UNMACK, P.J. (South Australian Research and Development Institute (SARDI), Inland Waters Section, Adelaide, Australia.)

Desert fishes down under

Los peces del desierto de Australia

KEYWORDS: Australia; fish distribution; habitat; threats; management; springs

ABSTRACT

Australia contains vast areas of desert relative to North America although much of it contains little permanent water and remains ichthyologically unexplored. Thirty three native and eight introduced species have been recorded. I begin with a history of ichthyological exploration in central Australia. Then I provide a brief summary of Central Australian fish habitats and an annotated list of native and introduced species. Finally, I review the threats to central Australian fishes

CLAVES: Australia; distribución de peces; hábitat; amenazas; manejo; manantiales

RESUMEN

Australia contiene extensas áreas de desierto en relación a América del Norte, muchas de las cuales contienen poca agua permanente y que permanecen ictiológicamente inexploradas. Están registradas 33 especies nativas y ocho introducidas. Empiezo con la historia de exploraciones ictiológicas el Australia Central. Entonces doy un sumario breve de los habitats de peces en al zona, con una lista anotoda de especies, y termino con un repaso sobre las amenazas a peces Australianos.

CONTRIBUTED PAPER

INTRODUCTION - Australia has been isolated from the rest of the world for 50 million years, providing the flora and fauna a chance to evolve in unique ways, and develop a high degree of endemism. Unlike North America, Australia has been tectonically very stable for a considerable period of time; no major mountain building has occurred for tens of millions of years. Parts of the Finke River are thought to have followed the same course for at least 65 million years (my) and possibly up to 350 my (Cook 1968 cited in Pickup et. al. 1988). Significant streamflow in parts of central Australia ceased around 15 my ago (Van De Graaff et. al. 1977), marking the time that aridity first began in central Australia.

Today, 70% of Australia is semi-arid to arid desert (Fig. 1). In central Australia, average daily summer temperatures are typically 37-39°C (100°F). Occasionally, they may climb into the low 50's. Average daily winter temperatures range from 16 to 24°C. Night time temperatures in winter rarely drop below -2 or 3°C. In central Australia, annual evaporation varies between 2400 and 4400 mm. Average annual rainfall ranges from 110 mm around Lake Eyre to 300-450 mm on the margins. Rainfall is very sporadic. Droughts are the normal situation in central Australia. However, localized falls can be extremely heavy, for instance, 300 mm in an overnight storm at Merty Merty homestead, (near Innamincka) (Bonython 1989).

Not surprisingly, the desert region of Australia supports a limited, highly localized fish fauna. Only 11 families are represented by 33 native species, and two subspecies. The fish show a high degree of endemism and extraordinary adaptations for desert existence. In this paper, I provide an historical perspective on the ichthyological exploration of central Australia. Then I provide a brief summary of central Australian fish habitats and an annotated list of the fish species, both native and exotic. It concludes with an overview of the threats to central Australian fish.

PAST AND PRESENT ICHTHYOLOGICAL WORK - Prior to 1894, only three species had been recorded from central Australia. The Horn Expedition (Spencer 1896) was the first to investigate central Australian fishes. It made a number of important observations including the lack of evidence for aestivation by desert fish and the importance of flooding for dispersal. Several new species were described and new records made of others. This expedition raised the number of species in central Australia to 10, representing 7 families.

In the years between 1894 and 1971, sporadic collecting raised the total number of native fish recorded to 26 species from 9 families and 3 exotics from two families (Glover & Sim 1978a; 1978b). Detailed work on central Australian fishes really only began when John Glover, the Curator of Ichthyology at the South Australian Museum (SAM), undertook studies from 1967 until his death in 1992. He conducted many expeditions throughout central Australia, publishing several new records and discoveries, including the fishes from Dalhousie Springs. In the last checklist of central Australian fishes, Glover (1982) recorded 26 native species from 10 families and 4 exotic taxa from 3 families. The total numbers still recognized today is 22 native and two exotic species respectively.

Several other workers have made, or are continuing to make contributions to central Australian ichthyology. Hamar Midgley has irregularly sampled the larger Queensland Rivers and the Barkley Drainage since the late 1960's. Helen Larson, the Curator of Ichthyology at the Nothern Territory Museum (NTM), has sampled many of the drainages in the Northern Territory, adding several new records. Since 1986, Jim Puckridge from Adelaide University has been conducting a study of the fish community dynamics in relation to the hydrological regime at Coongie Lakes. Work has also been conducted since 1988 in the South Australian portion by Bryan Pierce from the South Australian Research and Development Institute. This includes further genetic analysis of fish populations (independent of, though incorporating and expanding upon some of Glover's electrophoretic work), as well as the dynamics of fish populations, habitat assessment, management research and other ecological work. My own investigations started in 1985, and I have since sampled most drainages and habitats in the Lake Eyre drainage. Presently I am involved with work on South Australian springs with B. Pierce. Mark Adams from the SAM Evolutionary Biology Unit, and Terry Sim from the SAM Ichthyology Department, are continuing electrophoretic studies on central Australian fishes initiated by John Glover. Rob Wager from the Queensland Department of Primary Industries-Fisheries, is presently involved in endangered species research at Edgbaston and Elizabeth Springs, as well as some broader survey work in Queensland. The only taxonomists to recently deal with fishes of the region were Lucy Crowley and Walter Ivantsoff from Macquarie University. Their atherinid studies have recognized several new species from central Australia.

HABITATS - **Lakes** - Lakes in central Australia provide a very minor and irregular habitat for fish. Despite the great size of some lakes, most rarely contain water. Two exceptions to this are Woods Lake in the Wiso system and the Coongie Lakes in the Cooper Creek system; both are a series of interconnected, shallow lakes that rarely dry out (Reid and Puckridge 1990). Little data exist for Woods Lake, but the Coongie Lakes are rarely over 2m deep (Reid and Puckridge 1990) (Plate 1). When full, lakes such as Lake Eyre and Frome contain massive, although short lived fish populations that die off as salinity levels rise following evaporation (Ruello 1976).

Lake Eyre is the eighteenth largest lake in the world (Kreig 1989). It has a total area of 9,000 km^2, but is thought to have been three times larger and permanent around 50,000 years ago (Dulhunty 1982). During the record 1974 floods, the lake peaked at an estimated 32.5 million megalitres or 26 million acre feet. After some minor inflows in the intervening years, it was virtually dry again by 1979-80 (Bye & Will 1989). While rarely completely dry, it probably doesn't contain resident fish populations.

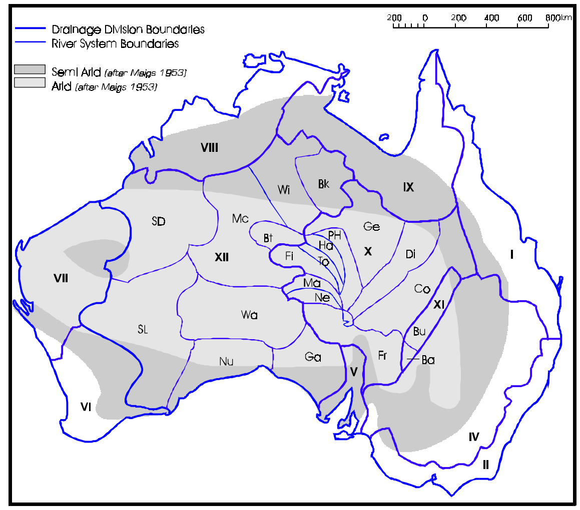

Figure 1. Australian Drainage Divisions (I=NE Coast; II=SE Coast; III=Tasmanian; IV=Murray-Darling; V=S Australian Gulf; VI=SW Coast; VII=Indian Ocean; VIII=Timor Sea; IX=Gulf of Carpentaria; X=Lake Eyre; XI=Bulloo-Bancannia; XII=Western Plateau) and Central Australian river systems: **Ba**-Bancannia; **Bk**-Barkley; **Bt**-Burt; **Bu**-Bulloo; **Co**-Cooper; **Di**-Diamantina; **Fi**-Finke; **Fr**-Frome; **Ga**-Gairdner; **Ge**-Georgina; **Ha**-Hale; **Ma**-Macumba; **Mc**-MacKay; **Ne**-Neales; **Nu**-Nullabour; **PH**-Plenty/Hale; **SD**-Sandy Desert; **SL**-Salt Lake; **To**-Todd; **Wa**-Warburton; **Wi**-Wiso.

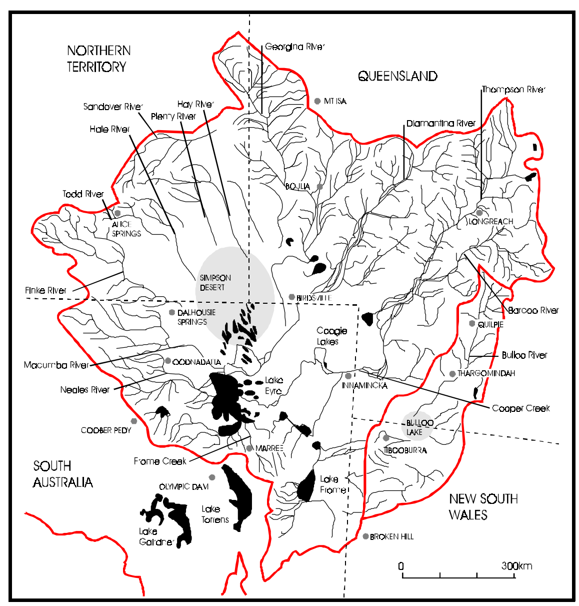

Figure 2. Lake Eyre and Bulloo-Bancannia drainage basins (modified from Allan 1989).

