A biodiversity conservation plan for Shield and Central subregions of the Great Victoria Desert

Review of literature and research records

Prepared for the review by the Department of the Environment– under the EBPC Approval EPBC 2008/4270 Section 6 (a)(i)

Executive Summary

This document represents a collaboration between diverse stakeholders to collate biodiversity information on the Shield and Central subregions (SCS) of the Great Victoria Desert. Overwhelmingly, in reading this document the paucity of knowledge on the region will be become clear. In a very remote region, with no major settlements, distance and inaccessibility have limited the ability of researchers to conduct broad scale studies across the region.

Some of the information in this plan is determined from broad scale national data sets. Other information comes from regional centres just outside, or on the edges of the SCS, and is extrapolated to apply to the region. Information also spans decades as important research conducted in the 1980's and 1990's has not been repeated and still represents the best available state of knowledge for biodiversity in the region. Much of the current information on the region comes from studies commissioned by mining and exploration activities. These reports have greatly increased knowledge of species and habitat in specific areas of the SCS.

Taken together, the information captured helps to provide a baseline for the current understanding of the region and the biodiversity wherein. In this initial document, planning for future activities in the region, both in terms of research and on-ground land management are primarily extracted from existing documents. Planning is underway to ensure this plan evolves to further engage and consult with the diverse stakeholders in the region. By conducting a series of planning workshops which will develop priorities and analyse available knowledge and resources, a strong road map for future biodiversity activities in the region will be created. This document represents the first milestone along this journey and provides all stakeholders with a shared information platform on which to build knowledge and increase the holistic understanding of the region.

The Great Victoria Desert Biodiversity Trust would like to thank all the stakeholders who provided resources and reports for the compilation of this document. The stakeholders who reviewed the document, and provided their insights and expertise about the region, have ensured this document is reflective of genuine, on-ground knowledge of the region.

Contents




1. Introduction

The development of a biodiversity conservation plan for the Great Victoria Desert -Shield and Central subregions (SCS) was driven a need to better understand the environment in the Great Victoria Desert (GVD) and the processes effecting the natural functioning of ecosystems. Due to limited settlements in the region and vast distances, the region has had limited research or land management.

In 2014 the Great Victoria Desert Biodiversity Trust (the Trust) was established. This was a result of negotiations between Tropicana Joint Venture (AngloGold Ashanti Australia, Independence Group NL) and the federal Department of the Environment (at the time named the Department of Sustainability, Environment, Water, Population and Communities) as well as the Western Australian Department of Parks and Wildlife (DPaW). The Trust was formed as part of the venture's offset strategy for the Tropicana Gold Mine in the Western Australia GVD under the Environmental Protection and Conservation Act 1999. The purpose of the Trust is '*Conserving and increasing knowledge of biodiversity in the Great Victoria Desert'*. This is achieved through four objectives:

1) Develop a Bioregional Management Plan (the Plan) for the GVD bioregions 1 and 2

2) Facilitate priority research identified in the Plan at the landscape level and into threatened species including species considered to be Matters of National Environmental Significance (MNES) under the EPBC Act with emphasis on Sandhill Dunnart (*Sminthopsis psammophila),* Malleefowl (*Leipoa ocellata*) and Southern Marsupial Mole (*Notorcytes typhlops)*.

3) Fund on-ground environmental and conservation management at the landscape level, with emphasis on net conservation benefits to threatened species including those considered of MNES under the EPBC Act with emphasis on Sandhill Dunnart (*Sminthopsis psammophila)*, Malleefowl (*Leipoa ocellata*) Southern Marsupial Mole (*Notorcytes typhlops)*.

4) Facilitate Indigenous involvement in land management and conservation activities in support of the above objectives.

This plan, designed to meet the first objective, is a product of commitments between the Tropicana Joint Venture, the Trust, DPaW and the federal Department of the Environment to capture existing information on the region and start to outline future research and land management activities that would be necessary in order to better understand and protect the biodiversity of this region. It is aimed that this plan will help assist the Trust in the allocation of funds and resources. It is also the aim that any stakeholders, undertaking biodiversity related work in the region, will use this plan to guide resource allocation.

This plan represents an attempt to gather available biodiversity related data, both historical and current in the SCS region. By collecting and collating this information, this plan forms a baseline of existing knowledge and helps demonstrate where gaps in knowledge exist. In addition to funding this plan, the Trust has announced it will support the 'Adaptive Management Partnership' (AMP) to actively consult with stakeholders in the region and use their on-ground knowledge to develop priority actions for research and land management both at the species level and the landscape scale level.

The AMP consists of Traditional Owners partners and five key stakeholders with interests in SCS: Pila Nguru (representing the Spinifex), the Pilki people (representation to be agreed / confirmed), Rangelands NRM, Greening Australia, Central Desert Native Title Service (representing the Yilka people), Conservation Management and the Department of Parks and Wildlife (WA).

These groups have each contributed to the pool of information used in the collation of this report. As a supporting project, the Trust has also created a 'Knowledge Hub' (KH). This hub is an electronic database for these reports and spatially represents on a map the locations of study areas identified in the reports.

Together, as these three projects evolve, they are expected to create a strong, interactive knowledge platform by:

-creating a baseline of existing knowledge for the region based on available reports, information and data sets

- creating a visual platform allowing all stakeholders in the region view location specific information and fully conceptualise work undertaken in the region

- bringing stakeholders together to discuss the main issues, threats and research and land management actions needed in the region.

2. The Great Victoria Desert - regional overview

The GVD is Australia's largest desert and covers an area of 418,800 km^2 within Western and South Australia. The GVD as a bioregion comprises six separate subregions, each of which are defined by common characteristics such as geology, landform patterns, climate, ecological features and plant and animal communities (see Section 6.1 for further details).The Shield and Central subregions combine to cover 173,327 $km^2$of the bioregion.

In Western Australia, the GVD is bordered to the south by the Nullarbor Plain, in the north by the Musgrave Ranges and the Gibson Desert, and to the west by the East Murchison and Eastern Goldfields region. While the GVD is well vegetated, the lack of surface water has limited settlement and conversion to other land uses over most of the region. There are no major towns in the SCS region (see Figure 1). The closest towns are Kalgoorlie-Boulder, approximately 300km south-west of the GVD border and Warburton to the north. There are some Aboriginal settlements in or close to the boundary of the region.

The lack of major settlements and limited access to most of the region has resulted in a paucity of knowledge about the biodiversity in the region however it has also limited the

exposure of the area to invasive species.

Figure 1. Map of SCS region. Dark orange is the combined Shield and Central regions, the pale orange is GVD3.

Historically, the GVD was named by the explorer Ernest Giles in 1875, the first of many European explorers to venture across the region. Pearson (1994), in researching the history of botanical knowledge of Queen Victoria Spring at the southwestern edge of the GVD, has collated many of the exploratory journeys in the 19th and early-mid 20th centuries. Most of these refer frequently to the Aboriginal occupation of the region at that time, and European explorers were often dependent on their assistance in finding water.

3. Shield and Central Subregion: Existing environment

The Trust focus is on the Shield (GVD01) and Central (GVD02) subregions (SCS) of the GVD. Background, descriptions and definitions to follow are for the SCS unless otherwise stated in which case they are for the Western Australian portion of the GVD.

3.1. Climate

The climate of the GVD is classified as arid desert under the modified Köppen classification system used by the Australian Bureau of Meteorology (BoM) (GHD, 2008), being warm to hot in summer and cool in winter. Tille (2006) placed the GVD within the Eremaean (summer

and winter rain desert) bio clime identified by Beard (1990[1]) based on the classification of Bagnouls and Gaussen (1957).

Rainfall

The SCS region's climate is arid, with evaporation exceeding average rainfall. The mean average rainfall averages between 150 mm to over 250 mm, making it one of the driest areas in Australia (Figure 2).

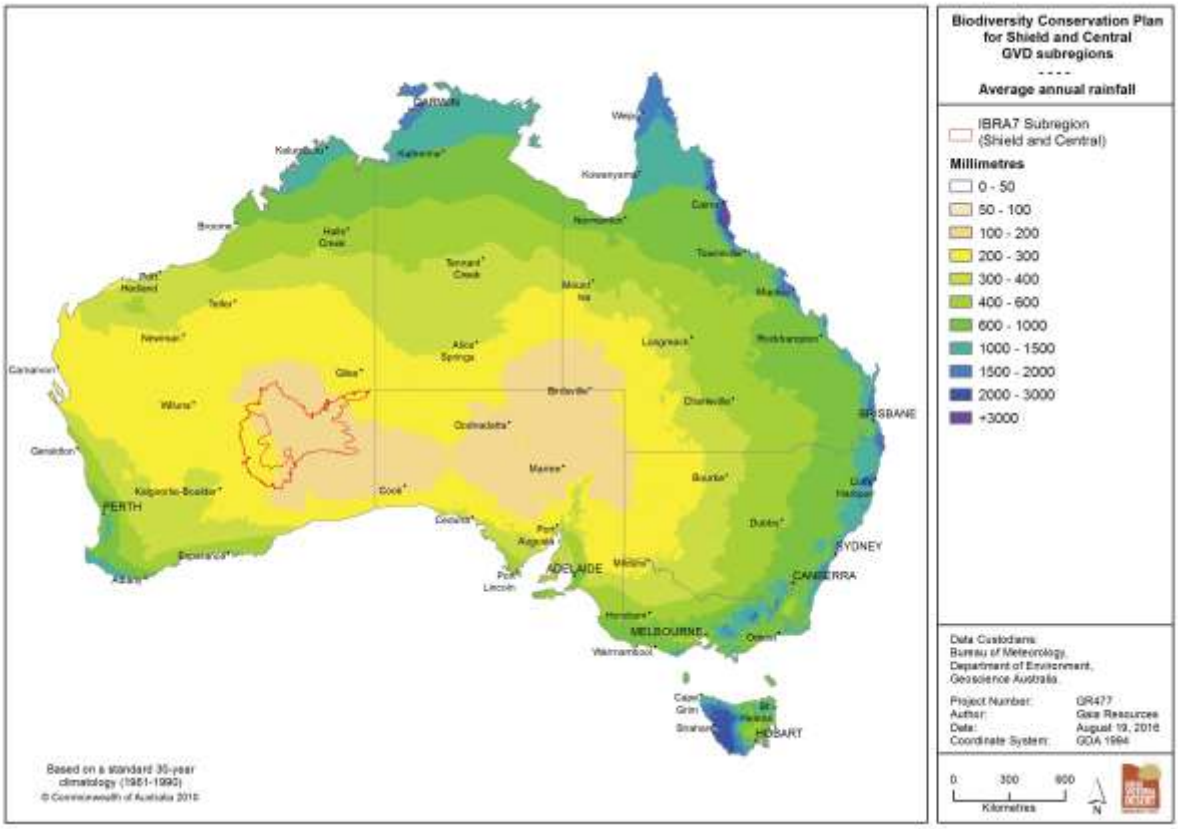


Figure 2. Average annual rainfall across Australia with SCS region highlighted in red.

Rainfall is highly variable and unreliable in both summer and winter. The majority of rainfall appears to fall in summer however there are limited permanent rainfall data sites within the GVD. Nearest settlements include Leonora and Kalgoorlie. Data from the BoM historical records show Leonora Aero station average rainfall is 288.1mm with the majority of rain falling over the summer months. Likewise in records for Warburton, the average rainfall is 244.3mm, with rainfall predominately falling over the summer months. Ilkurlka, in the centre of the GVD has climate data for the last 10 years. This station has an annual rainfall of 228.6mm and rainfall falls between November and April. Figures 4 and 5 show the generalised BoM rainfall data for WA based on summer (October to April) rainfall and winter (April to November). These demonstrate the change in rainfall across the year, with the majority of the SCS experiencing very low (50 -100mm) of rain in the winter period.

[1] This reference (Beard 1990) was not able to be accessed for this review.

Occasional heavy rainfall events can occur throughout the year at all these sites. The heavy, infrequent rainfall events can result in pulses of activity (Langlands *et al*. 2006), stimulating plant growth and animal activity. Some claypans will retain surface water for extended periods after heavy rains, becoming focus points for both native and introduced animals.

Burrows *et al*. (1987) noted a high incidence of thunderstorms, particularly in the summer months, as part of a fire study of Queen Victoria Spring Nature Reserve in the southwestern part of the GVD where the climate is more Mediterranean (ie. most rainfall in winter months). Burrows *et al*. (1987) also note that the reserve lies close to the boundary between predominantly winter rainfall (to the south and west) and predominantly summer rainfall (to the north and east).

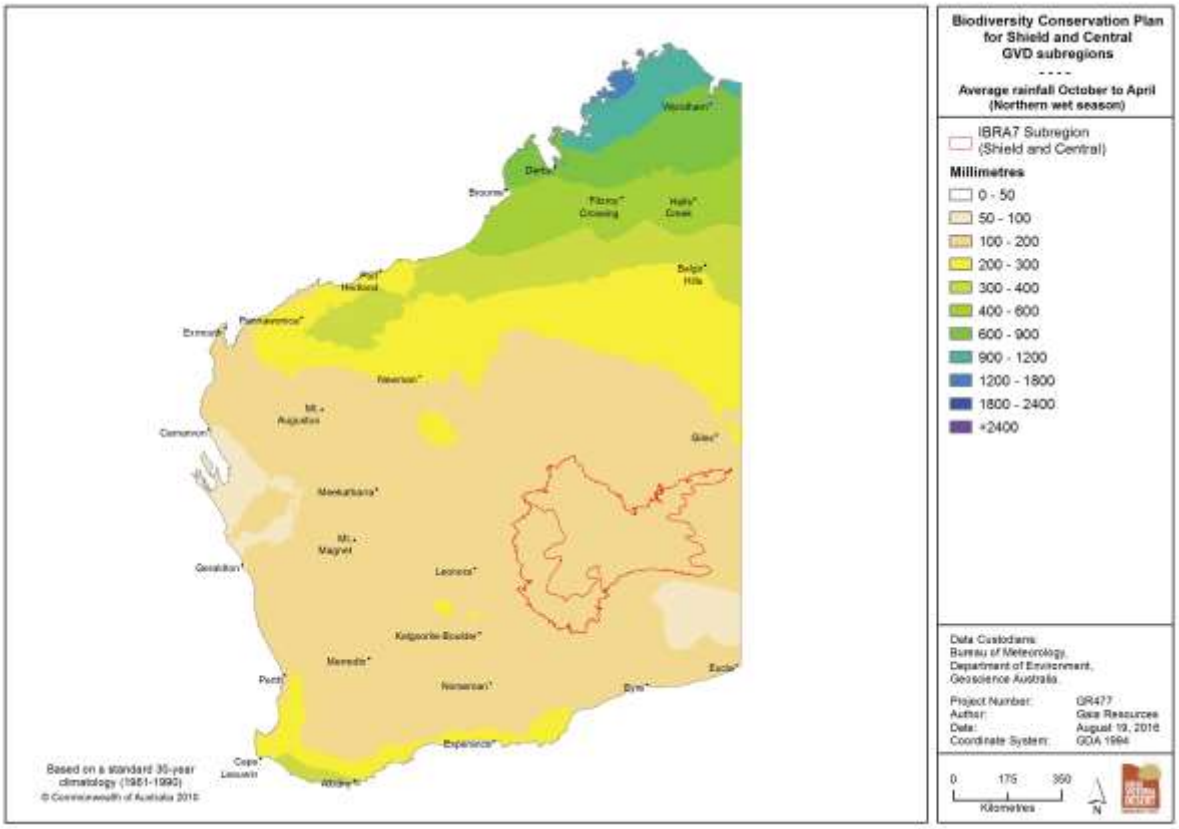


Figure 3 Average Western Australian rainfall over the 'summer' months with SCS region highlighted in red

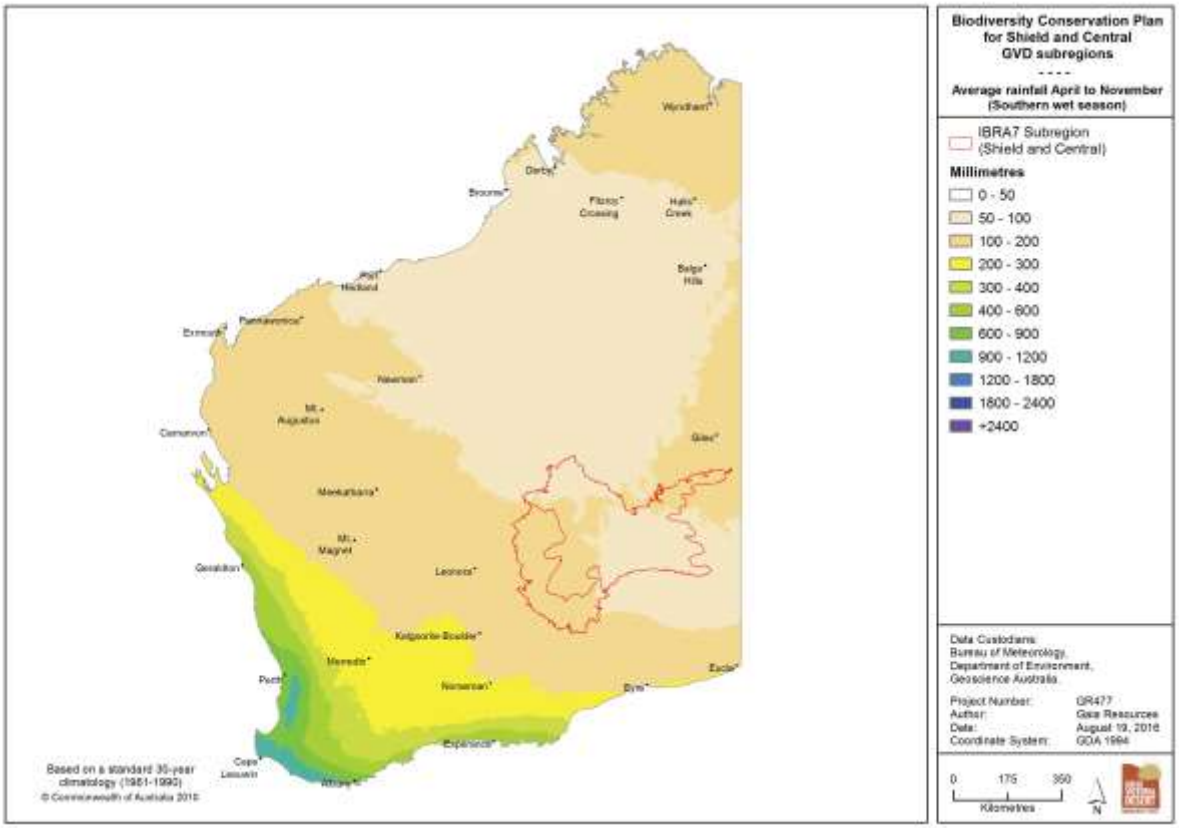


Figure 4. Average Western Australian rainfall over the 'winter' months with SCS region highlighted in red

Temperature

Summer temperatures are often hot with mean maxima between 32°C and 35°C (ecologia 2009b) but highest maxima can exceed 45°C (Langlands *et al.* 2006). Diurnal ranges are also large and winter minima can be below 0°C (Pearson 1994, Langlands *et al*. 2006, ecologia 2009b).

The BoM has limited temperature data for sites within the GVD. Warburton Airfield has an average temperature of 29.9°C, with summer averages between 36.6°C and 38°C. Winter temperatures are the lowest, ranging between 20.7°C and 23.3°C.

Climatic changes

Understanding if and how the climate is changing in the region plays a key role in managing the biodiversity values. The lack of detailed data sets for the region makes it difficult to accurately assess the changes that may be occurring. Generalised data about climate change from CSIRO (http://www.climatechangeinaustralia.gov.au/) indicates that across the rangelands temperatures will continue to increase in all seasons. Extreme temperatures, in terms of actual temperature, frequency of hot days and duration of hot spells are all expected to increase. Changes in average rainfall are less certain, however current predictions suggest that winter rainfall will decrease in the southern rangelands. There is a high degree of certainty around the potential increase in extreme rainfall events and a medium degree of confidence regarding increase in periods of drought (http://www.climatechangeinaustralia.gov.au/).

The impacts of climate change will be further discussed in section 9.6.

3.2. Population

The population of the region is difficult to determine as population statistics are collated by the Australian Bureau of Statistics (ABS) based on local government areas (LGAs). The SCS is predominately in the Shires of Laverton (population in 2013: 1357) and Menzies (population in 2013: 422), with the outer areas in Wiluna (population in 2013: 1279), Ngaanyatjarraku (population in 2013: 1584) and Kalgoorlie-Boulder (population in 2013: 33,763). As previously outlined, none of the major towns for these LGAs are in the SCS region making the actual permanent population in the SCS difficult to estimate.

In terms of settled areas in the SCS, there are approximately 10 pastoral stations in or overlapping the SCS region. There is 5,703,590 ha (32%) of native titled determined country however the only Aboriginal settlement that occurs within the SCS is Cosmo Newberry. The 2006 ABS census estimated the population of Cosmos Newberry at 51. Over 75% of the SCS is either nature reserve or unallocated crown land (UCL). These factors indicate that the permanent population of the SCS is likely to be very low.

The itinerant populations associated with mining and exploration operations either proposed or operational have the potential to vastly increase the population. For the life of a mine site, the population of fly-in, fly-out workers has a substantial impact on a local area through housing, facilities, waste generation and roads, and to some degree acts in a similar manner to other permanent settlements. Tropicana Joint Venture's operation, for example, includes provision for a workforce of up to 700 people during construction and up to 400 during operations (Tropicana Joint Venture, 2009a).

3.3. Main industries

Mining

Mining operations and the activities associated with mining are the most significant industries in the region, both in terms of employment and income generation for the region.

In the SCS region, deposits of gold and uranium are the most significant resources with some mining for mineral sands in the WA area of GVD03. Exploration is underway for the copper, nickel and rare earth deposits. This is particularly occurring in the Fraser Ranges in the south of the SCS.

Currently Tropicana Gold Mine is the only operational mine in the SCS. The mine, in collaboration with APA Group, has recently commissioned a gas pipeline which runs 293 km. The pipeline became operational in February 2016. The disturbance caused by the pipeline has the potential to impact on some species in the region however it will also reduce the usage of roads for the transportation of diesel for fuelling the mine.

