FITZGERALD BIOSPHERE REVIEW

The state of knowledge of the Fitzgerald Biosphere

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Paula Deegan

2006

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Foreword

This report was prepared to summarise the available information on the nature of the Fitzgerald Biosphere area. It is a result of a project initiated by the Friends of the Fitzgerald River National Park, administered by the Fitzgerald Biosphere Group and funded by Lotterywest. The project also produced a searchable bibliographic database in Filemaker format on CD and intended to be made available through the websites of the Fitzgerald Biosphere Group and the GondwanaLink partnership.

It was originally intended that this report would provide a summarised overview of all research findings for the Fitzgerald Biosphere area, together with recommendations for future research and monitoring. The number of references (nearly 400) and the range of topics, detail and accessibility of some of those references made summarising all the available information a very arduous task and beyond the capacity of the project's resources. Making recommendations for research and management, while still considered a priority, was not possible without a comprehensive and participative process that allowed the objectives for future management of the Biosphere to be determined by all stakeholders. The project has, however, provided a basis for that process to now occur with a clearer understanding of the available knowledge for this special part of the world.

Many of the references unearthed during the course of the study were difficult to find and, wherever possible, copies have been made and are now housed at the office of GondwanaLink, 146 Aberdeen Street, Albany. This will assist researchers, students and others interested in furthering their own knowledge of the Fitzgerald, or to follow up on information in this report.

The report and bibliography are as complete as the project resources allowed, but there are undoubtedly other references relevant to the area that are yet to be uncovered. Additions to the bibliography are encouraged.

Paula Deegan
Project Officer
2006

Acknowledgements

Many people assisted in the completion of this project. Special thanks are due to the members of the Friends of the Fitzgerald River National Park, especially Angela Sanders, Andrew Chapman, Gil Craig and Nathan McQuoid; Ross and RhondaWilliams, Joanna Tomlinson and Katrina Sait from the Fitzgerald Biosphere Group; Keith Bradby and Amanda Keesing from GondwanaLink; Sarah Comer and Lisa Wright from the Department of Conservation and Land Management; Margaret Triffit from the WA Museum Library; Ron Wooller and his colleagues at Murdoch University; David Jan from the South Coast Regional Initiative Planning Team (SCRIPT), particularly for assistance with the database development; and Faye Overheu from Lotterywest.

1. INTRODUCTION

The Fitzgerald Biosphere[1] is situated on the central south coast of Western Australia. It has a land area of around 1.4 million hectares and includes around 250 km of coastline (Map 1). It consists of all of the Shire of Jerramungup, part of the Shire of Ravensthorpe west of the Rabbit Proof Fence, and the northern parts of the Fitzgerald and Gairdner River catchments that lie in the Shires of Kent and Lake Grace (RAP and SCRIPT 1997).

The region is characterised by a complex geology, including the ancient granite of the Yilgarn Craton, coastal granites of the Albany Fraser system, the quartzites of the Barren Ranges, the greenstone system of the Ravensthorpe Range, marine plains of spongolite overlain by laterite rock, and coastal dunes. Several south-flowing rivers incise the Yilgarn block and marine plains, and form estuaries that are normally only seasonally or infrequently open to the Southern Ocean.

The region has a rich floristic diversity that was noted soon after European exploration of the south coast began. Several maritime expeditions to the south coast in the late eighteenth and early nineteenth centuries included naturalists who made observations and collected specimens of plants and animals. Early botanical collectors, such as William Baxter in the 1820s, and James Drummond, who visited the Fitzgerald River area in the 1840s, began to identify a vast array of species, many endemic to the area.

Pastoralism began in the area around 1849, with John Hassell's settlement at Jerramungup ('Jarramongup'), followed soon after by John Wellstead at Bremer Bay and John Dunn at Cocanarup. The towns of Ravensthorpe, Hopetoun and Kundip were surveyed in 1901 after gold was discovered nearby.

Alienation and clearing of land for agriculture proceeded rapidly after the Second World War, and today a little over half of the land area has been alienated, with nearly 80% of that area cleared of native vegetation and under crops or pasture, with an increasing area under timber plantations.

The remaining uncleared land includes the Fitzgerald River National Park, considered by Chapman and Newbey (1995b) to be one of the most important reserves in Western Australia for its rich diversity of flora and because it provides refuge for several fauna species that have become rare or endangered because of the widespread loss of their former habitats. Other largely intact areas within the Biosphere include the Ravensthorpe Range, coastal and river corridors. There are a number of nature reserves including Corackerup and Peniup Nature Reserves on the western edge of the Biosphere, and timber reserves, such as Cocanarup.

While the significance of the Biosphere's natural values are being increasingly recognised, its biodiversity continues to be threatened by some agricultural practices, expansion of mining, fire, dieback, salinity, climate change, and pressure from coastal

[1] Section 2 discusses Biosphere Reserves and the use of the term "Fitzgerald Biosphere" in this report.

development and recreation. In response to these threats, there are also some ambitious and innovative actions taking place including the Gondwana Link project[2].

1.1 The Fitzgerald Biological Review Project

Throughout the 1960s and 1970s, there were contentious proposals to mine areas of the Fitzgerald River National Park for lignite and for manganese, and to release additional Vacant Crown Land in the North Fitzgerald area (since included in the National Park) for agriculture. Opposition to these proposals came from local people, scientists and some government departments but highlighted the lack of understanding and documentation of the Fitzgerald's significance for conservation. In 1978, the National Park area was nominated and listed as an International Biosphere.

In 1980, a meeting at the Department of Conservation and Environment in Perth proposed that the National Parks Authority should prepare a document to summarise the existing knowledge of the Fitzgerald River National Park and for "clarifying the reasoning behind the Park's classification as an International Biosphere Reserve" (Muir, 1980). An additional reason for the document was to identify further research needed to assist in management of the Park.

The resulting document was prepared by Barry Muir and highlighted the dearth of biological data for the Park. Muir identified two main problems that contributed to this paucity of knowledge: the unavailability of data from research that had been undertaken, including vegetation and geological surveys; and the "almost total lack of knowledge of certain faunal groups" (Muir 1980).

Muir's report also noted that, despite the land use controversies generating discussion about the "important" areas within the Park, no real attempt had been made to identify a basis for determining priority areas. The report therefore included work by Ken Newbey, who had been studying aspects of the soils, landforms and flora since the early 1960s, and who developed a series of hand drawn maps that attempted to rank areas systematically on criteria such as species richness, diversity and rarity.

Following the production of the report, the Fitzgerald River National Park Association received a funding grant from the WA Heritage Committee that allowed a two-year biological survey to be undertaken in 1985-1987 by Ken Newbey and Andrew Chapman (Chapman and Newbey, 1987a, 1987b, 199b). Other studies into the biology of the Park have since been conducted but, as Muir observed in 1980, many research studies are conducted in relative isolation and the findings are sometimes

[2] Gondwana Link is a landscape scale vision involving individuals and groups working together to achieve reconnected country across south-western Australia in which entire ecosystems, and the ecological processes that underpin them, are restored and maintained. The Gondwana Link groups are doing this by restoring ecological connectivity across south-western Australia, from the woodlands of the drier interior to the tall wet forests in the far south-west corner; protecting and re-planting bushland over more than 1,000 kilometres; and building a living link that reaches eastward across the continent. More information, including how to participate or support the project, can be found at www.gondwanalink.org

difficult to access. There has been no further attempt made since 1980 to collate the various studies in the area, or to assess their implications for management.

The Fitzgerald River National Park Association later became the Friends of the Fitzgerald River National Park (FFRNP) and continued trying to improve the state of knowledge of the Park. Recognising that the management plan for the National Park and the Department of Conservation and Land Management's South Coast Regional Plan is due for review, in 2004 the FFRNP joined with the Fitzgerald Biosphere Group Inc and obtained funds through Lotterywest to review the physical and biological knowledge of the wider Biosphere area.

The aims of this project were to:

1. document the biological studies, both terrestrial and marine, that have occurred in the Fitzgerald Biosphere since the review by Muir (1980);
2. digitally map the locality of research sites;
3. identify key outcomes of research in the Fitzgerald Biosphere and present the information to the public; and
4. document future research needs.

It was intended that the review would form the basis for identifying the research required to improve understanding of ecological processes in the Biosphere, and the future monitoring and evaluation requirements.

Most importantly, the review would produce a bibliographic database that would help to make information on the Biosphere more widely accessible to students, researchers, land managers and planners, and the local community. In turn, it was intended that this may encourage further research to be undertaken to help conserve the area's natural values in the long term. The database, which has been produced on CD and is also available through the Gondwana Link website (www.gondwanalink.org) is intended to be updated regularly, and contribution of additional reference information is invited.

Information sources and accessibility

A fairly broad definition of "scientific research" was used in the project, and any information relevant to the physical and biological nature of the Biosphere has been included. This included published and unpublished sources.

Information was sourced through several means:

- personal contacts with people known to have worked within the Biosphere or likely to have knowledge of studies undertaken;
- requests to Government departments both within the region and in Perth for access to files and reports;
- searches of the WA Museum, Department of Conservation and Land Management, University of WA, and Murdoch, Edith Cowan and Curtin University libraries; and
- internet searches.

Responses to requests for information were varied, and the limitations on time and resources for the project meant that some potential sources of information were

unable to be fully explored. Publication of the bibliographic database and report at this time may prompt additional responses which can be incorporated into future revisions.

1.2 About this report

This report outlines the state of knowledge by referring to studies, surveys and other work undertaken, and provides a brief overview of the available information. It does not provide detailed reviews or a full synthesis of all information available. The report is intended to be accessible to a wide audience – scientists, land managers, students and any one with an interest in this area of the south coast – and, by providing an extensive reference list and the bibliographic database, to encourage further exploration of the wonders of the Fitzgerald Biosphere.

What the report does not include:

Taxonomic studies.
A region as rich in species of flora and fauna, and with such a high representation of endemics and hybrids as the Fitzgerald Biosphere, inevitably attracts considerable attention from plant and animal taxonomists. Many taxa have been collected in the area and are still awaiting description. The resource limitations in the current project precluded taxonomic studies being included here, although some examples are shown as reminders of these additional sources of knowledge. Instead, some appropriate website links to floristic and faunal databases that allow searches to be made of taxonomic data on a geographic basis have been included.

Indigenous knowledge.
There were many thousands of years of human life in this environment before European settlement, and the indigenous peoples of the south-west of WA are probably among the most dispossessed and displaced people in Australian history. Despite this, the Noongar culture has survived and includes knowledge of the natural environment that developed through that long and close dependence of people on their land. Any sharing of that knowledge through documentation or other means is the right of the Noongar people themselves. This project and report therefore do not attempt to discuss Noongar culture or history, other than to acknowledge that a full picture of the Biosphere's natural history is incomplete without Noongar participation.

History of European exploration, land settlement and agricultural development.
The natural environment of the Fitzgerald Biosphere has been subject to huge changes since European settlement began in the area and some of the papers included in this review relate to particular impacts of clearing, changed fire management and the introduction of alien species. To understand these changes, and the changing perceptions of the values of the area, requires a more thorough review of the historical, political and social events of the past 200 years: from first observations by early European explorers; the land release period of the 1950s and 1960s; the efforts to secure the Fitzgerald

River National Park from mining and extend its area; the heart-breaking events of the 1980s when land degradation particularly through wind erosion was devastating for many landowners; the subsequent growth of the landcare movement within the rural communities of this region; and more recently the impetus for conservation through investment of private funding, many hours of volunteer efforts, and an emphasis on establishing environmentally-benign commercial industries using native plant products.

There are several documents that cover parts of this history. The history of the Fitzgerald River National Park has been well documented by Keith Bradby (1989) in "Park in Perspective", and the growth of the Fitzgerald Biosphere concept in Thomas (1989), Switzer (1988) and the Fitzgerald Biosphere Project (1989).

