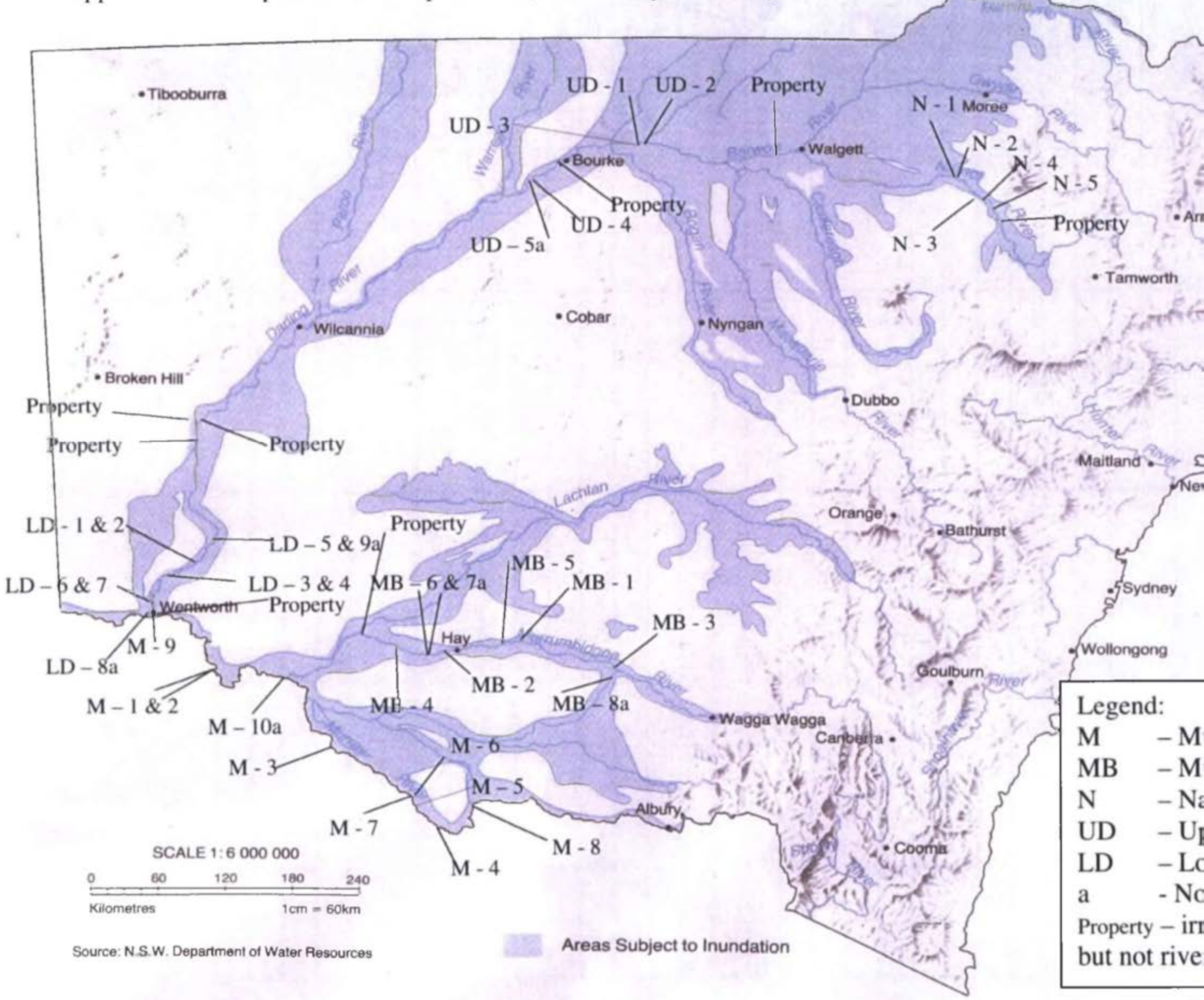
Appendix 1 Map of NSW Sample Sites (Source: *Department of Water Resources*)



Appendix 2 Live macroinvertebrates collected throughout the MDB (sorted to Family, Order (O), Subclass (SC) or Class (C)).