Other significant operations which currently have Environmental Impact Assessments (EIAs) with the Environmental Protection Authority include Mulga Rock uranium (Vimy Resources) in the south of the SCS.

Other potential projects in the region include Gold Road in the north-west area and Sheffield Resources in the south western most corner of the SCS. Sheffield Resources are focussing on nickel and copper deposits in the Fraser Ranges.

Mining brings with it several adverse impacts to biodiversity. There is direct land clearing associated with mine sites and the facilities to accommodation staff. Roads directly clear large areas of land along their length. Mine sites also have a substantial impact on feral animal numbers. Increased water availability can increase herbivore numbers and this, combined with increases in food availability (ie possible scavenging) can increase the number of predators in the areas surrounding the mine site, which in turn impacts many of the native species in the vicinity. Section 9.5 discusses in more details the threats on biodiversity caused by mining.

Figure 5 Sandalwood camp - historical image from Westcorp

Sandalwood

Sandalwood has a long history in the GVD which started in 1844 and continues today. In the period 1844 to 1929 Western Australia was a dominant exporter of sandalwood and stocks rapidly declined as sandalwood trees can take between 50 and 90 years to mature (Statham, 1990). Evidence of historical sandalwood cutting camps can still be seen across the SCS today.

In the late 1920's, the government drew up strict regulations on cutting due to fears that the wood was being over cut, resulting in the Sandalwood Act 1929 (Statham, 1990). Since this time prices of sandalwood have fluctuated and sandalwood harvesting has varied accordingly. In the late 1980's prices for sandalwood averaged $5757 per ton for green wood and $7573 per ton for roots and butts (Statham, 1990). Today the majority of wild sandalwood harvesting comes from the GVD (eastern goldfields) region and 90% grows on Crown land including pastoral leases (DPaW, 2015). There is an annual quota for the harvest of sandalwood at 3,000 tonnes of wood, being 1,500 tonnes of green and 1,500 tonnes of dead wood (DPaW, 2015). Sandalwood harvesting on Crown land is managed by the Forest Products Commission (FPC) under a contract system. Currently there are proposals to substantially increase the annual quota of Sandalwood harvesting.

Across the state there is one licence, held by Wescorp, to take sandalwood on Crown land. This licence has 24 FPC contractors listed on the licence. There are 22 private property

sandalwood licences. In addition there are five major wholesaling operations in Western Australia (DPaW, 2015). High quality sandalwood is currently exported for over $15,000 per tonne (DPaW, 2015). Illegal harvesting of sandalwood is a major issue for the industry with an estimated 308.8 tonnes of illegal harvest seized in 2013 (DPaW, 2015).

Natural regeneration of sandalwood is hampered by feral herbivore grazing and reductions in natural seed dispersal (Sawyer, 2013). Fire, drought and climate change may be reducing sandalwood seedling survival (Sawyer, 2013; DPaW, 2015).

Tourism

Limited formal, permanent tourism exists within the SCS. Several tour companies operate camping / 4wd holidays which focus on providing an 'Outback' experience to visitors. There are two major roads passing through the SCS – the Great Central Road and the Anne Beadell Hwy. The Spinifex Rangers have established tourist facilities along the Anne Beadell Hwy, including campsite and toilet blocks. The Great Central Road is part of a road system called the 'Outback Way' or 'Australia's longest short cut' which connects Western Australia to Queensland, passing through the Northern Territory. The Anne Beadell Highway connects Laverton in Western Australia to Coober Pedy in South Australia and runs directly through the GVD. Companies such as Coates Wildlife Tours and Diamantina Touring Company offer trips traversing the GVD from South Australia through Western Australia. The Ilkurlka Roadhouse is a central point on the Anne Beadell Highway for camping and for refuelling.

Other tourism areas in the SCS include the Neale Junction camping area and the Yeo Lake Homestead camping area which are both administered by DPaW. In order to access large sections of the SCS, permits are required from Traditional Owners. Tourism is likely to generate limited income for the region.

3.4. Landforms and Soils

The Great Victoria Desert is located in the Northwestern Great Victoria Desert Zone (NWGVDZ) and Southern Great Victoria Desert Zone (SGVDZ) within the Gunbarrel Province of the Sandy Desert Region (Tille, 2006). These zones have an area of 94,450km2 and 87,550km2 respectively.

The NWGVDZ is located in the southern Arid Interior sitting between Lake Carnegie, Rason Lake and Warburton. This zone is dominated by sandplains and dunes (with some undulating plains and uplands) on sedimentary rocks of the Gunbarrel Basin (Tille, 2006). The soils are predominantly red sandy earths and red deep sands with some red loamy earths and red-brown hardpan shallow loams (Tille, 2006).

The SGVDZ is also in the southern Arid Interior and lies between Lake Minigwal and the South Australian border. This zone is also dominated by sandplains and dunes (with some gravelly plains and calcrete plains) on sedimentary rocks of the Gunbarrel (and Officer) Basin (Tille, 2006). The soils in this region are dominated by red deep sands and red sandy earths with some red loamy earths.

Across both the NWGVDZ and SGVDZ sandplains are the dominant feature with east-west longitudinal and ring dunes separated by interdune corridors and plains (Tille, 2006). These sandplains sit at an elevation of 350-500 AHD30, dropping to 300 m or less AHD30. Dunes have an average height of around 10 m (typically between 2 m and 15 m) and 1.5 km to 5

km in length. Dune width varies between 100 m and 200 m and the interdune areas can vary between 250 m and 800 m in width (GHD, 2008) and in some areas dunes overlie duricrust residuals. Irregularly shaped network dunes are also common, especially in paleodrainage depressions (Jackson, 1987 in D'Ercole *et al.* 2005).

The sandplains contain occasional outcrops of sandstones, laterites and silcretes, some calcareous mounds, and occasional salt pans. Across the SCS region there are the occasional scarpland-breakaways which are usually surrounded by stone and gravel pavements.

Playa lakes make up a small part of the regional landform however they are numerous and some of which are several kilometres wide and tens of kilometres long and form chains generally trending towards the southeast and occupying the lower areas (Chan *et al.* 1992). These chains act as drainage lines after rains and are part of palaeochannels drainage systems or palaeorivers (Bunting *et al.*, 1973; Beard, 2002). The playa lake channels are mostly devoid of true soils, however gypsiferous and saline loams, highly calcareous earths and occasional yellow duplex soils occur in the fringing areas (Chan *et al.* 1992). See Figure 6 for soils and landscapes in the SCS region.

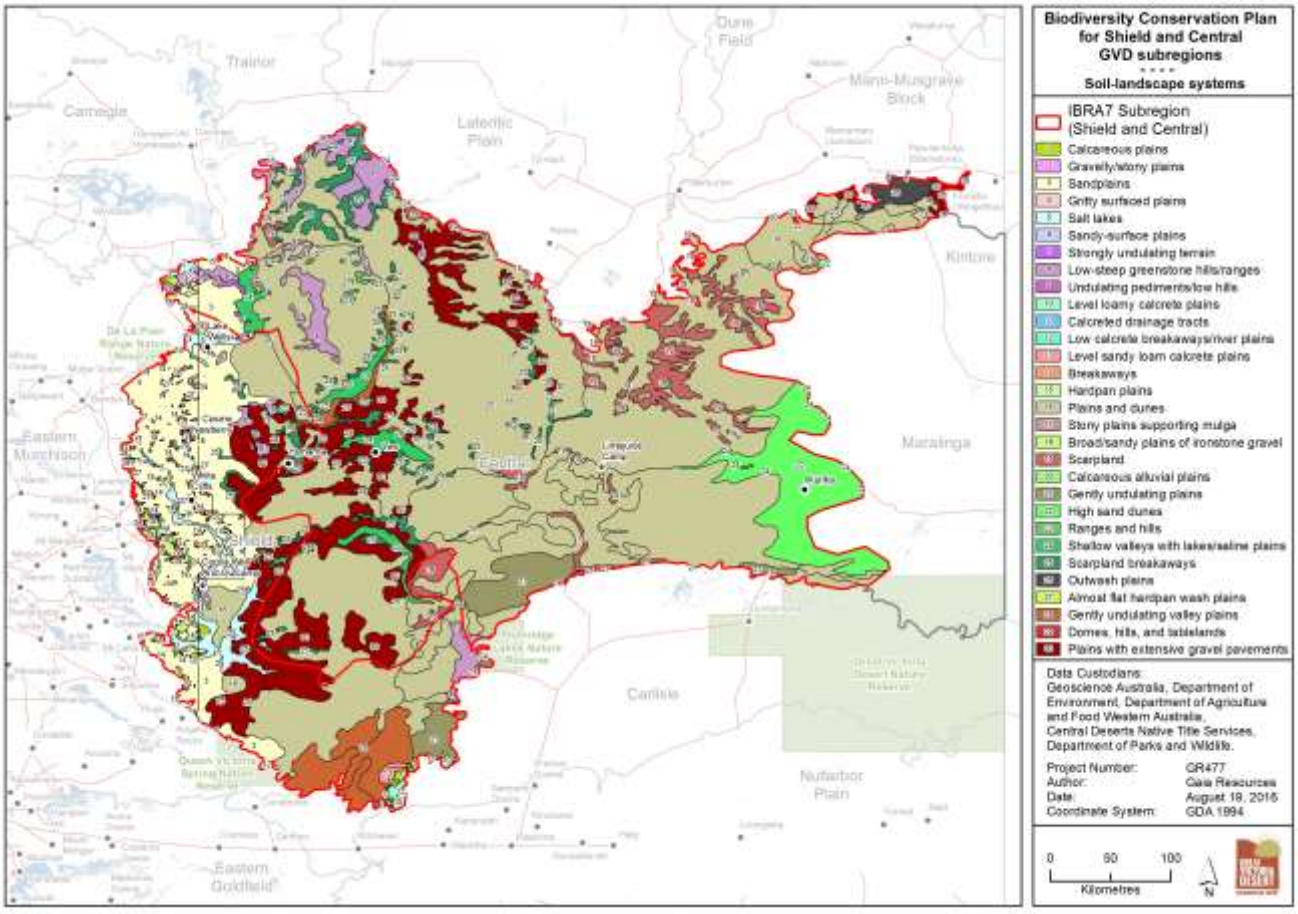


Figure 6 Soil and landscapes of the SCS region

Few detailed analyses of soil physical and chemical parameters are readily accessible. Pearson's 1994 thesis on the Queen Victoria Spring Nature Reserve, is one exception.

Pearson (1994) found that soil particle size analysis followed the geological surface classes, with:

- sandy soils tending to occur in areas of Quaternary aeolian sandsheets
- sandy skeletal loams around rock outcrops
- more clayey soils on colluvium derived from the erosion of Archaean rocks, and
- heavier clay soils along the paleo-drainage of Ponton Creek.

There were few trends and relationships in the soil chemistry but certain geological surfaces, such as the Quaternary sands, had particularly nutrient-depauperate soils (Pearson 1994).

3.5. Geology

In the GVD deep Quaternary Aeolian sands overlie the Gunbarrel Basin (Barton and Cowan, 2001). The western end of the GVD is underlain by the Yilgarn Craton, containing some of the oldest rocks of the Shield region. This area is dominated by granite with belts of greenstone rocks. Adjoining the Yilgarn Craton is the Albany-Fraser Province and its transition zone. In this area Archaean rocks have been metamorphosed and intruded by granite during the Protezoic (van de Graff and Bunting, 1977). To the east of the transition zone lie the Gunbarrel and Officer Basins.

The sedimentary rocks of the Gunbarrel Basin include sandstone, glacigene, marie and continental siliclastic and arenite. The Gunbarrel overlies the Officer Basin, a former marine trough, which comes to the surface in the north-east of the GVD (along the boundary with the Musgrave and Warburton Range Provinces) which is immediately north of the SCS region. In this area there is neoproterozoic conglomerate, sandstone and arenite (Tille, 2006). See Figure 7 for visual representation of the geology of the region.

Chan and colleagues (2009) describe the geology and geomorphic evolution of the Officer Basin as:

- Permian glaciation of bedrock;
- Mesozoic deep weathering, with minor planation;
- Drainage patterns with major valleys several kilometres wide (playa lakes Paleodrainage)
- The breakup of Gondwanaland;
- Cainozoic landscape evolution involved renewed weathering and duricrust formation;
- Climate change from a warm and moist climate in the Mesozoic and Cainozoic to a period of aridity involving salt weathering, Aeolian deposits, limited drainage and the formation of remnant lake systems.

In the south-west of the GVD are the Mesoproterozoic granite, dolerite, gabbro and ultra-basic intrusions, and archaean gneiss of an outlier of the Biranup Complex (Tille, 2006).

The western part of the GVD is underlain by a moderately well-developed laterite crust or by ferruginised silcrete. These laterite and silcrete crusts form a resistant caprock broken in places by erosion which carved out a typical mesa and butte topography, with flat tops and breakaways. Pediments are formed in front of breakaways and are often covered by a thin veneer of alluvial and colluvial sediments (Blair and McPherson, 2008).

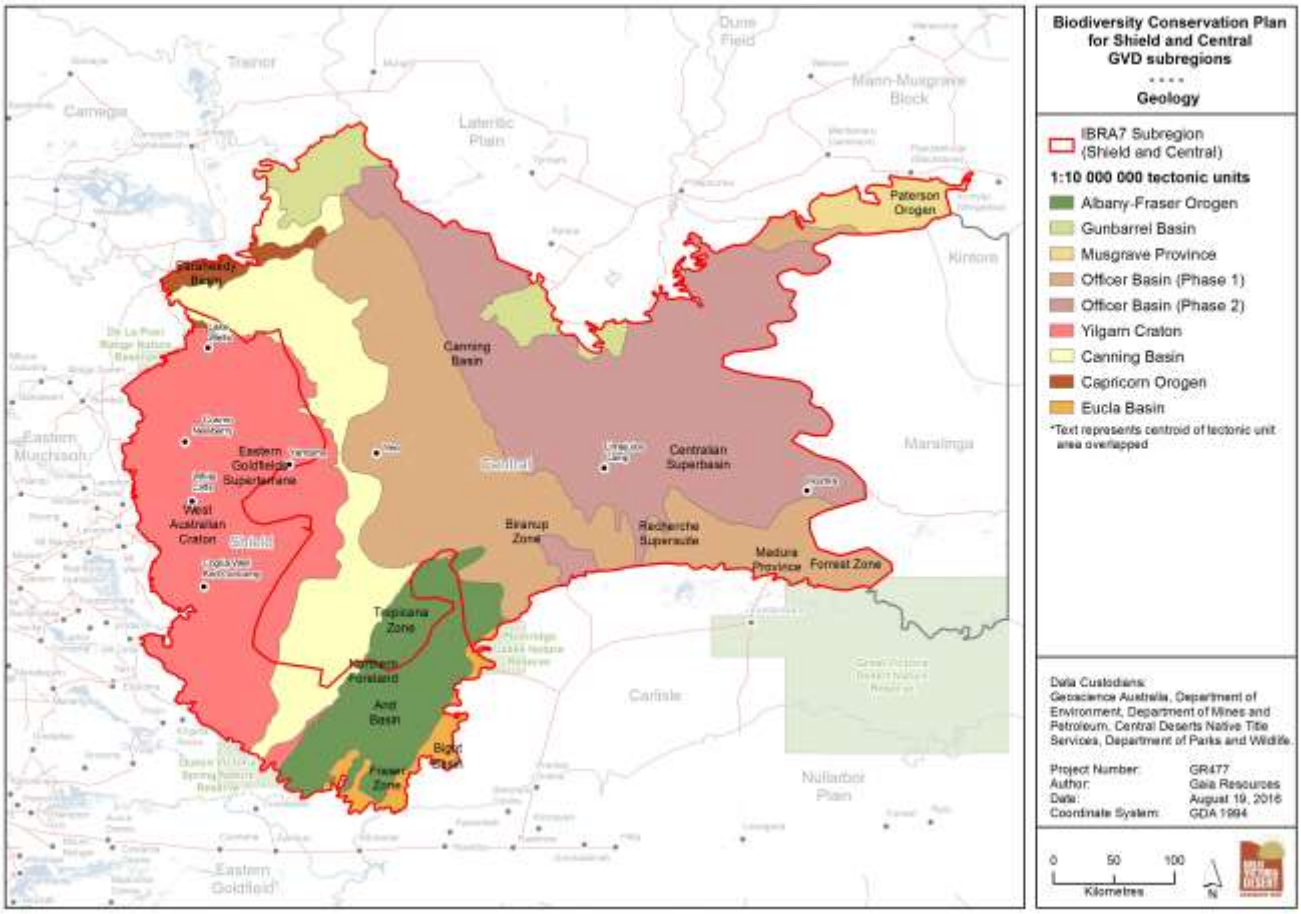


Figure 7 Geology of the SCS region

3.6. Water

3.6.1 Groundwater

There are several reports that describe the Officer Basin and its potential for groundwater, but detailed investigations have only been done in the vicinity of potential or current mine areas, including Lake Minigwal/Mulga Rock (Energy and Minerals Australia 1984, 1985 and 1986), Cyclone Zircon Project (Lost Sands) (Australian Groundwater Resources 2012 and MWH 2015) and Tropicana Gold Project (GHD 2008).

Pennington Scott (2009) investigated the cenozoic palaeochannels deposits infilling the Lake Rason drainage valley as possible water sources for the Tropicana Gold Mine and found they lacked aquifer storage and were mostly hypersaline with salinities up to 270,000 mg/L TDS. Water for theTropicana Gold Mine was found in the Minigwal Trough area of the Officer Basin, immediately to the south of Lake Rason which describes a 300km by 50km wide north-south sedimentary trough abutting the western margin of the Archean basement of the Fraser Range (Pennington Scott 2009).

Lau *et al* (1987) identified the Paterson Formation, an aquifer overlying the western part of the Officer Basin and indicated that the limited information available suggested a fairly flat water-table below the level of the Tertiary drainages and perhaps 100 m deep. The few bores that had been tested at that time showed salinities of 1000 to 3000 mg L^{-1}. MWH (2015) suggested salinities from the southern part of the Officer Basin of around 35,000 mg L^{-1}.

Town water supplies for the majority of Aboriginal communities in the GVD in Western Australia are extracted from low-yielding wells, from aquifers of limited extent. This includes weathered and fractured rock aquifers or dunefields where localised recharge creates discrete pockets of fresh water. Some groundwater within the Officer Basin is also extracted for stock and domestic purposes (Australian Groundwater Resources 2012).

3.6.2 Surface Water

No permanent creeks, lakes or rivers exist within the region due to the combination of topography and arid climate. Significant streamflow can occur but flow is generally only every few years after heavy rains. Additionally, flow may only occur for a short period and over small stream sections based on the location and intensity of rainfall events. Stream contribution (if any) to groundwater is poorly understood and likely to be very long (Watts and Berens 2011; Pennington Scott, 2009).

Several large salt lake systems lie within the palaeochannels described by Beard (2002), including the Serpentine, Wanna and Waigen Lakes systems, Lake Kodga, Baker Lake, the Throssell-Yeo Lakes system, Lake Rason and Lake Minigwal. Other lake systems are on the southern edge or just outside the GVD bioregion, and include the Plumridge, Jubilee, Carlisle, Shell and Forrest Lakes. See Figure 8 for map of surface water systems in the region.

In addition to the major salt lakes are many smaller soaks, usually clay lined depressions, that only hold water for limited periods after rains. One of these is Queen Victoria Spring, not actually a spring but a depression, which holds water draining from the surrounding sand dunes (Pearson 1998). Soaks, rockholes (kapi) and wells were the main water sources that allowed Aboriginal people to inhabit the GVD for many thousands of years and usually have highly significant cultural value as well as being physically essential to survival. Bayly (1999) has reviewed these and other sources, such as the use of mallee roots, used in Australian deserts generally to obtain water.

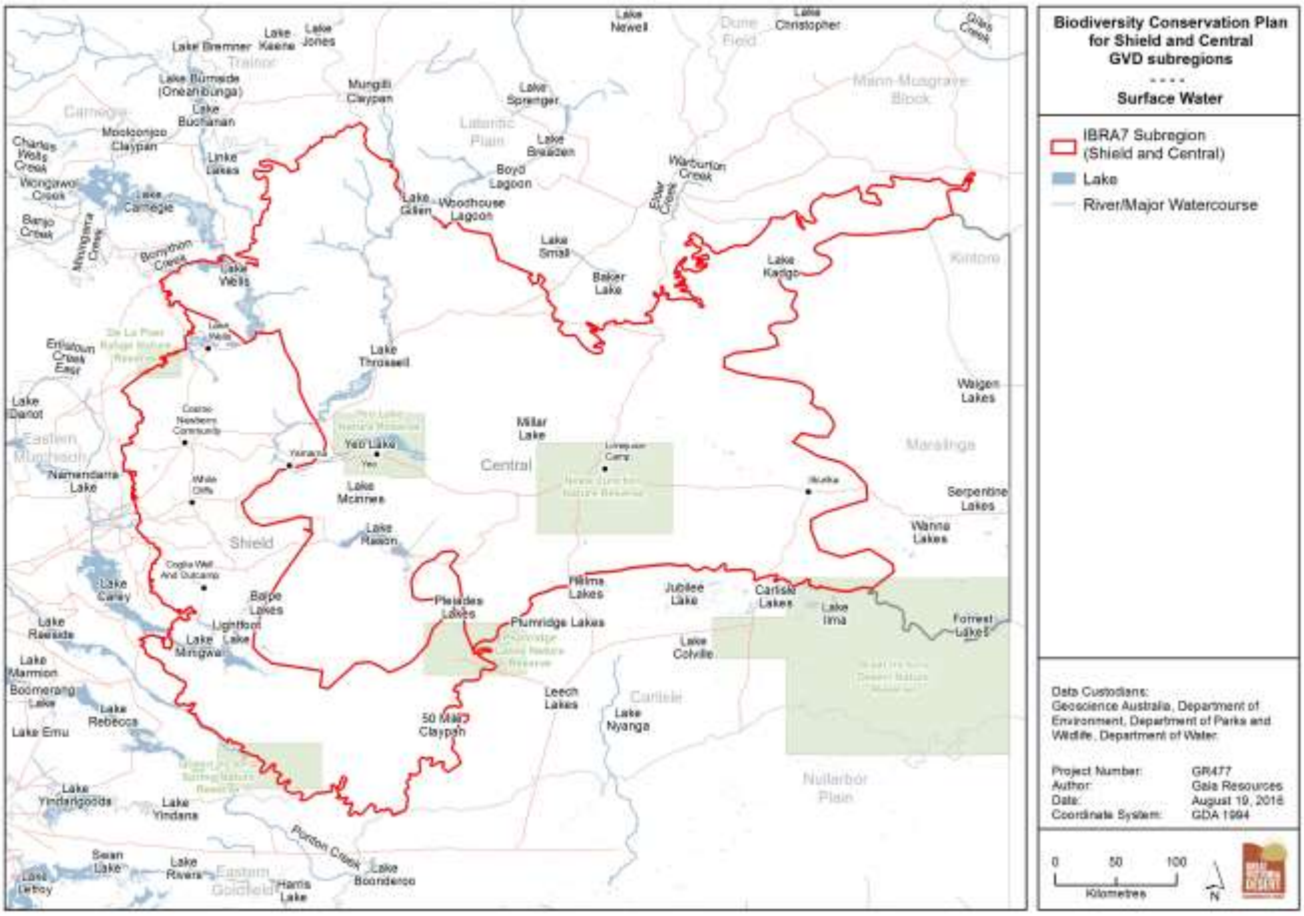


Figure 8 Surface water features of SCS region

3.6.3 Significant wetlands

Yeo Lake is the only lake that is listed in the Directory of Important wetlands in Australia (DIWA). A Resource Condition Report on Yeo Lake in 2009 (Department of Environment and Conservation 2009) described the inflow to Yeo Lake being derived from two creeks, which enter from the south, and direct precipitation. The western creek is a linear drainage approximately 20 km long and the eastern one is a forked drainage approximately 15 km long. Yeo Lake and nearby Lake Throssell were formerly part of a major river system (the Throssell Palaeoriver) which flowed south-east to the ocean, but are now ponding areas for the modern internal drainage (Jaensch 1992, in DEC 2009).

