VERTEBRATE FAUNA;
VALUES AND GROUNDWATER DEPENDENCE
IN THE GNANGARA STUDY AREA

Prepared for: Water and Rivers Commission

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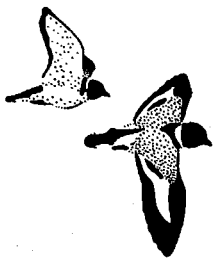

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INTRODUCTION

The Water and Rivers Commission and the Water Corporation are currently investigating the environmental effects of groundwater extraction from the Gnangara Groundwater Mound. In parallel with the preparation of this statement on the impact of groundwater extraction on vertebrate fauna values, a range of experts is also preparing statements on the impact to wetland vegetation, terrestrial vegetation, organic mound springs, macroinvertebrates and cave ecosystems.

The aims of this fauna assessment are as follow:

- List vertebrate fauna species present or expected in the study area and comment on the importance of wetlands and phreatophytic vegetation for this fauna.
- Identify significant species of vertebrate fauna potentially sensitive to changes in groundwater levels.

This assessment is being carried out at the same time as an assessment of fauna in relation to groundwater in the Jandakot area.

METHODS

Sources of Information

This report is based on a similar report prepared by Bamford Consulting Ecologists for Welker Environmental Consultancy and the Water Corporation (Bamford 2002). The original report was primarily a review of available information and relied to a great extent on previous experience in the region, including detailed fauna studies near Gingin over the period 1983 to 1986 (Bamford 1986), although a small amount of fieldwork was also conducted.

Published and unpublished reports that provided information for this study include: Storr *et al.* (1978), Storr and Johnstone (1988), Bush *et al.* (1995), Blakers *et al.* (1984), Johnstone and Storr (1998), the database of birds of Western Australia (maintained by the WA Group of Birds Australia), W.A. Museum specimen records, the threatened fauna database maintained by the Department of Conservation and Land Management (CALM) and the RAOU 1981-1984 Waterbird survey database (maintained by Australian Ecological Services). Species lists presented in Perth's Bush Forever (Government of Western Australia 2000) were also examined.

The literature available on fauna of the region, and personal experience in the region, made it possible to prepare detailed species lists for vertebrate fauna. In addition, the level of information allowed for at least general comments to be made on the distribution of the fauna in relation to phreatophytic vegetation.

Taxonomy and nomenclature for fauna species used in this report generally follow Aplin and Smith (2001) for amphibians and reptiles, How *et al.* (2001) for mammals and Johnstone (2001) for birds. Alternative names, including common names recommended for national and international use by Christidis and Boles (1994) for birds, are also given.

Assessment of Conservation Significance

The conservation status of fauna species is assessed under Commonwealth and State Acts such as the *Commonwealth Environment Protection and Biodiversity Conservation Act* (EPBC Act) 1999 and the *Western Australian Wildlife Conservation Act* 1950. The significance levels for fauna used in the EPBC Act are those recommended by the International Union for the Conservation of Nature and Natural Resources (IUCN) and reviewed by Mace and Stuart (1994). The *WA Wildlife Conservation Act* 1950 uses a set of Schedules but also classifies species using some of the IUCN categories. These categories and Schedules are described in Appendix One.

The EPBC Act also has lists of migratory species that are recognised under international treaties such as the China Australia Migratory Bird Agreement (CAMBA), the Japan Australia Migratory Bird Agreement (JAMBA) and the Bonn Convention (The Convention on the Conservation of Migratory Species of Wild Animals). Those species listed in JAMBA are also protected under Schedule 3 of the *WA Wildlife Conservation Act.* In addition, Environment Australia has supported the publication of reports on the conservation status of most vertebrate fauna species e.g. reptiles (Cogger *et al.* 1993), birds (Garnett and Crowley 2000), monotremes and marsupials (Maxwell *et al.* 1996), rodents (Lee 1995) and bats (Duncan *et al.* 1999); while the Threatened Species and Communities Section of Environment Australia has produced a list of Threatened Australian Fauna (Environment Australia 1999), although this list is effectively a precursor to the list produced under the EPBC Act. These publications also use the IUCN categories, although those used by Cogger *et al.* (1993) and Wager and Jackson (1993) differ in some respects as this report pre-dates Mace and Stuart's review (1994).

In Western Australia, the Department of Conservation and Land Management has produced a supplementary list of Priority Fauna, being species that are not considered Threatened under the WA Act but for which the Department feels there is cause for concern. Some Priority species, however, are also assigned to the IUCN Conservation Dependent category. Levels of Priority are described in Appendix One.

Fauna species included under conservation acts and/or agreements are formally recognised as of conservation significance under state or federal legislation. Species listed only as Priority by CALM, or that are included in publications such as Garnett and Crowley (2000) and Cogger *et al.* (1993) but not in State or Commonwealth Acts, are also of recognised conservation significance. In addition, species that are at the limit of their distribution, those that have a very restricted range and those that occur in breeding colonies, such as some waterbirds, can be considered of conservation significance, although this level of significance has no legislative or published recognition and is based on interpretation of distribution information. The WA Department of Environmental Protection (2000) used this sort of interpretation to identify significant bird species in the Perth metropolitan area as part of Perth Bushplan.

On the basis of the above comments, three levels of conservation significance are recognised in this report:
Conservation Significance (CS) 1: Species listed under State or Commonwealth Acts.

Conservation Significance (CS) 2: Species not listed under State or Commonwealth Acts, but listed in publications on threatened fauna or as Priority species by CALM.
Conservation Significance (CS) 3: Species not listed under Acts or in publications, but considered of at least local significance because of their pattern of distribution.

Assessment of Sensitivity to Drawdown

With the exception of primarily aquatic species that occur in wetlands dependent upon groundwater, the dependence of fauna upon groundwater is largely indirect, with the fauna dependent upon vegetation that itself may or may not be groundwater dependent. These varying levels of groundwater dependence of fauna can be reflected by assigning each species to one of categories as below. The original Yarragadee report (Bamford 2002) used 3 categories (low, moderate and high dependence on groundwater dependent ecosystems), however a later report for the Blackwood area (Bamford 2003) used 4 categories (low, moderate, high and very high dependence on groundwater dependent ecosystems) which enabled more precise classification. The use of categories in this manner applies unnatural constraints across a continuum of dependence, but helps to recognise patterns and identify species of particular significance. This process was carried out for the vertebrate fauna of the study areas in what must be recognised as an interpretive and to some extent subjective exercise, based upon available information and personal knowledge of the habitat requirements of each species. The categories were as follows:

1. Low dependence upon groundwater. This was applied to species that occur primarily in upland habitats throughout the year or which show no special preference for groundwater dependent vegetation. Changes to groundwater levels are unlikely to affect such species, but see below.
2. Moderate dependence upon groundwater. This was applied to species that make some use of habitats that are themselves moderately dependent upon groundwater, such as vegetation not closely associated with wetlands but in which major components are groundwater dependent. This was also applied to species that make seasonal use of vegetation that is moderately or highly dependent upon groundwater. Changes to groundwater levels would affect these fauna species, at least insofar as the vegetation assemblages upon which they dependent wholly or seasonally are affected. The effect may be for both the vegetation and the fauna to move lower in the landscape.
3. High dependence upon groundwater. This was applied to species that are dependent upon phreatophytic vegetation. Because this vegetation occurs low in the landscape, a lowering of groundwater could cause a reduction in habitat area rather than shift in its position in the landscape. Associated fauna species would therefore decline in abundance or disappear.
4. Very high dependence upon groundwater. This was applied to species that rely on aquatic habitats in wetlands and that are therefore likely to become locally extinct if a fall in the groundwater level leads to the disappearance of surface water in wetlands.