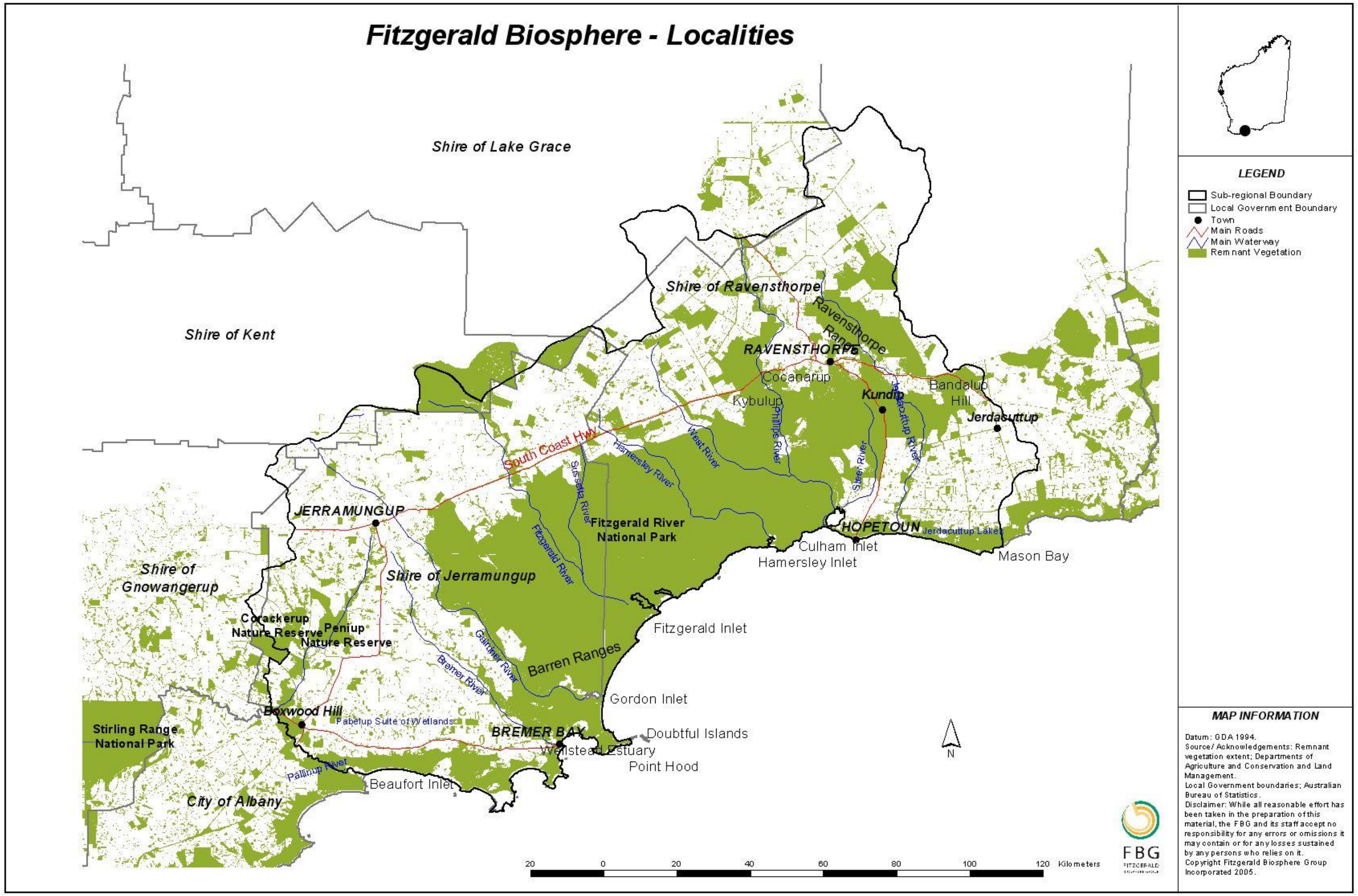
The documentation of agricultural research and studies relevant to the Fitzgerald area is also not within the scope of this report. The Fitzgerald Biosphere Group Inc and its eastern neighbour, the Ravensthorpe Agricultural Initiative Network (RAIN), continue to work on developing and implementing better farming systems that treat the land and its people more kindly.

1.3 Future research priorities

The project included in its original aims the documentation of future research needs and some assessment of their priorities. It will become apparent from reading this report than there are many areas in which research and other knowledge is sparse. However, identifying priorities for research is a more complex task than could have been undertaken with the resources available to the project. Even identifying gaps in knowledge is a large task and would evoke different responses from, for example, scientists, land managers or other interested individuals. It is hoped that the report will provide some stimulus for the different interests to identify what knowledge is available to them and can therefore perhaps be used to assist in better managing the Biosphere area now and provoke some discussion on what additional studies need to be encouraged and supported in future.

1.4 The Fitzgerald Biosphere Collection

Gathering the wide range of papers and reports that comprise the reference lists for this report was a time-consuming and sometimes frustrating process. Some papers, while included in the reference list, have not been located. To encourage wider use of the material, a physical collection of all the papers that were located has been assembled and will be housed in the Gondwana Link office in Albany.


Fitzgerald Biosphere - Localities
Shire of Lake Grace
Shire of Kent
Shire of Ravensthorpe
Ravensthorpe Range
RAVENSTHORPE
Cocanarup
Kybulup
Kundip
Bandalup Hill
Jerdacuttup
South Coast Hwy
Hamersley River
West River
Phillips River
Steer River
Jerdacuttup River
Susetta River
Fitzgerald River
Fitzgerald River National Park
JERRAMUNGUP
Shire of Jerramungup
Shire of Gnowangerup
Corackerup Nature Reserve
Peniup Nature Reserve
Gairdner River
Bremer River
Barren Ranges
HOPETOUN
Jerdacuttup Lakes
Culham Inlet
Hamersley Inlet
Mason Bay
Fitzgerald Inlet
Gordon Inlet
Doubtful Islands
Point Hood
Wellstead Estuary
BREMER BAY
Boxwood Hill
Pabelup Suite of Wetlands
Pallinup River
Beaufort Inlet
Stirling Range National Park
City of Albany
N
20 0 20 40 60 80 100 120 Kilometers
LEGEND
Sub-regional Boundary
Local Government Boundary
Town
Main Roads
Main Waterway
Remnant Vegetation
MAP INFORMATION
Datum: GDA 1994.
Source/ Acknowledgements: Remnant vegetation extent; Departments of Agriculture and Conservation and Land Management.
Local Government boundaries; Australian Bureau of Statistics.
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Map 1

2. BIOSPHERE RESERVES

The concept of biosphere reserves was initiated under UNESCO[3]'s Man and the Biosphere (MAB) Program which began in 1970. One of the MAB's main objectives was to balance the sometimes conflicting goals of conserving biological diversity, promoting economic development and maintaining associated cultural values. The world network of Biosphere reserves are sites where this objective is intended to be tested, refined, demonstrated and implemented.

Each biosphere reserve is intended to fulfil three basic functions:

- a conservation function - to contribute to the conservation of landscapes, ecosystems, species and genetic variation;
- a development function - to foster economic and human development which is socio-culturally and ecologically sustainable;
- a logistic function - to provide support for research, monitoring, education and information exchange related to local, national and global issues of conservation and development.

Reflecting these three functions, biosphere reserves are organized into three interrelated zones, known as the core area, the buffer zone and the transition area. Only the core area requires formal legal protection. A number of biosphere reserves simultaneously encompass areas protected under other systems (such as national parks or nature reserves) and other internationally recognized sites (such as World Heritage or Ramsar wetland sites).

Biosphere Reserves are not covered by an international convention but at the International Conference on Biosphere Reserves, held in Seville (Spain) in 1995, a statutory framework for their management was developed. Also arising from this conference was the “Seville Strategy”, which identified key directions and “implementation indicators” for biosphere reserves to fulfil properly their three functions.

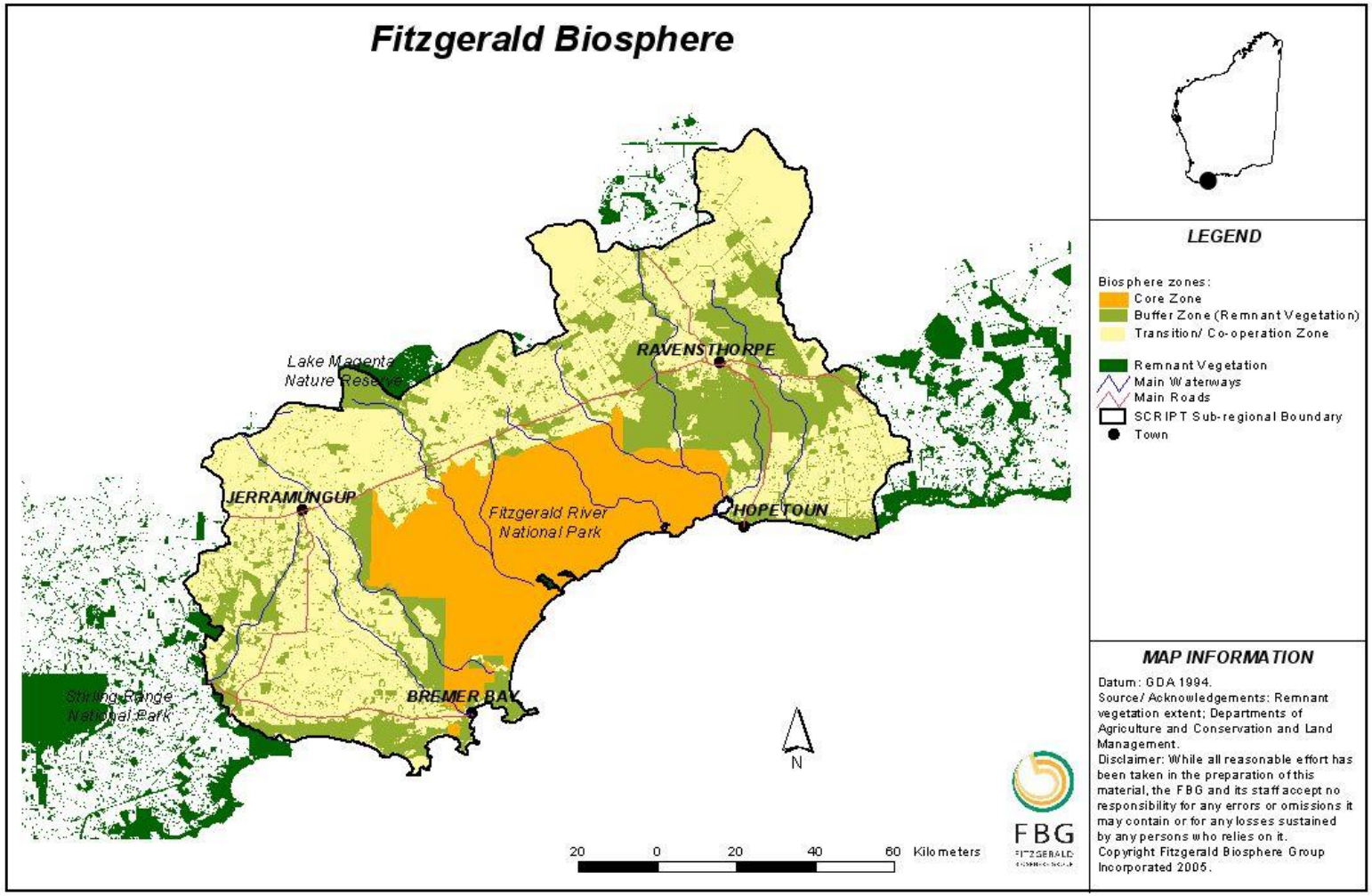
2.1 The Fitzgerald River Biosphere Reserve

In 1978, the area that was then included within the Fitzgerald River National Park was accepted as a Biosphere Reserve after nomination by the WA Government, primarily because of its outstanding floristic diversity. Only the area gazetted as National Park at that time was included in the nominated area, so the three zones were not identified at that time. It was not until the mid 1980s that members of the community living in the area began to question the Biosphere designation and subsequently initiated the Fitzgerald Biosphere Project (Bradby 1989). Since then, the other zones have been informally recognised by many people living within the area, particularly the transition zone, or the “zone of cooperation” which is where the social and economic activities of the region are most evident (see Map 2).