Rivers - Rivers in central Australia are unusual in that they all rise and end in the arid zone. In most of the world, desert rivers enter deserts from humid areas. There is no permanent flowing water in any waterways except springs and streams flow only after rainfall events. Central Australia does not have a wet and a dry season, however, large storms tend to be more common in summer when the occasional remnants of tropical cyclones drift over central Australia. Australian rivers are up to 1000 times more variable in mean annual discharge than most European and North American rivers (Gale & Bainbridge 1990). In small catchments streamflows are relatively short; perhaps a few hours to a few days. At any one site on a larger river, flow typically lasts for a few days to a few weeks, and flows lasting greater than one month are rare. Streamflow tends to travel slowly along the length of the river. Cooper Creek for example is reported to have gradients as low as 3cm/km. Thus, it may take one or two months for water to travel from upper to lower reaches. When in flood, rivers such as Cooper Creek may spread as wide as 50 km (Plate 2). Most rivers contain very little permanent water, other than a few permanent waterholes, most water disappears after a year or two with no flow (Plates 3, 4). What little available physiochemical data demonstrate that most waterbodies have very broad temperature and salinity ranges (Glover 1982). Doddridge (1992), working in lower Cooper Creek, recorded an annual temperature range of 13 to 34°C. Turbidity, caused by fine clay particles, is typically exceptionally high.

Australia is divided up into twelve major drainage divisions, with 3 in central Australia (Figure 1). The Bulloo-Bancannia Drainage Division covers approximately 100,570 km^2. It consists of the Bulloo River system which terminates in Bulloo Lake, a series of large ephemeral swamps on the Queensland-New South Wales border (Fig. 2). The Bancannia system consists of a series of small, isolated creeks and lakes, which along with the Bulloo River, remain poorly sampled, with most fish known only from a few specimens. Curiously, the Bulloo River's fish populations are far less abundant than expected compared to other central Australian rivers. This may be due to much higher turbidity levels relative to other central Australian rivers. Previous authors have incorrectly considered that the Bulloo River is, or was, part of the Murray-Darling Drainage Division (Lake 1971; Llewellyn & Pollard 1980). The present topography indicates that the most likely place for historical drainage was towards Lake Frome, and the fish fauna of the Bulloo River most closely resembles that of Cooper Creek, which had past connections to Lake Frome.

The Lake Eyre Drainage Division covers approximately 1,300,000 km^2, only 30% of which exceeds 250 m above sea level. Lake Eyre, at 15.2 m below sea level (Kotwicki 1989) is the terminus for all the drainage (Fig. 2).

Despite the relatively long and large size of the rivers, permanent water is quite limited in the Lake Eyre Division. The Neales River, for example, is reported to have two permanent waterholes. The Macumba (Plate 5), Finke (Plate 6), Todd, Hale Rivers and all of the Frome System have no permanent waterholes, while the

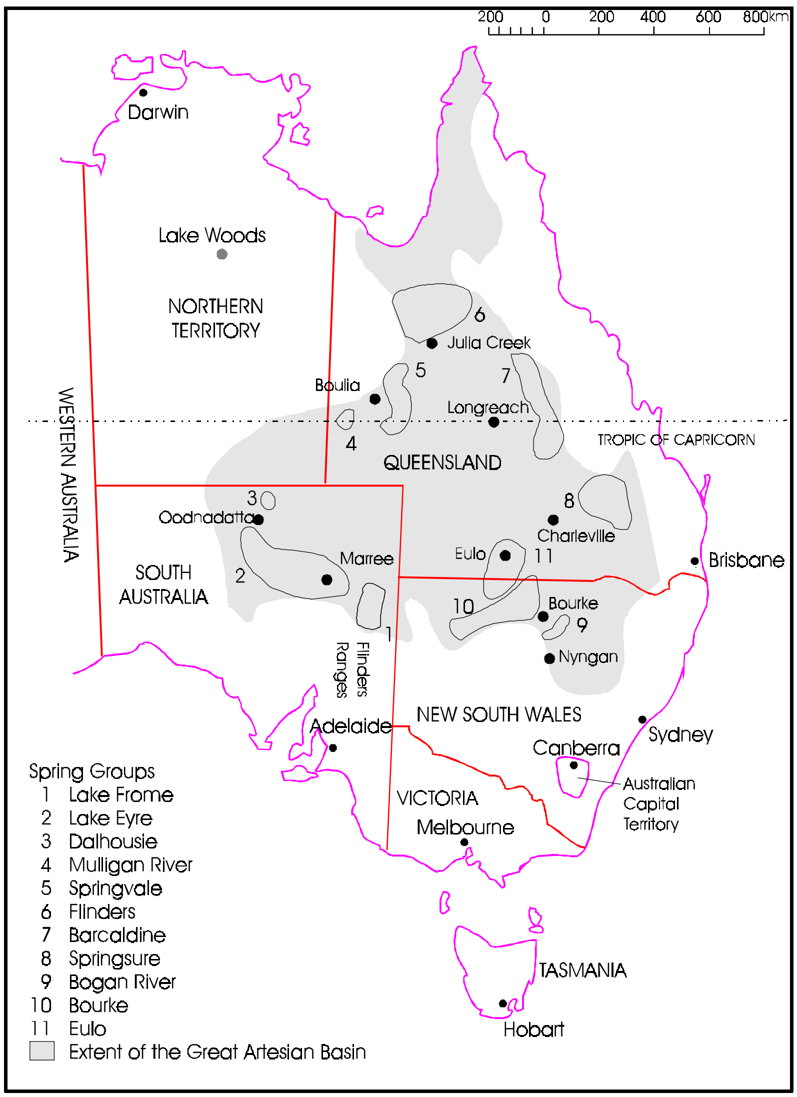

Figure 3. Spring Supergroups associated with the Great Artesia Basin (redrawn from Habermehl (1982) and Ponder (1986).

Plenty and Hay Rivers have only a couple of tiny springfed pools. The Georgina River has only one waterhole which has not dried since European settlement, although there are many which usually have water (Randal 1978). The Diamantina River has quite a few permanent waterholes, while Cooper Creek, in the least arid area, has the most waterholes, and not surprisingly the highest fish diversity.

Despite the appearance on a map that most of the larger rivers connect to Lake Eyre, the lake appears to act as a physical barrier to migration by some fish species. Most of the rivers that contribute water to the lake each have distinctive fish faunas (see Table 1). Several species are endemic to Cooper Creek, while the Diamantina River has no endemic species, though both rivers occasionally flow into Lake Eyre at the same time. There are no obvious reasons why the Cooper Creek endemics couldn't survive in the Diamantina River today. Although data are lacking on what lives in the lake, most species can access the lake during floods, and the lake habitat is not that different from their usual habitat. Nobody really knows why the endemics don't cross between the rivers.

The Western Plateau Drainage Division is around 2,455,000 km^2 and is mostly between 450 and 600 m above sea level. Primarily because most of it is inaccessible due to a lack of roads, its fish are very poorly known, especially in Western Australia. It consists of a series of fragmented drainages (Van De Graaff et. al. 1977); no major rivers exist and permanent water is apparently scarce. Despite lack of collecting, spangled perch (*Leiopotherapon unicolor*) have been recorded from all but three rive systems.

SPRINGS - All of the larger, and most permanent springs in central Australia are associated with the Great Artesian Basin (GAB) (Fig. 3). It is one of the largest artesian or groundwater basins in the world and covers 1.76 million km^2 or 22% of Australia (Ponder 1986). Eleven "supergroups" of springs are recognized (Habermehl 1982, Ponder 1986). Habermehl (1982) estimates there are approximately six hundred "springs"; however one "spring" may represent anywhere from two to 400 individual spring outlets (Ponder 1986). Most Australian springs are relatively small with a discharge of <1 l/s. Only 11 have discharges of 5 - 138 l/s, and all of these are located at Dalhousie Springs (Smith 1989). Many springs have a distinctive mound, and are thus often referred to as mound springs, although the size and composition of mounds vary greatly. Springs which do not form mounds are often referred to as artesian springs. Water from most of the springs is sufficiently low in dissolved solids to be suitable for stock and/or human consumption. Harris (1981) provides a short summary of the Aboriginal and European history of the springs. Relatively few springs harbor fishes, and only those known to contain endemic fishes are discussed here. A number are known to contain endemic invertebrates, although, with the exception of some groups, i.e. hydrobiid snails (Ponder & Clarke 1990), amphipods, ostracods, and isopods, most invertevrates are poorly studied. Many of the springs remain uncollected, however, most are relatively small and/or degraded. Despite this, chances of new discoveries are high.