The above categorisation of dependence upon groundwater indicates that species most dependent upon groundwater and therefore generally at the lowest point in the landscape are likely to be affected to the greatest extent by falls in groundwater level. This is because the ecosystems on which they depend are likely to disappear or alter

drastically; the ecosystems will have no-where to go if groundwater levels fall. Other species are likely to shift down in the landscape in response to catenary changes. They will change in landscape position but probably not in area occupied. It is also possible, however, that there may be large impacts at the top of the landscape. This is because with respect to groundwater, there are very large areas of upland habitats that have low dependence upon groundwater. If such upland habitats are affected, such as through slight changes in soil moisture levels above the groundwater, the effect would occur over large areas. All upland habitats would become slightly more xeric. Therefore, the equivalent upland habitat to what occurs over large areas now would be reduced to a narrow zone on the upper slopes. The significance of this impact cannot be assessed but this sort of effect needs to be recognised.

Site Description

The Gnangara study area roughly extends from the Moore River to the north, the Brand/Great Northern Highway to the east, the general metropolitan area to the south and the coast to the west. The following habitat features are considered significant:

- The study area is located on the Swan Coastal Plain where the landforms range from undulating, stabilised sand-dunes to broad, level and low-lying areas. These low-lying areas are especially significant in the study area, as they support damplands and seasonal wetlands because the water table is close to the surface at least seasonally. The key areas encompass most of these low lying areas (see below).
- The native vegetation has been partly replaced by pine plantations, agricultural land and urban development, but there are large tracts of native vegetation in reserves, other crown land and private property, especially in the north of the study area.
- The native vegetation varies with the position in the landscape, with Banksia woodlands and low woodlands on higher ground and a complex of vegetation assemblages in low-lying areas associated with damplands and seasonal wetlands. In low-lying areas and around wetlands, the vegetation includes dense thickets of *Melaleuca* sp. and *Kunzea* sp, and emergent *Eucalyptus rudis*. In some locations where the ground surface is low–lying but very level, there are extensive low, dense heathlands fringed with thickets of *M. priessiana*, and open woodlands of Marri *Corymbia calophylla* over heath.
- Although wetlands are indicated and named on maps, many of these are better described as damplands where the ground may be seasonally damp or even waterlogged, but surface water occurs only rarely. For example, within Yeal Swamp, excavations reaching nearly 2 m below the surrounding ground level were dry. However, there were dead stands of Bulrush *Typha* sp. in one of these excavations, indicating that it contains water for a substantial period in winter and spring. Some of the critical areas do contain permanent or reliably seasonal wetlands and these are noted below.

Key Areas

Key areas are those areas where the ground surface is low-lying and the vegetation and therefore fauna habitats are influenced by having water at or close to the surface

at least seasonally. They include areas with seasonal or permanent wetlands. Some of these areas are:

Big Carine Swamp
Coonabidgee Swamp
Deepwater Lagoon
Ellen Brook Swamp
Emu-Ballajura Ponds
Lake Bambun
Lake Beermullah
Lake Carabooda
Lake Chandala
Lake Culcadarra
Lake Goollelal
Lake Gwelup
Lake Jandabup
Lake Joondalup
Lake Nambung
Lake Nowergup
Loch McNess
Mariginiup Lake
Mungala Lake
North and South Neerabup Lake
Star Swamp
Wallering Swamp
Yeal Swamp

Please note that this list is far from comprehensive.

FAUNA OF THE GNANGARA STUDY AREA

Frogs

Ten species of frogs may occur in the study area (Table 1). With the exception of the Turtle Frog that breeds terrestrially and lives in woodland or heathland with sandy soil (Roberts 1981), all species rely on wetlands for breeding. Some of the frog species remain around wetlands as adults, but several are known to move long distances into terrestrial habitats outside the breeding season. For example, the Moaning Frog and Pobblebonk occupy woodland several kilometres from the wetlands where they breed (Bamford 1992).

Because of their need for wetlands to breed, 9 of the 10 frog species could be affected by drawdown. Most sensitive would be species that rely on wetland-associated habitats throughout the year and breed in spring/early summer. The Moaning and Marbled Frogs are likely to be least affected by drawdown, as they breed in early winter and occur in terrestrial habitats outside the breeding season. The mobility of the Moaning Frog and the Pobblebonk, and possibly also the Marbled Frog, means that they may breed in wetlands of the Wanneroo linear system but still occur in other critical areas outside the breeding season. Both these species breed in seasonal wetlands and the margins of permanent wetlands, with seasonal wetlands possibly being favoured by them because of the absence of introduced fish. There is the potential that some currently suitable seasonal wetlands will become less favourable for them, but some currently permanent wetlands may become more suitable. This would result in a localised contraction of breeding range but probably would have little effect on the distribution in the non-breeding season. Studies currently underway for the Water and Rivers Commission as part of monitoring of the Lexia wetlands have found that breeding by the Moaning Frog failed on some wetlands in winter 2002 due to low water levels. However, adult frogs returned to these wetlands to attempt to breed in winter 2003 (Bamford unpubl. data).

Two frog species are considered to be of Conservation Significance Level 3

Quacking Frog *Crinia georgiana*

Glauert's Froglet *Crinia glauerti*

Both of these species are at the northern limit of their distributions in the general area and remain around wetlands throughout the year.

Reptiles

The Study Area is located in a region of high reptile diversity, with a total of 54 species expected (Table 2). The majority of these occur in upland habitats and are therefore likely to be little affected by drawdown, but 5 species are associated with dense vegetation and seasonally damp soils around wetlands, while the list includes 2 freshwater tortoises.

Conservation Significance Level 1

Short-necked or Western Swamp Tortoise *Pseudemydura umbrina*

The Western Swamp Tortoise is listed as Endangered under the EPBC Act, and as Critically Endangered under the WA Wildlife Conservation Act and by Cogger *et al.* (1993). This species is confined to seasonal wetlands near Bullsbrook, with water levels in at least one of the sites being artificially manipulated and therefore protected from drawdown.

South-west Carpet Python *Morelia spilota imbricata*

The South-west Carpet Python is classified as Specially Protected Fauna under the WA Wildlife Conservation Act, Priority 4 by the DCLM and Vulnerable by Cogger *et al.* (1993). Although the species may occur near wetland habitats, it is not reliant on phreatophytic vegetation and is therefore not expected to be sensitive to the effects of groundwater drawdown. In the Gnangara area, it is reported to be most abundant in areas where limestone occurs at the surface (Bush *et al.* 1995).

Conservation Significance Level 2

skink *Lerista christinae*

This skink is classified as Rare or Insufficiently known by Cogger *et al.* (1993) and was formerly listed as a Priority species by the DCLM. The species has a restricted distribution, only occurring on the northern Swan Coastal Plain with a preference white-sand habitats (Bush *et al.* 1995).

Black-striped Snake *Neelaps calonotos*

The Black-striped Snake is classified as Endangered by Cogger *et al.* (1993) and was formerly listed as a Priority species by the DCLM. This species has a restricted distribution, only occurring on the Swan Coastal Plain, usually in Banksia sandplain habitats.

Conservation Significance Level 3

Oblong or Long-necked Tortoise *Chelodina oblonga*

Although the Long-necked Tortoise is widespread in the South-West, the study area is close to the northern limit of its distribution and it is highly sensitive to the effects of groundwater drawdown. During studies carried out in the Lexia wetlands (Bamford unpubl. data), Long-necked Tortoises in poor condition (under-weight) were found in

a wetland that contained water for only about a month in winter 2002. This species is generally associated with permanent or semi-permanent wetlands (Bush *et al.* 1995), suggesting that conditions in the wetland had changed. Persistence of this population of tortoises seems unlikely.