Yeo Lake is episodically inundated. Although the lake is usually dry, its sediments are saturated with salt water. Data on Yeo Lake's water regime are lacking, but it is expected the maximum water depth when inundated may be no more than 0.1 m (Jaensch 1992, in DEC 2009).

The objective of the Yeo Lake Resource Condition Report was to identify, describe and quantify the critical components and drivers of the wetland's natural environment that determine the site's ecological character and are the variables that should be addressed in any ongoing monitoring. The values of the wetland, including to the Yilka traditional owners, were identified and the threats to the site discussed.

Wetlands of subregional significance identified in the 2002 Biodiversity Audit of Western Australia's IBRA subregions include Lake Minigwal and Lake Rason. Both were considered at risk from feral herbivores and predators, and from mining including the disposal of hypersaline water from mining operations into Lake Minigwal. Ponton Creek is also included, although this lies mostly within the East Murchison and Eastern Goldfields IBRA subregions and within the Queen Victoria Spring Nature Reserve. Threatening processes for Ponton Creek were not identified (Barton and Cowan 2002a).

4. Biodiversity and key natural values

4.1. Biogeography

The GVD is one of the 89 Australian bioregions which are categorised as based on common climate, geology, landform, vegetation communities and species information. The GVD bioregion extends across Western Australia and South Australia and contains 6 sub-regions. Two of the sub-regions (Shield-GVD1, and Central-GVD2) are entirely within Western Australia, and two (Eastern Maralinga-GVD3, and Kintore-GVD4) extends across the WA-SA border (Figure 9). Two subregions are entirely within South Australia (GVD5-Tallaringa and GVD6-Yellabinna).The Western Australian extent of the GVD covers 19,729,736ha. See Figure 9 for IBRA sub-regions of Australia.

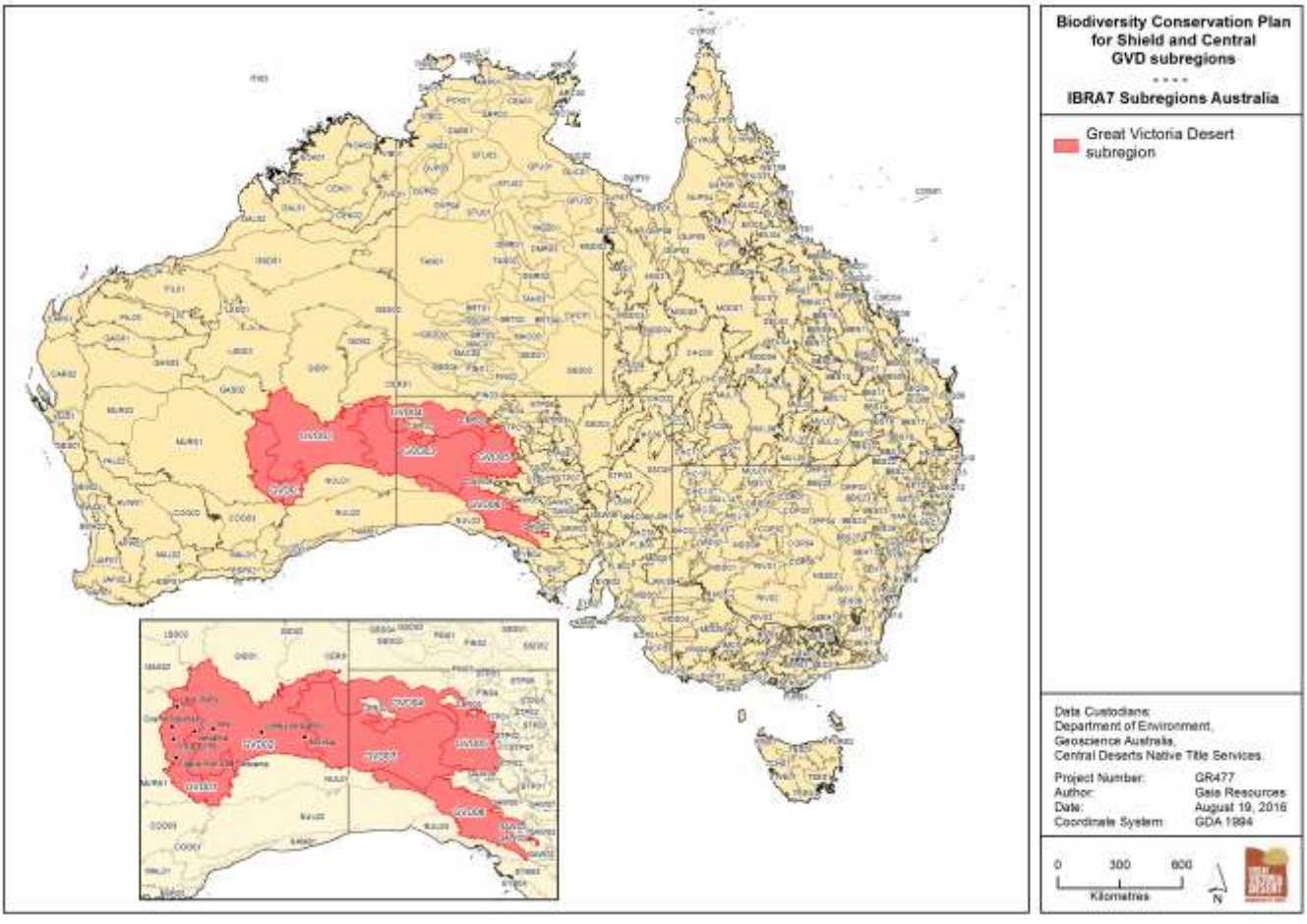


Figure 9 IBRA subregions with 6 GVD subregions highlighted

In Western Australia, the IBRA bioregions were largely based on Beard's phytogeographic or natural regions with some minor changes based on updated boundaries (Beard *et al* 2013). In 2002, the bioregions formed the basis for a systematic Biodiversity Audit for Western Australia (McKenzie *et al*., 2002) to identify priorities for conservation management, survey and future research across the State. More detailed subregional assessments were also prepared (Barton and Cowan 2002a, 2002b, 2002c); the brief descriptions of Shield-GVD1, and Central-GVD2 are given in Table 1.

Table 1: Summary descriptions of Shield-GVD1 and Central-GVD2 Subregions (from Barton and Cowan 2002a and 2002b)

Shield - GVD1	Central- GVD2
Description	
The western end of GVD1 is underlain by Yilgarn Craton. There is a higher proportion of sandplains in comparison to the entire bioregion. To the east is an arid active sand-ridge desert of deep Quaternary aeolian sands overlying Permian and Mesozoic strata of the Officer Basin. Landforms consist of salt lakes and major valley floors with lake derived dunes. Sand plains with patches of seif dunes running east west. Areas of moderate relief with out-cropping and silcrete-capped mesas and plateaus (breakaways). The subregion contains the major palaeochannels of Ponton Creek.	Arid active sand-ridge desert with extensive dune fields of deep Quaternary aeolian sands overlying Permian strata of the Gunbarrel Basin. Landforms consist of salt lakes and major valley floors with lake derived dunes. Sand plains with extensive seif dunes running east west, occasional outcropping (breakaways) and quartzite hills provide minor relief.
Vegetation	
Spinifex (*Triodia* spp.) and mallee (*Eucalypt*us *kingsmillii, E. youngiana*) over hummock grassland dominated by *T. basedowii* occur on the aeolian sand plain. Scattered marble gum (*E. gongylocarpa*) and native pine (*Callitris*) occur on the deeper sands of the sand plains. Mulga and acacia woodlands occur mainly on the colluvial and residual soils. Halophytes such as salt bush (*Atriplex*), Bluebush (*Maireana*), and samphire (*Tecticornia*) occur, margins of salt lakes and in saline drainage areas.	Vegetation is primarily a Tree steppe of *Eucalyptus gongylocarpa*, Mulga and *E. youngiana* over hummock grassland dominated by *Triodia basedowii* on the aeolian sands. *Acacia* dominates colluvial soils with *Eremophila* and *Santalum* spp., halophytes are confined to edges of salt lakes and saline drainage systems.
Climate	
Arid, with summer and winter rain approximately 190mm per annum.	Arid, with summer and winter rain averaging 150 – 180mm per annum.
Area	
4,741,826.82ha.	12,590,900.48ha

Differences across the two subregions are largely explained by climate and by underlying geology. The southern part of Shield sub-region abuts the Eastern Goldfields Subregion, which is botanically an interzone between the South West and Eremaean Botanical Provinces, so exhibits elements of both mesic and arid systems.

4.2. Vegetation

The SCS is situated in the Helms Botanical District with small amounts of the Eyre Botanical district in the south. Both these areas are in the Eremaean Botanical Province. The only regional scale mapping to have been completed for the GVD is Beard (1975) at 1:1,000,000 scale. This mapping was used in the compilation of a statewide dataset that has been revised and refined to be consistent with the National Vegetation Information System (NVIS) and is the basis of much of the conservation planning and assessment processes at state and regional scale (Shepherd *et al.* 2001; Beeston *et al.* 2002).

The state-wide dataset uses 817 Beard Vegetation Associations, 39 of which occur in the GVD. Of these all but one occurs within the SCS represented by 27 in the Shield and 33 in the Central subregion (Table 2 and Figure 10). According to vegetation statistics maintained by Parks and Wildlife (DPaW pers comm. 2015) the extent of native vegetation in the Shield and Central subregions has remained unchanged since European settlement.

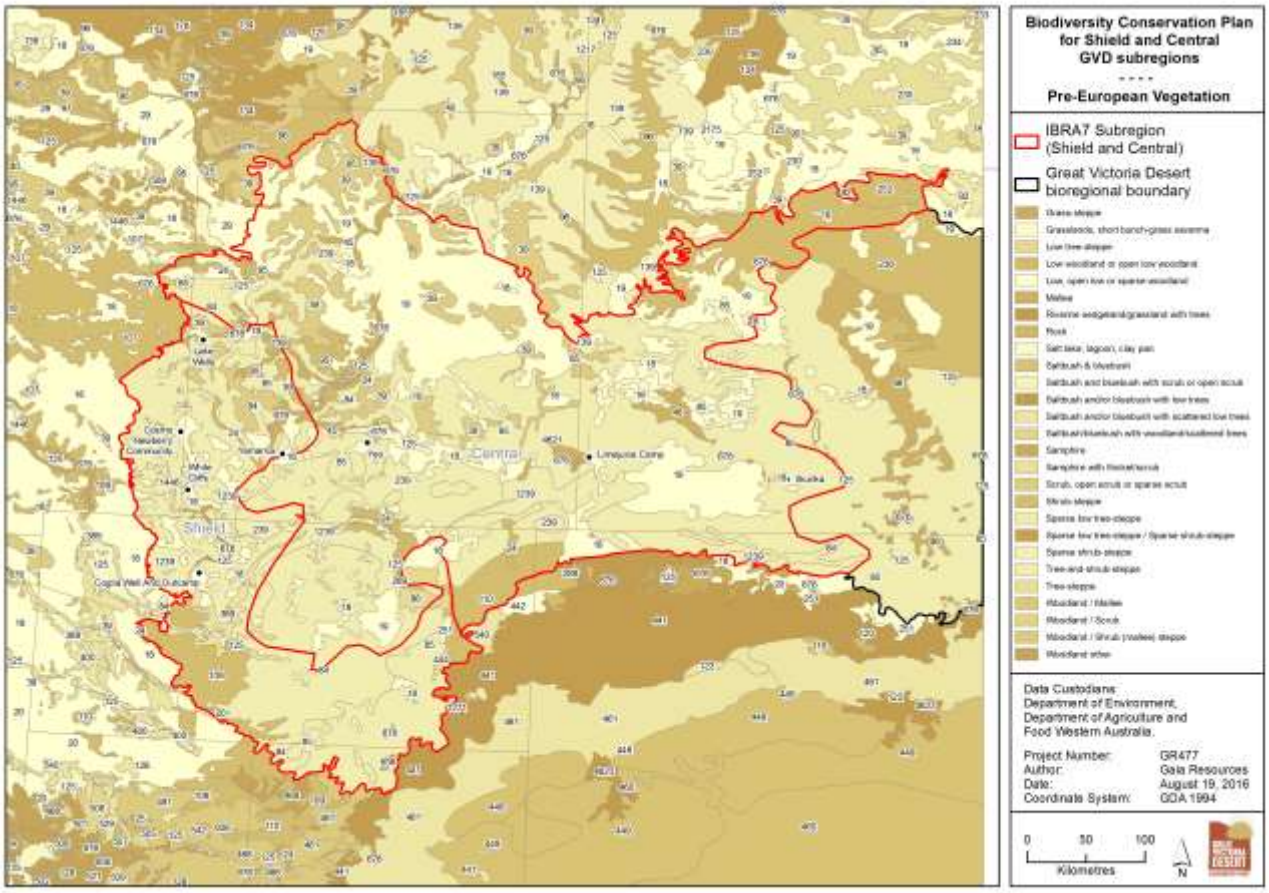


Figure 10 Beards pre-European vegetation map of the SCS region

Table 2: Beard Vegetation Associations occurrence within the GVD (From Parks and Wildlife (supplied 2015; area statistics from Gaia Resources, December 2015)

Beard Veg Assoc	Ecosystem Description	IUCN I-IV	Non IUCN Reserve	Priority	Area (sq km)	% of GVD	GVD Sub region
18	Low woodland; mulga (*Acacia aneura*)	X		L/M/L	19546	9	1/2/3
19	Low woodland; mulga between sandridges			L/H/L	28666	13	1/2/3
20	Low woodland; mulga mixed with *Allocasuarina cristata* & *Eucalyptus* sp (e6?)			L	56	<1	1
24	Low woodland; *Allocasuarina cristata*			L/H	2263	1	1/2
39	Shrublands; mulga scrub			L	11839	5	2
45	Shrublands; mallee scrub (Great Victoria Desert)	X		M/L/H	1703	<1	1/2/3
46	Shrublands; mallee scrub (e=?)			L-M/H	5782	3	2/3
84	Hummock grasslands, open low tree & mallee steppe; marble gum & mallee *(Eucalyptus youngiana*) over hard spinifex *Triodia basedowii* between sandhills	X		L/M/L	17815	8	1/2/3
85	Hummock grasslands, open low tree & mallee steppe; marble gum & mallee (*Eucalyptus youngiana*) over hard spinifex on sandplain	X		M/L/L	63517	29	1/2/3
86	Hummock grasslands, open low tree steppe; mulga, *Allocasuarina cristata* & hard spinifex between sand ridges	X		H/H	964	<1	1/2
92	Hummock grasslands, sparse tree steppe; bloodwood over hard spinifex *Triodia basedowii*			L/M	279	<1	2/3
95	Hummock grasslands, shrub steppe; acacia & grevillea over *Triodia basedowii*			L/L	1390	<1	1/2
96	Hummock grasslands, shrub steppe; acacia species (+grevillea) over *Triodia basedowii* often between sandridges			L	4	<1	2
107	Hummock grasslands, shrub steppe; mulga and *Eucalyptus kingsmillii* over hard spinifex			L/L	9	<1	1/2
109	Hummock grasslands, shrub steppe; *Eucalyptus youngiana* over hard spinifex	X		H/L	3741	2	1/2
110	Hummock grasslands, shrub steppe; red mallee over spinifex *Triodia scariosa*	X		L/M	3191	1	1/2
120	Succulent steppe with open low woodland; mulga & sheoak		X	L	8	<1	3
125	Bare areas; salt lakes	X		M/L/L	2251	1	1/2/3
128	Bare areas; rock outcrops			L/L/L			1/2/3
139	Hummock grasslands, patchy shrub steppe; mulga over hard spinifex on laterite			L	63	<1	2
236	Hummock grasslands, shrub steppe; mulga and mallee (marble gum)			H/H	16192	7	2/3

	over hard spinifex						
239	Hummock grasslands, open medium tree & mallee steppe; marble gum (*E. gonglocarpa* & mallee (*Eucalyptus youngiana*) over hard spinifex *Triodia basedowii* between sandhills	X		M/M/H	10364	5	1/2/3
251	Low woodland; mulga & *Allocasuarina cristata*			L	1490	<1	1
252	Hummock grasslands, shrub steppe; mulga and mallee over soft spinifex			H	1092	<1	2
289	Succulent steppe; saltbush & bluebush			L/H	382	<1	1/2
389	Succulent steppe with open low woodland; mulga over saltbush			H/L	1477	<1	1/2
441	Succulent steppe with open low woodland; mulga & sheoak over bluebush	X	X	L/L	15	<1	1/2
442	Low open woodland; mulga & *Allocasuarina cristata*	X		L	<1	<1	2
444	Hummock grasslands, open low tree steppe; mulga over *Triodia scariosa*			M	112	<1	1
467	Mosaic: Medium woodland; salmon gum & gimlet/Hummock grasslands, mallee steppe; red mallee over spinifex *Triodia scariosa*			L	10	<1	1
676	Succulent steppe; samphire	X		L/L/L	2066	1	1/2/3
936	Medium woodland; salmon gum			L	85	<1	
1239	Hummock grasslands, open medium tree & mallee steppe; marble gum & mallee (*E. youngiana*) over hard spinifex *Triodia basedowii* on sandplain	X		H/L	22337	10	1/2
1446	Succulent steppe with scrub; mulga over bluebush			M/L	130	<1	1/2
4621	Shrublands; mallee scrub, *Eucalyptus eudesmioides*	X		H/L	427	<1	1/2

Table 2 demonstrates the approximate area attributed to each of the major vegetation types and hummock grasslands with scrubs dominates, with low woodlands (mulga) also having a large representation. Ecologia Environmental (2008) provides a summary of the 11 vegetation communities in their study area, the south-west of the SCS, many of these are prevalent across the wider SCS region:

1) In the interdune swales and sand plains: mixed Eucalypt woodland (dominated by *Eucalypt trivalva, E. concinna, and E. youngiana)* with the groundcover dominated by open to moderately dense *Triodia basedowii.*

2) In the south west, in swales between dunes and lower dunal slopes: *Eucalyptus gongylocarpa* (marble gum) over *Triodia desertorum* or *T.basedowii.*

3) In longitudinal sand dunes: scattered : *Eucalyptus gongylocarpa* over mixed shrubs and *Triodia desertorum* or *T.basedowii.*

4) Undulating plains: Open mallee (*Eucalyptus concinna)* over scares to open low shrubs over open *Triodia scariosa.*

5) Clay Pan: Scattered *Acacia nyssophylla / Grevillea sarissa* over open herbs and grasses (*Zygophllum aurantiacum* and *Ennapogon caerulescen* are dominant).

6) Major saline clay pan complexes dominated by halophytic taxa from the *Chenopodiacae* family.

7) Clay loam Plains: *Acacia aneura* woodlands over soft grasses and *Triodia basedowii*

8) Rocky breakaways and associated slopes: Open *Acacia quadrimarginata/Dodonea rigida* over sparse mixed shrubs over mixed soft grasses (dominated by *Eragrostis pergracilis and Enteropogon ramosus).*

9) Open to moderately dense *Cauarina pauper* woodland over mixed shrubs and scattered soft grasses (dominated by *Enneapogon poluphyllus* and *Paspalidium basicladium)* and/or *Triodia scariosa.*

10) Scattered trees over open low shrubs and moderately dense tussock grasslands.

11) Narrow drainage channel: Sparse *Acacia aneura* over sparse to open shrubs and moderately dense tussock grasses.

Whilst no finer scale mapping and descriptions have occurred across the wider SCS region, location specific flora and vegetation survey have been undertaken at some sites (Table 3).

Table 3. Summary of vegetation surveys within the SCS

Locality	Reference	Area (ha)	Number of communities described/ mapped
Mulga Rock	Martinick and Assoc 1986		4 formations, 28 associations, 3 complexes
Queen Victoria Springs Nature Reserve	Pearson (1994)	272,607	9 general categories; 24 communities
Plumridge Lake NR	Law 2005		7 veg units
Tropicana Gold Project Access Road	ecologia Environment 2006	(140km length of track)	5 communities; 11 sub-communities (described, not mapped)
Tropicana Gold Project Operational Area	ecologia Environment 2009 and Tropicana Joint Venture 2009a	230,000	11 major communities, 18 sub-communities
Mulga Rock Project Area	Mattiske Consulting Pty Ltd 2013	20,813	22

With only a very small portion of the vegetation of the SCS intensively surveyed and mapped, it is difficult to define how isolated or widespread some of the vegetation communities identified during intense surveys are.