Dalhousie Springs (Plate 7) are thought to have formed one to two million years ago (Kreig 1989). Within the Dalhousie springs complex there are 100 individual spring outlets, of which approximately 80 are still active and account for 41% of the natural spring discharge from the GAB (Habermehl 1982). These occur over an area of about 70 km^2 (Zeidler & Ponder 1989a). Dalhousie Springs are the only major group which produces warm water outflows; many springs have temperatures between 30 and 46°C. These springs have by far the most significant spring fauna in Australia with 6 fish species, 4 of them endemic, at least six endemic hydrobiid snails, and several small crustaceans, including a blind amphipod (Zeidler 1991). In addition, a crayfish and a frog are also possibly endemic (Zeidler and Ponder 1989b). Due to its isolation there are currently no introduced aquatic animals in any of the springs and there has been very little modification to the springs except for the introduction of date palms (*Phoenix dactylifera*). In 1985, the property containing Dalhousie Springs was purchased by the South Australian Government to form Witjira National Park (Harris 1989), making Dalhousie Springs the first complete spring group in Australia to be protected.

The Lake Eyre supergroup (Plates 8-10) is the largest spring complex in terms of the number of individual springs. These occur in a band approximately 400 km long by 20 km wide around Lake Eyre (Ponder et. al. 1989). Although around 100 "spring groups" have been named (Casperton 1979), there are perhaps several thousand individual outlets, most of which are very small. The average age of water emerging from springs in the Southwest is one million years (Bentley et. al. 1986). Desert goby (*Chlamydogobius eremius*) has been recorded in thirty springs. Lake Eyre hardyheads (*Craterocephalus eyresii*) and spangled perch are occasionally recorded, and one exotic, "dambusia" (*Gambusia holbrooki*) is found in a few springs. Endemic invertebrates include ten species of hydrobiid snails from two genera (Ponder et. al. 1989), several ostracods (DeDeckker 1979), amphipods, an isopod (Nicholls 1943), and a Platyhelminth (Sluys 1986). Few other groups have been studied.

Edgbaston Springs (Plate 11) are a part of the Springsure supergroup. At least 44 springs have been identified at Edgbaston Springs (Wager 1994), some of which have naturally gone extinct. Most are very small, shallow, marshy, and none form mounds. Four native fishes have been recorded, redfinned blue eye (*Scaturiginichthys vermeilipinnis*), Edgbaston goby

(*Chlamydogobius sp. C*), Myross hardyhead (*Craterocephalus sp.*), (all endemic) and spangled perch (recorded once). Dambusia are also present in many springs. These springs contain the smallest natural habitat of any fish in Australia; the area inhabited by the redfinned blue eye is approximately 6-8,000 m^2 . Edgbaston Springs also contains some of the harshest freshwater environmental conditions; temperatures may vary diurnally by up to at least 21°C (Wager & Unmack in prep.). Despite their small size, Edgbaston Springs contains a very significant fauna which rivals that of Dalhousie Springs. It includes 7 congeneric snails, with up to 6 sympatric in some springs (Ponder & Clarke 1990). There are also undescribed ostracods, amphipods and other invertebrates (Ponder 1986).

Elizabeth Springs (Plate 12) are a part of the Springvale supergroup, which had several active springs prior to water extraction. Today, only Elizabeth Springs, which was once probably the second or third largest spring in the GAB, remains active, flowing at <5% of its original rate. It discharges through approximately 30 individual spring outlets spread over an area of 0.6 km^2. One fish, the Elizabeth Springs goby (*Chlamydogobius sp. A*), and one hydrobiid snail are known endemics (Unmack & Wager in prep. b).

FISH - **General Remarks** - There appear to be two reasons fishes have been able to persist in central Australia despite the lack of permanent water. First, it is generally rare for all waterholes in a particular system to be dry at the same time, and second, the permanency of some waterholes is affected by floods. Most species are very effective at migration. Within each river system, fish distribution is fairly uniform; most waterholes will typically contain 80-100% of the total fauna. During floods virtually every water body above the point where flow ceases are connected, albeit perhaps briefly, but the very low gradient allows flood water to persist for longer periods.

Most central Australian fishes have very broad environmental tolerances. All can tolerate temperatures between 15 and 35°C, and most would tolerate 7 to 37°C; a few, such as desert goby and spangled perch (*Leiopotherapon unicolor*) (Merrick & Schmida 1984), can tolerate lows of 4 and highs of 42°C for short periods. Virtually every Australian fish examined can tolerate direct transfer into 50% sea water. However, few can tolerate 100% sea water. Most can generally survive in relatively low oxygen concentrations, although specific data are lacking. The recruitment of most species is linked to flooding. Several species can spawn independently of flooding, but significant juvenile recruitment occurs only after floods. Most species generally spawn at temperatures above 20 to 26°C. Most of the smaller species, especially hardyheads, rainbows, smelts, and glassperches, tend to lay relatively few (20-60) eggs daily during the warmer months. Larger species, such as catfish, grunters, and perches tend to spawn large numbers of small eggs during floods. All of the gobies and gudgeons tend to attach eggs onto hard surfaces. The male guards the eggs until hatching, after which no further parental care occurs.

SPECIES ACCOUNTS - Central Australian fishes and data on their distribution are presented in Table 1. Brief accounts of each species biology, ecology and life history follow. Most ecological information given is based on populations outside of central Australia as most central Australian populations have not been studied.

Clupeidae - herrings - Bony bream or gizzard shad *Nematalosa erebi* (Gunther 1868) - Bony bream are very similar ecologically to the North American genus *Dorosoma* (J. Puckridge, pers. comm.). It is the second most widespread fish in Australia, and is abundant in central Australia. In the Murray River, individuals grow to 470 mm and spawn in early summer independent of flooding. They are highly fecund, with 199 - 403 mm TL females producing 33,000 - 880,000 eggs (Puckridge & Walker 1990). In Cooper Creek, bony bream have a much broader spawning period, and they don't grow as large (J. Puckridge pers. comm.). Annual kills of bony bream, common during winter, have been attributed to several causes, including achlya (Puckridge et. al. 1989) or parasitic infections (Langdon et. al. 1985), and low water temperatures.

Retropinnidae - smelts - Australian smelt *Retropinna semoni* (Weber 1895) - The Australian smelt is widespread in Southern Australia, but within central Australia it is restricted to Cooper Creek, where it is abundant. Maximum size is 100 mm TL. Spawning can begin in mid-winter and may extend into early summer in Cooper Creek (J. Puckridge pers. comm.). Fecundity is probably low (Merrick & Schmida 1984).

Plotosidae - eeltailed catfish - Hyrtl's catfish *Neosilurus hyrtlii* Steindachner 1867 - Hyrtl's catfish is the third most widespread fish in Australia and is usually abundant in central Australia, where it grows to 350 mm TL. Spawning has been observed during floods, and fecundity ranges from 1,600 to 15,300 eggs for females from 186 - 267 mm TL (Orr & Milward 1984).

Dalhousie catfish *Neosilurus sp.* - The Dalhousie catfish is restricted to fourteen springs at Dalhousie Springs (Kodric-Brown & Brown 1993) where it is generally abundant. It is listed as Threatened by the Australian Society for Fish Biology (ASFB) (Jackson 1992). Maximum size is 120mm (Glover 1989), although specimens will grow to 180mm in captivity.

TABLE 1. DISTRIBUTION RECORDS FOR CENTRAL AUSTRALIAN FISHES

	BBDB		------LAKE EYRE DRAINAGE BASIN -----											WESTERN PLATEAU DRAINAGE									HAB.		
NATIVE SPECIES	**Bu**	**Ba**	**Co**	**Di**	**Ge**	**LE**	**Fr**	**Ne**	**Ma**	**DS**	**Fi**	**To**	**PH**	**Bk**	**Wi**	**Bt**	**Mc**	**SD**	**SL**	**Wa**	**Nu**	**Ga**	**Ri**	**Sp**	**CS**
bony bream	X	-	X	X	X	X	X	X	X	-	X	-	-	X	X	-	-	-	-	-	-	-	X	-	-
Australian smelt	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
Hyrtl's catfish	X	-	X	X	X	-	-	X	-	-	X	-	-	X	X	-	-	-	-	-	-	-	X	-	-
Dalhousie catfish	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	V
false-spined catfish	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	U
Cooper Creek catfish	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
silver tandan	X	-	X	X	X	-	-	-	X	-	-	-	-	X	X	-	-	-	-	-	-	-	X	-	-
Finke hardyhead	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	R
Dalhousie hardyhead	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	V
Lake Eyre hardyhead	-	-	X	X	-	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-
Glover's hardyhead	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	V
Myross hardyhead	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	E
desert rainbowfish	X	-	X	X	X	-	-	X	X	-	X	-	-	X	X	-	-	-	-	-	-	-	X	-	-
red-finned blue eye	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	E
western chanda perch	-	-	X	X	X	-	-	-	-	-	X	-	-	X	X	-	-	-	-	-	-	-	X	-	-
Lake Eyre golden perch	-	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
Bulloo River golden perch	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
banded grunter	-	-	-	-	X	-	-	X	-	-	X	-	-	X	-	-	-	-	-	-	-	-	X	-	-
Welch's grunter	X	-	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
spangled perch	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	-	X	X	-
Barcoo grunter	X	-	X	X	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-
Western carp gudgeon	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
Midgley's carp gugeon	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
Lake's carp gudgeon	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
Finke mogurnda	-	-	-	-	-	-	-	-		X	X	-	-	-	-	-	-	-	-	-	-	-	X	X	-

(Continued)

TABLE 1. DISTRIBUTION RECORDS FOR CENTRAL AUSTRALIAN FISHES (CONTINUED)