Other species of Conservation Significance Level 3 (see Table 2) are at either the northern or southern limit of their distribution in the study area. Four of these species (the skinks *A. trilineata* and *H. quadrilineata*, the Tiger Snake and the Crowned Snake) have some association with wetland vegetation and are at the northern limit of their distribution. This makes them vulnerable to the effect of groundwater drawdown.

Birds

Because of the mobility of birds, over 200 species could be expected to be recorded in the Gnangara area over time, but many of these would be vagrants of little or no significance from a conservation and impact perspective. Therefore, Table 3 lists 172 species that have been observed or are expected to make regular use of the area. This includes nine species that have been observed but are vagrants only, and five introduced species.

The birds can be divided into waterbirds such as ducks, herons, coots and sandpipers, and landbirds. Most of the landbird species occur in upland habitats although many will also utilise vegetation close to wetlands and damplands, but 19 landbird species tend to be associated with vegetation around wetlands, at least in this particular region. For example, north of Perth, New Holland Honeyeaters (and some other honeyeater species) are seasonal visitors to flowering plants that grow close to wetlands, so have some degree of dependency upon such phreatophytic vegetation. Similarly, the Grey Fantail and Silvereye are usually seen close to wetland vegetation rather than in upland areas, while the White-breasted Robin, some fairy-wrens and the White-browed Scrubwren occur mainly in dense vegetation around wetlands.

The large amount of information available on wetland usage by waterbird species in the south-west (see Jaensch *et al.* 1988, Storey *et al.* 1993) enables us to compare values of wetlands in the study area as they relate to this fauna group. Table 4 presents the highest count of each waterbird species made in the Gnangara area and the wetland where this occurred. Of the 67 waterbird species for which count data were available, highest counts were made for 26 species on Lake Joondalup, for 17 species on Lake Jandabup and for five species on Lake Chandala, with three species each on Lakes Goollelal, Mangala and Bambun. Lake Nowergup, Emu-Ballajura Ponds, Big Carine Swamp, Lake Beermullah, Diamond Island, Blyth's Lake and Loch McNess each had the highest count for one or two species. Big Carine Swamp, Blyth's Lake and Emu-Ballajura Ponds also had records of more than five breeding species, but breeding records are probably under-represented. Bamford and Bamford (2003), however, noted that small wetlands are often more important for breeding than large wetlands.

A number of conservation significant bird species are likely to occur in the study area and are discussed below. This excludes species that occur only as vagrants.

Conservation Significance Level 1

Peregrine Falcon *Falco peregrinus*

This species is classified as Schedule 4 – Other Specially Protected Fauna by DCLM. Although the Peregrine Falcon is expected to occur around wetland habitats, it is unlikely to be sensitive to the effects of groundwater drawdown.

Carnaby's Black-Cockatoo *Calyptorhynchus latirostris*

This species is classified as Endangered under the EPBC Act, WA Wildlife Conservation Act and by Garnett and Crowley (2000). Although this species is not expected to be directly affected by groundwater drawdown, some of its preferred food plants e.g. *Banksia*, *Hakea* and *Eucalyptus*, may be affected. Deaths of banksias have been observed due to drawdown and this could potentially affect the foraging value of large areas that are currently important for Carnaby's Cockatoo.

Australasian Bittern *Botaurus poiciloptilus*

This species is classified as Vulnerable under the EPBC Act, WA Wildlife Conservation Act and by Garnett and Crowley (2000). This species relies heavily on wetland habitats and as such, is expected to be very sensitive to the effects of groundwater drawdown.

The following 13 species are considered to be migratory species under the JAMBA, CAMBA and/or Bonn Convention, and are thereby protected under the EPBC Act with JAMBA species also being protected under Schedule 3 of the WA Wildlife Conservation Act. The majority of the species, excepting the Fork-tailed Swift, are waders or shorebirds and it is expected that these species will be very sensitive to the effects of groundwater drawdown.

Great Egret	*Egretta alba*
Glossy Ibis	*Plegadis falcinellus*
Black-tailed Godwit	*Limosa limosa*
Marsh Sandpiper	*Tringa stagnatalis*
Common Greenshank	*Tringa nebularia*
Wood Sandpiper	*Tringa glareola*
Common Sandpiper	*Tringa hypoleucos*
Red-necked Stint	*Calidris ruficollis*
Long-toed Stint	*Calidris subminuta*
Pectoral Sandpiper	*Calidris melanotos*
Sharp-tailed Sandpiper	*Calidris acuminata*
Curlew Sandpiper	*Calidris ferruginea*
Fork-tailed Swift	*Apus pacificus*

Conservation Significance Level 2

Barking Owl (southern subspecies) *Ninox connivens connivens*

The southern subspecies of the Barking Owl is classified as Priority 2 by DCLM and Near Threatened by Garnett and Crowley (2000). This species is usually associated with phreatophytic vegetation and as such is expected to be moderately sensitive to the effects of groundwater drawdown.

Masked Owl (southern subspecies) *Tyto novaehollandiae novaehollandiae*

The southern subspecies of the Barking Owl is classified as Priority 3 by DCLM and Near Threatened by Garnett and Crowley (2000). As this species prefers forest habitats, it is unlikely to sensitive to the effects of groundwater drawdown.

Little Bittern *Ixobrychus minutus*
The Little Bittern is classified as Priority 4 by DCLM and Near Threatened by Garnett and Crowley (2000). This species relies heavily on wetland habitats and as such, is expected to be very sensitive to the effects of groundwater drawdown.

Conservation Significance Level 3
The majority of bird species classified as CS3 are listed in Bush Forever (Department of Environmental Protection 2000) as Significant species of the Swan Coastal Plain. A number of these are waterbirds or landbirds with some dependence upon phreatophytic vegetation, including:
Freckled Duck
Blue-billed Duck
Musk Duck
Australasian Shoveler
Pink-eared Duck
Hardhead (White-eyed Duck)
Nankeen Night Heron
Dusky Moorhen
Red-kneed Dotterel
Common Bronzewing
Brush Bronzewing
Western Rosella
Splendid Fairy-wren
Red-winged Fairy-wren
Southern Emu-wren
White-browed Scrubwren
New Holland Honeyeater
White-breasted Robin
Grey Shrike-thrush

Mammals

The mammal fauna expected in the Study Areas consists of 23 native and 5 introduced species (Table 5). A number of other native species are regionally extinct as part of a massive loss of mammal species across much of mainland Australia that has been attributed to changes in fire regime, habitat loss and predation by Foxes and Cats (Burbidge and McKenzie 1989, Paton 1991).

The majority of mammal species occur in upland habitats, but several species rely to at least some extent on wetlands or vegetation around wetlands. The Rakali is semi-aquatic and occurs in permanent wetlands in the area, but will also disperse to seasonal wetlands during winter, while the Quenda favours dense vegetation around wetlands. The only record of the Pygmy Possum in the area came from Marri/banksia woodland on the margins of a wetland. Several other species rely to some extent upon vegetation close to wetlands. The majority of species of conservation

significance are also at least to some degree dependent upon wetlands and therefore potentially sensitive to changes in groundwater levels.

Eight mammal species are considered to be of conservation significance:

Conservation Significance Level 1

Chuditch *Dasyurus geoffroii*

The Chuditch is listed in Vulnerable under the EPBC Act, the WA Wildlife Conservation Act and by Maxwell *et al.* (1996). It has recently been reported from Lennard's Brook near Gingin (CALM's Threatened Fauna Database) and from Ellenbrook, south of the Neaves key area (M. Bamford, pers. obs), so is still present in the region. It is probably surviving at low population densities in large tracts of native vegetation, but may increase in numbers as Fox control is undertaken nearby. Wetlands and their margins may be particularly productive habitats for it, so the species may be indirectly affected by groundwater drawdown.