Pearson (1994) points out that fine scale mapping across a region as large as the SCS is unlikely to become affordable, so identifying priority areas for detailed mapping is necessary.

The vegetation patterns are largely defined by geology, soils, landscape position and climate, but strongly influenced by water availability and fire, so using these drivers to identify priority areas for more detailed vegetation surveys may be feasible.

In addition to the values inherent in the vegetation itself, its value in providing connectivity particularly for birds between woodland and semi-arid mallee areas of Western Australia and South Australia has been recognised by Ford and Sedgwick (1967) and Ford (1971).

The vegetation across the SCS is usually described as being largely in Excellent (near Pristine) to Very Good condition. Away from roads and tracks (such as the Anne Beadell Highway) where there is disturbance, it is likely to be due to grazing by camels and rabbits, especially to the southwest and along palaeochannels. Several of the vegetation and flora surveys commented on fire scars making vegetation descriptions and mapping difficult as successional stages could mask changes in vegetation structure and floristics.

4.3. Flora

There are currently over 1200 plant species recorded for the SCS region based on an interrogation of FloraBase (https://Florabase.dpaw.wa.gov.au/) and NatureMap, (https://NatureMap.dpaw.wa.gov.au/) (accessed 12/1/2016). Table 4 breaks down the species by ubregion.

Table 4: Numbers of plant species recorded and vouchered from the Western Australia GVD subregions

Subregion	Total number of taxa	Number of species based on WA Herbarium records	Number of vouchered taxa in WA Herbarium	Number of conservation significant taxa	Number of alien taxa
Shield	961	763	2,407	33	8
Central	822	649	1,747	30	3

Within the SCS there are 972 vouchered plant species, 51 of which are of conservation significance and a further nine which are alien. Within these two subregions there are also 19 taxa which appear to be endemic, 11 within the Shield subregion and nine within the Central subregion. Table 5 provides a breakdown of species based on their family.

Most of the flora surveys included in the reference collection used to prepare this document resulted in one or more records that either were was previously undescribed, previously unrecorded in the GVD, or represented range extensions.

Table 5: Number of species, by family group, by each region.

	Shield	Central
Bryopsid (Moss)	7	2
Dicotyledon	814	171
Fungus	11	5
Gymnosperm	4	4
Hepatic (Liverwort)	2	2
Lichen	22	12
Monocotyledon	129	94
Pteridophyte (Fern)	5	6
Slime Mould	1	0

It is interesting to note that Queen Victoria Spring Nature Reserve has recorded 562 taxa (https://NatureMap.dpaw.wa.gov.au/, accessed 12/1/2016). This reserve straddles three subregions (Shield, Eastern Murchison and Eastern Goldfields) and has a more complex geology and landforms than other parts of the SCS. The Eastern Goldfields subregion forms the Southwest Interzone where floras of the mesic southwest interchange with the arid and semi-arid flora of the Eremaean Province, so a high species richness here is to be expected. The Nature Reserve harbours genera common to the south west of Western Australia or eastern Australia, such as *Banksia, Phebalium*, and *Conospermum* (Pearson 1994) and gives rise to unusual communities including outlier populations of the Desert grass tree *Xanthorrhoea thorntonii* and the swordfish banksia *B. elderiana*. These species occur in groups on deep yellow sands and at widely scattered intervals from the tops of the dunes and through the inter-dune swales. *Banksia elderiana* occurs principally on yellow sandplains in the eastern wheatbelt and throughout the Great Western Woodlands however there is disjunct sparsely distributed populations in the western SCS centred on Queen Victoria Spring Nature Reserve a (Kealley 1993).

4.3.1. Conservation Significance Vegetation and Flora

There are no Threatened Ecological Communities (TEC) listed either under the *EPBC Act* or by the Western Australian Department of Parks and Wildlife that occur within the SCS.

In Western Australia Priority Ecological Communities (PEC) are ecological communities with insufficient information available to be considered a TEC, or which are rare but not currently threatened. There is one PEC within the SCS listed as P3iii:

"*Poorly understood ecologicial communities; with communities made up of large and/or widespread occurences, that may or may not be represented in the reserve system, but are under threat of modification across much of their range from process such as grazing by domestic and/or feral stock, and inappropriate fire regimes* "

This PEC is the 'Yellow sandplain vegetation of the Great Victoria Desert with diverse vertebrate fauna', described as:

*"*Undulating yellow sandplain with an open upper stratum of *Eucalyptus gongylocarpa*, with or without a diverse mallee stratum of *E. youngiana, E. mannensis, E. platycorys*, over a sparse, though diverse shrubs layer over hummock grasses of *Triodia desertorum* or *T. scariosa*. Very high vertebrate diversity and unusual combinations of species (mixture of south-western and arid inter zones)."

Threats to this PEC include mining and exploration, extensive summer wildfire and the impacts of feral predators on the faunal assemblage (http://www.dpaw.wa.gov.au/plants-and-animals/threatened-species-and-communities/wa-s-threatened-ecological-communities, Accessed 14/12/2015)

One other community within the SCS was included in the Biodiversity Audit (2002) as potentially an ecosystem at risk:

- Assemblages of Queen Victoria Spring

Two flora species are listed as Vulnerable under the *EPBC Act* 1999:

- Ponton Creek Mallee *(Eucalyptus articulata*); and
- Ooldea Guinea-flower (*Hibbertia crispula*)

Eucalyptus articulata is Declared Rare Flora (DRF – Endangered) under the Western Australia *Wildlife Conservation Act* 1950, and *Hibbertia crispula* is Priority 1 taxa.

Other priority flora recorded within the SCS are given in Table 6.

Table 6: Threatened and Priority flora known to occur in the SCS (http://www.dpaw.wa.gov.au/plants-and-animals/threatened-species-and-communities/threatened-plants?view=categories&id=108**)**

Taxon	Status	EPBC	Distribution	Shield or central
Acacia eremophila numerous-nerved variant (A.S. George 11924)	P3		Norseman, Neale Junction, Great Victoria Desert, Balladonia, Plumridge Lakes	1,2
Acacia eremophila var. *variabilis*	P3		Ardath, Comet Vale, Zanthus, Balladonia, Lake Moore	2
Acacia microneura	P1			1
Baeckea sp. Sandstone (C.A. Gardner s.n. 26 Oct. 1963)	P3		Wiluna, Sandstone, Agnew, Great Victoria Desert,	2
Bossiaea eremaea	P3		Merolia Stn, Sandstone, White Cliffs Stn	1
Caesia rigidifolia	P1		Queen Victoria Spring	1,2
Caesia talingka	P2		Plumridge Lakes N.R.	1,2
Calotis latiuscula	P3		Giles, Warburton, Blackstone Range, Rawlinson Range, Hamersley Range	1,2
Calytrix hislopii	P3		Black Range Stn., Lake Mason Stn., White Cliffs Stn.	1
Calytrix praecipua	P3		Melita Station, Laverton, Youno Downs, Wanjarri, Marymia, Erong Hmstd, Niagara Dam	1
Calytrix warburtonensis	P2		Neale Junction, Muggan Rockhole, Babbagoola Rockhole	1,2
Cassinia arcuata	P2		Cocarnarup, Ravensthorpe, Queen Victoria Spring, Lake Magenta	1
Comesperma viscidulum	P4		Queen Victoria Spring, Little Sandy Desert, Carnarvon Range, Great Victoria Desert	1,2

Conospermum toddii	P4			N of Queen Victoria Spring in Great Victoria Desert	1,2
Dampiera eriantha	P1			Great Victoria Desert	1,2
Dicrastylis cundeeleensis	P4			Cundeelee, Plumridge Lakes, Rawlinna	1,2
Eremophila arachnoides subsp. *tenera*	P1			Kambalda, Laverton	1
Eremophila aureivisca	P1			Rason Lake	2
Eremophila dendritica	P2			Rawlinna, Plumridge Lakes	1
Eremophila sp. Great Victoria Desert (R. Davis 10621)	P2			Plumridge Lakes N.R., Great Victoria Desert	1
Eremophila forrestii sub sp. Viridis	P3				1
Eremophila undulata	P2			Lake Gidgi, Neale Junction	1
Eucalyptus articulata	T	EN	VU	NW of Queen Victoria Spring	1
Eucalyptus nigrifunda	P4			Lake Barlee, Rason Lake, Newman Rock, Merolia Stn	1,2
Eucalyptus pimpiniana	P3			Lake Minigwal, Great Victoria Desert	1,2
Eucalyptus sparsa	P3			Rawlinson Range, Blackstone Range	2
Frankenia glomerata	P4			Waeel, Cunderdin, Lake King, Northam, Little Sandy Desert, Carnarvon Range, Norseman, Arrino, Kellerberrin, Three Springs, Yenyenning Lakes, Eneabba	1
Grevillea secunda	P4			Queen Victoria Springs	1,2
Gyrostemon thesiodes	P2				1
Hibbertia crispula	P1		VU	Great Victoria Desert, South Australia	1
Hibiscus krichauffianus	P3			Belele Stn., Coodardy Stn., Kanandah Stn., Eastern States	2
Isotropisaustraliensis	P3				1
Isotropis canescens	P2			Queen Victoria Spring	1
Labichea deserticola	P1			Great Victoria Desert	2
Labichea eremaea	P3			West of Sandstone, Bimbijy, Mt Jackson, Black Range Stn	1
Lechenaultia aphylla	P1			Cosmo Newbey - Laverton, SA	1
Lechenaultia divaricata	P1			Plumridge Lakes	1
Malleostemon sp. Officer Basin (D. Pearson 350)	P2			Officer Basin, Queen Victoria Spring	1,2
Melaleuca apostiba	P3			Carnegie Hstd - Giles, Lake Minigwal	1,2
Micromyrtus helmsii	P1			Near Mt Squires	2

Micromyrtus serrulata	P3	Karonie, Coonana, Melita, Jeedamya, Niagara Dam NR, Cardunia Rocks, Queen Victoria Spring NR	1
Neurachne lanigera	P1	Wiluna, Warburton	1
Olearia arida	P4	Neale Junction, Plumridge Lakes, Great Victoria Desert	1,2
Philotheca linearis	P1	White Cliffs Stn, Central Australia	1
Philotheca tubiflora	P1	E of Laverton	1
Phyllanthus baeckeoides	P3	Laverton, Merolia Stn, White Cliffs Stn, Windimurra Station, Cashmere Downs Stn, Leinster, Banjawarn Stn	1
Physopsis chrysotricha	P2	Victoria Desert Camp 54, Queen Victoria Spring	1
Ptilotus blackii	P3	Plumridge Lakes N.R., Zanthus, Queen Victoria Springs N.R., S.A. N.T.	1,2
Stackhousia clementii	P3	Warburton, Wiluna, Karratha, Little Sandy Desert, NT, SA, Gnaraloo Stn, Burrup Peninsula	2
Styphelia sp. Great Victoria Desert (N. Murdock 44)	P2	Great Victoria Desert, Cundeelee, Queen Victoria Spring N.R.	1
Thryptomene eremaea	P2	Menzies, Queen Victoria Spring, Comet Vale, Edjudina Station, Kirgella Rocks	1
Thryptomene nealensis	P3	Leinster, White Cliffs Stn, Neale Junction, Gt Victoria Desert	1,2
Triodia bromoides	P4		1
Trachymene pyrophila	P2	Cundeelee Mission, Queen Victoria Springs, Zanthus	1
Verticordia jamiesonii	P3	Mt Hale, Yalgoo, Cue, Sth Warburton, Waterfall Gorge, Rowe Hills	2
Verticordia mirabilis	P1	Sth Warburton	2
Vittadinia pustulata	P3	Plumridge Lakes N.R., Morgan Range	1,2

The relatively large number of Priority species recorded within the SCS may be a consequence of the paucity of botanical survey work conducted in the area and the extremely low specimen vouchering rate as a results of survey(ecologia Environment 2005).

The paucity of alien plant species within the SCS reflects limited sampling and vouchering in the region along with the low incidence of pastoralism and vehicular movement and the isolation of the area. With an increase of mining exploration and tourist access, the potential for introduction of alien species is likely to increase. Alien species (weeds) are discussed IN more detail in Section 9.3.

4.4. Fauna

Similarly to the flora, the fauna over much of the SCS reflects the semi-arid environment, but with an intermingling toward the southwest of species more common in mesic environments of the South West Interzone. There have been few systematic fauna surveys conducted across the SCS.

Figure 11 shows a concentration of threatened fauna records from roadsides and the nature reserves, particularly Queen Victoria Springs Reserve. There is also a concentration of records around the TGM and other mining / exploration related locations.

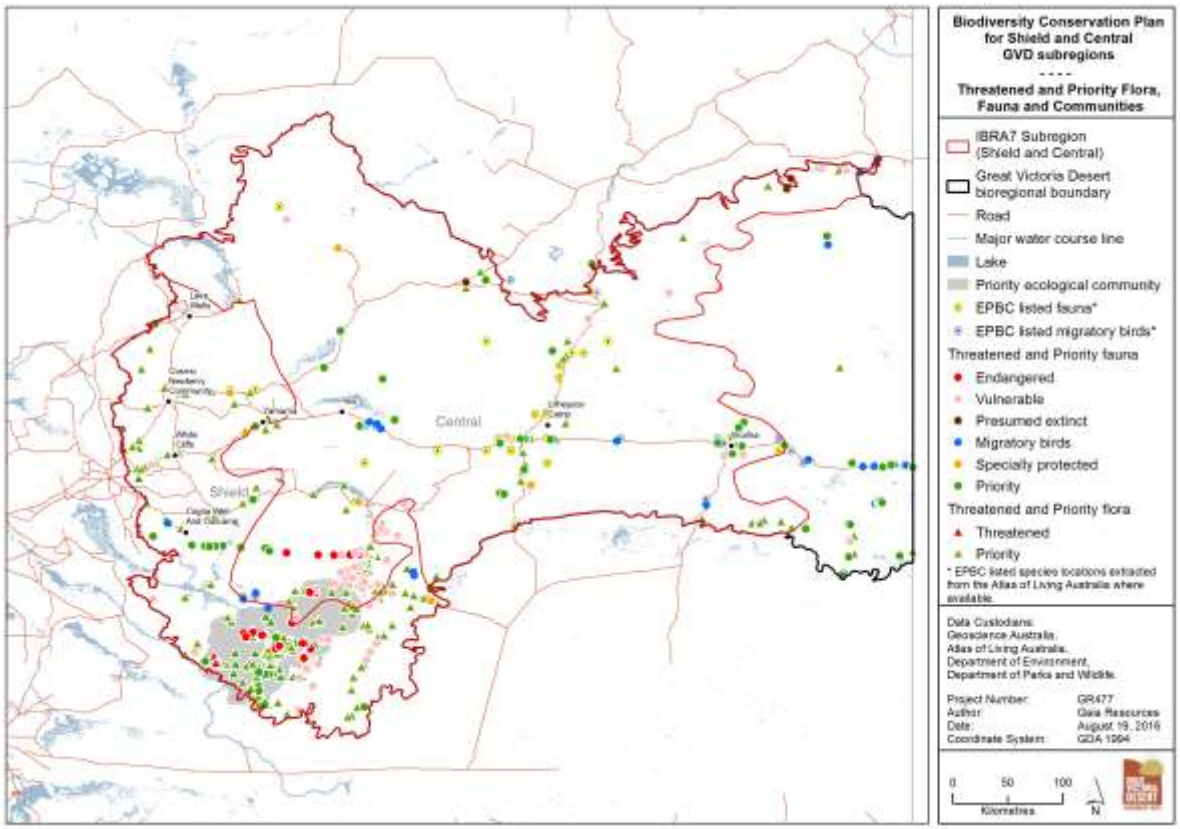


Figure 11 Fauna of conservation significance

Fire, rainfall and their interactions have significant impacts on many of the fauna groups (eg Langlands *et al.* 2006 for spiders; Pianka and Goodyear 2012 for lizards; Gosper 2011 for birds; McKenzie and Burbidge 1979 for mammals, especially rodents; Gaikhorst and Lambert 2008a for Sandhill Dunnarts), and being able to respond rapidly to favourable conditions or to exploit refugia are some of the adaptations that allow a diverse fauna to persist.

There has however been a serious loss of species, particularly mammals, from Central Australia and a high proportion of remaining species are threatened or vulnerable. Altered

fire regimes, the effects of introduced carnivores are frequently cited as the most likely causes for this decline along with competition from feral herbivores and climate change.

4.4.1. Mammals

Mammals in the SCS, as with any arid or semi-arid environment, must be adapted to cope with heat, limited water and periods of limited food availability. A total 35 native mammals species are known to inhabit the SCS (see Table 7) plus eight introduced species. Table 8 provides a summary of the numbers in the Shield and Central regions. In addition, 20 species believed to be now regionally extinct (Burbidge et al. 2009)(Table 9). Processes that may be causing or contributing to this loss will be discussed in Section 10.

Table 7: Numbers of extant mammal species recorded from the Western Australia GVD subregions. (https://NatureMap.dpaw.wa.gov.au/, accessed 12/1/2016)

Subregion	Total number of extant mammals species	Number of conservation significant species	Number of introduced species
Shield	41	3	7
Central	45	7	7

Table 8: Extant native mammals of the SCS. (https://NatureMap.dpaw.wa.gov.au/, accessed 12/1/2016)

Species	Common name	SCS subregion
Cercartetus concinnus	Western pygmy possum	1
Chalinolobus gouldii	Gould's wattled bat	1,2
Chalinolobus morio	Chocolate wattle bat	2
Dasycercus blythi	Brush-tailed mulgara, Ampurta	1,2
Dasycercus cristicauda	Crest-tailed mulgara	2
Macropus fuliginosus	Western grey kangaroo	1,2
Macropus robustus	Euro	1,2
Macropus rufus	Red kangaroo, Marloo	1,2
Mormopterus planiceps	Inland free-tailed bat	1
Ningaui ridei	Wongai ningaui	1,2
Ningaui yvonnae	Southern ningaui	1,2
Notomys alexis	Spinifex hopping mouse, Tarrkawarra	1,2
Notomys mitchellii	Mitchell's hopping mouse, Pankot	1
Notoryctes typhlops	Southern marsupial mole, Itjaritjari	1,2
Nyctophilus geoffroyi	Lesser long-eared bat	1,2
Pseudantechinus macdonnellensis	Fat-tailed pseudantechinus	1,2
Pseudantechinus roryi	Rory's pseudantechinus	2
Pseudantechinus woolleyae	Woolley's pseudantechinus	1,2
Pseudomys desertor	Desert mouse, Wildjin	1,2
Pseudomys hermannsburgensis	Sandy inland mouse, Mingkin	1,2
Rattus fuscipes	Southern bush rat, Mootit	1
Scotorepens balstoni	Inland broad-nosed bat	1,2
Sminthopsis crassicaudata	Fat-tailed dunnart	1,2
Sminthopsis dolichura	Little long-tailed dunnart	1,2
Sminthopsis hirtipes	Hairy-footed dunnart	1,2
Sminthopsis longicaudata	Long-tailed dunnart	2
Sminthopsis macroura	Stripe-faced dunnart	1,2
Sminthopsis ooldea	Ooldea dunnart	1,2

Sminthopsis psammophila	Sandhill dunnart	1,2
Sminthopsis youngsonii	Lesser hairy-footed dunnart	2
Tachyglossus aculeatus	Echidna	1,2
Tadarida australis	White-striped Free-tailed bat	1,2
Taphozous hilli	Hill's sheathtail bat	2
Vespadelus finlaysoni,	Finlayson's cave bat	1,2
Vespadelus regulus	Southern forest bat	1

The majority of mammals in the region are small marsupials within the critical weight range (CWR: 35–5500g). Some research suggests that the smallest species are the least extinction-prone (Cardillo and Bromham, 2001). Smaller species have lower energy requirements which would allow a greater population density in a particular area. Smaller species often have higher reproductive potential which may benefit survival following disturbance (Cardillo and Bromham, 2001).

The distribution of mammals is highly influence by habitat variables especially post-fire vegetation succession and rainfall events (Letnic *et al*, 2004). Significant rainfall events can cause dramatic increases in populations though the time delay between this increase varies between species (Dickman *et al,*1999). Dickman et al (1999) particularly note that the domestic mouse numbers increased within two months of a significant rainfall event whereas species such as *Notomys alexis*, *Pseudomys hermannsburgensis* and *P. deserto* numbers increased after about 10 months after the rainfall event.

More than one third of the mammal species of the Central Australian deserts have vanished within the past 70 years (Burbidge *et al*, 2009). Aboriginal people who lived traditional lifestyles in the desert regions still have knowledge of some of these species and, as Burbidge *et al* discovered, were able to shed light on geographical ranges and habitat types for some of them, and also to help define more accurately when the extinctions took place. Chapman *et al.* (1995) recorded the names that Spinifex people have for 65 plants and 42 animals that occur in the southern SCS. More recently, Brennan *et al.* (2009) found that older Spinifex People can recall eating *Wayurta* (Brushtail Possums) when living traditionally in the bush, but they have not been seen in recent decades. This further emphasises the value and the urgency of employing effective cross-cultural methods for combining indigenous traditional ecological knowledge (TEK) with western science to manage land and its biodiversity values.

Table 9: List of the 20 extinct mammals previously recorded from the SCS (extracted from Burbidge et al. 2009).