	BBDB		------LAKE EYRE DRAINAGE BASIN -----										WESTERN PLATEAU DRAINAGE									HAB.		
NATIVE SPECIES	**Bu**	**Ba**	**Co**	**Di**	**Ge**	**LE**	**Fr**	**Ne**	**Ma**	**DS**	**Fi**	**To**	**PH**	**Bk**	**Wi**	**Bt**	**Mc**	**SD**	**SL**	**Wa**	**Nu**	**Ga**	**Ri**	**Sp**	**CS**
Flinders Ranges mogurnda	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	V
Bulloo mogurnda	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	Ex
Frew mogurnda	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-
desert goby	-	-	-	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-
Elizabeth Springs goby	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	E
Dalhousie goby	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	R
Edgbaston goby	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	E
Finke goby	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-
flathead goby	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
Total	12	-	19	11	11	5	5	7	4	6	9	1	1	9	6	1	1	1	1	-	-	-	26	12	12
TRANSLOCATED NATIVES																									
silver perch	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
Murray-Darling golden perch	-	-	-	-	-	-	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	X	-	-
Murray cod	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
INTRODUCED EXOTICS																									
dambusia	X	-	X	X	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	-
goldfish	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-
carp	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-

BBDB=Bulloo-Bancannia Drainage
Bu=Bulloo River system
Ba=Bancannia system
Lake Eyre Drainage
Co=Cooper Creek system
Di=Diamantina River system
Ge=Georgina River system
LE=Lake Eyre
Fr=Frome River system
Ne=Neales River system
Ma=Macumba River system
DS=Dalhousie Springs
Fi=Finke River system
To=Todd River system
Ha=Hale River system
PH=Plenty/Hale River system
Western Plateau Drainage
Bk=Barkley system
Wi=Wiso system
Bt=Burt system
Mc=MacKay system
SD=Sandy Desert system
SL=Salt Lake system
Wa=Warburton system
Nu=Nullabour system
Ga=Gairdner system
Habitat
Ri=Rivers, lakes, anything but a spring
Sp=Springs
CS=Conservation Status (Jackson 1992)
Ex=Extinct (not in Jackson 1992)
E=Endangered
V=Vulnerable
PT=Potentially Threatened
R=Restricted
U=Uncertain Status

Fecundity ranges from 136 to 1,197 eggs for 72 - 120mm TL females. It is not known if spawning is seasonal or occurs all year round (Glover 1989). This species occurs voluntarily in water up to 40°C (Unmack pers. obs. 1994). Glover & Sim (1978a) originally proposed that this species and Dalhousie hardyheads were both limited to thermal waters because they appeared to have low tolerance to temperatures below 20°C. However, this appears inaccurate, as once acclimated, Dalhousie catfish will feed, and show no sign of distress, at 16°C (Unmack unpub. data).

False-spined catfish *Neosilurus sp.* - This rare species is known only from two specimens from central Australia that were collected in 1974 from the Bulloo River. Virtually nothing known of this species except that it grows to at least 300 mm TL (Allen 1989).

Cooper Creek catfish undescribed genus and species (Plate 13) - The Cooper Creek catfish is an undescribed species and genus which is very poorly known. It is confined to Cooper Creek where it is widespread and usually common, though not abundant. It appears to be a distinct lineage of Plotosidae. Maximum size is at least 600 mm. It has the largest egg size and lowest fecundity per unit length of any fish in central Australia, or any other Australian freshwater plotosid. A 450 mm female contains approximately 1,000 eggs (Unmack in press).

Silver tandan *Porochilus argenteus* (Zeitz 1896b) - Silver tandans are found in most of the larger rivers where they can be very abundant at times. They probably spawn during flooding, undertake substantial migrations, and grow to 300 mm TL.

Atherinidae - hardyheads or silversides - Finke hardyhead *Craterocephalus centralis* Crowley & Ivantsoff 1990b - The Finke hardyhead is a recently described species. It is generally widespread and abundant, though restricted to the Finke River, where it grows to 64 mm TL. It is listed as Restricted by ASFB (Jackson 1992). Like most craterocephalids they probably spawn during the warmer months, laying a few eggs daily.

Dalhousie hardyhead *Craterocephalus dalhousiensis* Ivantsoff & Glover 1974 (Plate 14) - This species is restricted to approximately 7 springs at Dalhousie Springs (Kodric-Brown & Brown 1993). It is listed as Vulnerable by the ASFB (Jackson 1992). Growing to 78 mm TL, this is the only member of the genus known to be morphologically sexually dimorphic (Ivantsoff & Glover 1974). In aquaria, this species lays a few eggs a day when temperatures are maintained over 24°C. It is not known whether they reproduce throughout the year or seasonally under natural conditions. Dalhousie hardyheads have the highest recorded voluntary temperature tolerance of any Australian fish; they will live in 40°C and make very brief excursions into water of 41.8°C (Glover 1989).

Lake Eyre hardyhead *Craterocephalus eyresii* (Steindachner 1884) - Three isolated populations of Lake Eyre hardyheads exist, Lake Eyre, Northern Flinders Ranges and Lake Torrens/Willochra Creek (which is not a central Australian drainage). Their abundance and distribution fluctuates widely. They may occasionally be found in the lower reaches of most rivers draining into Lake Eyre, e.g. Cooper Creek and Diamantina River, however, these are probably ephemeral populations. In fact, throughout most of their range there is no permanent water, and they appear to persist by leap-frogging between semi-permanent waterholes. Despite having the highest and widest salinity tolerance of any Australian fish, 0-110 ppt (Glover & Sim 1878a), it was estimated (Ruello 1976) that at least twenty million of them died in Lake Eyre in 1975 when salinity levels rose with dropping water levels. They can grow to 100 mm TL. Most previously published information on this species was obtained from, and is now largely applicable, only to Murray hardyhead (*Craterocephalus fluviatilis*), which were considered synonymous with Lake Eyre hardyheads until Crowley and Ivantsoff (1990b) separated them.

Glover's hardyhead *Craterocephalus gloveri* Crowley & Ivantsoff 1990a - Glover's hardyhead is known from only three springs at Dalhousie Springs. It is listed as Vulnerable by the ASFB (Jackson 1992). Morphologically they are very similar to Dalhousie hardyhead, making them difficult to distinguish. This species tends to inhabit slightly cooler springs than Dalhousie hardyhead, but the two appear to be sympatric in one spring. This species attains 50 mm TL, and in aquaria, it lays a few eggs a day and appears to spawn at slightly lower temperatures than Dalhousie hardyhead (Unmack unpub. data). It is not known whether they reproduce year round or seasonally in the wild.

Myross hardyhead *Craterocephalus sp.* - This species was only discovered during mid-1994. It's restricted to one spring-fed pool in the Edgbaston Spring complex, and will probably be considered endangered. Ecological work, and a description are being prepared by Wager and Brooks.

Melanotaeniidae - rainbowfishes - Desert rainbowfish *Melanotaenia splendida tatei* (Zietz 1896a) - The desert rainbowfish is widespread and abundant in all the larger rivers, where they grow to 80 mm TL. In aquaria, *M. splendida* (all subspecies) generally lay 50-100 eggs daily whenever temperatures are adequate (generally > 20-24°C). Life history data are available only on other subspecies from outside central Australia.

Pseudomugilidae blue eyes - Redfinned blue eye *Scaturiginichthys vermeilipinnis* Ivantsoff, Unmack, Saeed & Crowley 1991 - The redfinned blue eye, discovered in 1989, is listed as Endangered by the ASFB (Jackson 1992). Though recorded from eight springs at Edgbaston Springs, it's abundance and occurrence varies, such that presently it is known from only five springs. Principal threats include dambusia, sheep and cattle fouling the water, and/or dying in springs. They are known to reach 28mm TL (Wager & Unmack in prep), making them the smallest freshwater fish in Australia with the longest scientific name! In aquaria, redfinned blue eye lay a few eggs daily at temperatures over 20°C, although temperatures over 26°C are preferred (Unmack & Brumley 1990). Little is known of their breeding behavior in the wild.

Ambassidae - glassfishes - Western chanda perch *Ambassis mulleri* Klunzinger 1879 - Though widespread in the larger rivers, abundance of this species fluctuates greatly. Due to a revision of Ambassidae (Allen & Burgess 1989), all previous records of *A. castelnaui* for central Australia are now applicable to western chanda perch, and past records of pennyfish (Denariusa bandata) (Glover & Sim 1978a; Glover 1982 and others), were misidentifications of this species. Western chanda perch can grow to at least 60 mm TL.

Percichthyidae - cods and perches - Lake Eyre golden perch, yellowbelly or callop *Macquaria* sp. ssp. (Plate 15) - This is the largest species found in central Australia, growing to around 600 mm and 5.6 kg. It was recently recognized as distinct from the larger (760 mm and 23 kg) Murray-Darling golden perch (*M. ambigua ambigua*) by Musyl & Keenan (1993), but not not described. It is widespread and abundant in most of the larger rivers, and is a major angling species. A small commercial fishery exists in lower Cooper Creek in South Australia. All biological information provided here is for Murray-Darling golden perch since this little-known species is likely similar in most regards. Spawning occurs during a flood at temperatures over 23°C and fecundity is between 100,000 and 1,000,000 eggs. One of few freshwater fish in the world known to lay pelagic eggs (Merrick & Schmida 1984), this species' migrations of up to 2300 km (Reynolds 1983) are some of the longest migrations recorded by any fully freshwater fish.