Conservation Significance Level 2

Quenda or Southern Brown Bandicoot *Isoodon obesulus*

The Quenda is classified as Priority 4 – Conservation Dependent by DCLM and Lower Risk by Maxwell *et al.* (1996). This species prefers areas of denser vegetation, and in the Perth area, is often associated with wetland habitats (Strahan 1998). Consequently it is expected that the species may be moderately sensitive to groundwater drawdown. Furthermore, the Gnangara area is close to the current northern limit of this species' core distribution.

Brush-tailed Phascogale *Phascogale tapoatafa*

The Brush-tailed Phascogale is classified as Priority 3 by DCLM and Lower Risk (near threatened) by Maxwell *et al.* (1996). Although the species does not show a particular preference for wetland habitats, such areas are probably the most productive habitats in the landscape for this small predator. As such, the species may be indirectly affected by groundwater drawdown.

Kwoora or Brush Wallaby *Macropus irma*

The Kwoora or Brush Wallaby is classified as Priority 4 by DCLM and Lower Risk – Near Threatened by Maxwell *et al.* (1996). This species has been recorded from Banksia woodland habitats north of Perth, and its preference for "open, seasonally wet flats with low grasses and open scrubby thickets" (Strahan 1998), suggests that it would be moderately sensitive to groundwater drawdown. Bamford and Bamford (2002) found that the Brush Wallaby relied on dense vegetation around wetlands to provide shelter during the day.

Western False Pipistrelle *Falsistrellus mackenziei*

The Western False Pipistrelle is classified as Priority 4 by DCLM and Lower Risk – Near Threatened by Duncan *et al.* (1999). One documented capture of this species on the Swan Coastal Plain, was from an area of "low open forest dominated by *Melaleuca preissiana* and *Eucalyptus rudis* close to Lake Banganup and Banksia woodland" (Hosken and O'Shea, 1994), however it is not expected that the species would be overly sensitive to groundwater drawdown.

Rakali or Water Rat *Hydromys chrysogaster*

The Rakali is classified as Priority 4 by DCLM and although it is not formerly assessed by Lee (1995), he does recognise that the south-western population has experienced significant declines as a result of habitat degradation. The species is abundant in the Wanneroo linear wetlands (M. Bamford pers obs.) and due to its reliance on riverine/wetland habitats, is likely to be highly sensitive to groundwater drawdown.

Conservation Significance Level 3

Mardo or Yellow-footed Antechinus *Antechinus flavipes*

Although the Mardo is only classified as Lower Risk – Least Concern by Maxwell *et al.* (1996), it appears to have experienced significant declines within the Perth area. The species prefers dense vegetation like that associated with wetland areas (Department of Environmental Protection, 2000) and, if it does still occur in the study area, may be moderately sensitive to groundwater drawdown.

Brush-tailed Possum *Trichosurus vulpecula*

The Brush-tailed Possum is classified by Maxwell *et al.* (1996) as Lower Risk – Near Threatened and is towards the northern edge of its distribution in the study area. This species generally occurs in areas with trees, therefore it is not particularly reliant on wetlands, although it is expected to occur in woodland habitats associated with wetlands. It is not expected to be overly sensitive to groundwater drawdown.

Western Pygmy Possum *Cercartetus concinnus*

The Western Pygmy Possum is classified as Lower Risk – Least Concern by Maxwell *et al.* (1996) but it has largely disappeared from the coastal plain in the vicinity of Perth, with the only recent record from near a wetland between Muchea and Ellenbrook (Bamford, unpubl data, June 2003). This species may favour the high density of trees and shrubs close to wetlands and damplands and consequently may be sensitive to the effects of groundwater drawdown.

Moodit or Bush Rat *Rattus fuscipes*

Although the Moodit is classified as Secure by Lee (1995), it is recognised as having declined in the Perth area (Department of Environmental Protection, 2000). The species' preference for dense vegetation, such as that often found around wetlands, makes it moderately sensitive to groundwater drawdown.

Noodji or Ashy-grey Mouse *Pseudomys albocinereus*

The Noodji has experienced declines on the Swan Coastal Plain (Department of Environmental Protection 2000) with the last record from Whiteman Park being in 1975 (Arnold *et al.* 1991). The study area represents the southern boundary of the species' distribution. This species is not expected to be overly sensitive to the effects of groundwater drawdown.

Little Long-tailed Dunnart *Sminthopsis dolichura*
White-tailed Dunnart *Sminthopsis granulipes*
Grey-bellied Dunnart *Sminthopsis griseoventer*

These three dunnart species have experienced declines on the Swan Coastal Plain with populations in the study area now representing the southern boundary of their distribution. These species are not expected to be overly sensitive to the effects of

groundwater drawdown, although their patterns of distribution across the landscape in relation to micro-topography and vegetation is poorly understood.

DISCUSSION

The Importance of Wetlands and Phreatophytic Vegetation for Fauna

As noted previously, while drawdown may have the most dramatic impact on habitats at the lowest points in the landscape, such as wetlands, it can affect the entire catenary sequence. Therefore, no fauna may be immune from the impacts of drawdown. Despite this, impacts can be expected to occur most rapidly and to be greatest where the fauna habitats are most sensitive to drawdown, and these are habitats associated with wetlands and damplands.

The impact on species will be determined by their dependence upon sensitive habitats, and the review of the fauna of the Gnangara area attempts to categorise the species in this way. As would be expected, most frogs are either sensitive or very sensitive to drawdown, and the very sensitive species could become locally extinct as a result of drawdown. This process may already be happening, as breeding failure by the Moaning Frog *Heleioporus eyrei* has been found in some wetlands (Bamford, unpubl. data).

In contrast and as would be expected, most reptiles are probably insensitive to the effects of drawdown. Despite this, too little is known about patterns of distribution of reptiles in relation to vegetation floristics and structure to be able to predict impacts of changes to these vegetation characteristics. In long-term studies being undertaken near Badgingarra, it has been found that local patterns of reptile abundance are very complex and vary over distances of tens of metres with vegetation structure and floristics (Bamford and Bamford 1992). Therefore, the death of some understorey species in upland woodland due to drawdown could have a considerable impact upon the reptile assemblage. One of the most sensitive and conservation significant species, the Short-necked Tortoise *Pseudemydura umbrina*, is present in wetlands in the Gnangara area were water levels are already being artificially manipulated.

The predicted bird fauna of the area includes many waterbirds that are likely to be very sensitive to drawdown, as well as upland birds that make some use of dense vegetation around wetlands. Because of their mobility, birds are able to make use of different parts of the landscape in different seasons, and the range of habitats provided from uplands to wetlands contributes to the diversity and abundance of the bird fauna. Drawdown can be expected to reduce that range of habitats.

Waterbirds are a particularly important component of the region's avifauna and available data suggest that they are concentrated in a small number of wetlands, although this relies on maximum counts that tend to be made during summer in lakes that act as seasonal drought refuges. Small wetlands that may be important for breeding are usually poorly surveyed and are difficult to survey. Bamford and Bamford (2003), working on wetlands in the Jandakot area, have made the point that small wetlands tend to be important for breeding and this is influenced by peak winter/spring water levels, while large wetlands are often important as seasonal

drought refuges, when the persistence of water levels into summer and autumn is important.

The mammal fauna includes one species that is very sensitive to drawdown, and several that are to some extent reliant on habitats that may be impacted. Additional species that are not considered to be sensitive to the impacts of drawdown may be affected to some extent. For example the Honey Possum relies upon high floristic diversity to ensure that it has a year-round supply of nectar. The decline or loss of a plant species anywhere in the landscape could be important if that species were a major seasonal source of nectar.