Species	Common name
Bettongia lesueur	Boodie
Bettongia penicillata	Woylie
Dasyurus geoffroii	Chuditch
Isoodon auratu	Golden bandicoot, Wintaroo
Lagorchestes hirsutus	Rufous hare-wallaby
Leporillus apicalis	Lesser stick-nest rat, Djooyalpi
Leporillus conditor	Greater stick-nest rat, Wopilkara
Macroderma gigas	Ghost bat
Macrotis lagotis	Bilby, Ninu
Macrotis leucura	Lesser bilby, Djoonpi
Myrmecobius fasciatus	Numbat
Notomys amplus	Short-tailed hopping-mouse, Yoontoo

Notomys fuscus	Dusky hopping-mouse, Wilkinti
Notomys longicaudatus	Long-tailed hopping-mouse, Koolawa
Onychogalea lunata	Crescent nailtail wallaby, Djawalpa
Perameles eremiana	Desert bandicoot, Walilya
Petrogale lateralis	Black-footed rock-wallaby, Warru
Phascogale calura	Red-tailed phascogale
Pseudomys fieldi	Shark Bay mouse, Djoongari,
Trichosurus vulpecula	Brushtail possum, Wayurta

The feral animals in the region (as listed by DPaW NatureMap) are:

- *Camelus dromedarius* (Dromedary, Camel)
- *Canis lupus subsp. dingo* (Dingo)[2]
- *Equus asinus* (Donkey)
- *Equus caballus* (Horse)
- *Felis catus* (Cat)
- Mus musculus House Mouse
- Oryctolagus cuniculus Rabbit
- Vulpes vulpes Red Fox

4.4.1.1 Mammals of conservation significance

In the SCS region there are seven species of conservation significance (including the Chuditch which is presumed to be regionally extinct) (see Table 10).

Table 10: Mammals of conservation significance known to be present in SCS.

	Species	Common name	Conservation status EPBC	WA	IUCN
1	*Dasycercus blythi*	Brush-tailed mulgara, Ampurta	-	Priority 4	
2	*Dasycercus cristicauda*	Crest-tailed mulgara	Vulnerable	Threatened	
3	*Dasyurus geoffroii*	Chuditch, Western Quoll	Vulnerable	Threatened	Near threatened
4	*Macrotis lagotis*	Bilby, Dalgyte		Threatened	
5	*Notoryctes typhlops*	Southern marsupial mole, Itjaritjari	-	Priority 4 (threatened)	
6	*Sminthopsis longicaudata*	Long-tailed dunnart	-	Priority 4	LC
7	*Sminthopsis psammophila*	Sandhill dunnart	Endangered	Endangered (Threatened)	

1. Brush-tailed mulgara (Murrtja)

[2] The status of the dingo as a native or non-native species is debatable. Under Western Australia the dingo is not considered to be native fauna, hence it is listed under the feral under section.

Mulgaras are small carnivorous marsupials with short round ears, sandy coloured hair on their backs, light grey hair on their underside and a short tapering tail with a reddish tinge near the body and black. The brush-tailed Mulgara tails taper to a round sharp point (AWC website, accessed March 2016). Males are larger than females, reaching 22cm (head to body) and weighing up to 190grams. Females are about three-quarters of this size. The Brush-tailed mulgara is also a Priority 4 species in Western Australia but is not listed by the Commonwealth.

2. Crest-tailed mulgara

The Crest-tailed mulgara is listed as Vulnerable under the *EPBC Act* while it is afforded a Priority 4 status under Western Australian legislation. The crest-tailed mulgara is differentiated from the brush-tailed mulgara by the dorsal, fin-like crest of hair on distal half of the tail.

A comprehensive review of the distribution of the mulgara in 2013 by Woolley *et al*. founded on museum records concluded that the Crest-tailed mulgara was now extinct in Western Australia having not been cited (or collected) for over 50 years. The review by Woolley *et al.* (2013) confirmed the persistence of the Brush-tailed mulgara in the SCS.

Surveys specifically targeting mulgara were undertaken at the sites of the Tropicana Gold, and Mulga Rock projects. One Mulgara (species not identified) was reported to be caught at the Mulga Rock site in 1985 (Ninox Wildlife Consulting 2010). A survey of the southern end of Plumridge Lakes Nature Reserve for mulgara and other fauna by ecologia Environmental (2005) found suitable habitat but no evidence of the species. Potential mulgara habitat was identified in the Tropicana Operational area, but no mulgara were sighted and no potential burrows identified.

Both species have been identified in Queen Victoria Spring Nature Reserve and the Brush-tailed mulgara has been recorded at Neale Junction Nature Reserve (Brennan *et al.* 2009). Habitats known to support mulgara generally have a spinifex cover of between 10 to 60% with a preference for species such as *T. basedowii,* which forms neat hummocks which enable mulgara to move freely around (ecologia Environmental 1997). In their report ecologia Environmental state:

> "Baker (1993) recorded mulgara in habitats ranging from "*T. pungens* dominated sandy rises, through to laterite slopes supporting *T. basedowii* steppe amidst open mulga woodlands with no understorey." In all areas, however, the following five attributes are required for an area to be suitable for mulgara:
>
> 1. Heavier sandy soils, i.e. clayey sand and sandy loam soils;
> 2. Preference for *T. basedowii* where present;
> 3. Spinifex hummocks that are compact with clear open ground between hummocks;
> 4. Presence of shrub or tree layer (suggesting ground water influence); and
> 5. Mature but not senescent spinifex dependent on appropriate fire regimes (Baker 1993)"

According to ecologia Environmental (1997), mulgara populations are thought to be transitory, possibly due to populations occurring in marginal or fragmented habitat or because climatic or vegetation differences encourage a boom and bust cycle (ecologia Environmental, 1997 and 2005). Consequently, failure to find evidence of mulgara during a

survey cannot be taken as conclusive evidence that the species is not present. Fire succession stage will also affect the suitability of habitat for mulgara at any particular time as will the abundance of feral predators.

3. *Chuditch*

The Chuditch is Western Australia's largest endemic carnivore: at maturity it is the size of a small domestic cat. It is reddish-brown to grey in colour with distinctive white spots and a long tail with a black brush on the distal half (Van Dyck & Strahan 2008). Females are smaller than males, weighing 900 g on average compared to 1300 g for males (Orell & Morris 1994).

Nature Map shows one record, dated 1962, of the Chuditch in the Central region of the GVD (NatureMap accessed February 2016). Since this time, work by Burbidge and Fuller (1988) suggest that the Chuditch along with several other immediate sized mammals are now extinct from the Warburton region. Burbidge and Fuller (1988) describe discussions with different groups of Traditional Owners, all of whom agreed that the species was no longer present in their region.

4. Bilby (Ninu)

The Greater Bilby is widely considered to be regionally extinct in the SCS and entire GVD although it was once abundant (Copely 2015). Brennan *et al.* (2012) mention that Elders of the Spinifex People who took part in a cross-cultural survey near Ilkurlka believe that *Ninu* (Spinifex people's name for the Greater Bilby) may still occur near Laverton however no evidence of the species was detected in the survey.

5. Southern Marsupial Mole (Itjaritjari)

Until November 2015, the Itjaritjari was considered to be Endangered under Western Australia legislation but has now been re-categorised as a Priority 4[3] species. In December 2015, it was de-listed from the EPBC Act and is no longer considered to be Endangered.

The Itjaritjari is a blind marsupial mole that lives its life underground and "swims" through the soil, refilling the tunnels it creates by means of powerful spade-like claws on their front limbs. They inhabit sand dunes and adjacent swales where there is suitable deep, loose sand and only very occasionally come to the surface, where they remain for only a short time. This may make them less prone to predation, although their remains have been found in fox, cat and dog scats (Brennan *et al* 2009). Itjaritjari are most likely to come to the surface after rain and in cool conditions.

When an Itjaritjari has passed through a soil profile, an oval shaped differentiation in soil texture and colour can be seen and this provides a way of detecting their presence. However, it can be difficult to distinguish a fresh trail from an old one. Where Itjaritjari occur,

[3] i.e **Rare, Near Threatened and other species in need of monitoring:** (a) Rare. Species that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection, but could be if present circumstances change. These species are usually represented on conservation lands. (b) Near Threatened. Species that are considered to have been adequately surveyed and that are close to qualifying for Vulnerable, but are not listed as Conservation Dependent. (c) Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy

their underground backfilled tunnels are often very common and these may represent an important source of soil disturbance (biopedturbation) (Whitford and Kay, 1999, reported in http://www.environment.gov.au/biodiversity/threatened/species/pubs/296-listing-advice-2015123.pdf).

The fauna surveys that have been conducted as part of conservation reserve assessments or environmental impact assessment studies for mining operations have shown that the Itjaritjari is more widespread than was formerly believed, but the nature and severity of the threats to it are still unclear, and the current trench method of surveying for their presence is not suitable for estimating numbers or density of animals.

6. Long tailed dunnart

The long-tailed dunnart is a small carnivorous marsupial with a body mass of 15-20 g. It is immediately identifiable by its long tail that is twice the length of the head-body. The tail ends in a tuft of long hairs. The upper body is grey and the ventral surface is pale cream to white. The legs and feet are white and the feet have striated pads (ALA website, accessed March 2016). NatureMap (accessed March 2016) has two records dated 2010 of the long tailed dunnart being captured in the Central region of the GVD. The long tailed dunnart is described as a rare species, that is patchily distributed, but at times it can be locally common (Burbidge *et al.* 2008).

7. Sandhill Dunnart

The Sandhill Dunnart is a carnivorous/insectivorous mammal and the largest of the five dunnart species that occur in the SCS. It was first discovered in the Northern Territory in 1894, and was then not seen again until five specimens were captured in 1969 in land-clearing operations on the Eyre Peninsula in South Australia. Another five specimens were captured in 1985 near Mulga Rock in SCS, and in the next two years, four more specimens were caught in Queen Victoria Spring Nature Reserve. In the same year, five animals were caught at three locations in South Australia (Churchill 2001a).

Hart & Kitchener (1986) described the habitat where the first five specimens were caught in Western Australia as a mosaic of woodland of *E. gongylocarpa* and mallee, over spinifex *(T. basedowii)* and some shrubs. The soils were deep sand (mostly yellow but with some red) and small areas of heavier earths. The landscape was flat to gently undulating with some sand ridges, that were generally low but with occasional large, well-defined sand dunes. The area had not been burnt for at least 8 years and there had been at least one major rainfall event in each of the preceding three summers. The spinifex was in small hummocks averaging about 30cm in height.

The specific habitat requirements for Sandhill Dunnarts in Western Australia was described by Gaikhorst and Lambert (2008b) as:

- Deep yellow sands (occasionally orange) ranging from very gently undulating sand plains to well defined dunes up to 30m in height. The species can also be found in swale areas associated with dunes.
- Preferred vegetation structure consists of tall mallee (10-30% cover), mixed shrubland (10-30% cover), and/or a combination of mallee, marble gum, *Callitris* and shrubland.

- Presence of dense, compact hummocks of spinifex (at least 10-30% cover) which have been unburnt for between approximately 10 and 30 years with spinifex life stages of 2 to 3.5. (Based on a 5 stage lifeform key developed by the Department for Environment and Heritage, South Australia).
- Optimum spinifex size at life stage 3 is 70-100cm in diameter, and about 40cm tall.

Fire is needed to ensure rejuvenation of spinifex hummocks, but large fires leave insufficient hummocks for the animals to be able to survive and recolonise. Gaikhorst and Lambert (2008a) also found that trapping returns were always quite low, but particularly so after dry years, and that capture success may take several years to recover after a fire. Whilst time since fire is thought to have a major effect on size of spinifex, the amount of rainfall and soil moisture of an area receives also effects the size.

A Threatened Species Recovery Plan has been developed and is being implemented (Churchill 2001b). A review of this Recovery Plan has been undertaken by the Sandhill Dunnart Recovery Team and is soon to be finalised. The main actions proposed for the SCS population are further survey, study of reproductive behaviour in captivity (undertaken at Perth Zoo), and monitoring of the known populations. The Trust has also produced a draft 'Research and Adaptive Management Plan for the Sandhill Dunnart', further details are provided in Section 10.6.

4.4.2. Birds

Bird species richness is not as high in the GVD as in many other bioregions (GHD 2008). Most of the species that occur are widespread across the region and highly mobile in response to productivity pulses in activity and vegetation growth associated with heavy rainfall. Ford and Sedgewick (1967) and Ford (1971) refer to the broad east-west orientated habitat zones of the Nullarbor and GVD, including, from south to north, open plain shrub steppe, low layered myall woodland, low layered mallee, desert dune complex, breakaway and mulga country, desert complex, and mulga scrub. Many bird species have an east-west strip distribution correlated with these habitats which connect woodland and semi-arid mallee areas of Western Australia and South Australia.

Relative richness of bird species was compared for different habitat types in the Cyclone Sands project area (Outback Ecology 2014) and may be applicable to the SCS though slightly east of the region. The greatest richness was observed at the Claypan habitat type and this was attributed to the habitat provided by the fringing trees, the water and food resources provided by the claypans. Sheoak woodland and Mulga/mallee woodland habitats had the next highest relative species richness, due to their representing excellent habitat for woodland birds and generally being in good condition. The Dunefield and Mallee over spinifex habitat types had the lowest avifauna species richness, presumably due to the presence of fewer tall trees and less dense vegetation than other habitat types. Homogeneity of the Mallee over spinifex habitat is thought to make this habitat less suitable for birds compared to other habitat types with more diverse microhabitats.

As for other fauna types, there have been few systematic surveys and most information comes from environmental impact assessment studies or the few surveys within the nature reserves. Several of those studies comment on the low numbers of birds and species, and most often attribute this to dry conditions in the study area and/or wetter conditions elsewhere in the desert (e.g. Gosper 2011, Eastwood 2004).

Using the Parks and Wildlife NatureMap portal to interrogate bird records for the GVD (https://NatureMap.dpaw.wa.gov.au/, accessed 12/1/2016) it is estimated there are 186 species of birds in the SCS region with no non-native species recorded (Table 11). Only one species the Night parrot (*Pezoporus occidentalis)* is presumed to be locally extinct in the SCS.

Table 11: Numbers of bird species recorded from the SCS. (https://NatureMap.dpaw.wa.gov.au/, accessed 12/1/2016)

Subregion	Total number of bird species recorded	Number of conservation significant species
Shield	116	5
Central	171	9

4.4.2.1 Birds of conservation significance

Nine species of bird within the SCS are of conservation significant (Table 12)

Table 12: Birds of conservation significance known to be present in SCS.

Species	Common name	Conservation status		
		EPBC	WA	IUCN
Amytornis striatus subsp. *striatus*	Striated Grasswren (inland)	-	Priority 4	-
Amytornis textilis subsp. *textilis*	Thick-billed Grasswren (western)	-	Priority 4	-
Ardeotis australis	Australian Bustard	-	Priority 4	LC
Cacatua leadbeateri	Major Mitchell's Cockatoo	-	Specially protected	LC
Falco hypoleucos	Grey Falcon		Threatened	VU
Falco peregrinus	Peregrine Falcon	-	Specially protected	LC
Leipoa ocellata	Malleefowl	Vulnerable	Threatened	VU
Merops ornatus	Rainbow Bee-eater	Migratory	Protected under international agreement	LC
Pezoporus occidentalis	Night Parrot	Endangered	Presumed locally extinct	EN
Polytelis alexandrae	Princess Parrot	Vulnerable	Priority 4	

Striated Grasswren (inland)

The Striated Grasswren (inland) is found in central and northern Western Australia as well as all other states (except Tasmania). This subspecies of Striated Grasswren inhabits spinifex on sandhills and rocky hillslopes and may occur in the survey area. The species' presence is strongly correlated with vegetation communities that support hummock grassland (Triodia sp.).

Thick-billed Grasswren (western)

The Thick-billed Grasswren was found in areas of 'thick bush' or 'thickets', dense Saltbush, in 'marlock' or low Mallee scrub and in 'large clumps of bushes which had extremely dense masses of foliage.

Australian Bustard

Australian Bustards are found in tussock grassland, Triodia hummock grassland, grassy woodland, low shrublands. They will also use denser vegetation when recent burning has temporarily opened up these areas.

Major Mitchell's Cockatoo

Inhabits a wide variety of semi-arid and arid inland habitats, provided there is fresh surface water and large hollow trees for nesting. It has been recorded in forest, woodland and shrubland, including Mulga, Mallee, Acacia, and Callitris associations.

Grey Falcon

Usually restricted to shrubland, grassland and wooded watercourses of arid and semi-arid regions, although it is occasionally found in open woodlands near the coast. They also occur near wetlands where the surface water attracts the prey.

Peregrine Falcon

The species prefers habitat with rocky ledges, cliffs, watercourses, open woodland or margins with cleared land.

Malleefowl (Nganamarra)

Evidence of Malleefowl has been found in most of the studies within the SCS and there is anecdotal information of their wider occurrence (Outback Ecology 2014) across the GVD. However, little documentation of the possible densities or trends in their populations was found in the literature search. Habitat types that are considered suitable for Malleefowl based on work at the Cyclone Sands project area included Dune fields (possibly suitable for foraging in the swales, but not recorded there); Mulga/mallee woodland (also possibly as a foraging area or being resident although not recorded there); Sheoak woodland (appeared to be the best potential habitat type due to litter cover for mound building, but also not detected there during project surveys); and Mallee over spinifex (Malleefowl recorded here).

Anangu Rangers working with the Spinifex Land Management Program have identified five active Malleefowl sites (i.e. active nests) within the Spinifex Native Title Determination in recent years (Adam Pennington, pers. comm).. These sites have been monitored since 2012 using motion-sensor cameras. Track-based monitoring methodologies developed by Benshemesh (pers. Communication. It is likely Malleefowl (*Nganamara*) are widely distributed in low numbers throughout the SCS based of the survey effort of the Anangu Rangers and Spinifex Rangers (Adam Penningtom, personal communication, January 2016).

Rainbow bee eater

The Rainbow Bee-eater is a medium-sized bird, and the only species of bee-eater in Australia. The males measure 25 cm in length and the females 22 cm. Both length

measurements include the central tail-streamers, which project 2 - 6 cm beyond the rest of the tail in the male and 1 - 2 cm in the female. The wingspan is 34 cm in the male and 31 cm in the female (Higgins 1999).

The Rainbow Bee-eater is distributed across much of mainland Australia and is thinly distributed in the most arid regions of central and Western Australia (Barrett et al. 2003; Blakers et al. 1984; Higgins 1999).

Night Parrot

Most records for this species come from hummock grasslands with spinifex (*Triodia spp*.) or from areas dominated by samphire. They have also been reported in low chenopod shrub lands with saltbush and bluebush, and from areas of mtchell grass (*Astrebla spp.*) with scattered chenopods. Many records have come from waterholes, and interestingly, almost all reports from areas of *Triodia spp* have noted the presence of water nearby.

Princess Parrot

The Princess Parrot has been confirmed to occur at several localities in the SCS. It is known to use mature marble gums as its principal breeding habitat (Ford 1971; Outback Ecology 2014; Brennan *et al.* 2009).

4.4.3. Reptiles

Due to their tolerance of heat and low water conditions, reptile diversity in the SCS is thought to be some of the highest in the world. In the SCS 139 reptiles have been recorded. Table 13 provides an overview of the species numbers in the Shield and Central subregions.

Table 13. Reptile species in the Shield and Central subregions

Subregion	Total number of reptile species recorded	Number of conservation significant species
Shield	106	4
Central	120	3

Families of reptiles in the region include:

- Agamidae (dragons)
- Gekkonidea (geckoes)
- Pygopodidae (legless lizards)
- Scincidae (skinks)
- Varanidae (goannas)
- Typhlopidae (blind snakes)
- Boidae (pythons)
- Elapidae (poisonous snakes)

Lizards

In the GVD lizards have been extensively studied, in research spanning decades. Most research has been conducted by Eric Pianka and colleagues who noted some of the most diverse lizard assemblages on the planet occurring in the Australian deserts (Pianka, 1995).

Pianka (1969) recorded 16 different species of lizards on a pure spinifex flat, while a nearby sand ridge area had 53 lizard species coexisting (Pianka 1969, 1996). Nearly half the species exhibit habitat specificity, with sand ridge, shrub-*Acacia* and sandplain-*Triodia* habitats being particularly important for specialists (Pianka 1972).

Both short-term fire succession cycles and longer term rainfall patterns impact food webs and hence the regional biota (Pianka and Goodyear 2012). The heterogeneity of habitats produced by small scale burning and their spatial and temporal variability is believed to contribute to the diversity of lizards coexisting within relatively small areas, with a high degree of habitat specialisation (Pianka 1969b, 1972, 1973, 1975, 1985, 1989).

Snakes

Research on snakes is less extensive than on lizards. Few studies have targeted snakes in the SCS specifically. Snakes which occur in the region include:

- Antaresia stimsoni subsp. orientalis (Stimson's Python)
- Aspidites ramsayi (Woma)
- Brachyurophis fasciolatus subsp. fasciatus (Narrow-banded Shovel-nosed Snake)
- Brachyurophis semifasciatus (Southern Shovel-nosed Snake)
- Demansia psammophis (Yellow-faced Whipsnake)
- Demansia psammophis subsp. cupreiceps (Yellow-facedWhipsnake)
- Demansia psammophis subsp. psammophis (Yellow-faced Whipsnake)
- *Morelia spilora subsp. imbricata* (Carpet python)
- Neelaps bimaculatus (Black-naped Snake)
- Oxyuranus temporalis (Central Ranges / Western desert Taipan)
- Pseudechis australis (Mulga Snake)
- Pseudonaja mengdeni (Western Brown Snake)
- Pseudonaja modesta (Ringed Brown Snake)
- Pseudonaja nuchalis (Northern Brown snake)
- Ramphotyphlops margaretae *(*Buff-snouted blind snake)
- Simoselaps anomalus (Desert Banded Snake)
- Simoselaps bertholdi (Jan's Banded Snake)
- Suta fasciata (Rosen's Snake)

In a biological survey in October 2010 at Ilkurlka two central ranges taipans (Oxyuranus temporalis) were found. Studies into the lethality of *O. temporalis* indicate it is highly toxic, though less than the Inland taipan (*O. microlepidotus*) which has the most deadly poison in the world (Barber *et al*, 2014).

4.4.3.1 Reptiles of conservation significance

Four species of reptile within the SCS are of conservation significance (Table 14).