Bulloo golden perch or yellowbelly *Macquaria sp. ssp.* - Considered common throughout the Bulloo River, this species was recently recognized, but not described, as a separate subspecies (Musyl & Keenan 1993). Biological information is the same as for previous species.

Terapontidae - grunters - Banded grunter *Amniataba percoides* (Gunther 1864) - The banded grunter is probably the fourth most widespread fish in Australia. In central Australia, it is found only in the Finke and Georgina Rivers, Barkley Drainage, and (from a single record) the Neales River (Glover 1984). Typically they are common and may grow up to 200 mm TL. Fish between 70 and 90g produce 40,000-77,000 eggs and spawning occurs at temperatures ranging from 26 to 33°C (Merrick & Schmida 1984). No research has been carried out upon central Australian populations.

Welch's grunter *Bidyanus welchi* (McCulloch & Waite 1917) - Welch's grunter, reaching at least 350 mm TL, is widespread and often abundant in most of the larger rivers. Spawning appears to be associated with flooding, with 280 mm females producing 100,000 pelagic eggs. Like golden perch, this species also produces fully pelagic eggs. Most information on their breeding biology is derived only from laboratory studies (Merrick & Schmida 1984).

Spangled perch *Leiopotherapon unicolor* (Gunther 1859) (Plate 16) - The spangled perch is the most widespread fish in Australia, and is known from all but three separate basins (which haven't had any native fish recorded from them) in central Australia. They can reach a length of 300 mm TL, but females mature at 78 mm TL. Spawning occurs at temperatures over 26°C and flooding is not necessary to induce it. A 24 g fish produces 24,000 eggs, and a 65g fish produces 113,200. Because of its ability to rapidly colonize new waterbodies, it has often been proposed that this species can aestivate, either as eggs or adults, however there is no evidence to support this claim (Llewelyn 1973). It is also commonly reported in so called "rains of fish", where usually spangled perch can be found scattered on the ground after heavy downpours. These fish have clearly not fallen from the sky, but have migrated there via overland flow (Glover 1990). This species has particularly good dispersal abilities; Shipway (1947) recorded hundreds of young spangled perch swimming 10miles in six hours along a wheel rut.

Barcoo grunter *Scortum barcoo* (McCulloch & Waite 1917) - The Barcoo grunter is generally widespread in the larger rivers where it may be locally abundant at times. Prior to about 1975 it was only known to science by the single holotype collected in 1916 (Vari. 1978; Merrick & Barker 1975).

Eleotridae - gudgeons - Western carp gudgeon *Hypseleotris kluzingeri* (Ogilby 1898) - The western carp gudgeon is widespread and usually abundant in Cooper Creek and the Bulloo River. Individuals reach 60 mm TL, and usually spawn in spring and early summer, during flooding, at temperatures over 20°C. Flooding may not be a prerequisite to spawning. Females mature at 30mm and deposit between 1,000-2,000 eggs on a hard object near the water surface. Males guard the eggs until fry hatch in fifty hours (Lake 1967). There is no further parental care.

Midgley's carp gudgeon *Hypseleotris sp.* - Midgley's carp gudgeon is widespread, though typically less abundant than western carp gudgeon, in Cooper Creek and the Bulloo River. They grow to 40 mm TL, and usually spawn in spring and early summer at temperatures over 20°C. Flooding is not considered necessary for spawning. Females mature at around 25 mm TL, and lay 200-400 eggs on a hard object (not near the surface like in western carp gudgeon). The male guards the eggs until hatching occurs in 7-8 days (Unmack unpub. data).

Lake's carp gudgeon, *Hypseleotris sp.* (?) - Lake's carp gudgeon has only been collected in upper portions of the Barcoo and Thompson Rivers in the Cooper Creek Drainage. It appears to be the rarest of the three *Hypseleotis* subspecies. It strongly resembles Lake's carp gudgeon from the Murray-Darling System, although its specific status remains unclear.

Flinders Ranges, Balcanoona or Barcoo mogurnda or purple spotted gudgeon *Mogurnda* sp. - The Flinders Ranges mogurnda is restricted to a couple of creeks in the Flinders Ranges, but was also recently recorded from a very short section of the upper Barcoo River. It is listed as Vulnerable by the ASFB (Jackson 1992). It was only recently recognized as different from the northern purple spotted gudgeon (*M. mogurnda*) (Glover 1989). It grows to around 150mm. Spawning for all Australian *Mogurnda spp.* is basically the same. In nature, they probably spawn throughout the warmer months of the year. In aquaria, they spawn at temperatures over 20°C and females lay between 200-800 eggs, usually on the underside of a hard object. The male guards the eggs until fry hatch in seven days. Spawnings are generally repeated, as long as temperature is maintained above 20°C (Young 1987; Hanson 1988). The genus is one of the few for which life history studies have included central Australian populations.

Finke or Dalhousie mogurnda or purple spotted gudgeon *Mogurnda* sp. (Plate 17) - The Finke mogurnda is restricted to Dalhousie Springs and the Finke River, where it is usually common, but never abundant. Its taxonomic status is still uncertain, however, I believe it will be recognized as distinct from northern purple spotted gudgeon, a species I no longer consider to be part of the central Australian fauna. It biology is the same as the previous species.

Bulloo mogurnda or purple spotted gudgeon? *Mogurnda* sp. - Taxonomic status of the single specimen collected from the Bulloo Drainage in 1955 is unclear. It may represent an extirpated population of the Flinders Ranges mogurnda.

Frew mogurnda or purple spotted gudgeon *Mogurnda* sp. - The Frew mogurnda is presently know only from a small portion of the Barkley Drainage. Its present taxonomic status is unknown, but, due to its long isolation, I feel it is likely to prove to be a new species once closely studied.

Gobiidae - gobies - Desert goby *Chlamydogobius eremius* (Zietz 1896a) - The desert goby is widespread and often abundant in the Neales River, and extends southwards around Lake Eyre to Clayton Bore. It is typically found in rivers, springs and bore drains. This is the only species in central Australia which has undergone extensive field study (Glover 1971; 1973). Known to reach 60 mm TL, in aquaria, spawning generally occurs at temperatures above 26°C with females typically laying 50-250 eggs on the ceiling of a cave. Males guard the eggs until hatching, which typically occurs in 10 days. They rarely seem to live longer than one year (Thompson 1983). Desert gobies are the Australian "equivalent" of the pupfishes (*Cyprindon*). They can tolerate temperatures from 5 to at least 40°C, salinities as high as 60 ppt, and have been collected at oxygen concentrations as low as 0.8 mg/l (Glover 1973; Glover 1982).

The genus *Chlamydogobius* is presently being revised by H. Larson who will describe the following species:

Elizabeth Springs goby *Chlamydogobius sp. A* - Restricted to Elizabeth Springs, population size of this species is estimated at 1,000-2,000 individuals. It is listed as Endangered by the ASFB (Jackson 1992). They will grow to a maximum size of 62 mm TL. Spawnings have been recorded at temperatures over 20°C. Around 40-100 eggs are laid on the ceiling of a cave, with males guarding the eggs until hatching occurs ten days later (Unmack & Wager in prep. a).

Dalhousie goby *Chlamydogobius sp. B* (Plate 18) - The Dalhousie goby is restricted to approximately 28 springs at Dalhousie Springs where it is usually common (Kodric-Brown & Brown 1993). It is listed as Restricted by the ASFB (Jackson 1992), and its biology is probably similar to the above species.

Edgbaston goby *Chlamydogobius sp. C* - The Edgbaston goby occurs in small numbers in approximately 11 of the Edgbaston Springs. It is listed as Vulnerable by the ASFB (Jackson 1992) as a result of various threats, including dambusia, cattle and sheep fouling the water, and dying in springs. Their breeding biology is almost identical to the desert goby (Unmack and Wager unpub. data).

Finke goby *Chlamydogobius sp. D* - The Finke goby is generally restricted to the upper Finke River, where it may be common, though typically not abundant. It should probably be considered Restricted. Its breeding biology is probably similar to the above congeners.

Flathead goby *Glossogobius giurus* (Hamilton 1822) - The flathead goby is widespread through out Northern Australia and the Indo-Pacific region. In central Australia, it is found only in the Georgina River where it appears to be common, growing to at least 200 mm TL. It apparently has a marine larval stage (Allen 1989), and it is quite possible that this population, which has not been studied, is one of the only populations that does not have access to the sea. Very little known of its biology in Australia in general.

EXOTIC SPECIES - **Poeciliidae - livebearers** - Dambusia *Gambusia holbrooki* (Girard 1859) - Dambusia is widespread and common in the Neales and Diamantina Rivers and Cooper Creek. A few other populations exist around Lake Eyre, isolated parts of the

Bulloo-Bancannia Drainage Division, and in the Nullabour and Gairdner Drainages (Glover 1982). All records of mosquito fish (*G. affinis*) for Australia are now considered to be dambusia (Lloyd & Tomasov 1985). Dambusia appear to have caused few problems to native fish populations, probably because of the lack of alteration to river flows. However, they are reported to have caused a decrease in fish populations inhabiting non-riverine habitats, for example, Clayton Bore (Glover 1989), and springs (Unmack & Brumley 1990; Unmack 1992; Wager & Unmack in prep.).