Overall, a decline in fauna species richness and the abundance of some species can be expected as a result of drawdown. This would occur because drawdown would result in a narrowing of the range of fauna habitats available. The decline in habitats associated with the mesic end of the habitat spectrum would not be balanced by a slight increase in habitats at the xeric end of the spectrum, mainly because it is habitats where moisture is most available that are most productive and most limited in the existing landscape.

Significant Fauna Sensitive to the Impacts of Drawdown

Many of the species that are considered to be sensitive or very sensitive to drawdown in the Study Areas are of Conservation Significance. For vertebrate fauna, numbers of species either sensitive or very sensitive to drawdown, and the number of these that are of conservation significance are as follows:

Taxon	Number of native species	Sensitivity				Conservation significance		
		1 (low)	2	3	4 (high)	CS1	CS2	CS3
Frogs	10	1	-	4	5	-	-	2
Reptiles	56	46	2	3	2	2	-	13
Birds	149	76	10	6	57	21	3	41
Mammals	24	18	5	-	1	1	5	7

A high proportion of sensitive or very sensitive species are of conservation significance, especially among the mammals and birds. Among birds, a large proportion of these are sandpiper species listed as migratory and/or waterbird species with reduced populations on the Swan Coastal Plain.

With frogs, reptiles and mammals, the high proportion of species likely to be affected by drawdown that are of conservation significance occurs because these species are at the northern limit of their range in the area. They are at the northern limit of their range because they are generally associated with damp habitats that are more widespread to the south. The Study Area is in a region that can be described as transitional between the relatively high rainfall areas of the South-West and the lower rainfall areas of the northern coastal plain, and such transitional areas often coincide with the limits of species' ranges. For example, of the 4 native mammals sensitive to

drawdown, all are of Conservation Significance and all are near the northern limit of their ranges.

In addition, the Study Area is just beyond the northern limit of the substantially developed coastal plain that extends from Perth's northern suburbs south to Dunsborough. As a result, there are several species, notably among the mammals, that are today at the southern limit of their range in the Study Area. These species tend not to be closely associated with mesic habitats.

Water Requirements to Maintain Fauna Values

The water requirements needed to maintain the fauna of the Study Area can only be discussed in a general sense. For some species of fauna, such as frogs, the species present may be determined by the lowest water levels experienced in the recent past. These would have acted as a bottleneck through which only the more tolerant species could pass. For other faunal groups, however, water levels over successive years will have influenced the abundance and presence of species. In contrast, waterbirds are highly mobile and can respond to current water levels almost immediately. All that can be confidently stated is that the faunal assemblage present now has been influenced by the recent history of water levels in the area and by the current levels. This faunal assemblage is also likely to be dynamic, and may still be changing due to changes in water levels that happened decades ago. This means that maintaining current water levels could still lead to changes in the faunal assemblage, as it is very likely that the assemblage is still influenced by high water levels probably experienced in the 1950s and 1960s.

Significance of Impacts of Drawdown upon Fauna

Groundwater drawdown in the Gnangara area will result in the decline in abundance and possible disappearance of some fauna species. These impacts will take place in the most southerly of extensive native vegetation remaining on the Swan Coastal Plain, including but not limited to areas reserved for nature conservation. Species of conservation significance will be affected to a disproportionate degree, mostly because of the location of the Gnangara area in a region transitional between high and low rainfall zones.

TABLE ONE. Frog species known or expected in the Gnangara Study Area. Sensitivity to drawdown is classified as 1 (low), 2 (moderate), 3 (high) or 4 (very high). Conservation Significance is classified as CS1, CS2 or CS3 (see Assessment of Conservation Significance section for details).

Species		Drawdown sensitivity	Conservation significance
Myobatrachidae (ground frogs)			
Quacking Frog	*Crinia georgiana*	4	CS3
Glauert's Froglet	*Crinia glauerti*	4	CS3
Sandplain Froglet	*Crinia insignifera*	4	
Moaning Frog	*Heleioporus eyrei*	3	
Marbled Frog	*Heleioporus psammophilus*	3	
Pobblebonk	*Limnodynastes dorsalis*	3	
Turtle Frog	*Myobatrachus gouldii*	1	
Guenther's Toadlet	*Pseudophryne guentheri*	3	
Hylidae (tree frogs)			
Slender Tree Frog	*Litoria adelaidensis*	4	
Motorbike Frog	*Litoria moorei*	4	

TABLE TWO. Reptile species recorded or expected in the Gnangara Study Area. Sensitivity to drawdown is classified as 1 (low), 2 (moderate), 3 (high) or 4 (very high). Conservation Significance is classified as CS1, CS2 or CS3 (see Assessment of Conservation Significance section for details).

Species		Drawdown sensitivity	Conservation significance
Chelidae (side-neck tortoises)			
Long-necked Tortoise	*Chelodina oblonga*	4	CS3
Short-necked Tortoise	*Pseudemydura umbrina*	4	CS1
Gekkonidae (geckoes)			
Clawless Gecko	*Crenadactylus ocellatus*	1	CS3
	Diplodactylus alboguttatus	1	CS3
	Diplodactylus polyopthalmus	1	CS3
Spiny-tailed Gecko	*Diplodactylus spinigerus*	1	
Marbled Gecko	*Phyllodactylus marmoratus*	2	
Pygopodidae (legless lizards)			
Sandplain Worm Lizard	*Aprasia repens*	1	
	Aclys concinna	1	CS3
Fraser's Legless Lizard	*Delma fraseri*	1	
	Delma grayii	1	
Burton's Legless Lizard	*Lialis burtonis*	1	
	Pletholax gracilis	1	
Common Scaleyfoot	*Pygopus lepidopodus*	1	
Agamidae (dragon lizards)			
Western Bearded Dragon	*Pogona minor*	1	
Sandhill Dragon	*Rankinia (Tympanocryptis adelaidensis*	1	
Varanidae (monitors or goannas)			
Gould's Sand Goanna	*Varanus gouldii*	1	
Rosenberg's Goanna	*Varanus rosenbergi*	1	CS3
Black-tailed Tree Goanna	*Varanus tristis*	1	
Scincidae (skink lizards)			
	Acritoscincus (Bassiana) trilineata	3	CS3
Fence Skink	*Cryptoblepharus plagiocephalus*	1	
	Ctenotus australis	1	
	Ctenotus fallens	1	
	Ctenotus gemmula	1	
	Ctenotus impar	1	
King's Skink	*Egernia kingii*	1	
	Egernia multiscutata	1	
Salmon-bellied Skink	*Egernia napoleonis*	1	
	Hemiergis quadrilineata	2	CS3
	Lerista christinae	1	CS2
	Lerista elegans	1	
	Lerista praepedita	1	
Dwarf Skink	*Menetia greyii*	1	

Table 2 (cont.)