	Murray	Murrumbidgee	Lower Darling	Upper Darling	Namoi
INSECTA					
HEMIPTERA					
Corixidae	2125	182	8	233	183
Notonectidae	8	5		7	58
Gerridae		1			
Veliidae		5			
ODONATA					
Protoneuridae	2		2	18	4
Aesnidae			1		
Petaluridae	1				1
EPHEMEROPTERA					
Caenidae	4	1		10	
COLEOPTERA					
Gyrinidae				1	
Hydrophilidae				4	
Haliplidae	1				
Dystiscidae		7		4	8
MEGALOPERA (O)	1				
MECOPTERA (O)	1			1	1
DIPTERA					
Indeterminate (O)	1	2		2	
Culicidae				3	
Emphididae		1			
Ceratopogonidae	1				
Chironomidae	4	2		27	
TRICHOPTERA					
Ecnomidae			1		
Philopotamidae				27	
Leptoceridae				1	
PLECOPTERA					
Gipopterygidae		2			
COLLEMBOLA (C)	18				

CRUSTACEA					
DECAPODA					
Atyidae	372	37	193	56	68
Palaemonidae	6	7	148	75	20
Parasticidae			1		
ISOPODA					
Cirolanidae	2		21	7	25
Indeterminate (O)					1
OSTRACODA (C)	1			3	
CLADOCERA (O)				46	12
COPEPODA (SC)		7			
ARACHNIDA					
ACARINA (O)				18	
Pisauridae					1
ANNELIDA					
HIRUDINA					
Glossiphoniid	1				
MOLLUSCA					
BIVALVA					
Corbiculidae	1		1		

Appendix 3 Environments macroinvertebrates were collected within.

River

	Taxa Name	Common Name	Environment
Murray	Atyidae	Freshwater Shrimp	River/Irrigation
	Caenidae	Mayfly Nymph	River
	Chironomidae	Non-biting Midges	River
	Cirolanidae	Shrimp Parasites	River
	Collembolla		River
	Corbiculidae	Little Basket Shells	River/Irrigation
	Corixidae	Boatmen	River/Irrigation
	Diptera		River
	Haliplidae	Crawling water beetle	River
	Glossiponidae	Freshwater Leech	Irrigation
	Mecoptera	Scorpian fly nymph	River
	Megaloptera	Toebiters	River
	Notonectidae	Backswimmers	River/Irrigation
	Palaemonidae	Freshwater Prawn	River
	Protoneuridae	Damselfly nymphs	River
	Petaluridae	Giant Dragonflies	River
	Ostracoda		River
Murrumbidgee	Atyidae	Freshwater Shrimp	River/Irrigation
	Caenidae	Mayfly nymphs	River
	Ceratopogonidae	Pogs/Biting Midges	River
	Chironomidae	Non-biting Midges	River
	Copepoda		River
	Corixidae	Boatmen	River
	Diptera		River
	Dystiscidae	Diving Beetles	River
	Empididae	Dipteran Larvae	River
	Gerridae	Water striders	River
	Gipopteryidae	Stonefly Nymphs	River
	Notonectidae	Backswimmers	River
	Palaemonidae	Freshwater Prawn	River/Irrigation
	Veliidae	Small water striders	River
Namoi	Aesnidae	Aesnid-like Dragonflies	River
	Atyidae	Freshwater Shrimp	River/Irrigation
	Caenidae	Mayfly Nymph	River
	Cirolanidae	Shrimp Parasites	River/Irrigation
	Cladocera		River
	Corixidae	Boatmen	River/Irrigation
	Dystiscidae	Diving Beetles	River/Irrigation
	Isopoda		River
	Mecoptera	Scorpian fly nymph	River
	Notonectidae	Backswimmers	River
	Pisauridae	Nursery/Swamp/Fishing Spiders	River

	Palaemonidae	Freshwater Prawn	River
	Protoneuridae	Damselfly nymphs	River
Upper Darling	Acarina	Freshwater mites	River
	Atyidae	Freshwater Shrimp	River/Irrigation
	Caenidae	Mayfly Nymph	River/Irrigation
	Chironomidae	Non-biting Midges	River/Irrigation
	Cirolanidae	Shrimp Parasites	River
	Cladocera		River
	Corixidae	Boatmen	River/Irrigation
	Culicidae	Mosquitoes	River
	Diptera		River
	Dystiscidae	Diving Beetles	River
	Gyrinidae	Whirligig Beetles	Irrigation
	Hydrophilidae	Waterscavenger beetles	River/Irrigation
	Leptoceridae	Caddisfly larvae	River
	Mecoptera	Scorpian fly nymph	Irrigation
	Notonectidae	Backswimmers	River/Irrigation
	Ostracoda		Irrigation
	Palaemonidae	Freshwater Prawn	River
	Petaluridae	Giant Dragonflies	River
	Philopteridae	Caddisfly larvae	River
	Protoneuridae	Damselfly nymphs	Irrigation
Lower Darling	Aesnidae	Aesnid-like Dragonflies	Irrigation
	Atyidae	Freshwater Shrimp	River/Irrigation
	Chironomidae	Non-biting Midges	Irrigation
	Cirolanidae	Shrimp Parasites	River
	Corbiculidae	Little Basket Shells	Irrigation
	Corixidae	Boatmen	Irrigation
	Economidae	Caddisfly larvae	River
	Palaemonidae	Freshwater Prawn	River
	Parastacidae	Yabbie	River/Irrigation
	Protoneuridae	Damselfly nymphs	Irrigation