Table 14: Reptiles of conservation significance known to be present in SCS (https://NatureMap.dpaw.wa.gov.au/, accessed 12/1/2016)

	Species	Common name	Conservation status	
			EPBC	WA
1	*Aspidites ramsayi*	Woma	-	Specially protected
2	*Lerista puncticauda*	Dotty-tailed robust slider		Priority 2
3	*Liopholis kintorei*	Great desert skink	Vulnerable	Threatened
4	*Ramphotyphlops margaretae*	Buff-snouted blind snake		Priority 2
5	*Morelia spilora subsp. imbricata*	Carpet Python		Specially protected

1. Woma (Kuniya)

The Woma is associated with woodlands, heaths and shrublands, often with spinifex cover and the Sheoak woodland and Mulga/mallee woodland habitats in the GVD may therefore be suitable for it. A Woma was reported by Gaikhorst and Lambert (2003) while trapping Sandhill Dunnarts in the SCS.

2. Dotty-tailed robust slider

The Dotty-tailed robust slider has only been found in a highly localised area in the far southwest of the Queen Victoria Spring nature reserve (25km NNE of Queen Victoria Spring). They reach a maximum total length of 145mm and have a snout-vent length of about 85mm. It inhabits arid sparsely vegetated shrublands with Baarla (*Eucalyptus gongylocarpa*), and hummock grass (*Triodia basedowi*) ground cover on sandridges. It is presumed to be a largely nocturnal burrowing species that shelters beneath loose sand and leaf-litter under *Triodia* spp clumps, or under low shrubs which feeds on small invertebrates (Wells, 2012).

3. Great desert skink (Tjakurra)

It is not clear whether the Great deserts skink still occurs within the SCS and greater GVD in Western Australia. It is currently known from the APY lands in South Australia and from three locations in the Gibson and Great Sandy Desert at Patjarr, Lake Mackay and Rudall River National Park in Western Australia. It has previously been collected in the SCS however the Spinifex People were unaware of any area near Ilkurlka with the Great Desert Skink but thought they might occur in areas north of Spinifex Country (Brennan *et al.* 2012).

A National Recovery Plan for the species was adopted in 2001 (McAlpin 2001). Key objectives of the Plan are to:

- maintain or improve the conservation status of the Great Desert Skink over the next ten years.
- change fire and feral animal management in three focus areas of the western deserts to benefit populations of the Great Desert Skink.

4. Buff-snouted blind snake

The Buff-snouted blind snake is known only from two specimens, the original collected at Lake Throssell (Wilson and Swan 2010) and a second collected in Neale Junction Nature Reserve in 2008 (Brennan *et al*. 2009). It is a burrowing, worm-like snake that feeds mostly on the larvae and pupae of ants and termites. Very little is known of its ecology (Outback Ecology 2014).

5. Carpet python

Colour patterns vary across their geographic range. In Western Australia, the colour varies from pale to dark brown, with blackish blotches or variegations, which may form cross bands. The belly is white, cream or yellow, unmarked or with bold black blotches. The head tends to be paler. Only one specimen has been found in the SCS, this was found in 2007 40km south west of the Tropicana Mine. It was found as road kill.

4.4.4. Amphibians

Given the arid conditions in GVD there are only a small number of highly specialized amphibians in the region. There are 10 species of amphibians detected in the region (Table 15).

Table 15 Amphibians of the SCS region

Subregion	Total number of amphibian species recorded
Shield	7
Central	9

The amphibians in the SCS region are:

- *Cyclorana maini* (Sheep Frog)
- *Cyclorana sp.*
- *Cyclorana platycephala* (Water-holding Frog)
- *Neobatrachus aquilonius* (Northern Burrowing Frog)
- *Neobatrachus kunapalari* (Kunapalari Frog)
- *Neobatrachus sp.*
- *Neobatrachus sudellae* (Desert Trilling Frog)
- *Neobatrachus sutor* (Shoemaker Frog)
- *Notaden nichollsi* (Desert Spadefoot)
- *Pseudophryne occidentalis* (Western Toadlet)

Many of these species are burrowing ground frogs, with burrow to avoid dehydration. They are typically found in temporary clay pan areas and flooded grassland habitat. There are no frogs of conservation significance in the SCS.

4.4.5. Invertebrates

Invertebrates are likely to account for a high proportion of the total biodiversity in the SCS, but survey effort has been very slight.

A Landscope Expedition survey of Queen Victoria Spring Nature Reserve in 1996 collected six species of butterfly, including the first record for that reserve of Silky Azure (*Ogyris oroetes*).

The Neale Junction Nature Reserve fauna and flora survey in 2008 included pitfall trapping and hand collecting of invertebrates which resulted in the trapping of the spider *Aganippe* sp. and a huntsman spider, *Heteropoda hermitis*, filling a gap in the distribution of this species, which extends from the Gascoyne and Pilbara coasts into the Northern Territory (Brennan *et al* 2009).More than 90 species of moths were collected in the same survey, as well as scorpions, pseudoscorpions and centipedes. Several of Pianka's studies into lizard food webs and changes following fires examined lizard food chains and made some observations on invertebrate responses post-fire (Pianka, 1989, 1992,1994,1996).

One of the few long term and detailed studies into the ecology of invertebrates was by Langlands *et al* (2006) who studied spider populations over a 14 year period and through several fire succession stages to determine the impacts of fire and rainfall on spider species richness and abundance, and whether spider species composition was influenced by post-fire changes in ground cover. They found rainfall to be the dominant driver of the system, with a less pronounced impact of fire. The study area in Queen Victoria Spring Nature Reserve included 29 families, 67 genera and 186 species of spiders (Pianka, 1989, 1992,1994,1996).

Surveys of short-range endemics (SRE) have been carried out by ecologia Environment (2009b) at the Tropicana Gold Project and in Neale Junction Nature Reserve, the latter to try to give regional context to the project area surveys. Fifty eight species representing over 10 orders of invertebrate fauna were recorded during the seven day survey at Neale Junction Nature Reserve. Most of the invertebrates collected were species of insects and aranaeomorph spiders and it is unlikely that these species represent SRE taxa because most have strong powers of dispersal and are not habitat specialists. Relictual species of wet Karri forests that had been found at the Tropicana Gold Project were not found at Neale Junction.

Invertebrate studies conducted at the proposed Mulga Rock uranium project site in the far south-west of the SCS found 87 species of SRE within 250km^2 of the proposed site. The consultants (Bennelongia, 2015) determined that because of the relative uniformity of the landscape, most species belonging to the SRE groups would be widespread including those only found in the development envelope.

There are no invertebrates of conservation significance in the SCS.

4.4.6. Stygofauna and Troglofauna

Stygofauna are groundwater dwelling fauna present in some rock types including porous rock and karst limestone. They are typically subterranean with physical features including limited pigmentation, elongated appendages, worm-like body shape and reduced or absent (ecologia Environment, 2009c). Stygofauna feed on bacteria and matter percolating from above ground and are presumed to maintain water quality in underground systems. Utilising information from the Murchison bioregion, ecologia Environment determined, based on salinity levels, that stygofauna are likely to be present within the Tropicana project area however after extensive sampling no stygofauna was found within or outside the mine operational area (ecologia Environment, 2009c).

Troglofauna are communities of terrestrial subterranean animals that inhabit air chambers in underground caves or underground voids. They are divided into three ecological categories: a) troglobites – obligate underground species that are unable to survive outside of a subterranean environment, b) troglofiles – species that lives and reproduce underground but are also foundin appropriate environments on the surface; and c) troglexenes – species that regularly inhabit underground caves but return to the surface to feed. A fourth group, accidentals, wander into cave systems but do not survive there (Howarth, 1983 cited in ecologia Environment, 2009d). They resemble styglofauna in many ways as they also have limited pigmentation and elongated appendages. In the Tropicana study for troglofauna several troglobitic species were found representing three different order (Diplura, Chilopoda and Isopoda) and 1,500 specimens representing two troglophilic order (Collembolla and Acarina). The presence of troglofauna was unexpected as underground conditions did not appear suitable for their survival (ecologia Environment, 2009d).

The presence of centipede (Chilopoda Centripedes) and the dipluran troglofauna was restricted to the mine footprint. Isopods (slaters) were partially impacted as they were found both within and outside the mine footprint. It is thought that the troglofauna habitat is saprolitic clay and root mats which contain small voids created by decayed roots (ecologia Environment, 2009d). The assessment for Tropicana determined that it was likely that troglofauna were likely widespread in the region due favourable subterranean habitat including climate, biogeography, landform and regolith setting (ecologia Environment, 2009d).

Studies requested by Vimy resources for the MRUP detected both troglofauna and stygofauna in the groundwater (Rockwater, 2015). Families of stygofauna collected were:

- Enchytraeidae
- Tubificidae

Families of troglofauna detected were:

- Platyarthridae
- Scutigerellidae

To avoid impacting (or minimise impacts) the Vimy (2015) in their PER prosed four management actions:

- Minimise disturbance of habitats for both species
- Avoid hydrocarbons or other chemicals entering the soil or groundwater
- Progressively rehabilitate disturbed environments of subterranean fauna
- Ensure awareness of environmental factors amongst operating workforce

5. Legislation

In terms of biodiversity in the region there are several pieces of legislation or international agreements that shape the protection of species and habitat in the SCS.

5.1. International Agreements and Legislation

Migratory bird bilateral agreements and conventions

Data from the EPBC Act Protected Matters Report (15/8/2014) listed 5 migratory species in both the Shield and Central subregions. Lake Yeo / Lake Throssell and the Lake Carnegie System are the only nationally important wetlands listed in the EPBC Act Protected Matters

Report. Australia is party to a number of bilateral agreements, initiatives and conventions for the conservation of migratory birds.

JAMBA - The Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment, 1974;

CAMBA - The Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment, 1986;

ROKAMBA - The Agreement between the Government of Australia and the Republic of Korea for the Protection of Migratory Birds and their Environment, 2006; and

The Bonn Convention on Migratory Species (CMS) - The Bonn Convention adopts a framework in which countries with jurisdiction over any part of the range of a particular species co-operate to prevent migratory species becoming endangered. For Australian purposes, many of the species are migratory birds.

5.2. National Legislation

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

The *EPBC Act* is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places (www.environment.gov.au viewed February 2016). The focus of the Act is to protect matters of national environmental significance (MNES) with the state and territories having responsibility for matters of state and local significance.

The objectives of the EPBC Act are to:

- provide for the protection of the environment, especially matters of national environmental significance
- conserve Australian biodiversity
- provide a streamlined national environmental assessment and approvals process
- enhance the protection and management of important natural and cultural places
- control the international movement of plants and animals (wildlife), wildlife specimens and products made or derived from wildlife
- promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources
- recognise the role of Indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity
- promote the use of Indigenous peoples' knowledge of biodiversity with the involvement of, and in cooperation with, the owners of the knowledge.

Under the *EPBC Act*, actions that have, or are likely to have, a significant impact on a MNES require approval from the Australian Government Minister for the Environment. The Minister will decide whether assessment and approval is required under the *EPBC Act*.

The nine MNES protected under the *EPBC Act* are:

- world heritage properties
- national heritage places
- wetlands of international importance (listed under the Ramsar Convention)
- listed threatened species and ecological communities
- migratory species protected under international agreements
- Commonwealth marine areas
- the Great Barrier Reef Marine Park
- nuclear actions (including uranium mines)
- a water resource, in relation to coal seam gas development and large coal mining development

Currently in the SCS there are only two relevant MNES – nationally listed threatened species and migratory species.

Australian Heritage Council Act 2003

This Act establishes the Australian Heritage Council, the Register of the National Estate and the processes by which places may be legally registered as part of the National Estate. No places within the SCS are currently on the Register of the National Estate.

Aboriginal and Torres Strait Islander Heritage Protection Act 1984

The *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (*ATSIHP Act*) can protect areas and objects that are of particular significance to Aboriginal people. The *ATSIHP Act* allows the Environment Minister, on the application of an Aboriginal person or group of persons, to make a declaration to protect an area, object or class of objects from a threat of injury or desecration. (http://www.environment.gov.au/heritage/laws/indigenous accessed Feb 2016).

Native Title Act 1993

Native title describes the recognition by the Australian legal system of rights and interests of Aboriginal and Torres Strait Islander peoples to land and waters according to their traditional laws and customs. It may include the right to access an area of land or the right to participate in decisions concerning how the land or waters are used by other people. Native title may also vary according to the rights of other people and may exist alongside other rights (called 'co-existence').

Native title cannot be bought or sold. It can be transferred by traditional law or custom, or surrendered to government, which can then pay compensation to the native title holders in the same way as it does when acquiring rights to other property.

In the SCS region there are several Native Titled determined area, these are:

1) The Spinifex native title determination in 2000 was the first determination of native title in Western Australia. Full details of the determination are available at: http://www.centraldesert.org.au/native-title-item/spinifex/

2) Ngaanyatjarra lands, determined in 2005. This area is in the very north of the SCS. Full details of the determination are available at: http://www.centraldesert.org.au/native-title-item/ngaanyatjarra-lands-2/

3) Pilki Land determination is for 24,398 square kilometres in the centre of SCS. Full details of the determination are available at: http://www.centraldesert.org.au/native-title-item/pilki/

5) Yilka native title claim is currently before the court and has a claim area of 12,260 km^2. Full details of the claim are available at: http://www.centraldesert.org.au/native-title-item/yilka/

5) Cosmos Newberry native title claim was dismissed in 2007 and the decision was appealed. In June 2016 a decision was made to acknowledge the Yilka People as native title owners of the Cosmos Newberry Reserve, subject to the official determination later in 2016.. Full details of the claim are available at: http://www.centraldesert.org.au/native-title-item/cosmo-newberry/

5.3. Western Australian Legislation

Wildlife Conservation Act 1950

The Wildlife Conservation Act 1950 is an act of the Western Australian Parliament that provides the statute relating to conservation and legal protection of flora and fauna.The *Wildlife Conservation Act 1950* provides for the listing of threatened native plants and threatened native animals that need to be specially protected because they are under identifiable threat of extinction, are rare, or otherwise in need of special protection.

The Minister for Environment may list an ecological community as being threatened if it is presumed to be, or is at risk of becoming, totally destroyed.

Conservation and Land Management Act 1984

The Conservation and Land Management Act 1984 (WA) establishes a comprehensive set of legislative provisions dealing with state conservation and land management matters. It established a number of statutory bodies including the Conservation Commission of Western Australia, the Marine Parks and Reserves Authority, and the Marine Parks and Reserves Scientific Advisory Committee

In December 2012 changes to the Act and various regulations were amended to enable Aboriginal people to undertake certain activities for customary purposes on reserves and other lands.

These changes build on amendments to the CALM Act made in March 2012, which:

- established legal frameworks to enable joint management of lands and waters between the department and other parties
- allowed for customary activities to occur
- introduced a new management objective to protect and conserve the value of the lands and waters to the culture and heritage of Aboriginal people.

Aboriginal Heritage Act 1972

The *Aboriginal Heritage Act 1972* (AHA Act) which was introduced in Western Australia in 1972 to protect Aboriginal heritage. The Act recognises Aboriginal peoples' strong relationships to the land, which may go back many thousands of years.

The AHA Act provides automatic protection for all places and objects in Western Australia that are important to Aboriginal people because of connections to their culture. These places and objects are referred to as Aboriginal sites.

The Department of Aboriginal Affairs maintains a Register of Aboriginal Sites as a record of places and objects of significance to which the Act applies. The presence of an Aboriginal site places restrictions on what can be done to the land. Anyone who wants to use land for research, development or any other cause, must investigate whether there is an Aboriginal heritage site on the land.

Portions of Yeo Lake are a gazetted Protected Area under the Aboriginal Heritage Act 1972 due to their mythological, ceremonial and archaeological significance. In addition there are a large number of registered Aboriginal sites in the SCS registered on the Aboriginal Heritage Inquiry System (see: http://maps.dia.wa.gov.au/AHIS2/).

Aboriginal Affairs Planning Authority Act 1972 (AAPA Act)

The *Aboriginal Affairs Planning Authority Act 1972* (AAPA Act) established the Aboriginal Lands Trust. This Act also established the Aboriginal Affairs Planning Authority that is now known as the Department of Aboriginal Affairs. The Aboriginal Lands Trust became responsible for the administration of lands previously held by the Native Welfare Department and a number of State Government agencies. There are also lands that remain registered in the name of the *Aboriginal Affairs Planning Authority Act 1972*. Additionally, as a part of the effective management of the estate, the Aboriginal Lands Trust undertakes strategic land acquisitions.

The Aboriginal Lands Trust provides advice to the Minister for Aboriginal Affairs on Aboriginal Lands Trust land issues. The Aboriginal Lands Trust is a significant landholder with responsibility for approximately 27 million hectares or 11 per cent of the State's land mass. This land comprises different tenures including, reserves, leases and freehold properties. A significant proportion of this land comprises reserves that have Management Orders with the Aboriginal Lands Trust (generally having the power to lease), with their purposes mostly being for "the use and benefit of Aboriginal inhabitants".

Section 18 (1) of the Aboriginal Affairs Planning Authority Act 1972 states that there "shall be established a council, to be known as the Aboriginal Advisory Council, for the purposes of advising the Authority on matters relating to the interests and well-being of persons of Aboriginal descent". The Aboriginal Affairs Planning Authority Act 1972 also outlines that such a council shall consist of Aboriginal people. This council is now know as the Western Australian Aboriginal Advisory Council(WAAAC).

Biosecurity and Agriculture Management Act 2007 (BAM Act)

The Biosecurity and Agriculture Management Act and associated regulations were enacted on 1 May 2013.

The new BAM Act objective is to protect the state's agriculture and food sector and the environment. The main purposes of the BAM Act and its regulations are to:

- Prevent new animal and plant pests (vermin and weeds) and diseases from entering Western Australia.
- Manage the impact and spread of those pests already present in the state.
- Safely manage the use of agricultural and veterinary chemicals.
- Increased control over the sale of agricultural products that contain violative chemical residues.

Under the Biosecurity and Agriculture Management Regulations 2013, declared plant pests are placed in one of three control categories, C1 (exclusion), C2 (eradication) or C3 (management), which determines the measures of control which apply to the declared pest. According to section 30 (3) of the *BAM Act*, the owner or occupier of land, or a person who is conducting an activity on the land, must take the prescribed control measures to control the declared pest if it is present on the land.

The current listing of declared pest organisms and their control category is available on the Western Australian Organism List (WAOL) at https://www.agric.wa.gov.au/bam/western-australian-organism-list-waol. Weeds are listed under the *BAM Act* as one of the following:

- Plant pests
- Declared plants
- Crop weeds
- Weeds of National Significance (WoNS)

The EPBC Act Protected Matters Report (2014) for SCS lists three WoNS; *Carrichtera annua* (Ward's weed); *Cenchrus ciliaris* (Buffel-grass) and *Tamarix aphylla* (Athel Pine).

6. Land Tenure

The combined area of the SCS is 17,342,025ha and the underlying tenure consists of four types: Unallocated Crown Land (UCL), Nature Reserve and Pastoral and Native Title (determined). The majority of land in the SCS is UCL. There are six nature reserves either completely in or partially in the SCS. The area of the reserves within the SCS total 1,473,137 ha. The majority of pastoral leases are on the western most area of the SCS and very few are completely within the SCS. There are three determined Native Title areas in the SCS and two additional claims are before the courts. The claims partially overlie other tenure including nature reserves and UCL. Table 16 shows the percentage of each of the land tenures in the SCS.

Overlying these tenures are mining and exploration tenements. Mining related tenements fall into four categories:

- Mining lease (active)
- Mining lease (pending)
- Exploration lease (active)
- Exploration lease (pending)

The majority of exploration tenements (both live and pending) lie in the south western area of the SCS, with a cluster in the north-east of the region. Very few leases (active or pending) exist in the centre area of the Central region. There is only one mining lease in the region and this covers an area of 657.47km^2.

Native title lands will be discussed in more detail in Section 7.

Table 16. Areas of tenures in the SCS (hectares). Statistics provided by Gaia Resources

Category	Shield	Central	Total
Native Title (determined)	0	5,703,590.421	5,703,590.421
Conservation Reserves	332,342.79	1,140,795.82	1,473,138.61
Pastoral leases	798,440.57	226,198.46	1,024,639.03
Unallocated Crown Land and Crown Reserves	2926367.49	9877698.54	12,804,066.03

Conservation estate

Conservation reserves are areas of land specially set aside under law to protect the environmental values within them. In the SCS region all conservation estate are nature reserves. Nature reserves are established for wildlife and landscape conservation, scientific study and preservation of features of archaeological, historic or scientific interest. Recreation that does not harm natural ecosystems is allowed, but other activities are usually not permitted. Most conservation reserves are vested with the Conservation Commission, and managed by the Department of Parks and Wildlife on behalf of the Conservation Commission.

Reserves are managed under a management plan for each reserve. Where no management plan exists, only ‘necessary operations’ can be undertaken. ‘Necessary operations’ means operations that are necessary for the preservation or protection of persons, property, land, waters, flora or fauna, or the preparation of a management plan. There are currently no management plans for reserves in the SCS region.

Pastoral Leases

Pastoral leases are areas of Crown land leased for the limited purpose of grazing of stock. Specific conditions are often attached to pastoral leases, including a time period and the types of activity that may be permitted. Pastoral leases in the SCS occupy a small percentage of land (approximately 6%), primarily in the western areas.

The Rangelands of Western Australia, which includes pastoral leases, unallocated crown land and unmanaged reserves is currently undergoing a legislative change in the form of ‘Rangelands Reform’ or ‘Rangelands Bill’. The reform is aimed at addressing the issues of sustainable development, tenure security and economic diversification on pastoral leases. The additional aims are to increase compliance with land management laws relating to bushfires, and control, or eradication of pests, weeds and feral animals as well as increase condition management and monitoring.

Unallocated crown land

Unallocated crown land (UCL) in WA is technically administered by the Department of Lands under the *Land Administration Act 1997*. In 2003 the responsibility for managing fire and declared plants and animals on UCL was transferred to the Department of Parks and Wildlife (then Department of Environment and Conservation). A memorandum of understanding (MOU) was executed which details the roles of each agency in managing these lands. This MOU is supported by an order under section 33(2) of the *Conservation and Land Management Act 1984.*

Indigenous Protected Areas

In addition to the tenures outlined above a further category, Indigenous Protected Area (IPA), exists in the Ngaanyatjarra determined lands in the north west of the SCS. As with other IPAs across Australia, the Ngaanyatjarra IPA is a voluntarily established area on Indigenous owned or jointly managed land. Following dedication, IPAs are recognised by the Australian Government as part of the National Reserve System, protecting the nation's biodiversity for the benefit of all Australians.