Species		Drawdown sensitivity	Conservation significance
Spotted Morethia	*Morethia lineoocellata*	1	
Dusky Morethia	*Morethia obscura*	1	
Western Bluetongue	*Tiliqua occipitalis*	1	
Bobtail	*Tiliqua rugosa*	1	
Typhlopidae (blind snakes)			
	Ramphotyphlops australis	1	
Boidae (pythons)			
Carpet Python	*Morelia spilota imbricata*	1	CS1
Stimson's Python	*Antaresia stimsoni*	1	CS3
Elapidae (front-fanged snakes)			
Yellow-faced Whip-Snake	*Demansia psammophis*	1	
Bardick	*Echiopsis curtus*	1	
Tiger Snake	*Notechis scutatus*	3	CS3
Crowned Snake	*Elapognathus (Drysdalia) coronatus*	3	CS3
Mulga Snake	*Pseudechis australis*	1	CS3
Dugite	*Pseudonaja affinis*	1	CS3
Gwardar	*Pseudonaja nuchalis*	1	CS3
Gould's Snake	*Parasuta gouldii*	1	
	Parasuta nigriceps	1	CS3
Jan's Bandy-Bandy	*Simoselaps bertholdi*	1	
Black-naped Snake	*Neelaps bimaculata*	1	
Black-striped Snake	*Neelaps calonotos*	1	CS2
Half-ringed Snake	*Brachyurophis semifasciata*	1	
Narrow Banded Snake	*Brachyurophis fasciolata*	1	

TABLE THREE. Bird species recorded or expected in the Gnangara Study Area. Sensitivity to drawdown is classified as 1 (low), 2 (moderate), 3 (high) or 4 (very high). Conservation Significance is classified as CS1, CS2 or CS3 (see Assessment of Conservation Significance section for details). In the Conservation Significance column, Int. indicates introduced species, (Int.) indicates self-introduced species and vag. indicates species that have been recorded in the area as vagrants only.

Species		Drawdown sensitivity	Conservation significance
Dromaiidae (emus)			
Emu	*Dromaius novaehollandiae*	1	
Phasianidae (pheasants and quails)			
Stubble Quail	*Coturnix pectoralis*	1	
Anatidae (ducks, geese and swans)			
Plumed Whistling-Duck	*Dendrocygna eytoni*	4	vag.
Freckled Duck	*Stictonetta naevosa*	4	CS3
Black Swan	*Cygnus atratus*	4	
Australian Shelduck	*Tadorna tadornoides*	4	
Mallard	*Anas platyrhynchos*	4	Int.
Pacific Black Duck	*Anas superciliosus*	4	
Grey Teal	*Anas gibberifrons*	4	
Chestnut Teal	*Anas castanea*	4	
Australasian Shoveler	*Anas rhynchotis*	4	CS3
Pink-eared Duck	*Malacorhynchus membranaceus*	4	CS3
Hardhead (White-eyed Duck)	*Aythya australis*	4	CS3
Australian Wood Duck	*Chenonetta jubata*	4	
Musk Duck	*Biziura lobata*	4	CS3
Blue-billed Duck	*Oxyura australis*	4	CS3
Podicepididae (grebes)			
Great Crested Grebe	*Podiceps cristatus*	4	
Hoary-headed Grebe	*Poliocephalus poliocephalus*	4	
Australasian Grebe	*Tachybaptus novaehollandiae*	4	
Phalacrocoracidae (cormorants)			
Great Cormorant	*Phalacrocorax carbo*	4	
Pied Cormorant	*Phalacrocorax varius*	4	vag.
Little Black Cormorant	*Phalacrocorax sulcirostris*	4	
Little Pied Cormorant	*Phalacrocorax melanoleucos*	4	
Ardeidae (herons and egrets)			
White-faced Heron	*Egretta novaehollandiae*	4	
Little Egret	*Egretta garzetta*	4	
White-necked Heron	*Ardea pacifica*	4	
Great Egret	*Egretta alba*	4	CS1
Cattle Egret	*Ardea ibis*	4	vag.
Nankeen Night Heron	*Nycticorax caledonicus*	4	CS3
Little Bittern	*Ixobrychus minutus*	4	CS2
Black Bittern	*Ixobrychus flavicollis*	4	CS2
Australasian Bittern	*Botaurus poiciloptilus*	4	CS1

Table 3 (cont.)

Species		Drawdown sensitivity	Conservation significance
Plataleidae (ibis and spoonbills)			
Glossy Ibis	*Plegadis falcinellus*	4	CS1
Australian White Ibis	*Threskiornis molucca*	3	
Straw-necked Ibis	*Threskiornis spinicollis*	3	
Royal Spoonbill	*Platelea regia*	4	vag.
Yellow-billed Spoonbill	*Platalea flavipes*	4	
Accipitridae (kites, hawks and eagles)			
Osprey	*Pandion haliaetus*	4	vag.
Black-shouldered Kite	*Elanus notatus*	1	
Square-tailed Kite	*Lophoictinia isura*	1	CS3
Whistling Kite	*Haliastur sphenurus*	1	CS3
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	4	CS1 vag.
Spotted Harrier	*Circus assimilis*	1	
Swamp Harrier	*Circus approximans*	4	
Brown Goshawk	*Accipiter fasciatus*	1	CS3
Collared Sparrowhawk	*Accipiter cirrhocephalus*	1	CS3
Wedge-tailed Eagle	*Aquila audax*	1	CS3
Little Eagle	*Hieraaetus morphnoides*	1	CS3
Falconidae (falcons)			
Peregrine Falcon	*Falco peregrinus*	1	CS1
Australian Hobby	*Falco longipennis*	1	
Brown Falcon	*Falco berigora*	1	CS3
Nankeen Kestrel	*Falco cenchroides*	1	
Rallidae (crakes and rails)			
Buff-banded Rail	*Rallus philippensis*	4	
Baillon's Crake	*Porzana pusilla*	4	
Australian Spotted Crake	*Porzana fluminea*	4	
Spotless Crake	*Porzana tabuensis*	4	
Dusky Moorhen	*Gallinula tenebrosa*	4	CS3
Black-tailed Native-hen	*Gallinula ventralis*	4	
Purple Swamphen	*Porphyrio porphyrio*	4	
Eurasian Coot	*Fulica atra*	4	
Otidae (bustards)			
Australian Bustard	*Ardeotis australis*	1	CS2 vag.
Scolopacidae (sandpipers)			
Bar-tailed Godwit	*Limosa lapponica*	4	CS1 vag.
Marsh Sandpiper	*Tringa stagnatalis*	4	CS1
Common Greenshank	*Tringa nebularia*	4	CS1
Wood Sandpiper	*Tringa glareola*	4	CS1
Common Sandpiper	*Tringa hypoleucos*	4	CS1
Red-necked Stint	*Calidris ruficollis*	4	CS1
Long-toed Stint	*Calidris subminuta*	4	CS1
Sharp-tailed Sandpiper	*Calidris acuminata*	4	CS1
Curlew Sandpiper	*Calidris ferruginea*	4	CS1

Table 3 (cont.)

Species		Drawdown sensitivity	Conservation significance
Rostratulidae (painted snipe)			
Australian Painted Snipe	*Rostrastula benghalensis australis*	4	CS2
Recurvirostridae (stilts and avocets)			
Black-winged Stilt	*Himantopus himantopus*	4	
Banded Stilt	*Cladorhynchus leucocephalus*	4	
Red-necked Avocet	*Recurvirostra novaehollandiae*	4	
Charadriidae (lapwings and plovers)			
Red-capped Plover	*Charadrius ruficapillus*	4	
Black-fronted Dotterel	*Elseyornis melanops*	4	
Red-kneed Dotterel	*Erythrogonys cinctus*	4	CS3
Banded Lapwing	*Vanellus tricolor*	3	
Laridae (gulls and terns)			
Silver Gull	*Larus novaehollandiae*	4	
Whiskered Tern	*Chlidonias hybrida*	4	
White-winged Black Tern	*Chlidonias leucopterus*	4	
Turnicidae (button-quails)			
Painted Button-quail	*Turnix varia*	1	CS3
Little Button-quail	*Turnix velox*	1	
Columbidae (pigeons and doves)			
Rock Dove (Feral Pigeon)	*Columba livia*	1	Int.
Laughing Turtle-Dove	*Streptopelia senegalensis*	1	Int.
Spotted Turtle-Dove	*Streptopelia chinensis*	1	Int.
Common Bronzewing	*Phaps chalcoptera*	2	CS3
Brush Bronzewing	*Phaps elegans*	2	CS3
Crested Pigeon	*Ocyphaps lophotes*	1	(Int.)
Cacatuidae (cockatoos)			
Short-billed Black-Cockatoo	*Calyptorhynchus latirostris*	1	CS1
Galah	*Cacatua roseicapilla*	1	(Int.)
corella	*Cacatua* spp.	1	(Int.)
Psittacidae (lorikeets and parrots)			
Rainbow Lorikeet	*Trichoglossus haematodus*	1	Int.
Purple-crowned Lorikeet	*Glossopsitta porphyrocephala*	1	
Regent Parrot	*Polytelis anthopeplus*	1	
Red-capped Parrot	*Purpureicephalus spurius*	1	
Western Rosella	*Platycercus icterotis*	2	CS3
Australian Ringneck	*Barnardius zonarius*	1	
Elegant Parrot	*Neophema elegans*	1	
Cuculidae (cuckoos)			
Pallid Cuckoo	*Cuculus pallidus*	1	
Fan-tailed Cuckoo	*Cuculus pyrrhophanus*	1	
Horsfield's Bronze-Cuckoo	*Chrysococcyx basalis*	1	
Shining Bronze-Cuckoo	*Chrysococcyx lucidus*	1	