One spot livebearer *Phalloceros caudimaculatus* (Hensel 1868) - The one spot livebearer was recorded in 1973 from Trephina Creek in the Todd River Drainage (Victorian Museum records). None have been reported before or after this, and none were seen or caught during a recent survey (Unmack unpub. data).

Swordtail *Xiphophorus helleri* Heckel 1848 - Swordtails were reported by Thompson (1982) as being present in the Todd River, but none have been reported since, and a recent survey failed to find any (Unmack unpub. data).

Cyprinidae - carps - Goldfish *Carassius auratus* Linnaeus 1758 - There have been at least two independent introductions of goldfish in the Cooper Creek drainage. They have been in the upper reaches of the Barcoo River for many years (Merrick & Schmida 1984), are now widespread in the Thompson River (R. Wager, pers. comm.), and have recently been recorded from Coongie Lakes (Reid & Puckridge 1990; Glover 1990), although they were apparently first introduced there in the 1970's (Pierce 1993). Goldfish are also known from a reservoir associated with the sewage plant at Woomera in the Gairdner Drainage since 1956-7, where it was probably unintentionally introduced during local flooding (Glover 1979; Glover 1982).

Carp *Cyprinus carpio* Linnaeus 1758 - Carp are only known from the tailings dam at Leigh Creek coal mine, on a tributary to Frome Creek. Efforts will be made to poison this population in the near future (B. Pierce pers. comm.).

TRANSLOCATED NATIVE SPECIES - Percichthyidae - cods and perches - Murray cod *Macullochella peelii peelii* (Mitchell 1838) - Murray cod were first introduced into the Cooper Creek System by the Queensland Department of Primary Industries in 1989 and 1990. Specimens have been captured, although it is unknown if they will establish a self maintaining population. It has probably been introduced elsewhere, as it is a popular angling/eating fish, and fingerlings are readily available.

Murray-Darling golden perch, yellowbelly or callop *Macquaria ambigua ambigua* (Richardson 1845) - Two stockings of Murray-Darling golden perch have been recorded in the Hay/Plenty River Drainage (Unmack unpub. data). They have also been stocked in Clayton Bore which leads towards Lake Eyre (Unmack unpub. data). It has probably been introduced elsewhere as it is a popular angling/eating fish, and fingerlings are readily available. It is unknown whether this species will hybridize with related species.

Terapontidae - grunters - silver perch *Bidyanus bidyanus* (Mitchell 1838) - Silver perch have been stocked into Clayton Bore which leads into Lake Eyre (Unmack unpub. data). All comments for Murray-Darling golden perch (above) also apply here.

IMPACTS AND THREATS - Rivers and Lakes - Central Australia has largely avoided many of the typical impacts to aquatic ecosystems experienced elsewhere, probably as a result of central Australia's isolation and very low population density. No dams are present, although they are still occasionally proposed, but numerous impacts threaten the integrity of central Australia's unique aquatic ecosystems.

A total of eight exotic and translocated species have been recorded from central Australia. This includes the recent translocations of three native fish, Murray cod, Murray-Darling golden perch and silver perch, either by local landholders or government agencies for angling purposes. Five exotic species, dambusia, swordtails, one spot livebearers, goldfish, and carp, have been recorded, but only three remain, and this should reduce to two as the carp will be poisoned in the near future (B. Pierce pers. comm.). The impacts of exotic fishes have been low, primarily because natural flow regimes have been maintained and the area is naturally variable with few permanent habitats. This could easily change if a predatory species adapted to this environment is released. While no impacts have yet been shown for translocated native fish, the potential for disaster through hybridization with congeners is very serious. Two of the translocated species have closely related species in central Australia. Hybridization between local and translocated stocks could weaken the fitness of unique locally adapted stocks and lead to a decrease in native fish populations and irreplaceable genetic loss.

Unfortunately, the isolation of this area allows considerable illegal fishing to continue largely undetected. Many locals obtain fish for local consumption by use of gill nets, and dynamite is sometimes utilized. Others, however, take commercial quantities and transport them to interstate markets. Due to the low number of waterholes present during drought, such practices can result in severe reduction in year classes of fish susceptible to capture in gill nets.

Sediment loads have most likely increased since the introduction of rabbits and the overstocking of livestock since the late 1800's. Both are known to cause an overall loss in vegetation which increases soil erosion. While no direct impacts relating to this have been reported in Australia, it is likely to have caused some siltation to waterholes and changes to nutrient dynamics, although these rivers naturally carried large quantities of sediment.

Australia contains the largest populations of feral animals in the world including, goats, camels, horses and donkeys, as well as domesticated sheep and cattle. Aside from causing soil erosion and loss of vegetation, they foul waterholes through their faeces or carcasses, sometimes making them uninhabitable to fish (Pierce 1993). Because of the paucity of water, introduced herbivores congregate in the riparian zone and on floodplains, heavily trampling and overgrazing these areas.

A commercial fishery was recently established at Lake Hope on the lower Cooper Creek for Lake Eyre golden perch. This was allowed on the basis that this was a temporary lake/waterhole which was isolated from the system and would inevitably dry out. If this practice were expanded to include other waterholes, fish populations could easily be decimated due to the limited number of refuges present. A key consideration is the role of ephemeral waterbodies in sustaining fish populations in an exceptionally variable system. To what extent do these populations rely on the rare recruitment opportunities provided by inundation of outlying sites? What are the evolutionary implications of harvesting the colonizing populations in these outliers? Unfortunately, no biological studies have been completed to ascertain the sustainablility and management implications of these practices.

There have been numerous past proposals to dam several rivers and divert water into the Murray-Darling system for irrigation. Dams are also frequently proposed for flood control on the Todd River above Alice Springs. Fortunately all such proposals have been defeated so far. There are presently no catchment management arrangements for any rivers, and there is considerable resistance by the upstream state governments to consider the needs of downstream water users.

Springs - The following is an abbreviated summary of the extent of impacts largely drawn from summaries by Harris (1992) and Ponder (1986).

Water exploitation in the GAB started in the late 1870's when the first bores or wells were sunk. This caused an initial period of drawdown, or loss of pressure in the aquifer, and a decline in discharge of most springs within the GAB. Virtually all springs in the Bogan and Bourke supergroups are extinct, or nearly so (Pickard 1992), many in the Eulo supergroup are extinct (Ponder 1986), and only one spring, Elizabeth Springs (which flows at <95% of its original rate), remains active in the Springvale supergroup (Habermehl 1982). Comparisons with descriptions of early explorers indicate that flows of many of the Lake Eyre supergroup springs have also been reduced. The GAB is now in equilibrium between recharge and discharge; that is, no further decrease in spring flow is expected providing no new developments occur. In an effort to reduce wastage of water, there is an active program underway to control or cap flowing bores. This will hopefully enhance spring flows. One development that threatens the Lake Eyre supergroup is the Olympic Dam mining venture, which presently draws 15 megalitres per day, and plans to expand withdrawals to 33 megalitres per day (Harris 1992). The impacts of increased extraction are difficult to accurately predict, but present levels of extraction have impacted several nearby springs. There is also a proposal to establish an iron smelting plant near Coober Pedy, presumably using artesian water in considerable amounts, if not for industrial processes then certainly for the proposed township. Another mining proposal at Cloncurry (near Julia Creek, Queensland) also hopes to use GAB water (R. Wager pers. comm.).

Virtually every spring has cattle or sheep grazing on it except those at Dalhousie Springs, where grazing ceased in 1985 (Harris 1989). A few of the Lake Eyre Springs were fenced in 1986-1988 (Harris 1992), and a few springs are protected within Carnarvon Gorge National Park (Ponder & Clark 1990). Due to the lack of water and fodder, stock tend to congregate around springs, producing trampling of the surrounding area as well as disturbance to the spring itself. Faeces tend to pollute springs by causing high ammonia concentrations. Occasionally, stock get trapped in soft mud and die, or they just happen to be in a spring when they die. In very small springs this results in the complete loss of fauna, and in larger springs the total biomass tends to be reduced.

Many of the generally small springs in Queensland, which has a relatively higher density of people and pastoral properties (ranches) than elsewhere, have been dug out by pastoralists to improve water supply for stock (Ponder & Clarke 1990; R. Wager pers. comm.). None of the springs have been channelized or diverted, primarily because of their small size, and no irrigation has occurred in central Australia, but springs are generally easily accessible to stock.

The only recorded introduced species is dambusia, which occurs in a few springs in the Neales River and Frome Creek portions of the Lake Eyre supergroup, and a few scattered Queensland springs. The species range is gradually expanding, primarily through flood dispersal. Dambusia is a major threat to redfinned blue eye and Edgbaston goby at Edgbaston Springs. No efforts have yet been made to eradicate dambusia from any spring. Fortunately, due to its isolation, Dalhousie Springs remains free of exotic fish, however, this could easily change with increased tourism. The large warm pools (32-38°C) there would make ideal environments for many tropical fish species.