[3] UNESCO is the United Nations Educational, Scientific and Cultural Organisation

Although the official UNESCO boundary has never been revised, the term “Fitzgerald Biosphere” has therefore generally come to be accepted as applying to the larger area that includes the Shire of Jerramungup and the western part of the Shire of Ravensthorpe. This wider Fitzgerald Biosphere area is recognised as a subregion of the South Coast Natural Resource Management Region and is a convenient planning and management unit for several government departments and community organisations although, as with all “lines on maps”, some anomalies inevitably arise. In this report therefore, the term “Fitzgerald Biosphere” is used to refer to that wider area that includes the zones where human activities are dominant, including the near-shore marine environments.

More information on Biosphere reserves and the Seville Strategy can be found on https://www.fitzgeraldbiosphere.org/ the UNESCO MAB website https://www.unesco.org/en/mab


Fitzgerald Biosphere
Lake Magenta Nature Reserve
RAVENSTHORPE
JERRAMUNGUP
Fitzgerald River National Park
HOPETOUN
Stirling Range National Park
BREMER BAY
N
20 0 20 40 60 Kilometers
FBG
LEGEND
Biosphere zones:
Core Zone
Buffer Zone (Remnant Vegetation)
Transition/ Co-operation Zone
Remnant Vegetation
Main Waterways
Main Roads
SCRIPT Sub-regional Boundary
Town
MAP INFORMATION
Datum: GDA 1994.
Source/ Acknowledgements: Remnant vegetation extent; Departments of Agriculture and Conservation and Land Management.
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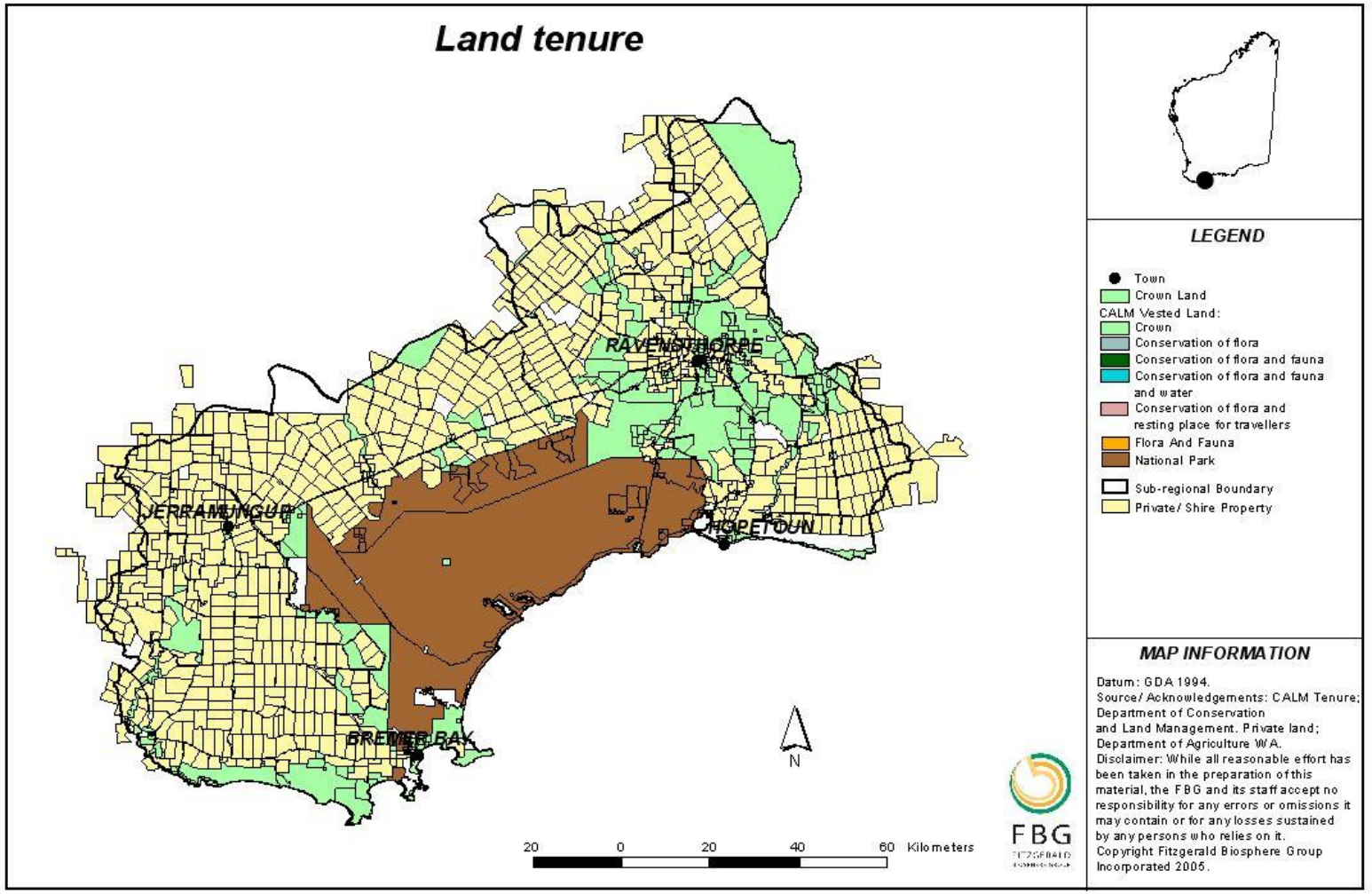
Map 2


Land tenure
RAVENSTHORPE
JERRAMUNGUP
HOPETOUN
GREEN BAY
N
20 0 20 40 60 Kilometers
FBG
LEGEND
Town
Crown Land
CALM Vested Land:
Crown
Conservation of flora
Conservation of flora and fauna
Conservation of flora and fauna and water
Conservation of flora and resting place for travellers
Flora And Fauna
National Park
Sub-regional Boundary
Private/ Shire Property
MAP INFORMATION
Datum: GDA 1994.
Source/ Acknowledgements: CALM Tenure; Department of Conservation and Land Management. Private land; Department of Agriculture WA.
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Map 3

3. CLIMATE

Many of the studies into physical and biological aspects of the Biosphere include some discussion of the area's climate. Only those providing the most detailed information, or which address specific climatic influences on other physical or biological parameters, are included in this section.

Rainfall, temperature and other statistics can be obtained from the Bureau of Meteorology website https://www.bom.gov.au/resources/data-services . This also provides some trend information, as well as details of sites for which long term records are available. Long term rainfall and maximum temperature sites within the Fitzgerald Biosphere are listed in Tables 2 and 3.

Current and historical weather data is also available through the Department of Agriculture website, including live data from the research station site north of Jerramungup (http://agspsrv34.agric.wa.gov.au/climate/livedata/jewebpag.htm).

The most thorough discussions of the climate of the Biosphere area are included in Chapman and Newbey (1995b) for the Fitzgerald River National Park, and by Overheu (2002, 2004) for the North Jerramungup – Fitzgerald and Bremer – Gairdner catchments. McCaw and Hanstrum (2003) discuss climate and weather factors of the Mediterranean south-west in relation to fire behaviour, and McCaw *et al* (1992) provides specific discussion of the weather events associated with fire behaviour during the December 1989 wildfires in the Fitzgerald River National Park. Some aspects of the cyclical patterns of rainfall over periods of decades are discussed by Clarke and Phillips (1953), McCaw and Hanstrum (2003) and Smith (1977).

Milewski (1984) also included a detailed comparison of the climate of the Barren Ranges with that of the Caledon Coast in South Africa and drew relationships between the height of vegetation and the amount of effective deep-wetting rainfall. Wooller *et al* (1998) looked at capture rates of honey possums in the Fitzgerald River National Park in relation to rainfall in the previous season and related this to nectar availability.

Esau and Lyons (2002) and Lyons (2002) discuss the effect of the changes in land surface characteristics when agriculture replaces native vegetation on cloud formation and rainfall, using the sharp demarcation between land uses at the Rabbit Proof Fence as a study area.

3.1 Climatic history

The long term (ie geological periods) climatic history of the region is important to understanding the present distributions and relationships of species and communities to their physical settings. Hopper *et al* (1996) provide a comprehensive discussion of the development of the distinctive species of the south-west, while some other papers that make reference to the influence of major climate changes on the development of the south coast's environment include Clarke and Phillips (1953), Hodgkin and Lenanton (1981), Hos (1975) and Smith (1977).

Current (or anticipated) climate change has not been studied specifically within the area, although there are numerous papers on climate change observations or modelled predictions at a state, national or global scale that are relevant to the Biosphere, and recognition of potential implications of climate change for the maintenance of species and communities is increasing. Some of the modelled predictions can be accessed through the websites of the Bureau of Meteorology (http://www.bom.gov.au/climate/change/); the Australian Greenhouse Office (http://www.greenhouse.gov.au/science/guide/); CSIRO's Climate Change Research Program (http://www.dar.csiro.au/div/CCRP/default.htm); the Indian Ocean Climate Initiative (http://www.ioci.org.au/index.html) or the Intergovernmental Panel on Climate Change (http://www.unep.ch/ipcc).

3.2 Summary

The region's climate is described as Mediterranean or Dry Mediterranean, which is characterised by cool, wet winters and dry hot summers.

The annual average rainfall varies from more than 600mm near Bremer Bay to less than 300mm inland. Rainfall decreases with distance inland and decreases from west to east. Although a winter rainfall area, some of the most significant rainfall events can occur in the summer months as the result of thunderstorms, sometimes associated with deteriorating tropical cyclones. The unpredictability of these events, and the effect of the El Niño – Southern Oscillation on early winter frontal rainfall, means that rainfall variability can be high, both from year to year and across the region within years. Some of this variability can be seen in Table 1 showing the wettest and driest years for some areas within the Biosphere.

Table 1: Mean, minimum and maximum annual rainfalls

Location	Mean (mm)	Minimum (year)	Maximum (year)
Bremer-Gairdner[1]	521	317 (1994)	732 (1971)
Upper Fitzgerald catchment[2]	398	186 (1994)	529 (1992)
Lower Fitzgerald catchment[2]	413	172 (1994)	573 (1971)
Ravensthorpe[3]	424	234 (1940)	734 (1951)

1= From Overheu (2004); driest and wettest years based on records from 1957.
2= From Overheu (2002)
3= From Department of Environment (2003)

Temperatures range from average summer highs of 29°C and winter highs of 16°C, to average summer lows of 14°C and winter lows of 6°C. Frosts are rare near the coast but can occur in winter particularly inland.

Wind is an important environmental factor, with strong north-westerly winds experienced in winter associated with the passage of cold fronts, and northerly or easterly winds in summer associated with high pressure systems in the Great Australian Bight. A south-easterly sea breeze is experienced in most coastal areas in summer.

3.3 Climate change

While there will continue to be debate and uncertainty over the extent and causes of climate change and variability, there is ample evidence that changes have occurred in rainfall and temperatures in the south-west in the last few decades. The observed changes have been summarised by the Indian Ocean Climate Initiative (IOCI, 2002) as:

- a substantial decrease in winter rainfall in the south-west of WA since the mid-twentieth century;
- pronounced decrease in May-July rainfall, whereas late winter (August-October) rainfall has actually increased, although by a smaller amount;
- a sharp and sudden decrease of about 15-20% in winter rainfall in the mid-1970s;
- a gradual but substantial increase in day time and night time temperatures in the last 50 years, particularly in winter and autumn.

There has been substantial climate change before now, and an unknown aspect of the observed changes is how much they are due to natural variations and how much is due to accelerated change due to greenhouse gas effects, atmospheric pollution or global land use changes. Despite the uncertainties, there is a general consensus from researchers on the nature, if not the magnitude, of predicted future trends. These are for a continued rise in temperatures and a likely continued reduction in winter rainfall.