Table 3 (cont.)

Species		Drawdown sensitivity	Conservation significance
Strigidae (hawk-owls)			
Southern Boobook Owl	*Ninox novaeseelandiae*	1	
Barking Owl (southern race)	*Ninox connivens connivens*	3	CS2
Tytonidae (barn owls)			
Masked Owl	*Tyto novaehollandiae*	1	CS2
Barn Owl	*Tyto alba*	1	
Podargidae (frogmouths)			
Tawny Frogmouth	*Podargus strigoides*	1	
Caprimulgidae (nightjars)			
Spotted Nightjar	*Eurostopodus argus*	1	
Aegothelidae (owlet-nightjars)			
Australian Owlet-nightjar	*Aegotheles cristatus*	1	
Apodidae (swifts)			
Fork-tailed Swift	*Apus pacificus*	1	CS1
Halcyonidae (forest kingfishers)			
Laughing Kookaburra	*Dacelo novaeguineae*	2	Int.
Sacred Kingfisher	*Todiramphus sanctus*	3	
Meropidae (bee-eaters)			
Rainbow Bee-eater	*Merops ornatus*	1	
Maluridae (fairy-wrens)			
Splendid Fairy-wren	*Malurus splendens*	2	CS3
Red-winged Fairy-wren	*Malurus elegans*	3	CS3
Variegated Fairy-wren	*Malurus lamberti*	1	CS3
White-winged Fairy-wren	*Malurus leucopterus*	1	CS3
Southern Emu-wren	*Stipiturus malachurus*	2	CS3
Pardalotidae (pardalotes)			
Spotted Pardalote	*Pardalotus punctatus*	1	
Striated Pardalote	*Pardalotus striatus*	1	
White-browed Scrubwren	*Sericornis frontalis*	2	CS3
Rufous Fieldwren	*Calamanthus campestris montanellus*	1	CS2
Weebill	*Smicrornis brevirostris*	1	CS3
Western Gerygone	*Gerygone fusca*	1	
Inland Thornbill	*Acanthiza apicalis*	1	CS3
Western Thornbill	*Acanthiza inornata*	1	CS3
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	1	CS3
Meliphagidae (honeyeaters)			
Red Wattlebird	*Anthochaera carunculata*	1	
Western Wattlebird	*Anthochaera lunullata*	1	CS3
Yellow-throated Miner	*Manorina flavigula*	1	CS3
Singing Honeyeater	*Lichenostomus virescens*	1	
Brown-headed Honeyeater	*Melithreptus brevirostris*	1	
White-naped Honeyeater	*Melithreptus lunatus*	1	
Brown Honeyeater	*Lichmera indistincta*	1	
New Holland Honeyeater	*Phylidonyris novaehollandiae*	2	CS3

Table 3 (cont.)

Species		Drawdown sensitivity	Conservation significance
White-cheeked Honeyeater	*Phylidonyris nigra*	1	CS3
Tawny-crowned Honeyeater	*Phylidonyris melanops*	1	CS3
Western Spinebill	*Acanthorhynchus superciliosus*	1	
White-fronted Chat	*Epthianura albifrons*	3	
Petroicidae (Australian robins)			
Western Yellow Robin	*Eopsaltria griseogularis*	1	vag.
White-breasted Robin	*Eopsaltria georgiana*	2	CS3
Scarlet Robin	*Petroica multicolor*	1	CS3
Red-capped Robin	*Petroica goodenovii*	1	
Hooded Robin	*Melanodryas cucullata*	1	
Neosittidae (sittellas)			
Varied Sittella	*Daphoenositta chrysoptera*	1	CS3
Pachycephalidae (whistlers)			
Crested Bellbird	*Oreoica gutturalis gutturalis*	1	CS2
Golden Whistler	*Pachycephala pectoralis*	1	CS3
Rufous Whistler	*Pachycephala rufiventris*	1	
Grey Shrike-thrush	*Colluricincla harmonica*	2	CS3
Dicruridae (flycatchers)			
Restless Flycatcher	*Myiagra inquieta*	1	
Magpie-lark	*Grallina cyanoleuca*	1	
Grey Fantail	*Rhipidura fuliginosa*	2	
Willie Wagtail	*Rhipidura leucophrys*	1	
Campephagidae (cuckoo-shrikes)			
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	1	
White-winged Triller	*Lalage sueurii*	1	
Artamidae (woodswallows)			
Black-faced Woodswallow	*Artamus cinereus*	1	CS3
Dusky Woodswallow	*Artamus cyanopterus*	1	CS3
Grey Butcherbird	*Cracticus torquatus*	1	
Australian Magpie	*Gymnorhina tibicen*	1	
Grey Currawong	*Strepera versicolor*	1	
Corvidae (ravens and crows)			
Australian Raven	*Corvus coronoides*	1	
Passeridae (finches and allies)			
Red-eared Firetail	*Stagonopleura oculata*	3	vag.
Dicaeidae (flower-peckers)			
Mistletoebird	*Dicaeum hirundinaceum*	1	
Hirundinidae (swallows)			
White-backed Swallow	*Cheramoeca leucosternus*	1	
Welcome Swallow	*Hirundo neoxena*	1	
Tree Martin	*Hirundo nigricans*	1	
Fairy Martin	*Hirundo ariel*	1	

Table 3. (cont.)

Species		Drawdown sensitivity	Conservation significance
Sylviidae (Old World warblers)			
Clamorous Reed-Warbler	*Acrocephalus stentoreus*	3	
Little Grassbird	*Megalurus gramineus*	3	
Rufous Songlark	*Cincloramphus mathewsi*	1	
Zosteropidae (white-eyes)			
Silvereye	*Zosterops lateralis*	2	

TABLE FOUR. The highest count of each species made on any wetland in the Gnangara area 1981-1992 (Birds Australia/DCLM waterbird database). Values in parenthesis are from counts conducted in January 2003 by M. Bamford and M. Craig (unpubl. data). Wetland names taken from Storey *et al.* (1993).