There is considerable debate as to whether fencing springs to prevent animal grazing is threatening or protecting them. The few Lake Eyre supergroup springs which have been fenced have become overgrown with *Phragmites australis*. This may result in a change to the plant and animal communities of unknown proportions If the springs are not fenced, then they risk being destroyed by cattle trampling and pollution. There is also disagreement as to how much grazing occurred on the springs prior to European settlement. Did the spring flora and fauna ever experience grazing? Have the springs had time to come into equilibrium with cattle grazing? Have the springs changed to the point of being dependent upon grazing to maintain aquatic habitats? *Phragmites australis* tends to decrease water depth by collecting sediment, but it was present before cattle grazing; what was the water depth then? (Although the flow rate was higher then too). We also don't know how the Aborigines managed the springs. It is thought that they may have used fire to maintain access to the springs or to catch game. Another historical question asks what the springs were like when the mega-fauna roamed them prior to extinction of that fauna about 10,000 years ago? These are challenging management questions, which no one has yet attempted to answer.

CONCLUSIONS - The fishes of the Australian desert are in remarkably good condition compared to other deserts of the world such as those of North America. Australia has been fortunate to avoid two of the greatest threats to aquatic desert ecosystems; changes to flow regimes, and introduced species (Rinne & Minckley 1991). Major gaps remain in our knowledge of central Australian fishes. Little is known of the biology and ecology of most species, many of which remain undescribed. Extrapolations are often made from data on populations from elsewhere, yet these may prove to be different species once closely examined. Genetic techniques for sorting out these and other problems are just starting to be applied. There are regular proposals to either dam rivers, or exploit water from the GAB. Presently essentially unregulated, tighter restrictions need to be applied to stocking of native and translocated angling species. Finally, there are no management strategies or interstate agreements (fisheries are managed at the State level, not Federal) in place to deal with any sudden problems that might occur such as an outbreak of an introduced species or any other problem. We need to be diligent in the future in our efforts to maintain the status quo.

ACKNOWLEDGMENTS - I owe Robert Steele a great debt for the many hours spent producing the figures. Thanks to Dean Hencrickson, Michael Marchette, Dr Peter Moyle, Jim Puckridge and Rob Wager for their comments and useful ideas on earlier drafts. Thanks also to Ross Felix and Bryan Pierce for permission to reproduce their photographs.

LITERATURE CITED

ALLAN, R. J. 1989. Climatic conditions during the 1973-76 Lake Eyre flooding period. In, **The Great Filling of Lake Eyre in 1974**. Eds. Bonython, C. W. & Fraser, A. S. Royal Geographical Society of Australasia, South Australian Branch, Adelaide. pp 10-31.

ALLEN, G. R. 1989. **Freshwater fishes of Australia**. T.F.H. Publications, New Jersey. 240pp.

ALLEN, G. R. & BURGESS, W. E. 1990. A review of the glassfishes (Chandidae) of Australia and New Guinea. **Records of the Western Australian Museum**. Supplement No. 34. pp 139-207.

BENTLEY, H. W., PHILLIPS, F. M., DAVIS, S. N., GOVE, H., HABERMEHL, M. A., AIREY, P. L., CALF, G. E., ELMORE, D., GOVE, H. E. & TORGERSON, T. 1986. Chlorine 36 dating of very old groundwater 1. The Great Artesian Basin, Australia. **Water Resources Research** 22: 1991-2001.

BONYTHON, C. W. 1989. Introduction and overview. In, **The Great Filling of Lake Eyre in 1974**. Eds. Bonython, C. W. & Fraser, A. S. Royal Geographical Society of Australasia, South Australian Branch, Adelaide. pp 1-9.

BYE, J. A. T. & WILL, G. D. 1989. The hydrology of the filling. In, **The Great Filling of Lake Eyre in 1974**. Eds. Bonython, C. W. & Fraser, A. S. Royal Geographical Society of Australasia, South Australian Branch, Adelaide. pp32-43.

CASPERSON, K. C. 1979. **Mound springs of South Australia. Part 1. Physical features, history, biota and conservation requirements**. South Australian Department of Environment & Planning, SADE 20.

COOK, P. G. 1968. **1:250 000 Geological Series-Explanatory Notes**. Henbury, N. T. Bureau of Mineral Resources, Geology and Geophysics. Canberra.

CROWLEY, L. E. L. M. & IVANTSOFF, W. 1990a. A second hardyhead, *Craterocephalus gloveri* (Pisces: Atherinidae), from Dalhousie Springs, central Australia. **Ichthyological Exploration of Freshwaters** 1(2): 113-122.

CROWLEY, L. E. L. M. & IVANTSOFF, W. 1990b. A review of species previously identified as *Craterocephalus eyresii* (Pisces: Atherinidiae). **Proceedings of the Linnean Society of New South Wales** 112(2): 87-103.

DE DECKER, P. 1979. Ostracods from the mound springs area between Strangways and Curdimurka, South Australia. **Transactions of the Royal Society of South Australia** 103: 155-168.

DODDRIDGE, L. K. 1992. **The autecology of the Cooper Creek tortoise, *Emydura sp.* (aff. *krefftii***. Unpublished dissertation, graduate diploma in science, University of New England, Armidale, New South Wales, Australia.

DULHUNTY, J. A. 1982. Holocene sedimentary environments in Lake Eyre, South Australia.

Journal of the Geological Society of Australia 29: 437-442.

GALE, S. J. & BAINBRIDGE, S. 1990. The floods of Eastern Australia. **Nature** 345: 767.

GLOVER, C. J. M. 1971. **The taxonomy and biology of *Chlamydogobius eremius* (Zeitz, 1896)**. M. Sc. Thesis, University of Adelaide.

GLOVER, C. J. M. 1973. Adaptations of a central Australian gobiid fish. **Bulletin of the Australian Society for Limnolnology**. 5: 8-10.

GLOVER, C. J. M. 1979. Studies on central Australian fishes: further observations and records, part 1. **South Australian Naturalist** 53(4): 35-44.

GLOVER, C. J. M. 1982. Adaptations of fishes in arid Australia. In, **Evolution of the Flora and Fauna of Arid Australia**. Eds. Barker, W. R. & Greenslade, P. J. M., pp 241-246. Peacock Publications, Adelaide.

GLOVER, C. J. M. 1984. Additions to the fish fauna of South Australia. **Transactions of the Royal Society of South Australia** 109(1): 59-60.

GLOVER, C. J. M. 1989. Fishes. In, **Natural History of Dalhousie Springs**. Eds. Zeidler, W. & Ponder, W. F. South Australian Museum, Adelaide. pp 89-112.

GLOVER, C. J. M. 1990. Fishes. In, **Natural History of the North-East Deserts**. Eds. Tyler, M. J., Twidale, C. R., Davies, M., & Wells, C. B. Royal Society of South Australia, Adelaide. pp 189-198.

GLOVER, C. J. M., & SIM, T. C. 1978a. A survey of central Australian ichthyology. **Australian Zoologist** 19(3): 245-256.

GLOVER, C. J. M., & SIM, T. C. 1978b. Studies on central Australian fishes: a progress report. **South Australian Naturalist** 52(3): 35-44.

HABERMEHL, M. A. 1982. **Springs in the Great Artesian Basin, Australia - their origin and nature**. Bureau of Mineral Resources, Geology & Geophysics, Australia Report No. 235.

HARRIS, C. 1981. Oases in the desert: the mound springs of Northern South Australia. **Proceedings of the Royal Geographers Society of South Australia** 81: 26-39.

HARRIS, C. 1989. Dalhousie Springs - An introduction. In, **Natural History of Dalhousie Springs**. Eds. Zeidler, W. & Ponder, W. F. South Australian Museum, Adelaide. pp 1-4.

HARRIS, C. 1992. Mound Springs: South Australian conservation initiatives. **The Rangeland Journal** 14(2): 157-173.

HANSEN, B. 1988. The purple-spotted gudgeon, *Mogurnda adspersa*. **Fishes of Sahul** 5(1):200-202.

IVANTSOFF, W. I. & GLOVER, C. J. M. 1974. *Craterocephalus dalhousiensis* n.sp., a sexually dimorphic freshwater teleost (Atherinidae) from South Australia. **Australian Zoologist** 18: 88-98.

IVANTSOFF, W., UNMACK, P., SAEED, B., & CROWLEY, L E. L. M. 1991. A redfinned blue-eye, a new species and genus of the family Pseudomugilidae from central Western Queensland. **Fishes of Sahul** 6(4): 277-282.

JACKSON, P. D. 1992. Australian Threatened Fishes, 1992 Supplement. **Australian Society for Fish Biology Newsletter** 22(2): 17-22.

KODRIC-BROWN, A. & BROWN, J. H. 1993. Highly structured fish communities in Australian desert springs. **Ecology** 74(6): 1847-1855.

KOTWICKI. V. 1989. Floods in the Western Lake Eyre Basin and their impact on Dalhousie Springs. In, **Natural History of Dalhousie Springs**. Eds. Zeidler, W. & Ponder, W. F. South Australian Museum, Adelaide. pp 41-46.

KRIEG, G. W. 1989. Geology. In, **Natural History of Dalhousie Springs**. Eds. Zeidler, W. & Ponder, W. F. South Australian Museum, Adelaide. pp 19-26.

LAKE, J. S. 1967. Rearing experiments with five species of Australian freshwater fishes I. Inducement to spawning. **Australian Journal of Freshwater and Marine Research** 18: 137-153.