The implications of these trends for conservation of nature are considerable: even if the climatic variability were to be shown to be within previous ranges of variability, the fragmented nature of the landscape now limits the resilience of natural systems to adapt. In light of this, and the other anthropogenic changes to climate, the work by Lyons (2002) and Esau and Lyons (2002) demonstrating the reduction in cloud formation over agricultural land compared to that over native vegetation, raises questions over the future prospects for influencing both climate and biological resilience through landscape-scale revegetation projects.

Table 2: Bureau of Meteorology rainfall station metadata listing

This Table has been adapted from information obtained from the Bureau of Meteorology website listing of rainfall sites and is included as an indication of the temporal and spatial spread of rainfall information that may be available. Sites have been selected for inclusion in this table if they occur *in* or *near* the Biosphere. To obtain data from these sites, refer to the Bureau's services information at http://www.bom.gov.au

Site	Dist	Site_name	ID	Start	End	Lat	Long	Source	Height (m)
009557	09A	HOPETOUN		1901	..	-33.9497	120.1258	GPS	15.0
009654	09A	BREMER BAY		1885	..	-34.3986	119.3778	GPS	20.0
009663	09A	BEDFORD HARBOUR RPF1		1957	1979	-33.8167	120.5167		
009751	09A	BREMER BAY POST OFFICE		1960	1969	-34.4000	119.4000		
009764	09A	BEDFORD HARBOUR 1		1967	1970	-33.7500	120.6000		70.0
009790	09A	YARRAMIE		1970	1972	-34.3000	119.1667		
009794	09A	BEDFORD HARBOUR		1969	..	-33.8039	120.6375	GPS	90.0
009798	09A	JERDACUTTUP		1970	..	-33.8847	120.4222	GPS	40.0
009829	09A	TALLANGATTA		1972	..	-33.8911	120.3256	GPS	40.0
009835	09A	WAYJO PARK		1963	..	-34.4033	118.9689	GPS	80.0
009837	09A	WELLSTEAD		1973	..	-34.4647	118.6528	GPS	110.0
009853	09A	QUAALUP		1921	1946	-34.2500	119.5000		
009861	09A	BEAUFORT PLN		1961	1978	-34.3833	118.8167		150.0
009865	09A	WARRA JARRA		1979	..	-34.3997	118.8867	GPS	90.0
009961	09A	HOPETOUN NORTH	HPTN	1995	..	-33.9306	120.1283	GPS	26.0
009995	09A	LAKE SHASTER		2003	..	-33.8175	120.7039	GPS	90.0
010533	10A	COCANARUP		1898	1986	-33.6369	119.8853		250.0
010541	10A	NYERILUP		1907	..	-33.8594	118.8158		280.0
010572	10A	JAM VALE		1921	..	-34.2675	118.5064	GPS	190.0
010580	10A	KAYBALLUP		1914	1986	-33.7822	119.9436		200.0
010594	10A	LAKE MAGENTA		1928	1980	-33.3333	119.1686		300.0
010611	10A	MOUNT MADDEN		1932	..	-33.2761	119.7753	GPS	310.0
010615	10A	NEEDILUP		1936	1949	-33.9833	118.8000		
010633	10A	RAVENSTHORPE		1901	..	-33.5797	120.0461	GPS	232.0
010640	10A	JERRAMUNGUP LIGHTNING		1999	2000	-33.9503	118.9203	GPS	320.0
010672	10A	JERRAMUNGUP		1895	1976	-33.9167	118.9500		300.0
010674	10A	RPF 173 MILE		1905	1955	-33.4000	120.2000		

Site	Dist	Site_name	ID	Start	End	Lat	Long	Source	Height (m)
010683	10A	KUNDIP		1923	1950	-33.7000	120.2000		
010686	10A	MUNSLEY		1973	..	-33.8272	119.2483	GPS	280.0
010689	10A	JACUP DAM		1954	2000	-33.8272	119.2483		260.0
010690	10A	NUNKERI		1954	1999	-33.4808	119.9622		280.0
010693	10A	WOOGANUP HEIGHTS		1956	1996	-33.7661	119.5583		270.0
010697	10A	CARLINGUP		1955	1961	-33.5667	120.1833		
010707	10A	JERRAMUNGUP		1962	..	-33.9411	118.9200		320.0
010709	10A	BREMER BAY POST OFFICE		1960	1969	-34.4000	119.4000		
010710	10A	BEAUFORT PLAINS		1960	1977	-34.3817	118.8233		150.0
010729	10A	CHILLINUP		1905	..	-34.3439	118.6306	GPS	104.0
010768	10A	CONNELL		1913	1936	-33.9833	118.8000		
010778	10A	STRACHANLY		1922	1942	-33.6000	120.2000		
010792	10A	GAIRDNER		1963	..	-34.1692	118.9444	GPS	180.0
010796	10A	ELVERDTON		1964	1970	-33.6333	120.1333		262.0
010811	10A	NTH RAVENSTHORPE		1968	..	-33.1806	120.0883	GPS	340.0
010817	10A	BOX GLEN		1968	1976	-34.0000	118.9167		303.6
010819	10A	KATTAGANNA		1965	1982	-33.7344	119.100		400.0
010829	10A	MAGEDUP		1908	1912	-33.9167	118.5333		
010838	10A	MARNINGARUP		1934	1941	-34.1000	119.1667		
010840	10A	MAGENTA SOUTH		1930	1933	-33.5000	119.2167		
010849	10A	MYOORA		1970	..	-34.3131	118.8281	GPS	160.0
010852	10A	LOS NEGROS		1970	1972	-33.6833	119.4500		152.0
010869	10A	CARLINGUP		1972	..	-33.5942	120.1833	GPS	150.0
010870	10A	MAINNERUP		1972	..	-33.6914	119.6619	GPS	290.0
010877	10A	COOMPERTUP		1977	2002	-33.7139	119.5403	GPS	290.0
010878	10A	CHESALON		1966	..	-33.5381	119.6564	GPS	350.0
010880	10A	GOLDEN PARK		1975	..	-34.3131	118.9894	GPS	100.0
010890	10A	GNAMMA		1983	2004	-33.6467	120.4319	GPS	210.0
010895	10A	MONTE VISTA		1968	..	-33.3994	119.9344	GPS	310.0
010896	10A	YOOROOGA		1984	..	-33.4331	120.1178	GPS	320.0
010902	10A	FITZGERALD		1989	..	-33.7781	119.5019	GPS	280.0
010905	10A	JACUP	JCUP	1993	..	-33.8878	119.1092	GPS	305.0

Table 3: Bureau of Meteorology maximum temperature station metadata listing

This Table has been adapted from information obtained from the Bureau of Meteorology website listing of maximum temperature sites and is included as an indication of the temporal and spatial spread of maximum temperature information that *may* be available. Sites have been selected for inclusion in this table if they occur *in* or *near* the Biosphere. To obtain data from these sites, refer to the Bureau's services information at http://www.bom.gov.au

Australian stations measuring air temperature — Produced: 05 May 2005

Site	Name	Lat	Lon	Start	End	Years	%
9754	METTLER	-34.5961	118.5519	Nov 1966	Feb 1997	30.3	88
9764	BEDFORD HARBOUR 1	-33.7500	120.6000	Aug 1967	Feb 1970	2.3	80
9868	MUNGLINUP	-33.7078	120.8653	May 1970	Dec 1973	3.7	91
9961	HOPETOUN NORTH	-33.9306	120.1283	Jan 1996	Apr 2005	9.3	96
10622	ONGERUP	-33.9644	118.4889	Aug 1966	Apr 2005	38.6	98
10633	RAVENSTHORPE	-33.5797	120.0461	Jan 1962	Apr 2005	43.0	87
10905	JACUP	-33.8878	119.1092	Aug 1993	Apr 2005	11.8	96
12044	CHEADANUP	-33.5547	120.6997	May 2002	Apr 2005	3.0	99
12281	MUNGLINUP MELALEUCA	-33.5969	120.7578	Apr 1975	Mar 2001	25.8	84

4. GEOLOGY

4.1 Mapping

The Fitzgerald Biosphere region is covered by the Newdegate, Bremer Bay and Ravensthorpe sheets of the 1:250,000 National Mapping Grid. The Geological Survey of Western Australia has produced geological maps at this scale using the same grid. The maps are each accompanied by notes (Thom and Chin 1984; Thom, Chin and Hickman 1984; Thom, Lipple and Sanders 1977). Notes and maps have also been published at 1:100,000 for the Ravensthorpe and Cocanarup Sheets (Witt, 1997).

An interactive GIS-based mapping system, GeoVIEW.WA, is provided by the Department of Industry and Resources and allows geological maps to be constructed at scales and for areas chosen by the user. A number of data layers are accessible. Access to this system and the resulting maps are available free of charge.
(See https://geoview.dmp.wa.gov.au/geoview/)

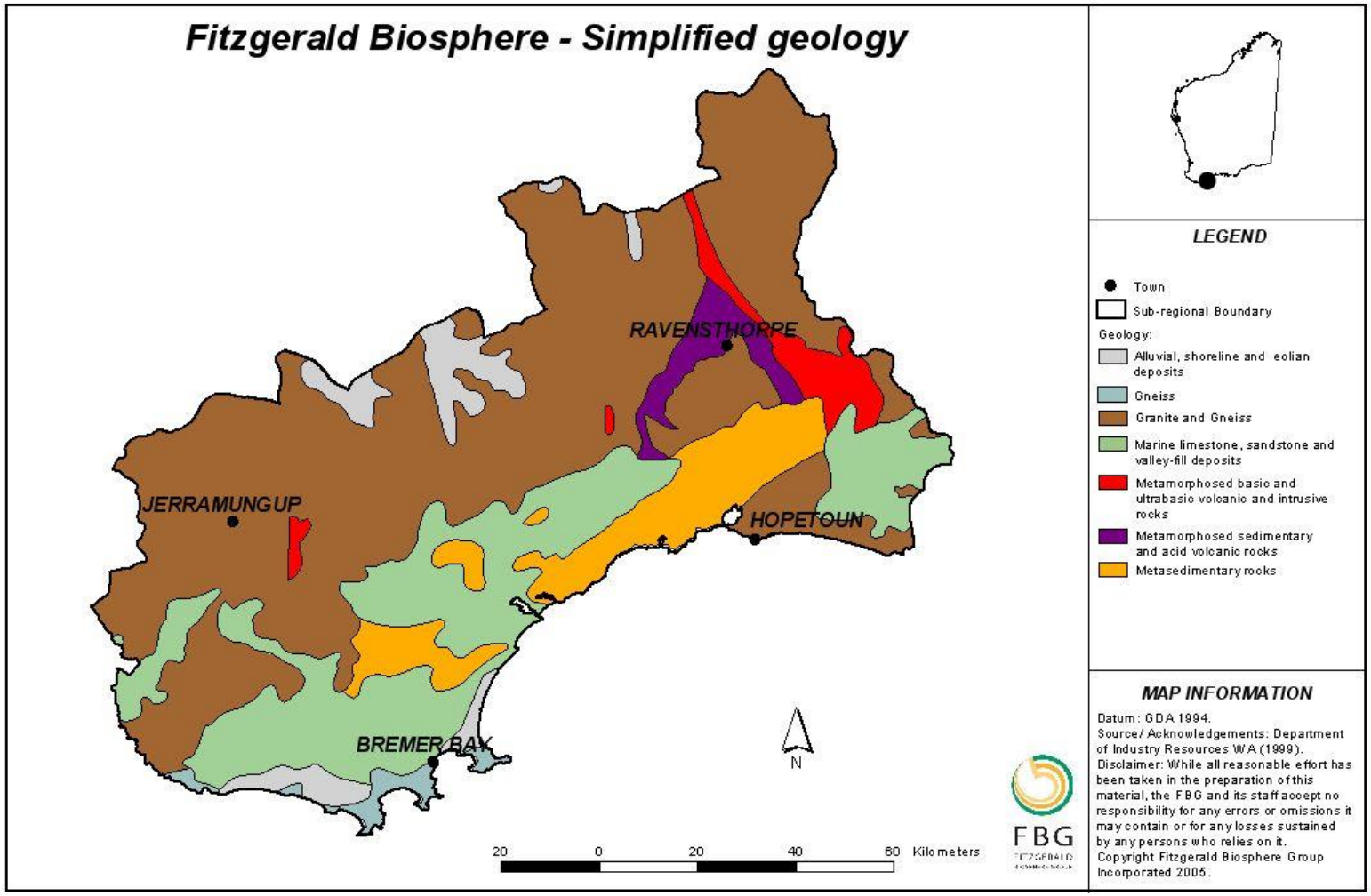
4.2 General geology and regional reviews

Clarke, Phillips and Prider (1954) described the Pre-Cambrian geology of the south coast from west of Albany to Israelite Bay.