Species Name	Maximum count	wetland
Plumed Whistling-Duck	(23)	Lake Joondalup
Freckled Duck	9	Lake Chandala
Black Swan	961	Lake Joondalup
Australian Shelduck	600	Lake Goollelal
Mallard	(7)	Lake Joondalup
Pacific Black Duck	(1660)	Lake Joondalup
Grey Teal	(5730)	Lake Joondalup
Australasian Shoveler	600	Lake Nowergup
Pink-eared Duck	1000	Mangala Lake
Hardhead	154	Lake Bambun
Wood Duck	600	Emu-Ballajura Ponds
Musk Duck	82	Lake Joondalup
Blue-billed Duck	302	Lake Bambun
Great Crested Grebe	(66)	Lake Goollelal
Hoary-head Grebe	(600)	Lake Joondalup
Australasian Grebe	580	Lake Bambun
Darter	41	Lake Joondalup
Great Cormorant	35	Bag Carine Swamp
Pied Cormorant	1	Lake Joondalup
Little Black Cormorant	237	Lake Beermullah
Little Pied Cormorant	78	Lake Beermullah
Australian Pelican	(197)	Lake Joondalup
White-faced Heron	(128)	Lake Joondalup
White-necked Heron	(56)	Lake Jandabup
Great Egret	(187)	Lake Joondalup
Little Egret	5	Big Carine Swamp
Cattle Egret	7	Lake Joondalup
Little Bittern	4	Lake Jandabup
Black Bittern	2	Lake Joondalup
Australasian Bittern	1	Lake Jandabup
Nankeen Night Heron	32	Lake Chandala
Glossy Ibis	21	Lake Chandala
Australian White Ibis	(69)	Lake Jandabup
Straw-necked Ibis	5000	Lake Chandala
Royal Spoonbill	6	Lake Jandabup
Yellow-billed Spoonbill	(152)	Lake Joondalup
White-bellied Sea-Eagle	(1)	Lake Joondalup
Osprey	1	Diamond Island
Swamp Harrier	3	Lake Jandabup

Table 4 (cont.)

Species Name		
Buff-banded Rail	1	Lake Goollelal
Australian Spotted Crake	2	Blyth's Lake
Baillon's Crake	1	Lake Joondalup
Spotless Crake	11	Lake Jandabup
Purple Swamphen	43	Loch McNess
Black-tailed Native-hen	107	Lake Chandala
Dusky Moorhen	16	Lake Joondalup
Eurasian Coot	(5977)	Lake Joondalup
Bar-tailed Godwit	2	Lake Joondalup
Marsh Sandpiper	6	Lake Joondalup
Common Greenshank	28	Lake Jandabup
Wood Sandpiper	16	Lake Jandabup
Common Sandpiper	3	Lake Joondalup
Red-necked Stint	650	Lake Jandabup
Long-toed Stint	10	Lake Jandabup
Sharp-tailed Sandpiper	28	Lake Jandabup
Curlew Sandpiper	44	Mungala Lake
Australian Painted Snipe	3	Bambun Lake
Black-winged Stilt	(2174)	Lake Joondalup
Banded Stilt	150	Lake Jandabup
Red-necked Avocet	1200	Lake Joondalup
Red-capped Plover	3000	Lake Jandabup
Black-fronted Dotterel	75	Lake Joondalup
Red-kneed Dotterel	90	Mungala Lake
Banded Lapwing	18	Emu-Ballajura Ponds
Oriental Pratincole	3	Lake Jandabup
Silver Gull	370	Lake Joondalup
Whiskered Tern	10	Lake Jandabup
Clamorous Reed Warbler	12	Lake Jandabup
Little Grassbird	15	Lake Jandabup

TABLE FIVE. Mammal species expected in the Gnangara Study Area. Sensitivity to drawdown is classified as 1 (low), 2 (moderate), 3 (high) or 4 (very high). Categories of Conservation Significance are discussed in the "Assessment of Conservation Significance" section.). In the Conservation Significance column, Int. indicates introduced species. An asterisk indicates species observed during the site inspection.

Species		Drawdown sensitivity	Conservation significance
Tachyglossidae (echidnas)			
Echidna	*Tachyglossus aculeatus*	1	
Dasyuridae			
Chuditch	*Dasyurus geoffroii*	1	CS1
Brush-tailed Phascogale	*Phascogale tapoatafa*	1	CS2
dunnart	*Sminthopsis dolichura*	1	CS3
White-footed Dunnart	*Sminthopsis granulipes*	1	CS3
dunnart	*Sminthopsis griseoventer*	1	CS3
Peramelidae (bandicoots)			
Quenda or Southern Brown Bandicoot	*Isoodon obesulus*	3	CS2
Phalangeridae (possums)			
Brush-tailed Possum	*Trichosurus vulpecula*	2	CS3
Burramyidae (pygmy possums)			
Western Pygmy Possum	*Cercartetus concinnus*	2	CS3
Tarsipedidae (honey possum)			
Honey Possum	*Tarsipes rostratus*	1	
Macropodidae (kangaroos and wallabies)			
Western Grey Kangaroo	*Macropus fuliginosus*	1	
Brush or Black-gloved Wallaby	*Macropus irma*	3	CS2
Mollosidae (mastiff bats)			
White-striped Bat	*Tadarida australis*	1	
	Mormopterus planiceps	1	
Vespertilionidae (vesper bats)			
Gould's Wattled Bat	*Chalinolobus gouldii*	1	
Chocolate Wattled Bat	*Chalinolobus morio*	1	
King River Eptesicus	*Vespadelus (Eptesicus) regulus*	1	
	Falsistrellus mackenziei	1	CS2
Lesser Long-eared Bat	*Nyctophilus geoffroyi*	1	
Gould's Long-eared Bat	*Nyctophilus gouldii*	1	
Greater Long-eared Bat	*Nyctophilus timoriensis*	1	
Muridae (rats and mice)			
House Mouse	*Mus musculus*	2	Int.
Noodji or Ashy-grey Mouse	*Pseudomys albocinereus*	1	CS3
Moodit or Bush Rat	*Rattus fuscipes*	3	CS3
Rakali or Water Rat	*Hydromys chrysogaster*	4	CS2
Black Rat	*Rattus rattus*	2	Int.

Table 5 (cont.)

Species		Drawdown sensitivity	Conservation significance
Leporidae (rabbits and hares)			
Rabbit	*Oryctolagus cuniculus*	1	Int.
Canidae (foxes and dogs)			
European Red Fox	*Vulpes vulpes*	1	Int.
Felidae (cats)			
Feral Cat	*Felis catus*	1	Int.

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APPENDIX ONE. Categories used in the assessment of conservation status.

Environmental Protection and Biodiversity Conservation Act and the WA Wildlife Conservation Act (categories mainly from IUCN, based on review by Mace and Stuart 1994).

Extinct. Taxa not definitely located in the wild during the past 50 years (included in Schedule 1 of WA Act).

Extinct in the Wild. Taxa known to survive only in captivity (included in Schedule 1 of WA Act).

Critically Endangered. Taxa facing an extremely high risk of extinction in the wild in the immediate future (included in Schedule 1 of WA Act).

Endangered. Taxa facing a very high risk of extinction in the wild in the near future (included in Schedule 1 of WA Act).

Vulnerable. Taxa facing a high risk of extinction in the wild in the medium-term future (included in Schedule 1 of WA Act).

Near Threatened. Taxa that risk becoming Vulnerable in the wild.

Conservation Dependent. Taxa whose survival depends upon ongoing conservation measures. Without these measures, a conservation dependent taxon would be classed as Vulnerable or more severely threatened (Schedule 2 of WA Act).

Other Specially Protected Fauna (Schedule 4 of WA Act).

Data Deficient (Insufficiently Known). Taxa suspected of being Rare, Vulnerable or Endangered, but whose true status cannot be determined without more information.

Least Concern. Taxa that are not Threatened.

WA Department of Conservation and Land Management Priority species (species not listed under the Conservation Act, but for which there is some concern).

Priority 1. Taxa with few, poorly known populations on threatened lands.

Priority 2. Taxa with few, poorly known populations on conservation lands; or taxa with several, poorly known populations not on conservation lands.

Priority 3. Taxa with several, poorly known populations, some on conservation lands.

Priority 4. Taxa in need of monitoring.