The federal government supports IPA projects through multi-year funding agreements. The aim of the IPA system is to protect biodiversity and encourage Indigenous organisations to lead conservation management through a community-based approach. IPA projects also provide training and career pathways for Indigenous people in land and sea management. Over 60 per cent of IPAs are managed by Working on Country funded Indigenous ranger groups.

The Ngaanyatjarra IPA is 9.8 million hectares and protects high levels of biodiversity through traditional land management practices. Ngaanyatjarra has four ranger teams which conduct work on the IPA: the Blackstone, Warakurna and Warburton Men and Warburton Women rangers. Rangers conduct work including:

- Surveys and management of threatened species such as the black-footed rock-wallaby, great desert skink and bilby.
- Fire management,
- Cleaning and maintaining rock holes (gnamma) to provide water for a range of native fauna
- Managing the impact of feral animals such as camels
- Supporting traditional ecological knowledge and cultural activities and;
- Continuing to develop tourist management strategies.

6. Regional stakeholders

There are a number of groups and agencies operating in the region. Some of the groups, such as Traditional Owners and mining operations have a continual presence in the region. Other groups may have a continual interest in the region but intermittent on-country visits. Other groups have very low levels of ongoing involvement or interest in the region but may conduct specific projects in the region.

It is useful to know the different stakeholders in the region and potentially utilise their different expertise, areas of knowledge and resources to increase knowledge of biodiversity in the region.

Federal Government

- Department of the Environment

State Government

- Department of Aboriginal Affairs
- Department of Agriculture and Food
- Department of Lands
- Department of Mines and Petroleum
- Department of Parks and Wildlife
- Environmental Protection Agency
- State NRM Program

Local Government

- Shire of Laverton
- Shire of Menzies

Traditional Owners / Aboriginal representative groups

- Central Desert Native Title services (representative organisation)
- Cosmos Newberry Aboriginal Corporation
- Ngaanyatjarra Council (Aboriginal Corporation)
- Pila Nguru Aboriginal Corporation (PNAC)
- Pilki People
- Spinifex Rangers
- Wongatha people
- Yilka Traditional Owners

Mining and exploration companies

- AngloGold Ashanti Australia (AGAA)
- Gold Road
- Tropicana Joint Venture (AGAA and IGO)
- Vimy Resources
- Exploration mine companies

Not-for-profits and community groups

- Rangelands NRM
- Greening Australia WA
- Western Australian Museum
- Botanic Gardens and Parks Authority
- Outback WA (collaboration between PEW, CCWA, Wildflower Society and Bush Heritage)

Other groups

- Pastoral lessees
- Universities
- Experts
- Consultants

6.1. Identification of potential issues, challenges and opportunities

There are several challenges to stakeholder engagement and collaboration in the SCS region. Overall the largest challenge is the large distances involved in travel within the SCS

and the lack of population centres. The Aboriginal communities in the GVD are very remote from one another. SCS are two sub-regions within the wider GVD IBRA bioregion that extends into South Australia. Another challenge in acknowledging the knowledge and information that exists in South Australia and determining how to effectively collaborate across borders, with different jurisdictions and legislation involved.

These factors contribute to the high costs and time required to collaborate and meet in a face-to-face context. The large area of the SCS also makes it difficult to know the interactions between different places in a landscape context when limited knowledge exists about vast areas within this region.

Additional to the issues associated with size and distances are potential issues in different values attached to the region. The activities associated with mining and exploration activities have the potential to conflict with the values of conservation or Indigenous groups. There are also potential challenges in the alignment between utilising traditional ecological knowledge and implementing western science and conservation management practices.

Within each of these challenges or potential issues there are also opportunities. With relatively few stakeholders in the region, there is the possibility of forming a genuine collaboration, to develop a shared vision and to pool resources to address knowledge gaps and landscape scale biodiversity issues. By utilising the different strengths and resources of each stakeholder, it may be possible to develop a joint / collaborative approach which builds the capacity of all stakeholders. This is particularly important in terms of the Indigenous ranger groups who are best placed to manage the wider landscape.

Gaining a holistic picture of biodiversity in the region and the factors influencing biodiversity will only be gained when groups work together to collect and share data and knowledge, measure results and regularly communicate results across all the stakeholders in the region.

7. Traditional owners

7.1 Active Native Title Claims:

- Yilka

7.2 Native Title Determinations:

- Spinifex People
- Ngaanyatjarra Lands (Part A and B)
- Pilki People
- Mantjintjarra Ngalia #2

7.3 Inactive Native Title Claims:

There is currently no active native title claim between the Pilki Native Title Determination and Yilka Native Title Claim (i.e. central GVD, ‘East Wongatha’)

7.4 Administrative arrangements

Anangu tjuta pilanguru – translating to ‘many Aboriginal people from Spinifex’ or, simply, Spinifex People (Cane, 2002) – are the traditional owners and custodians of the country and the cultural sites, knowledge and stories within it. Spinifex People are directly supported through Pila Nguru (Aboriginal Corporation) RNTBC and are provided with

administrative/legal support from Central Desert Native Title Services Ltd. Tjuntjunjara community is located in the Shire of Menzies

Yarnangu Ngaanyatjarraku Parna (Aboriginal Corporation) RNTBC holds and manages native title rights and interests on behalf of the Ngaanyatjarra native title holders for the Ngaanyatjarra Native Title Determination. More than half of the Ngaanyatjarra Native Title Determination Lands have been dedicated as an Indigenous Protected Area (August 2002). The native title holders are supported by Ngaanyatjarra Council's Land and Culture Unit in the management of the Ngaanyatjarra Native Title Determined lands, including the Ngaanyatjarra IPA

Central Desert Native Title Services Ltd provides legal and financial management support to Yilka native title claimants and occasional natural and cultural resource management project support when requested to do so. Ngaanyatjarra Council (Aboriginal Corporation) provides a level of community development support to Yilka people living in the Cosmo Newberry community in the Shire of Laverton on the edge of the Great Victoria Desert.

Central Desert Native Title Services Ltd provides legal and corporate governance support to Pilki People and their native title exists in the Shires of Laverton and Menzies. Central Desert Native Title Services is currently working with Pilki people to establish their prescribed body corporate to hold and manage their native title rights and interests.

7.5 Current land management activities

Spinifex Rangers

Spinifex People and the Spinifex Land Management Unit based in the community centre of Tjuntjunjara have an established ranger program covering their 5.5 million hectares (55,000 sq km) area of sand hills and sand plains, salt lakes and breakaways. The *Spinifex Healthy Country Plan* (DRAFT, Conservation Management for Spinifex Land Management *In preparation, 2016)*, funded by Rangelands NRM (Australian Government's *Caring for Our Country* funding) is being used to inform the Spinifex Land Management Unit's program of priority land and cultural management activities. A new funding contract with Rangelands NRM's *National Landcare Program* funding is being negotiated to allow further priority work to be carried out in accordance with the Spinifex Healthy Country Plan. Earlier planning exercises have been undertaken (i.e. the *Spinifex Country Strategic Property Management Plan* (Pennington, 2012)), which have subsequently informed the Spinifex Land Management Unit's current Healthy Country Planning.

Additional support for the resourcing of the Spinifex Land Management Unit, both in terms of employment of their Ranger Coordinator position and their ranger equipment and training needs has come from the Australian Government's legacy program, the Biodiversity Fund. This support, which commenced in 2013 before other federal support programs and runs through to 2017, provided the original seed-funding for the development of the Spinifex Land Management Unit.

Ngannyatjarra

Currently the Ngaanyatjarra Land & Culture program runs men's and women's ranger team activities on the Ngaanyatjarra Lands. They also have in place a 'Plan of Management for the Ngaanyatjarra Lands Indigenous Protection Area' (Noble and Ngaanyatjarra Council 2002). Ngaanyatjarra also have the 'Ngaanyatjarra Camel Company', this companies role is

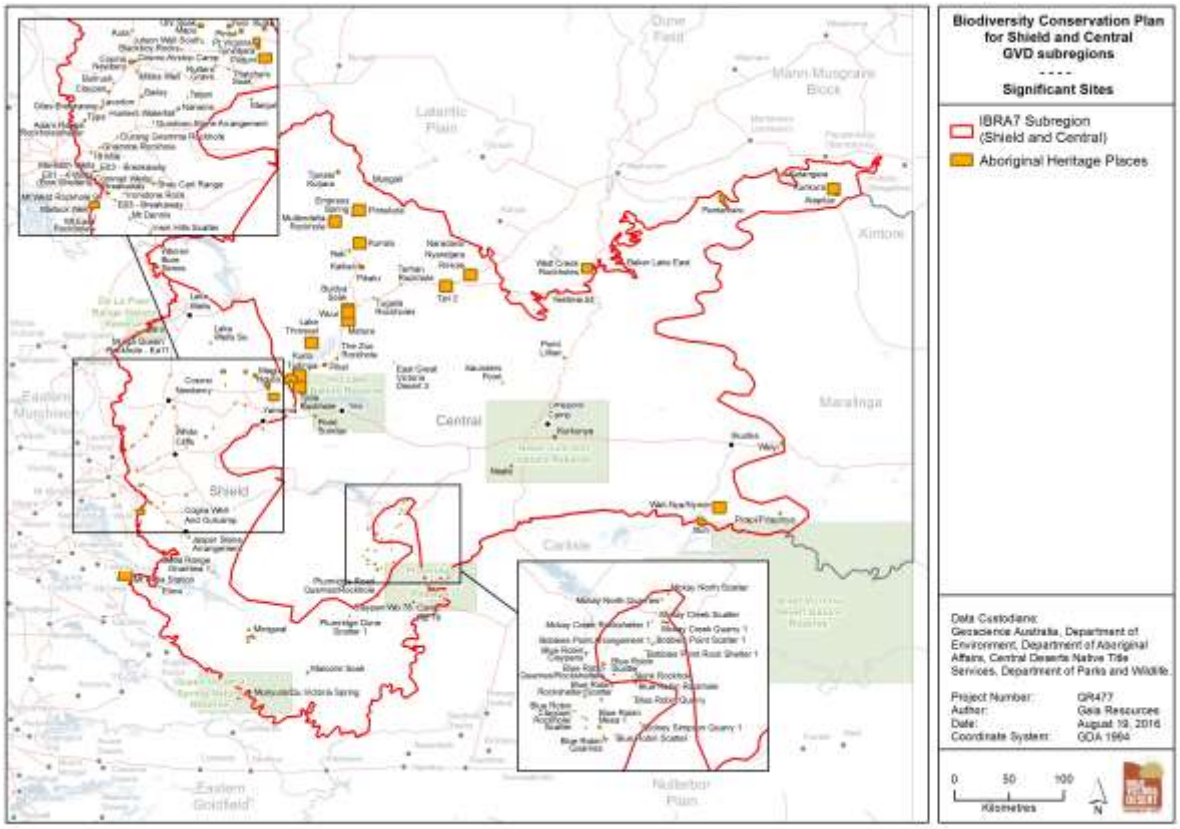
to muster and sell feral camels. This company provides ongoing and regular employment to the traditional owners of their lands.

Yilka

Yilka people do not currently have a structured ranger program or a written plan for managing country. They have identified activities such as environmental monitoring (including water quality/quantity and culturally significant fauna), feral animal and weed control, threatened species monitoring (including malleefowl), protection of significant sites, securing of land management fee-for-service contracts and the development of a community based ranger/land management program as high priorities. They currently undertake regular land management activities including patch burning of country, feral herbivore control and contract earthworks. In recent years, they have been engaged in a range of small scale natural and cultural resource management projects, including the Rangeland NRM-supported 'Keeping Desert Country Healthy' project.

7.6 Significant sites

The Aboriginal Heritage Inquiry System lists a large number of sites in the SCS area. These range from water sources, ceremonial areas, areas where artefacts have been found, man-made structures and places of mythological significance. Figure 12 shows Aboriginal Heritage places listed on the Department of Aboriginal Affairs.



Substantial limitations exist on published information on culturally significant sites and the public access to significant sites and cultural knowledge in Western Australia. This is important for respecting the privacy and sacredness of sites. Traditional Owners hold the ultimate source of knowledge for significant sites and cultural values for country. The

passing on of this knowledge to younger generations is a common high priority aspiration for Traditional Owners across the desert regions of Australia.

7.7 Role of Traditional Owners in Biodiversity Management

Indigenous people have long-held cultural and traditional responsibilities to protect and manage their country. They own an estimated 20 per cent of the Australian continent, upon which lies some of the most environmentally important natural assets and, for Indigenous people, is rich in cultural and spiritual meaning. Indigenous Rangers build on Indigenous traditional knowledge to protect and manage country. More than 680 Indigenous rangers are employed in around 95 ranger teams across Australia to deliver environmental outcomes. There are many more Indigenous individuals and groups across Australia's deserts that are seeking to secure the resources to develop and implement community based ranger teams.

It is expected that the active leadership shown by the Spinifex People in establishing their Spinifex Land Management Unit and the land management programs being undertaken by the people of the Ngaanyatjarra Lands will inspire other Traditional Owner groups in the Great Victoria Desert to also develop Indigenous ranger teams of their own. The Yilka people from Cosmo Newberry have begun organising themselves towards planning on Country for their Yilka land management aspirations.

8. Threatening processes for conservation

Across the Rangelands of Australia, there are a number of threatening process affecting the biodiversity of the natural environment. The DoE lists a number of key threatening processes affecting biodiversity across Australia. Some of these threats are localised and some applicable to wide regions of Australia. Potentially applicable to the SCS are:

- Predation by European red fox
- Predation by feral cats
- Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases
- Competition and land degradation caused by rabbits

The DPaW Biodiversity Audit (2002) lists the key threatening processes, impacting on species of conservation significance in the SCS as the following:

- Feral animals (cats, foxes, rabbits)
- Changed fire regimes

Based on these assessments this plan will examine four key threats, thought to be having the largest impacts on biodiversity in the region: introduced herbivores, introduced predators, changed fire regimes and climate change.

8.1. Introduced herbivores

One of the greatest changes to semi-arid and arid areas of Australia post-settlement has been the number of introduced fauna and the consequent impacts on landscapes and native species. Introduced herbivores each have the potential to damage the biodiversity in different ways, whether through damage to waterholes, competition for food, changing the

structure of habitat or competing for shelter. The sections below describe the main threats posed by each of the feral herbivores in the SCS.

8.1.1. Camels

High densities of feral camels cause damage to native vegetation, rockholes (gnamma) and soaks, infrastructure, degrade biodiversity and degrade cultural values. Camel densities in the SCS have been surveyed several times between 2005 and 2013. In 2008 densities were determined to be very low, at 0.05 camels per km2 which is low in comparison with densities recorded in other parts of the country. This survey took place in near drought conditions and most camels were detected close to lakes or other water points.

Over 2,000 camels were removed by aerial shooting in the period 2012-2013 as part of the Australian Feral Camel Management Project (AFCMP). Additionally over 1,000 camels have been removed through ground-based shooting operations conducted by Spinifex Land Management Rangers.

Camels browse on more than 80% of the plant species in arid Australia (Dorges and Heucke, 2003, reported in Giustiniano, 2007)). When camel densities are low they may not have a major impact on the environment but when numbers expand in periods of water and food abundance they have significant impacts on water sources, shelter for small desert mammals and food sources traditionally harvested by Traditional Owners. Additionally during dry spells when camels congregate at waterholes and soaks, they can destroy waterholes, frequently falling in and contaminating the water source for other species. Other possible impacts such as the disruption of feeding and nesting activities of ground and lower canopy bird species, and trampling or removal of cover for ground dwelling fauna, are less well understood (Peeters *et al* 2005).

8.1.2. Rabbits

Nationally, rabbits are one of the most serious and costly vertebrate pests in Australia (http://www.environment.gov.au/ accessed March 2016). They are recognised as a potential threat over 300 threatened species under the *Environment Protection and Biodiversity Conservation Act 1999*.

Rabbits are distributed across Australia except for the northernmost area. In arid areas, rabbits need access to water but elsewhere they can obtain enough moisture from their food.

Rabbits compete with native wildlife for food and nesting areas, they damage vegetation and degrade the land (DoE Rabbit factsheet, 2011). Their impact increases during drought and immediately after a fire, when food is scarce and they eat whatever is available. It is estimated that rabbits may have caused the extinction of several small ground-dwelling mammals in arid areas and contributed to the decline of many native plants and animals.

The numbers of rabbits in the SCS hasn't been estimated but it is likely that their numbers vary substantially with rainfall events as female rabbits have the ability to produce up to 40 offspring in 12 months when conditions are suitable.

8.1.3. Mice (Mus musculus)

The house mouse has been detected in the SCS region. Burbidge and Fuller (1979) noted that they detected two specimens of *Mus musculus*, one in a tussock grassland and another in a dry creek in the region. They also noted that the WA Museum has numerous specimens from the Warburton region. Across arid regions, the domestic mouse is known to survive

and rapidly increase in numbers following heavy rains and prolonged periods of vegetation abundance (Newsome and Corbett, 2012). The main threat caused by the house mouse is competition for food and habitat with small native marsupials, disease spread and destruction of the natural environment if populations reach plague proportions (Newsome and Corbett, 2012).

8.1.4. Horse and donkeys

The numbers of horses and donkeys in the SCS are not well qualified and the damage caused by them is also largely unknown. Due to their water requirements, it is unlikely they cause significant damage in the region. Reports from the DoE suggest feral horses and donkeys are unlikely to occur in the SCS (Clarke, 2000).

8.2. Introduced predators

There is very little documentation of current populations or distributions of cats, foxes or dogs/dingos within the SCS. Most fauna surveys note evidence of feral predators, either as sightings or, more often, tracks and scats.

Burbidge et al (1988) discusses the timing of the disappearance of native fauna species from central Australia in relation to the timing of Aboriginal people leaving or being removed from their country and to the reported time at which cats and foxes became established in the deserts.

The presence of species such as *Iltjaritjari* in cat and fox scats (Brennan et al 2009) does emphasize that regardless of whether feral predators played the major role in species extinctions and reductions in the past, they are now a significant threat to the remaining small mammals, reptiles and birds. A brief description of the threat caused by the feral predators in the SCS and other desert environments is outlined below.

8.2.1. Feral cats

Predation by feral cats is listed as a key threatening process under section 188 of the *EPBC Act* due to their impact on native fauna and their presence across the whole of the Australian continent. This was further reinforced by a *National declaration* in July 2015 from state and federal Environmental Ministers of *feral cats as pests*.

Each feral cat kills between 5 and 30 animals per day with a preference for small mammals but including birds, lizards and amphibians (AWC website, accessed March 2016). Cats have also been found to kill at least 16 threatened species and 12 others classed as near-threatened, including the vulnerable malleefowl (Doherty *et al* 2015). This study also found that the diet of cats varied significantly depending on the rainfall of an area, with feral cats in central desert areas feeding most frequently on reptiles.

The numbers of feral cats in the SCS are difficult to determine. There have not been any surveys for cats in the SCS and current programmes such as feral cat scan (http://www.feralscan.org.au/) have not noted any detections of cats in the SCS. Studies in central Australia and arid areas of South Australia have estimated the home range of cats to be between 50 and 2210 ha.

The *'Threat abatement plan for predation by feral cats'* was updated in 2015. Management actions from this document for cats will be discussed in Section 10.

8.2.2. Foxes

Like the cat, the red fox is listed as a key threatening process due to its impact on native fauna. It is listed by the IUCN as one of the 100 worst invasive species in the world.

Foxes have a wide dietary range, few serious diseases and few natural enemies. They also have a high reproductive rate and a high rate of cub survival, although they only breed once a year. They also have very high dispersal rates with one study finding instances of a traversal distance of 300km (Saunders et al 2002).

The fox can survive in many different habitat types including arid and semi-arid environments. The fox is believed to have played a major role in the decline of ground-nesting birds, small to medium sized mammals and reptiles. Foxes have been seen in the SCS scratching at malleefowl mounds.

8.2.3. Dingo

The status of the dingo as an introduced species versus a native animal is contentious across Australia. Under WA legislation the dingo is not listed as native fauna (ie unprotected fauna) however in several states of Australia the dingo is a gazetted threatened native species. The dingo is listed in the category 'Vulnerable A2e' in the IUCN Red List. The population trend is one of decreasing numbers.

The impacts of dingoes on biodiversity is as controversial as its protection status. Some researchers suggest that the dingo is the native apex predator and plays an important ecological role whilst other researchers suggest that dingoes exploit populations of small and medium sized marsupials including threatened species hence impacting their survivability (Corbett 2009; Wallach *et al* 2009; Fleming, Allen and Ballard, 2012).

Many researchers have suggested that the presence of dingoes has a suppressing effect on cat and fox populations and therefore plays a crucial role in maintaining the survival of small ground dwelling marsupials (Johnson *et al* 2007). The lack of dingoes as an apex predator, called the mesopredator release hypothesis (MRH), suggests that fox and cat numbers expand and result in a massive decline in small prey species (Ritchie and Johnson, 2009).

Fleming and colleagues (2012) argue dingoes title as an apex predator is questionable and they still pose a risk to threatened species. Fleming and colleagues (2012) argue that humans occupy the role as apex predator and that the role that dingoes played in pre-European Australia may never be attained again in a post-European state, with all the changes to the environment that have occurred.

In arid regions have shown the abundance and persistence of many small mammals are positively associated with the abundance of dingoes and negatively with the presence of red foxes (Wallach *et al* 2009; Letnic *et al* 2012*).* However other studies point to evidence that wild dogs have been responsible for the decline in several species including the malleefowl, marsupial moles and several species of wallabies. This has resulted in the *'National Wild Dog Action Plan*' (2014).

Any management actions for dingoes in the GVD must be considered in light of the contrasting arguments surrounding the role of dingoes as positive or negative agents in the protection of threatened species.