A general description of the landforms of the south coast region, including the coastal formations and some parts of the near-shore sea floor is presented by Clarke and Phillips (1953).

Newbey's thesis (1979) gives a comprehensive overview of the geology of the central south coast, and he later summarised the geology of the Stirling Range-Ravensthorpe area, which covers most of the Biosphere (Newbey, 1985). Moir and Newbey (1995) described the physical environment, including the geology, soils and landforms of the Fitzgerald River National Park for the biological survey undertaken in the mid 1980s (Chapman and Newbey 1995). More recently, Green and Wetherley (2000) reviewed the geology and landforms and the mineral extraction occurring on the South Coast between Denmark and Eucla in a background paper to *Southern Shores 2001-2021: A strategy to guide coastal and marine planning and management in the South Coast Region of Western Australia* (South Coast Management Group, 2001).

The Geological Survey of Western Australia published a comprehensive account of the geology of Western Australia in 1990 in the third *Memoir* to be published by the GSWA in more than one hundred years. This publication provides an overview of the geological development and major geological units of WA and includes some revisions or clarifications of terminology.


Fitzgerald Biosphere - Simplified geology
RAVENSTHORPE
JERRAMUNGUP
HOPETOUN
BREMER BAY
N
20 0 20 40 60 Kilometers
FBG
LEGEND
Town
Sub-regional Boundary
Geology:
Alluvial, shoreline and eolian deposits
Gneiss
Granite and Gneiss
Marine limestone, sandstone and valley-fill deposits
Metamorphosed basic and ultrabasic volcanic and intrusive rocks
Metamorphosed sedimentary and acid volcanic rocks
Metasedimentary rocks
MAP INFORMATION
Datum: GDA 1994.
Source/ Acknowledgements: Department of Industry Resources WA (1999).
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Map 4

4.3 Detailed geological studies

JS Roe noted lignite in Fitzgerald River when travelling through the area in 1848 and after the discovery of gold near Ravensthorpe in 1899 there were several further studies made in the area, many of which were documented by Newbey (1985). The geology of the Phillips River Goldfield was comprehensively described by Sofoulis (1958), and a number of other papers written in the 1950s and 1960s described the geology of other parts of the region, or particular geological formations or rock types: for example Clarke and Phillips (1955) and Cockbain (1968) described the Plantagenet Beds generally, while Kay, Glover and Prider (1963) described its occurrence at Hummocks Beach near Bremer Bay; Cockbain and van den Graaf (1973) described the Fitzgerald River lignites; Wilson (1958) described granites and related rocks in the Jerramungup – Calyerup Creek area; Woodall (1958) describes the Pre-Cambrian rocks of the Cocanarup area; and Witt (1999) describes the Ravensthorpe Terrane unit of the Ravensthorpe greenstone belt.

Aspects of the evolution of the Mt Barren Group have been the subject of theses by Hollingsworth (1996), Stephens (1996) and Wetherley (1998). The origins or the fossil contents of some of the sedimentary formations have been investigated by Hos (1975), Darragh and Kendrick (2000), Gammon and James (2001) and Gammon *et al* (2000).

While several papers have included reference to the marine origins of parts of the region, few have addressed the geological features and topography of the current marine environment, although von der Borch (1968) describes some features of the submarine canyons that lie off the south coast and Clarke and Phillips (1953) give a very brief description of the physiography of the sea floor.

The geomorphology of the south coast's estuaries has been extensively described by Hodgkin (1998); Hodgkin and Clark (1987, 1988, 1990); Hodgkin and Hesp (1998) and Hodgkin and Kendrick (1984). These are discussed further in Section 9 along with other work on estuarine environments.

4.4 Other

Many other Biosphere references include some account of the geology as it affects other aspects of the environment, particularly the references to the soils and to the hydrogeology and hydrology of the area (see for example Dodson 1997, 1999; Johnson 1998; Overheu 2002, 2004). Other research has looked at relationships between geology and vegetation (eg Bennett 1987), geology and wetlands (eg Diamond 1996), or the impacts of geology on contemporary land degradation (Harper 1994).

There have been many other geological investigations related to mining and mineral potential, particularly in the Ravensthorpe Range area where nickel and other minerals have been mined, and also in areas where mineral sands or magnetite occur. Papers or information dealing mainly with mineral prospectivity have been excluded from this review and bibliography, as they are outside the scope of the project. Some

of this information can be accessed through the on-line databases of the Department of Industry and Resources (http://www.dmp.wa.gov.au), or is held by the mining companies active in the area (eg BHP Billiton Ravensthorpe Nickel Operations Pty Ltd, Tectonic Resources NL).

5. LANDFORMS

Since the early Dutch maritime explorations and reports of the south coast in the seventeenth century, many descriptions of the physical features have been contributed by explorers, surveyors and geologists. Bradby (1989) documents some of these observations in his chronology of the Fitzgerald River National Park.

A review of the physiography of the south coast region between Long Point (near Nornalup Inlet) and Israelite Bay is given by Clarke and Phillips (1955), with descriptions of the coast and adjacent seabed, the islands and some of the prominent features of the hinterland. Newbey (1979) gives detailed descriptions of geomorphology and soils at 756 sites across about 10,000 km^2 of the central south coast[4] and used valley types as the main landscape type descriptors. Moir and Newbey (1995) described the main geomorphological units of the Fitzgerald River National Park and similar units were used by Bradby (1989) in his description of the Park.

The evolution of the rivers of the southwest, including the south coast, is discussed by Beard (1999), while the geomorphology of wetlands has been used as the basis of wetland classification by V and S Semeniuk Research Group (1998) and by Ecologia (2000).

Coastal features have been described by Clarke and Phillips (1955) and by Green and Wetherley (2000). Estuarine geomorphology and form have been discussed extensively by Hodgkin and Lenanton 1981; Hesp 1984; Hodgkin and Kendrick 1984; Hodgkin and Clarke 1987, 1988, 1990; Hodgkin 1997; Hodgkin and Hesp 1998; and Bancroft et al 1997.

The Western Australian Department of Agriculture developed a system of soil-landscape mapping using a wide range of geology, geomorphology, soils and landscape information and have applied this at several scales within WA in land capability planning and assessment of risk from various land degradation processes. The methodology is described by Schoknecht et al (2001) and its outputs have contributed to descriptions of catchment characteristics for the Bremer-Gairdner (Overheu, 2004) and the North Jerramungup – Fitzgerald area (Overheu, 2002).

[4] Newbey's Central South Coast Study area includes most of the western part of the Fitzgerald Biosphere Region, and extends further west to 118°69′ and north to 33°67′S. It does not extend further east than the eastern boundary of the Fitzgerald River National Park.

6. SOILS

6.1 Soil Descriptions and Mapping

Soils have been extensively mapped, mostly at 1:250,000 although parts of the Biosphere have been mapped at a larger scale. Schoknecht, Tille and Purdie (2001) describe how mapping originally undertaken as part of the Atlas of Australian Soils (Northcote *et al* 1967) and subsequent soil surveys and site descriptions, have been used in the development of soil and landscape maps for Western Australia, including the south coast region.

For some catchments, such as the Jerdacuttup (Moore *et al* 2001), soil-landform maps have been produced at 1:50,000 as part of land resource capability studies. This also provides detailed soil and landform descriptions. Soil-landform units have also been mapped and described in detail in Rapid Catchment Appraisals for the North Jerramungup-Fitzgerald area (Overheu 2002, Schiller 2003) and the Bremer-Gairdner catchment (Overheu 2004).

Newbey (1979) described soils and landforms as part of his 1:40,000 vegetation mapping for the central south coast area, and described soils for the biological survey sites within the Fitzgerald River National Park (Chapman and Newbey 1995). Stoneman (1990) provided descriptions of the main soils of the Jerramungup agricultural area, and Overheu (1995, 1996) prepared soil information sheets for the Jerramungup and Ravensthorpe agricultural areas summarising soil physical and chemical properties and their main management considerations. Land resource capability studies are in preparation for the Jerramungup and Ravensthorpe areas (Overheu, Department of Agriculture pers. comm.).

6.2 Soil interactions

Soil type obviously influences vegetation and other aspects of ecology, so many of the references to vegetation, for example, also include discussion of the soils. Newbey (1979) related the vegetation associations and communities to soils, while Hopper (1979), Hopper *et al* (1996), Hopper and Gioia (2004) and McQuoid (2003) all include consideration of the mosaic of soil types among the reasons for the plant diversity and local endemism evident in the Fitzgerald area.

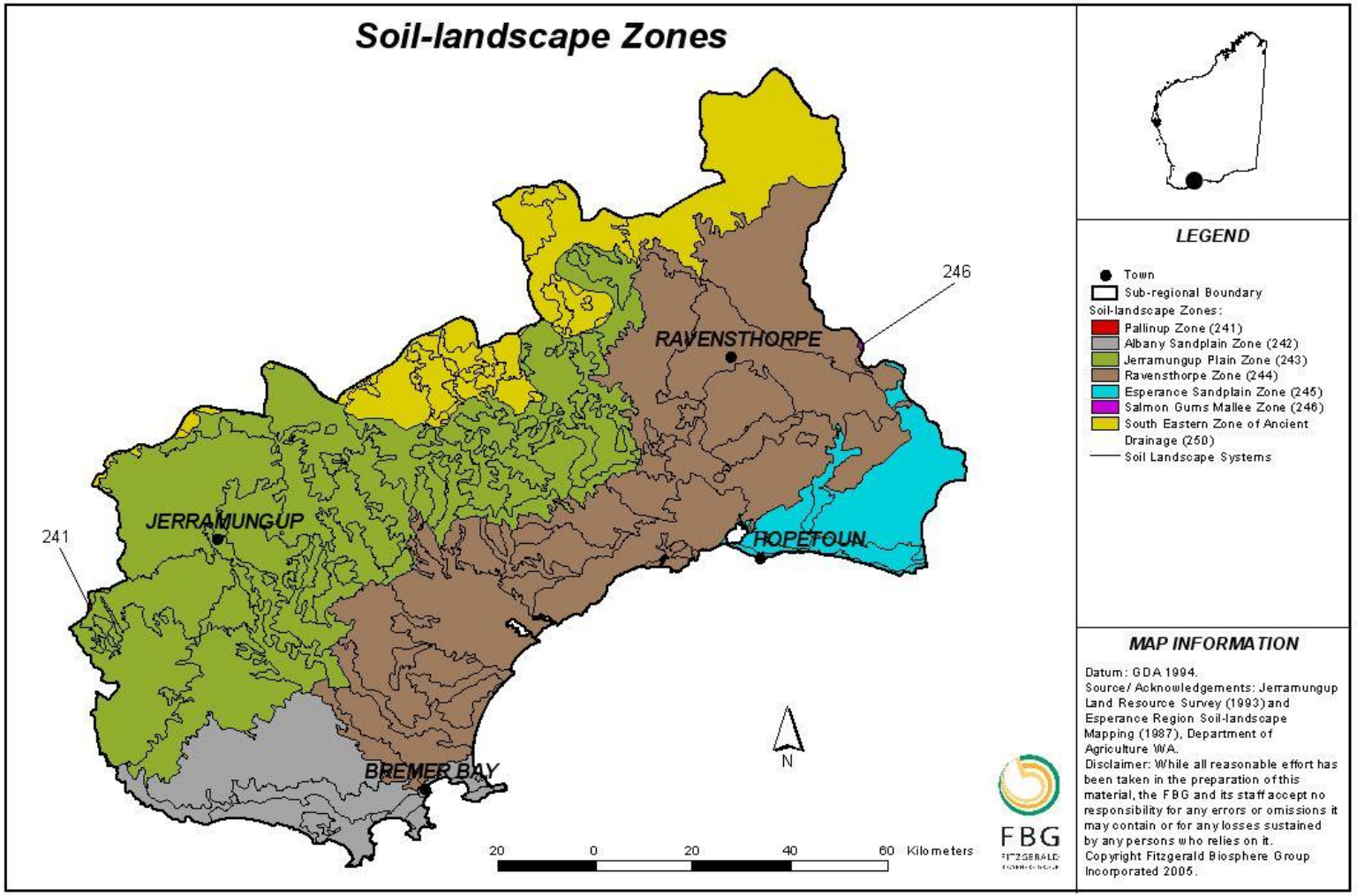
There have also been specific studies on the chemistry, physics or microbiology of particular soils of the region and their relationships to vegetation or fauna. For example, several studies by Cowling and Witkowski (1994), Cowling *et al* (1994), Milewski (1981, 1982, 1983, 1984, 1986), Milewski and Bond (1982) and Milewski and Cowling (1985) compared ecosystems at the Barren Ranges with systems in the Caledon Coast area of South Africa and related similarities and differences to a number of factors, including soil fertility and other edaphic conditions.