LAKE, J. S. 1971. **Freshwater Fishes and Rivers of Australia**. Thomas Nelson Australia Ltd, Melbourne. 61pp.

LANGDON, J. S., GUDKOVS, N., HUMPHREY, J. D. & SAXON, E. C. 1985. Deaths in Australian freshwater fishes associated with *Chilodonella hexasticha* infection. **Australian Veterinary Journal** 62(12): 409-413.

LLEWELLYN, L. C. 1973. Spawning, development, and temperature tolerance of the spangled perch, *Madigania unicolor* (Gunther), from inland waters in Australia. **Australian Journal of Freshwater and Marine Research** 24: 73-94.

LLEWELLYN, L. C. & POLLARD, D. A. 1980. Family Plotosidae. In, **Freshwater Fishes of South-eastern Australia**. Ed. McDowell, R. M. Reed, Sydney. Pp91-93.

LLOYD, L. N. & TOMASOV J. F. 1985. Taxonomic status of the mosquitofish, *Gambusia affinis* (Poeciliidae), in Australia. **Australian Journal of Marine and Freshwater Research** 36, 447-51.

MEIGS, P. 1953. World distribution of arid and semi-arid homoclimates. In, **Reviews of research on arid zone hydrology**. UNESCO, Paris. Arid Zone Program. 1: 203-209.

MERRICK, J. R. & BARKER, J. 1975. The Barcoo grunter rediscovered. **Australian Society for Limnology Newsletter** 12(4): 20-21.

MERRICK, J. R. & SCHMIDA, G. E. 1984. **Australian Freshwater Fishes: Biology and Management**. Griffith Press Ltd. 409pp.

MUSYL, M. K. & KEENAN, C. P. 1992. Population genetics and zoogeography of Australian freshwater golden perch, *Macquaria ambigua* (Richardson 1845) (Teleostei: Percichthyidae), and electrophoretic identification of a new species from the Lake Eyre Basin. **Australian Journal of Marine and Freshwater Research** 43(6): 1585-1601.

NICHOLLS, G. E. 1943. The Phreatoicoidea. Part 1. The Amphisopidae. **Papers and Proceedings of the Royal Society of Tasmania** 1942: 1-145.

ORR, T. M. AND MILWARD, N. E. 1984. Reproduction and development of *Neosilurus ater* (Perugia) and *Neosilurus hyrtlii* Steindachner (Teleostei: Plotosidae) in a tropical Queensland stream. **Australian Journal of Freshwater and Marine Research** 35: 187-195.

PICKARD, J. 1992. Artesian springs in the Western Division of New South Wales. **The Graduate School of Environment Working Papers Series, Macquarie University** Paper No. 9202. pp 123.

PICKUP, G., ALLEN, G. & BAKER, V. R. 1988. History, paleaeochannels and palaeofloods of the Finke River, central Australia. In, **Fluvial Geomorphology of Australia**. Ed. Warner, R. F. Academic Press, Sydney. pp 177-200.

PIERCE, B. E. 1992. Why chase fish in the desert? South Australia's inland water stock assessment program. **SAFISH Magazine** 17(1): 4-9.

PIERCE, B. E. 1993. "Up the creek" South Australia's channel country and its major waterways. **SAFISH Magazine** 17(4): 4-8.

PONDER, W. F. 1986. Mound springs of the Great Artesian Basin. In, **Limnology of Australia**. Eds. DeDeckker, P. & Williams, W. D. CSIRO, Australia and W. Junk, The Hague. pp 403-420.

PONDER, W. F. & CLARK, G. A. 1990. A radiation of hydobiid snails in threatened artesian springs in western Queensland. **Records of the Australia Museum** 42(3): 301-363.

PONDER, W. F., HERSHLER, R. & JENKINS, B. J. 1989. An endemic radiation of hydrobiid snails from artesian springs in Northern South Australia: their taxonomy, physiology, distribution and anatomy. **Malacologia** 30(1): 1-140.

PUCKRIDGE, J. T., WALKER, K. F., LANGDON, J. S., DALEY, C & BEAKES, G. W. 1989. Mycotic dermatitis in a freshwater gizzard shad, the bony bream, *Nematalosa erebi* (Gunther), in the River Murray, South Australia. **Journal of Fish Diseases** 12(3): 205-221.

PUCKRIDGE, J. T. & WALKER, K. F. 1990. Reproductive biology and larval development of a gizzard shad, *Nematalosa erebi* (Gunther) (Dorosomatinae: Teleostei). in the River Murray, South Australia. **Australian Journal of Freshwater and Marine Research** 41: 695-712.

RANDAL, M. A. 1978. Hydrogeology of the South-Eastern Georgina Basin and environs, Queensland and Northern Territory. **Geological Survey of Queensland, Publication No.** 366.

REID, J. R. W. & PUCKRIDGE, J. T. 1990. Coongie Lakes. In, **Natural History of the North-East Deserts**. Eds. Tyler, M. J., Twidale, C. R., Davies, M., & Wells, C. B. Royal Society of South Australia, Adelaide. pp 119-131.

REYNOLDS, L. F. 1983. Migration patterns of five fish species in the Murray-Darling River system. **Australian Journal of Freshwater and Marine Research** 34(6): 857-871.

RINNE, J. N. & MINCKLEY, W. L. 1991. Native fishes in arid lands: A dwindling resource of the desert Southwest. **USDA Forest Service General Technical Report** RM-206. pp 45.

RUELLO, N. V. 1976. Observations on some fish kills in Lake Eyre. **Australian Journal of Freshwater and Marine Research** 27: 667-672.

SHIPWAY, B. 1947. Rains of fishes? **Western Australian Naturalist** 1(2):47-48.

SLUYS, R. 1986. First representative of the order Macrostomida in Australia (Platyhelminthes, Macrostomidae). **Records of the South Australian Museum** 19 (18): 399-404.

SMITH, P. C. 1989. Hydrology. In, **Natural History of Dalhousie Springs**. Eds. Zeidler, W. & Ponder, W. F. South Australian Museum, Adelaide. pp 27-40.

SPENCER, B. 1896. **The Horn Scientific Expedition to Central Australia**. Dulace & Co., London.

THOMPSON, G. 1982. Fish collecting on a part round Australia trip. **Fishtales** 13(7) :6-10.

THOMPSON, G. 1983. The desert goby, *Chlamydogobius eremius*. **Fishes of Sahul** 1(2): 17-20.

UNMACK, P. 1992. Further observations on the conservation status of the redfinned blue-eye. **Australian and New Guinea Fishes Association Bulletin** 12: 8-9.

UNMACK, P. J. (IN PRESS) The unique Cooper Creek catfish from central Australia. **Fishes of Sahul**.

UNMACK, P. & BRUMLEY, C. 1991. Initial observations on the spawning and conservation status of the redfinned blue-eye, (*Scaturiginichthys vermeilipinnis*). **Fishes of Sahul** 6(4): 282-284.

UNMACK, P. J. & WAGER, R. N. E. (In prep a) Threatened Fishes of the World, Elizabeth Springs goby, *Chlamydogobius sp*.

UNMACK, P. J. & WAGER, R. N. E. (In prep b) The Elizabeth Springs goby, its aquarium care, habitat and conservation status.

VAN DE GRAAFF, W. J. E., CROWE, R. W. A., BUNTING, J. A. & JACKSON, J. 1977 Relict early Cainzoic drainage's in arid Western Australia. **Zeitschrift fur Geomorphologie** 21(4): 379-400.

VARI, R. P. 1978. The *Terapon* perches (Percoidei, Teraponidae). A cladistic analysis and taxonomic revision. **Bulletin of the American Museum of Natural History** 159(5): 175-340.

WAGER, R. 1994. **The distribution and status of the red-finned blue eye. Final Report Part B: The distribution of two endangered fish in Queensland**. Endangered species unit project number 276.

WAGER, R. N. E. & UNMACK, P. J. (In prep) Threatened fishes of the world, *Scaturiginichthys vermeilipinnis*.

YOUNG, M. 1987. A tank breeding of *Mogurnda mogurnda*. **Fishes of Sahul** 4(3): 174-177.

ZEIDLER, W. 1991. A new genus and species of phreatic amphipod (Crustacea: Amphipoda) belonging in the "chiltonia" generic group, from Dalhousie Springs, South Australia. **Transactions of the Royal Society of South Australia** 115(4): 177-187.

ZEIDLER, W. & PONDER, W. F. 1989a. Summary.. In, **Natural History of Dalhousie Springs**. Eds. Zeidler, W. & Ponder, W. F. South Australian Museum, Adelaide. pp 123.

ZEIDLER, W. & PONDER, W. F. 1989b. Conclusions and recommendations. In, **Natural History of Dalhousie Springs**. Eds. Zeidler, W. & Ponder, W. F. South Australian Museum, Adelaide. pp 125.

ZIETZ, A. H. C. 1896a. Pisces. In, Spencer, B. Ed. **Report on the work of the Horn Scientific Expedition to central Australia. Part 2. Zoology**. London. pp 176-180, pl 16.

ZIETZ, A. H. C. 1896b. Description of an additional new species of fish from the Finke and Barcoo Rivers. In, Spencer, B. Ed. **Report on the work of the Horn Scientific Expedition to central Australia. Part 2. Zoology**. London. pp 410-411, pl 16.

(See plates on following pages)