8.3. Fire

Fire is perceived as one of the largest threats facing biodiversity in the SCS due to the increasing scale and intensity of fires. Fires produce a patchwork of habitats in different stages of post-fire recovery, each of which can favour a different set of species (Pianka 1992b, 1996; Haydon *et al.* 2000a and 2000b; Langlands *et al* 2006). A habitat-specialized species, such as a lizard or spider, can become locally extinct within a habitat patch but persist in the area if it can re-colonise from nearby patches of suitable habitat. Whether it will be able to do so depends very much on the dispersal abilities of the species and the scale of the disturbance (Haydon *et al.* 2000a).

In parts at least of the SCS there appears to have been a large increase in the size and frequency of fires, resulting in large areas being at the same seral stage, with less of the "patchiness" that allows animals and plants to survive and recolonise (Burrows and Hamilton 2006). "Prescribed" burning in mild weather has been proposed to reduce the size of wildfires. However, Burrows and Hamilton also advise some constraint in introducing more fire into a mostly recently burnt landscape, and this is also urged by Pearson (1994) who proposed numerous, small fires to investigate responses, as well as leaving large areas of the GVD unmanaged for fire but monitored to ensure the impacts of both a highly managed and an unmanaged fire regime could be compared. Section 10.3 describes fire management activities that could be considered in the region.

Currently the mapping of fire scars across the GVD occurs at a course scale and it is difficult to determine patchiness or refuges that may occur within the footprint of the fire scar. The most utilised systems for fire mapping in the region are:

- National Oceanographic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR)
- Landsat
- Moderate Resolution Imaging Spectroradimeter (MODIS)

Rangelands NRM have commissioned the extension of the Northern Australia Fire Information program to the Western Australian Rangelands[4]. NAFI includes up-to-date information on fires as well as a detailed fire scar history. For the WA Rangelands, including the SCS, the fire scar mapping will be from 2006 – 2016.

8.3.1. Fire regimes

The fire regime of an area describes the frequency of fire at a particular location as well as the distribution, intensity, season of occurrence and type of fire (Brooks et al., 2004; Gill, 1975). To understand fire and its impacts on biodiversity, factors influencing the fire regime need to be better understood.

Fire ignition is either the result of lightning or humans. Lightning tends to strike higher areas, along ridges, whereas human ignited fires are more likely along roads or near settlements. Lightning fires are more common in warmer months (Marsden-Smedley 2012).

Other factors influencing the fire regimes are climate and weather, soil type, vegetation, fuel load and management strategies applied to an area. In the GVD, unallocated crown land is largely unmanaged due to lack of resources (EPA, 2006). Fire frequency in the GVD is

[4] The Trust has contributed funds to the development of this project

thought to average up to 20 years or more (Allan and Southgate 2002). With a changing climate, combined with limited management, fires are thought to increasing in both frequency and scale (Turner, 2008). As a result, in arid and semi-arid Australia individual fires now frequently exceed 1 million hectares (Turner, 2009).

8.3.2. Fuel Load / Vegetation

Across the arid zone of Australia there are different vegetation types with different susceptibilities to fire.

The dominant ground cover in the SCS is spinifex grasslands (Haydon *et al.* 2000a). Hummocks grow up to 30-60cm high and 30-100cm in diameter and can occupy 30-50% of the ground area with the ground between them normally bare (Turner, 2008). Spinifex is highly flammable however fire spread in spinifex grasslands often requires wind speeds to spread flames at a low angle over the hummocks (Turner, 2008; Edwards et al, 2008; Marsden-Smedley et al, 2012). Shrublands and low woodlands, often dominated by mulga, are generally less fire prone (Edwards et al, 2008; Marsden-Smedley et al, 2012).

Section 9.4 the impacts of weeds, particularly Buffel grass is discussed due to its high effect on vegetation composition and fuel loads.

8.3.3. Fire and climate change

The effects of climate change and fire are discussed in more detail in Section 9.6. Different climate models differ in their predictions of rainfall in the GVD. Any increase in rainfall may exacerbate fire spread as short grasses may grow in between hummocks (Cheney and Sullivan, 2008). Decreases in bare ground between hummocks combined with extreme weather conditions may increase the flammability and fire frequency in spinifex grasslands (Burrows et al. 2006). This in turn may cause contractions in other vegetation communities such as Mulga woodlands (Nano and Clarke 2009). Mulga woodlands are particularly vulnerable to large fires as estimates indicate that Mulga take between five and 15 years to produce seed following a fire. A fire frequency less than 10-15 years may therefore prevent Mulga from reseeding, leading to a contraction or complete loss of Mulga area (Latz 1990; Williams 2003).

Climate change has the potential to produce more extreme weather events, such as heavy rainfall. Pulses of heavy rain may lead to widespread fires due to increased fuel loads and continuity of vegetation. The cumulative rainfall in the preceding 24 months has been found to be a strong predictor of area burnt (Turner, 2005).

8.4. Weeds

Across the wider SCS region weeds are not perceived to be prevalent due to the limited accessibility across most of the region. In total 16 species of weeds have been found in the SCS. See table X for a list of the weeds in the SCS.

Table X: Weeds recorded from the SCS (https://NatureMap.dpaw.wa.gov.au/, accessed 12/1/2016)

Species	Common name
Acetosa vesicaria	Ruby dock
Brassica tournefortii	Mediterranean turnip

Carrichtera annua	Ward's weed
Chenopodium murale	Nettle-leaf goosefoot
Chloris virgata	Feathertop Rhodes grass
Emex australis	Doublegee
Erodium aureum	
Erodium botrys	Long dtorksbill
Juncus bufonius	Toad rush
Malvastrum americanum	Spiked malvastrum
Proboscidea louisianica	Purple flower Devil's claw
Schinus molle var. areira	
Sisymbrium orientale	Indian hedge mustard
Sonchus oleraceus C	Common sowthistle
Spergularia diandra	Lesser sand spurry
Tribulus terrestris	Caltrop

Another highly invasive weed, *Cenchrus ciliaris* Buffel grass, is present around Tjuntjuntjara just to the south of the GVD and within the Great Victoria Desert Nature Reserve. The management of Buffel grass has been listed by the Spinifex Rangers as their highest priority activity in their Healthy Country Plan due it potential to completely alter ecosystems and increase the fuel load for fires. It can form single-species stands and out compete native plant species, threatening native animal species through displacement of native vegetation (Martin et al. 2015). Buffel grass occurs within a fairly contained area around the community and in isolated patches alongside roads, so could be eradicated with a commitment of resources and ongoing management. Currently there is an initiative called “Buffel free GVD” led by the Ten Deserts Initiative which aims to substantially control and reduce buffel grass across the 6 IBRA subregions of the GVD. In parts of the South Australian GVD buffel grass is highly prevalent and the risk of further invasions into the WA. Under WA legislation Buffel grass is not a declared weed however South Australia declared it in in 2015 acknowledging not only that it is highly flammable but also is ‘transformer’ weed in that it can change the character of vegetation over wide areas (Bastin et al. 2008). Buffel grass, an African grass, is now highly prevalent across many parts of Australia. Pastoralist have intentionally spread Buffel seed, as a pasture crop, due to its effectiveness as a colonizer, high yield and drought resistance making it an ideal pasture for arid regions.

Saffron Thistle (*Carthamus lanatus*) has also been recorded in a few populations within 100 km of Tjuntjuntjara. Saffron Thistle is a Declared Pest plant in Western Australia.

Most flora studies in the area have found only very isolated and low numbers of weeds (e.g. ecologia 2005), but as vehicular traffic increases with mineral exploration and mining activity and with an increased numbers of tourists driving through, the potential for introduction of new weed species and increased populations exists.

8.5. Mining

Whilst mining contributes in many ways to a region economically it brings with it many potential impacts on biodiversity.

There is direct land clearing associated with mine sites, this includes the pit, tailing dams, resource sumps, processing facilities and offices. There’s also clearing associated with facilities, airplane strips and accommodation for staff. Along with the mine site there is clearing associated with road development. Roads are constructed to transport equipment and materials needed for the mine operations. In addition tracks are cleared or ‘driven over’

to reach new exploration areas. All of this clearing has the potential to disturb species directly, alter hydrology, increase contaminants, increase weed invasions and increase dust in an area. These factors may influence the ability of some species to survive and the vegetation composition in an area.

Whilst many of these impacts are a necessary result of mining activities, mining companies have programmes to minimise these impacts such as storing top soil, rehabilitating areas and minimising disturbance footprints.

Mining operations also have the potential to impact the hydrogeology of an area, especially in areas where deep pits are constructed and pits are not rehabilitated following the cessation of mining operations.

Mine sites also have a substantial impact on feral animal numbers. Feral animals use the roads to cross the landscape, potentially increasing their range and impacts on vulnerable species. Mine sites also increase the availability of water, which can dramatically increase herbivore numbers.

Many mine sites have problems with feral animals, particularly wild dogs and dingos, are their ability to destroy fencing to access food waste sites. Increase in food availability can increase the breeding rates of these predator species, which in turn impacts many of the native species in the vicinity of the mine

Mine site and the exploration activities associated with mining operate under strict environmental conditions set out by the federal Department of the Environment and by state government agencies including the Environmental Protection Authority, the Department of Mines and Petroleum and the Department of Parks and Wildlife. Whilst many mining companies actively seek to control the adverse environmental impacts created by a mine many are unavoidable or require continual learning and adjustment to achieve the best environmental outcomes.

8.6. Climate change

Most reports on climate change for the SCS are contained within wider reports for arid regions of Australia and contain very generalised predictions, with varying levels of confidence, about how the climate will change in the next 50 years.

8.6.1. Temperature

Temperatures have been rising in the Rangelands over the last century, with 0.9°C measured in the south Rangelands between 1910 and 2013. Continued substantial increases in temperature are projected, with very high confidence, with estimates of 0.6 to 1.4°C increase by 2030. By 2090 the rise is expected to be 1.3 to 2.6°C in the south Rangelands area (Watterson et al 2015).

The increases in temperature are also predicted, with very high confidence, to increase the temperatures reached on the hottest days, the frequency of hot days and the duration of warm spells (Watterson et al 2015).

Heat waves have led to catastrophic avian mortality events in hot desert environments (Mc Kechnie and Wolf 2009). Heat waves increae water requirements in many small birds by

150-200%, reducing their ability to survive extremes in hot weather (Mc Kechnie and Wolf 2009).

8.6.2. Rainfall

Watterson (2015) wrote a climate change report for the Rangelands cluster of Australia. The Rangelands cluster is defined as the region stretching across most of inland Australia but also encompassing coastal areas of Port Hedland, Carnarvon and the great Australian bite in the far south of Western Australia and across to South Australia. The SCS region is in the southern area of the Rangelands cluster. The report predicts less rain in the winter and spring with natural variability as the major driver of rainfall changes by 2030 with a range of −20 % to +10 %. By 2090, the report predicts with high confidence decreases in winter rainfall in the range of −45 % to 0 %. Changes in summer and autumn rainfall cannot be reliably projected. The uncertainty associated with these seasons highlights the unknowns in determining whether the region will become drier or wetter in the future. Watterson (2015) predicts, with high certainty, that the intensity of heavy rainfall will increase.

8.6.3. Wind

In terms of wind, there is medium confidence that in the southern rangelands surface wind speed will decrease in winter.

8.6.4. Solar radiation and humidity

In terms of solar radiation and humidity, little change is predicted up until 2030. For 2090, an increase in winter radiation is predicted, which is related to decreases in cloudiness and reduced rainfall. For 2090, humidity is expected to decrease through all months with a high confidence of a decrease in winter and spring.

The report predicts, with high confidence, a harsher fire weather climate due to higher temperatures and lower rainfalls. Bushfires, when they occur, are predicted to demonstrate more extreme fire behaviour (Watterson, 2015).

8.6.5. Effects on biodiversity

With the predicted changes described above, it is important to understand how these changes may impact species, particularly those with small ecological niches. Smyth and colleagues (2012) found that fine-scale variability in the arid landscape is critically important for many ecological processes and that there are low levels of local and regional buffers for most area. This highlights the importance of maintaining environmental heterogeneity in the landscape (Smyth et al 2012).

It is predicted that for less mobile species, places of such as ranges, rocky outcrops, paleodrainage systems, lakes, groundwater-dependent ecosystems, and outlying pockets of spinifex are already important, and will become more so (Dickman et al, 2001; Pepper et al, 2011). It is important to understand the role of these areas and other vegetation communities as refugia in changing environmental conditions.

Several small mammals use physiological mechanisms such as torpor to conserve water and energy and use deep burrows to buffer against climate extremes. Climate change has the potential to cause large impacts on species which depend on climate for food and shelter resources. If resources decline, species can become localised in refugia, where predator numbers are low and food resources are available (Dickman et al 2011).

8.7. Access

There is no literature on the threats posed by increased access, or lack of access as a threat, other than cursory mentions of the potential for vehicles associated with mining operations, or tourist use of roads opened for mining access, in transporting weeds. Limited road access was mentioned by some authors as a restriction on site selection for flora and fauna surveys.

Lack of access is a threat to maintenance of Indigenous culture which, in turn, threatens the health of the environment through a number of factors including lack of physical access to country and lack of cultural access to country (even in the presence of physical access) as younger generations are without sufficient knowledge of country to be able to access and manage it.

The contrary argument suggests that increased access, particularly through the construction of roads has a large potential to increase the distribution of weeds which often respond well in disturbed areas and are frequently transported from vehicles travelling through different regions. Feral animals have also been found to use tracks to traverse a landscape. Increased access therefore has the potential to increase the distribution of feral animals in the SCS region.

9. Conservation management

Understanding the conservation management actions needed for the region involves analysing existing plans prepared by different stakeholders for different purposes, and understanding how those plans can be utilised for understanding and protecting biodiversity in the SCS.

9.1. National Government / National Plans

In terms of national, government endorsed documents there are several key documents for threatened species and for managing key threats.

The Threatened Species Recovery Plans for fauna of conservation significance in the SCS include:

- Recovery Plan for the Sandhill Dunnart (Churchill 2001), currently being updated;
- Conservation Advice for the *Sminthopsis psammophila* (Threatened Species Scientific Committee, 2015).
- National Recovery Plan for Malleefowl (Benshemesh 2007);
- Recovery Plan for the Great Desert Skink *Liopholis Lipholis kintorei* 2001-2011
  (McAlpin 2001);
- National Recovery Plan for the Greater Bilby *Macrotis lagotis* (Pavey 2006);
- Recovery Plan for marsupial moles Notoryctes typhlops and N. caurinus, 2005-
  2010 (Benshemesh, 2004).
- Action Plan for Australian Birds (Garnett *et al* 2010); and
- Action Plan for Australian Reptiles (Cogger *et al* 2000)

The Threatened Species Recovery Plans provide a detailed description of knowledge about threatened species. The outline prioritised actions that should be undertaken at both a regional and local scale. The Plans provide some guidance to the estimated costs of different actions.

The several of the key threats to biodiversity, outlined in section 9 also have Threat abatement plans (TAPs) and national action plans.

These include:

- Threat Abatement Plan for predation by the European red fox (DEWHA, 2008).
- Threat Abatement Plan for predation by feral cats (Department of the Environment, 2015).
- Threat abatement plan for competition and land degradation by rabbits (DEWHA, 2008)
- National Feral Camel Action Plan (2010)

The TAPs include measures on how to:

- protect areas not currently affected by the threat
- protect species impacted by the threatening process
- better understand the threatening process and thereby manage its impacts and interactions with other native species
- to bait / control the populations of threatening species.

The TAPs also outline the importance of educating and collaborating with stakeholders. The detailed planning and costings in these plans can be utilised to guide planning activities to target threatening processes.

9.2. Western Australian government plans

The WA State government also has several plans which encompass the SCS region. These include:

- Goldfields Region: Regional Management Plan (1994-2004) – DPAW
- Draft Goldfields-Esperance Regional Planning and Infrastructure Framework (Department of Planning, 2014) – DOP

9.3. Fire Management

Defining optimal fire regimes for the GVD is difficult due to the limited ecological knowledge on plant species, seed biology, and habitat and food requirements of animals (Marsden-Smedley 2012). Fire regimes impact on species individually rather than on vegetation-habitat as a whole. The maturation of species as well as factors that influence time to maturity also effects the timing of fire management regimes. Without fire, floristic composition of an area is likely to shift over time.

The DPaW plan includes information on fire management in the region. DPaW also publishes '*Indicative Annual Prescribed Burn Programs'* which outline the Department's planned prescribed burns for the year. Fire management typically concentrates on conducting aerial burning and hand prescribed burns on Goldfields nature reserves.

Burrows and Hamilton (2006) proposed a model to have about 30% of the landscape in the early post-fire stage (<=6 years), about 35% in the intermediate post-fire seral stage (7-18 years) and about 35% in the late post-fire seral stage (19-45 years) They also proposed breaking up areas of younger vegetation as they reach the age where they can carry a fire, rather than targeting the relatively few remaining areas of long unburnt vegetation (Burrows and Hamilton 2006). Leaving some large areas unmanaged to compare to the area where (planned) fire is introduced was also recommended.

Some suggestions made include small scale spring patch burning with clear conservation objectives applied in areas where communities and species have specific fire requirements. Pearson (1994) conducted detailed fire studies in Queen Victoria Springs Nature reserve. As a result Pearson (1994) suggests targeting high productivity sites such as paleodrainages to encourage heterogeneity, and leaving other areas under “natural fire regimes”. Clear objectives and comprehensive monitoring pre- and post-fire would be required.

The lack of knowledge on the complex interactions between fire and climate, vegetation and land use is seen as a critical gap in developing appropriate management actions for biodiversity conservation (Duguid et al, 2009).

Aboriginal fire management is believed to have produced a finer-scale mosaic of post-fire ages than occurs at present (Burrows et al, 2006) however this is contested by other authors who suggest that the size of areas burnt was diverse and fine scale burning was conducted relative to the location of a foraging area and proximity to water (Bird et al, 2008).

9.4. Traditional Owners Planning

In the north of the SCS, the Ngaanyatjarra council has developed the Ngaanyatjarra IPA management plan (declared 2002). The Ngaanyatjarra IPA covers 98,129 km^2 (though only a small proportion of this is in the SCS. Major conservation actions in the this plan include the national Feral Camel Control Program, patch burning and maintaining the network of bores and hand pumps which allow the Ngaanyatjarra people to travel safely through their lands (http://www.ngaanyatjarraku.wa.gov.au/ accessed March 2016).

The Spinifex people have developed a Healthy Country Plan for their traditional lands. The aim of this plan is to articulate the aspirations for the management of natural and cultural values including threatened species and the inter-generational transfer of cultural knowledge for Spinifex Country (http://www.rangelandswa.com.au/ accessed March 2016). The Healthy Country Plans allows the Spinifex Rangers to set their priorities and manage the landscape accordingly. Existing management plans for the Spinifex land and assets include:

- Spinifex Country Strategic Property Management Plan (Pennington, 2012)

9.5. Mining Management Plans

Mining proposals or other significant projects that are likely to have an impact on the natural and cultural values of an area are often required to develop management strategies to protect these values and the species of conservation significance within the impact area. Whilst these management plans are localised, their management actions provide insights that may be applicable to the wider landscape.

Some of the plans currently developed include:

- Draft Goldfields-Esperance Regional Planning and Infrastructure Framework
- Tropicana JV Threatened Species and Communities Management Strategy
- Tropicana JV Cultural Heritage Management Strategy
- Tropicana JV Environmental Monitoring Strategy
  Tropicana's environmental management documents are all publically available at: http://www.tropicanajv.com.au/irm/content/management-strategies1.aspx?RID=475
- APA Operations – the Eastern Goldfields Pipeline Project – Threatened Species Management Plan
- The PER for the Mulga Rock Uranium Project which included:
  - camera trapping protocol for Sandhill Dunnarts (Vimy, 2015)
  - a fauna assessment for the Malleefow (Vimy, 2015)
  - updated report on the Southern Marsupial Mole (Ninox Wildlife Consulting, 2015)

9.6. Research and Adaptive Management Plan

Following several workshops on threatened species in late 2014, the Trust has developed Research and Adaptive Management Plans (RAMPs) for the Sandhill Dunnart and the Malleefowl in the SCS region. These plans, utilising expert knowledge from over 50 participants, outline priorities both in terms of research needed and on-ground management activities required to protect the species.

9.7. Key management research

Over the past decades, some important studies have taken place in the SCS. These studies point to key research and land management activities that should occur in the region.

Pianka (1996) suggests that different lizard species respond differently to fire with some populations recovering quickly and some going locally extinct. Pianka (1996) recommends long-term studies on lizards are needed to document changing relative abundances in the fire succession cycle.

Research on camels suggests the population is increasing by approximately 10% per year suggesting that there will be progressively more pressure from grazing over time if no control is undertaken (Edwards et al 2004). This suggests that approximately 10% of the camels need to be removed annually to maintain the stability of the population as numbers can double every six to eight years. Camel distribution is closely associated areas of high productivity associated with drainage patterns and certain land forms (Ward, 2007). Utilising this knowledge has important implications for the design of surveys and culling activities. The most commonly used culling techniques are aerial and ground shooting. These methods are most effective when conducted systematically rather than opportunistically (Giustiniano, 2007). Some indigenous people are not in favour of aerial culling, and so management may need to include other methods such as fencing off important sites. Live wild harvesting for commercial sale has been attempted in some areas, but the remoteness and access issues in the SCS may preclude this management method.

10. Conclusions

The SCS is a vast region, much of which is yet to have any intensive survey or research effort. Information presented in this plan represents the best available knowledge, from the stakeholders engaged with during the development of the document. Not all stakeholders in the region were contacted or provided information. This represents a potential gap in the report.

In addition, some of the information presented in the report refers to arid areas generally as it was not available for the SCS specifically. This is an unavoidable limitation of the report.

These limitations mean there is a huge potential for large changes in the biodiversity knowledge of the region as more research is conducted and further surveys are undertaken, whether through mining activities or organisations such as the Great Victoria Desert Biodiversity Trust.

This plan represents the first iteration of bringing together existing knowledge of the region including bringing together existing plans and on threatened species in the region. Building on this knowledge is vital to understanding the changes and challenges facing biodiversity in the region.

The next stage of this process will involve extensive consultation with stakeholders to gain their knowledge, perspectives and priorities for the region in terms of biodiversity and its management. This next stage is called the 'Adaptive Management Implementation Plan' and it will be appended to this document when completed.

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