Boulet (2004) examined the effect of ultramafic soils with high nickel content on mycorrhizal symbiosis, reproduction and survival of native plants near Bandalup Hill. Shearer and Crane (2003) looked at soil types within the Fitzgerald River National

Park and compared their effects on the mortality rates of *Banksia baxteri* infected by *Phytophthora cinnamomi.* Other microbial studies have included comparisons of *Rhizobium* strains collected from field sites with different soil salinities on growth of *Acacia* species (Craig 1989, Craig *et al* 1990, 1991).

Table 4: Simplified Description of Soil Landscape Zones occurring within the Fitzgerald Biosphere (see Map 5)

Soil-landscape Province, Zone	Code	Description
Stirling Province	24	Laterized plateau on Tertiary sediments, dissected at fringes. Emergent quartzite ranges, coastal headlands of gneisses and migmatites. Coastal dune systems in places.
Pallinup Zone	241	Undulating rises on Archaean granitic rocks in the Upper Pallinup catchment. Shallow duplex soils, commonly with sodic and alkaline subsoils. Woodlands of York and salmon gums, wandoo and yate dominate.
Albany Sandplain Zone	242	Gently undulating plain dissected by a number of short rivers flowing south. Eocene marine sediments overlying Proterozoic granitic and metamorphic rocks. Soils are sandy duplex soils, often alkaline and sodic, with some sands and gravels.
Jerramungup Zone	243	Level to gently undulating plain dissected by a number of short rivers flowing south. On Eocene marine sediments overlying Proterozoic granitic and metamorphic rocks. Alkaline sandy duplex soils with some clays, sands and gravels.
Ravensthorpe Zone	244	Rolling low hills on greenstone (mafic and ultramafic). Moderately dissected with south flowing rivers. Red, fine textured soils.
Esperance Sandplain Zone	245	Level to gently undulating plain dissected by a number of short rivers flowing south. Formed on Eocene marine sediments overlying Proterozoic granitic and metamorphic rocks. Soils are grey fine sandy duplex soils and fine sands.
Salmon Gums- Mallee Zone	246	Level to gently undulating plain, with Tertiary sediments over Proterozoic granites. Salt lakes, scattered or in swarms are a common feature. Drainage lines become indistinct towards the north.
Avon Province	25	The Avon Province comprises Precambrian granites and gneisses with past lateritic weathering. Soils may be calcareous, but red-brown hardpans are uncommon (Duric Great Groups).
South-eastern Zone of Ancient Drainage	250	A smooth to irregularly undulating plain dominated by salt lake chains in the main valleys with duplex and lateritic soils on the uplands. Mallee vegetation on duplex soils, Proteaceous vegetation on gravels and sands.
Extracted from: Schoknecht *et al* (2000) "*Soil-landscape mapping in south-western Australia. An overview of methodology and outputs*". Department of Agriculture, WA.		


Soil-landscape Zones
246
RAVENSTHORPE
241
JERRAMUNGUP
HOPETOUN
BREMER BAY
N
20 0 20 40 60 Kilometers
FBG
LEGEND
Town
Sub-regional Boundary
Soil-landscape Zones:
Pallinup Zone (241)
Albany Sandplain Zone (242)
Jerramungup Plain Zone (243)
Ravensthorpe Zone (244)
Esperance Sandplain Zone (245)
Salmon Gums Mallee Zone (246)
South Eastern Zone of Ancient Drainage (250)
Soil Landscape Systems
MAP INFORMATION
Datum: GDA 1994.
Source/ Acknowledgements: Jerramungup Land Resource Survey (1993) and Esperance Region Soil-landscape Mapping (1987), Department of Agriculture WA.
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Map 5

Table 5: Landforms, Soils and Vegetation of the Fitzgerald River National Park

Adapted from Department of Conservation and Land Management (1991)

LANDFORM	GEOLOGY	SOIL TYPE	VEGETATION	TOPOGRAPHY	DRAINAGE
Upland[5]	granites, gneisses	• extensive areas of shallow loamy sand • skeletal soils associated with granite exposures	• very open mallees of *E. redunca* or *E. tetragona* • Allocasuarina, Grevillea and Acacia scrub/heath associated with granite outcrops	• dominated by undulating plain: internal relief less than 10m, slopes less than 2° • v-shaped valleys: incised 100-160m, 3-12° slopes	• undulating plain: dendritic and coarse • v-shaped valleys: single channel with flows in winter/spring • generally moderately well-drained
Plain[6]	spongolite, siltstone	• duplex shallow sandy loams, colluvial sands and cracking clays • skeletal soils on bedrock exposures	• very open mallee of *E. decipiens* widespread • elsewhere open to very open shrub mallee	• flat plain: internal relief rarely exceeds 10m, generally less than 1° slope	• uncoordinated drainage: large areas with no run off, sumps and gilgais • dissected drainage on coast and river margins • water-logged winter/spring at least, generally poorly drained
Valleys[7]	spongolite, siltstone	• sandy loam – shallow on walls, deeper on valley floor	• open shrub mallee of *E. conglobata* and *E. incrassata* on valley floors and drainage lines • low woodland on slopes and rims • open mallee on mesas	• steep-sided valleys cut into flat plain; flat, broad valley floors	• broad valleys, intermittent flow, small flow in winter/spring, generally small linear pools • moderately well drained in upper reaches to poorly drained near inlets

[5] Source: Department of Conservation and Land Management 1991
[6] Source: Department of Conservation and Land Management 1991
[7] Source: Department of Conservation and Land Management 1991

LANDFORM	GEOLOGY	SOIL TYPE	VEGETATION	TOPOGRAPHY	DRAINAGE
Ranges [8]	quartzite, phyllite, dolomite, conglomerates	• quartzite sand on quartzite • phyllitic loamy sand or schist duplex soils	• Banksia scrub and Adenanthos open low scrub on quartzite • Very open shrub mallee of *E. incrassata*, and Banksia and Allocasuarina low scrub on phyllitic schists	• rugged hills and stony rises 500m ASL, slopes range from 45° to vertical	• rapid run-off • numerous short streams rapidly drain hills and rises • well drained
Ravensthorpe Range[9]	greenstone, sandstone and Banded Ironstone Formation, quartzite, lateritic caprock	• dependent on underlying rock and slope position • skeletal on ridges and upper slopes, deeper loamy sand to clayey sand on shallower slopes • red clay on middle slopes	• *E. astringens* low woodland intermixed with *E. gardneri* and *E. nutans* • open shrub mallee of *E. falcata* on quartzite sands and gravely sands; *E. flocktoniae* on clayey sands • Dryandra or Banksia low scrub on skeletal gravely sand	• hills to 150m above the surrounding plain, lower slopes of 5-10°, increasing upslope to 20-30°.	• well drained, unidirectional, becoming dendritic into Jerdacuttup River
Jerdacuttup Plain[10]	Granite, gneiss, quartzite, siltstone	• shallow to moderately deep duplex sand over gravel • significant area of deep uniform sands	• mallees, including *E. tetragona* and *E. teraptera,* and Banksia shrubland	• level to gently undulating plain, slopes generally less than 3° • some mound or depression micro-relief ; slopes of up to 10° on valley sideslopes near coast	• poorly drained, some waterlogging in depressions
Dunes[11]	sand over spongolite or	• loose calcareous or	• mallee and shrubland	• narrow sand-dunes occur	• well drained

[8] Source: Department of Conservation and Land Management 1991. Refers to Ranges within Fitzgerald River National Park
[9] Source: Chapman and Newbey 1995a
[10] Sources include Moore et al 1991, Craig 1995, Department of Environment 2004
[11] Source: Department of Conservation and Land Management 1991

LANDFORM	GEOLOGY	SOIL TYPE	VEGETATION	TOPOGRAPHY	DRAINAGE
	quartz	siliceous sands	becoming lower and denser heath closer to the coast	on several coastal sections: 2-5m high, verying slope depending on stability	• occasional areas of impeded drainage over limestone
Inlets[12]	incised in quartzite, spongolite or limestone	• saline soils next to inlet • narrow deposits of colluvium and alluvium spongolite, at some slope and cliff bases	• Melaleuca woodland or shrubland on edges • Samphire heath on flats	• all major rivers in Park terminate in an inlet: incised to 100m, only partially filled, expansive flat floors, generally fringed by steep slopes or cliffs	• water occupies only small portion of floor • generally barred from the sea • poorly drained
Rivers, swamps and lakes[13]	granites, spongolite, quartzite	• dependent on underlying rock	• *E. occidentalis* woodland dominant	• rivers generally single-channelled: v-shaped in upland; broad, cliffed meanders on plain • swamps generally on plain	• rivers moderately well drained • swamps poorly drained

[12] Source: Department of Conservation and Land Management 1991
[13] Source: Department of Conservation and Land Management 1991

7. HYDROGEOLOGY

The Department of Environment (formerly Water and Rivers Commission) produces 1:250,000 hydrogeology maps and accompanying explanatory reports for most of WA. The Biosphere area is covered by the Bremer Bay, Ravensthorpe and Newdegate sheets (Dodson 1997, 1999, Johnson 1998). These reports and information from the network of bores monitored by the Departments of Agriculture and Environment and by individual landowners, have been used by other authors in studies of groundwater at more localised scales. The Department of Agriculture maintains the AgBores database, while Department of Environment data is included in their WIN database.

Lillicrap (2004) described the groundwater flow systems and trends for the different soil-landscape zones within the Biosphere. Short *et al* (1997) described groundwater trends for the West River catchment. The Rapid Catchment Appraisal reports for the North Jerramungup-Fitzgerald (Overheu 2002) and the Bremer-Gairdner areas (Overheu 2004) include discussion of hydrogeology.

As part of the NHT-funded Chingarrup-Yenteyerrup Swamp Bushland Restoration and Preservation Project by the Swamp Road Catchment Group, Maxwell Geoservices compiled a Report on the Geophysical Interpretation and Database Compilation for that catchment (Maxwell Geoservices 2002).

Groundwater and salinity trends have also been addressed at a state and regional scale by Short and McConnell (2001) as part of the National Land and Water Resources Audit, and for the Biosphere subregion by Ferdowsian *et al* (1994).

The V & C Semeniuk Research Group (1998) included consideration of geology and hydrology in delineating wetland suites between Walpole and the Fitzgerald Inlet, while Diamond (1996) described the hydrogeology of the wetlands in the Bremer Bay area in more detail.

8. RIVERS AND WETLANDS

NOTE: The Convention on Wetlands (Ramsar, Iran, 1971; commonly known as the Ramsar Convention) defines a wetland as:

> *any area of marsh or water, whether natural or artificial, permanent or temporary, with water static or flowing, fresh, brackish or saline, including areas of marine water which support mangrove or samphire communities.*

For convenience in this report however, references are described under the headings of wetlands (meaning lentic or static water systems) or rivers (including creeks). Some of the references may be relevant to both types of wetlands.

The Biosphere area includes several river systems that flow south to estuaries or coastal lagoons before discharging into the Southern Ocean. The largest of these, based on length, catchment area and mean annual flow, is the Pallinup River at the western end of the Biosphere. The Pallinup also has one of the most heavily cleared catchments and flows mostly through farmland. Several rivers or creek systems have

their catchments entirely or mostly within the Fitzgerald River National Park and are therefore considered to be in near-pristine condition. Two of these, the St Marys and the Dempster Rivers, meet the criteria for Wild Rivers[14]. All of the rivers and creeks are either intermittent, flowing seasonally, or ephemeral, flowing only for short periods after rain.

The wetlands of the region have not been extensively studied but are also mostly intermittent or ephemeral.

8.1 Wetlands

V&C Semeniuk Research Group (1998) have applied a wetland classification system based on geomorphology and hydrology across the area from Walpole (west of the Fitzgerald Biosphere) to the Fitzgerald Inlet and identified wetlands into a series of consanguineous suites. Preliminary assessments of their conservation values were also identified and the wetlands mapped. The wetlands east of the Fitzgerald Inlet were similarly assessed and mapped by Ecologia (2000). The Department of Environment and GreenSkills have used the preliminary wetlands mapping and identification to undertake further assessments of individual wetlands and suites and to develop management plans with landholders (see for example, Hopkinson (2001) for management recommendations developed for the Bremer wetlands).

The hydrogeology of the Bremer wetlands was also described by Diamond (1996) and wetlands classified independently of the Semeniuk study. A similar grouping of wetlands was arrived at, with minor differences attributed to the paucity of information as well as the gradational nature of the wetland classifications.

There are very few reports on the biota of the wetlands specifically, although some information may be found in some of the broader works on vegetation and fauna. The Department of Conservation and Land Management and Birds Australia have, however, reported on annual waterbird counts across a number of wetlands in the south-west, including several in the Fitzgerald Biosphere region (Halse et al 1990, 1992, 1993, 1994, 1995). Halse, Pearson and Patrick (1993) also described the vegetation for some wetlands in nature reserves in the area.

The Yellilup Yate Swamp System, a system of twelve wetlands north of the Bremer Bay Road, is listed on the Directory of Important Wetlands for Australia. Information about the listing can be found on the Australian Wetlands Database at the Department of Environment and Heritage website
http://www.deh.gov.au/water/wetlands/index.html

[14] The Australian Heritage Commission, in association with the States and Territories, assessed the condition and "naturalness value" of rivers nationally to compile a "river wildness" index, primarily based on indices of catchment and waterway disturbance. See Environment Australia (1999) *Principles and a code for the management of Wild River values.* Environment Australia, Canberra; and Stein JL, Stein JA, Nix H (undated) *The identification of Wild Rivers; methodology and database development.* Environment Australia, Canberra.

8.2 Rivers

Information on the rivers of the Biosphere is sparse, although the Department of Environment collated all available monitoring information as part of the preparation of the Draft South Coast Regional Natural Resource Management Strategy (SCRIPT 2004).

Some "snapshot" water quality monitoring was undertaken in the rivers of the Fitzgerald River National Park under a grant to the Fitzgerald River National Park Association in 1985 (Chapman, 1985) and funding has recently (2006) been made available to repeat this monitoring.

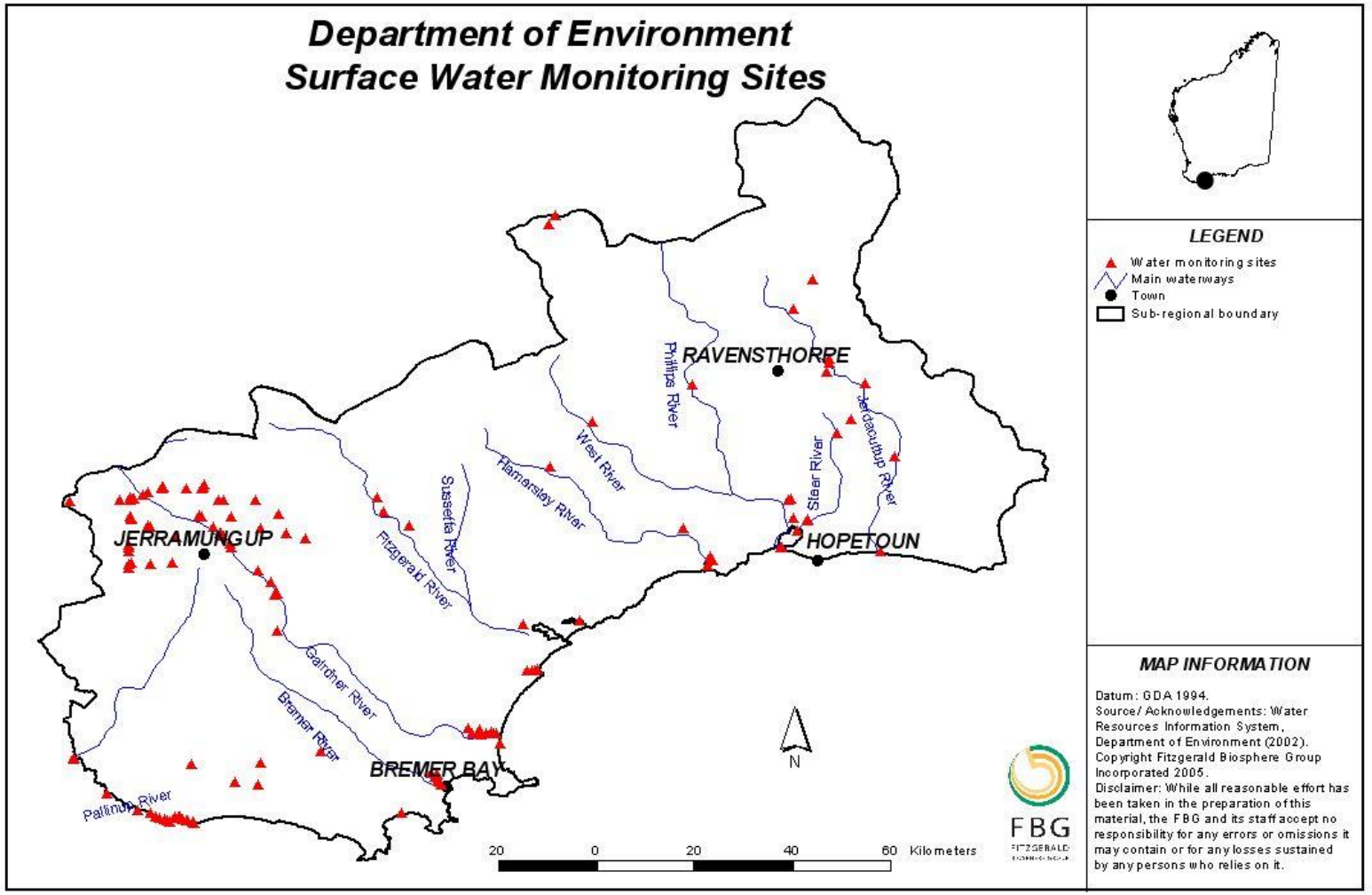
Other water quality and limited flow monitoring is undertaken by the Department of Water (formerly the Department of Environment) and can be accessed via their website (www.water.gov.au). Water monitoring sites are shown in Map 6.

Several sites within the Biosphere were included in the Australia-wide Monitoring River Health Initiative (commonly referred to as AusRivAS), funded through the Australian Government and conducted in WA by the Department of Conservation and Land Management (Halse, Scanlon and Cocking 2002). A student from Murdoch University has recently completed a PhD thesis in which specimens collected as part of the AusRivAS program were further analysed to determine the conservation status of aquatic insects in south-western WA (Sutcliffe 2003).

Fish and crustacean of the estuaries and rivers of the south coast were described by Lenanton (1974), and the biological survey of the Fitzgerald River National Park, conducted in 1985-1987 included collecting inland fish from the main rivers and several smaller creeks (eg Twertup, Woodenup Creeks) within the Park (Chapman 1995). One of the species collected was the Spotted Minnow *(Galaxias maculatus)* and Chapman has since written a thesis on the biology of this species on the south coast (Chapman 2003).

Leighton and Watson (1992) conducted preliminary biological surveys of the Fitzgerald River and Corackerup Creek corridors (and the Young and Lort Rivers to the east of the Biosphere) as part of the "Save the Bush: South Coast River Corridor Project" in 1991. Their report summarised available information for the areas surveyed and reports the results of fauna surveys conducted within the riverine zones.

The Department of Water (formerly the Department of Environment, and pre-2004 the Water and Rivers Commission) has prepared "River Action Plans" for the Bremer River and Devils Creek (Water and Rivers Commission 2001), the Phillips River (Water and Rivers Commission 2003) and for the Jerdacuttup River (Department of Environment 2004). These plans summarise catchment and river information, include foreshore vegetation assessments and develop management plans primarily addressing fencing of waterways and revegetation of streamsides in conjunction with riparian landholders. The Department compiled similar information for the Fitzgerald River which is included in a catchment folder for the Fitzgerald produced by the Fitzgerald Biosphere Group (Water and Rivers Commission 2003).


Department of Environment
Surface Water Monitoring Sites
RAVENSTHORPE
HOPETOUN
JERRAMUNGUP
BREMER BAY
Phillips River
West River
Hamersley River
Steer River
Jerdacuttup River
Fitzgerald River
Stasseita River
Gairdner River
Bramer River
Pallinup River
N
20 0 20 40 60 Kilometers
FBG
LEGEND
Water monitoring sites
Main waterways
Town
Sub-regional boundary
MAP INFORMATION
Datum: GDA 1994.
Source/ Acknowledgements: Water Resources Information System, Department of Environment (2002).
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Disclaimer: While all reasonable effort has been taken in the preparation of this material, the FBG and its staff accept no responsibility for any errors or omissions it may contain or for any losses sustained by any persons who relies on it.

Map 6

8.3 Hydrology, catchments and surface water management

Most work on the hydrology and surface water management in the area has been in relation to agricultural productivity and was not extensively reviewed in the current project. An exception is the thesis by Michelle Carey that looked at the impacts of hydrological change on Flat-topped yate (*Eucalyptus occidentalis* Endl.) and its associated communities, and the implications for management of salinity in the landscape (Carey 2004).

Farmer et al (2002) investigated aspects of the Upper Fitzgerald River, primarily to make recommendations on the management of the surface water to arrest degradation in the Lake Magenta Nature Reserve.

Groundwater trends in the Fitzgerald Biosphere have been described by Lillicrap (2004). The Department of Agriculture conducted "Rapid Catchment Appraisals" for the North Jerramungup-Fitzgerald area (Overheu 2002) and for the Bremer-Gairdner area (Overheu 2004) and the resulting reports collate resource information, assess the prospects for salinisation and other land degradation, and propose management actions for landholders to address the problems.

Several landcare and other catchment-based community groups in the region have produced reports resulting from projects conducted under the Natural Heritage Trust or National Landcare Programs. These reports generally include some discussion of the management issues and report on revegetation, fencing or surface drainage works to alleviate catchment problems. Examples include Tomlinson and Brown (1999) for the Upper Gairdner catchment, Schiller (2003) for the Fitzgerald River catchment and Lisson (1994) for the Swamp Road catchment. Major projects currently underway in the Fitzgerald and West River catchments, being managed by the Fitzgerald Biosphere Group and the Ravensthorpe Agricultural Initiative Network respectively, are compiling further catchment information, management and evaluation strategies.

9. NEAR SHORE MARINE ENVIRONMENT (INCLUDING ESTUARIES)

The geology of the south coast, including the near shore environment, has been described in a number of papers (see for example Clarke and Phillips, 1953 and other papers mentioned in the section on geology) although generally at a regional, rather than at a detailed or local scale. Submarine canyons off the southern coast were described by von der Borch (1968), and several papers have described the geomorphology of the south coast's estuaries (Hesp 1984; Hodgkin 1997, 1998; Hodgkin and Clarke 1987, 1988, 1990; Hodgkin and Hesp 1998; Hodgkin and Kendrick 1984).

The Marine Parks and Reserves Selection Working Group acknowledged the poor state of knowledge of marine biota when making its recommendations on marine

reserves for the south coast area (Department of Conservation and Land Management, 1994) and based their recommendations largely on shore geomorphology. The Working Group acknowledged however that the WA Museum had made some reference collections of marine fauna.

The populations of Australian sea lions and New Zealand fur seals along the south coast, including breeding and haul out sites in the Fitzgerald Biosphere, have been discussed by Abbott (1979), Gales (1990), Gales *et al* (1994, 2000) and Shaughnessy *et al* (1994). Bannister (1990, 2001, 2002) has described annual counts and photo-identifications of Southern Right Whales and Holst (year?) has speculated on the possible reasons for the high numbers of Southern Right Whales calving in Doubtful Islands Bay.

The Department of Conservation and Land Management's Marine Conservation Branch conducted marine biological surveys in waters offshore from the Fitzgerald Biosphere in 1997 as part of the South Coast Terrestrial and Marine Reserve Integration Study (Colman, 1998). As part of an Australia-wide project by the CSIRO, benthic habitats were mapped at 1:100,000 from Landsat TM imagery (Kirkman, Appendix 4 in Colman, 1998).

9.1 Estuaries

Hodgkin and Clark compiled information on estuaries of the south coast which were published by the Environmental Protection Authority as part of a series of reports titled "*An inventory of information on the estuaries and coastal lagoons of south Western Australia".* The three reports covering the Biosphere area included Wellstead Estuary (1987), Beaufort and Gordon Inlets (1988), and Fitzgerald, Hamersley, Dempster, Saint Mary and Culham Inlets, the Jerdacuttup Lakes and several smaller systems within the Fitzgerald River National Park (Quoin Head Creek, Boondadup River, Kelly's Creek and Lake Nameless) (1990). Each report summarises the catchment characteristics and gives information on the landforms, bars, water depths in the inlets, bottom sediments and water characteristics, as well as information on estuarine vegetation and fauna.

The geomorphology and evolutionary history of the south coast's estuaries, and the implications for their management, are discussed in several papers, including Hesp (1984), Hodgkin (1997, 1998), Hodgkin and Hesp (1998), Hodgkin and Kendrick (1984) and Hodgkin and Lenanton (1981).

As background to the South Coast Terrestrial and Marine Reserve Integration Study, Bancroft *et al* (1997) reviewed available information on estuaries and their catchments, with much of the available information coming from the studies by Hodgkin and Clarke (1987, 1988, 1990) described above. Congdon and McComb (1986) looked at aquatic macrophytes in Wellstead Estuary and Gordon Inlet in relation to salinity fluctuations associated with bar openings, and Forbes (2004) compared the relationships between benthic vegetation and invertebrate communities in Wellstead Estuary with those in Wilson Inlet near Denmark.

Lenanton (1974, 1984) has described some of the fish found in south coast estuaries, while Young and Potter (2002) studied the influence of extreme ranges of salinity due to bar openings and flooding on the fish communities in Wellstead Estuary. Sarre and Potter (1999, 2000) and Sarre *et al* (2000) investigated the diet, reproduction and growth of black bream in Wellstead Estuary as part of a wider comparative study into the effects of various estuary characteristics on this species. The Department of Environment and the Shire of Jerramungup are currently preparing a management plan for the Wellstead Estuary and are collating known biophysical information (Department of Environment 2004). The Department of Environment also has monitoring sites within several of the estuaries in the Biosphere, including Beaufort, Hammersley and Gordon Inlets, and measures nutrients, salinity and water levels quarterly. The monitoring of nutrients and the available macroinvertebrate monitoring was summarised by the Department of Environment in a background paper to the South Coast Regional Natural Resource Management Strategy (SCRIPT, 2004).

Waterbird use of a number of south-west wetlands, including the Jerdacuttup Lakes and the estuaries of the south coast, have been monitored annually for more than ten years and are summarised in a series of reports for the Department of Conservation and Land Management (Halse *et al* 1990, 1994, 1995).

Both Culham Inlet and the Fitzgerald Inlet system are listed on the Directory of Important Wetlands for Australia. Information provided as part of the nomination to the Directory can be found in the Australian Wetlands Database on the Department of Environment and Heritage website (http://www.deh.gov.au/water/wetlands/index.html)

10. VEGETATION & FLORA

10.1 Historical

The flora of the Fitzgerald Biosphere area was noted by many early explorers and collections were made in the area from at least the 1840s by collectors such as James Drummond, George Maxwell and, later, CA Gardner. These early botanical explorations in the area have been reviewed by Bradby (1989) and Craig (2000).

10.2 Significance of the area

The Gondwanan origins of the south-west of WA have been described by several authors, including for example Hopper *et al* (1996). These, and other studies of the evolution (for example Hopper 1979; Hopper and Gioia 2004) and phytogeography (eg Keighery 1996; Lamont and Connell 1996) of the vegetation and flora, assist to explain the extraordinary species diversity and endemism seen throughout the south-west and in the southern sandplains in particular. McQuoid (2003) has also summarised the reasons for this species richness within the Fitzgerald Biosphere area.

An analysis by Groom and Lamont (1996) of the occurrence of *Hakea* species identified the Barrens as one of four centres of diversity in the south-west for this genus.

10.3 Botanical surveys and reviews

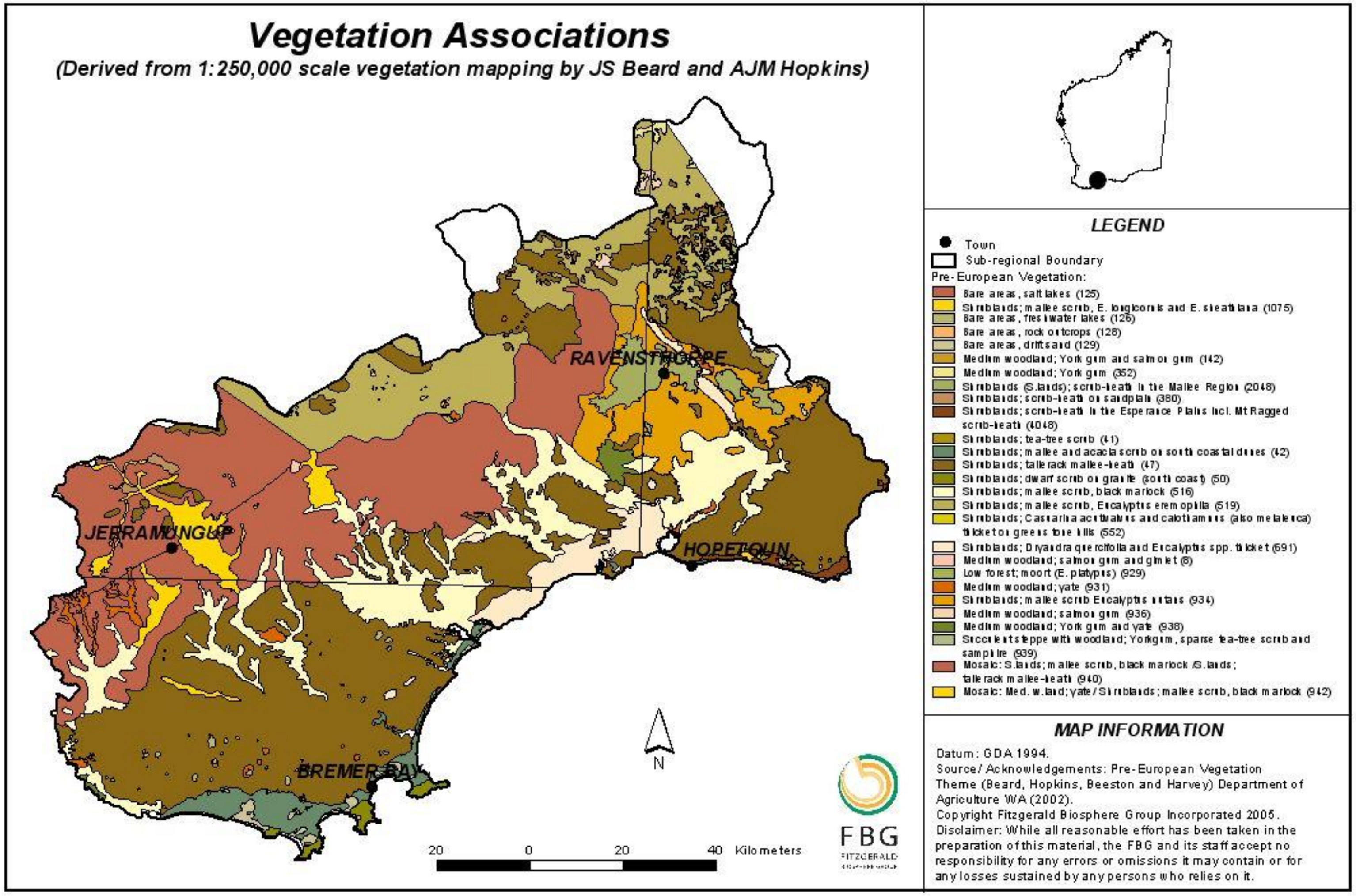
The vegetation and flora of the Fitzgerald River National Park was surveyed by Aplin in 1970-71 and the vegetation mapped at 1:250,000 (Aplin 1971; Aplin & Newbey 1990a, 1990b). Beard described vegetation surveys and mapped plant communities for the south-west of Western Australia at 1:250,000. The Fitzgerald Biosphere area is covered by the Bremer Bay, Newdegate and Ravensthorpe map sheets (Beard 1972a and b, 1979). Newbey (1979a) described plant associations for the central south coast and mapped them at 1:40,000. Newbey's thesis also included detail of geology, geomorphology and soils. These maps have recently been digitised (Mercer 2003b).

The 1985-87 biological survey of the Fitzgerald River National Park provided further detailed description of the Park's vegetation and flora and established permanent vegetation plots (Chapman and Newbey 1995b). Some of these have since been monitored again (Hopper 1992; Sanders 1997). Newbey (1986a, 1990) listed flora of the Fitzgerald River National Park that are rare, threatened or otherwise of special conservation value. The 1985-87 surveys and subsequent work on flora by Newbey have been used to prepare flora lists for the Park, most recently by Newbey and McQuoid (1997).

Craig (2000) reviewed and summarised the vegetation and flora of the south coast region for the South Coast Management Group as a background paper to the development of the south coast's regional coastal planning and management guide, *Southern Shores.*

Rare and threatened plant species in the Biosphere have been described by Robinson and Coates (1995) as part of a wider project detailing rare and poorly known flora for the Department of Conservation and Land Management's Albany District.

Numerous, more localised surveys have been undertaken throughout the Fitzgerald Biosphere. Many of these have been undertaken by mining companies or as a result of other development proposals. Only a very limited number of these studies have been accessible to the current project, but where known they have been listed in the accompanying bibliographic database. Most are associated with the Ravensthorpe Nickel Project (eg Cockerton & Craig 2000, 2001; Cockerton & Evelegh 2002; Cockerton, Evelegh & Craig 2002; Craig 1998a, 1998b, 1998c, 1999a, 1998b, 1999c; Craig & Chapman 1998), other mining developments in the Ravensthorpe/Kundip area (Craig 1992b, 2002a, 2003b, 2004a, 2004b; Outback Ecology 2003), or with townsite and infrastructure development, particularly around Ravensthorpe and Hopetoun (eg Craig 1998d, 2001a, 2001b, 2003c, 2003d; Ecologia 1998).



Vegetation Associations
(Derived from 1:250,000 scale vegetation mapping by JS Beard and AJM Hopkins)
RAVENSTHORPE
JERRAMUNGUP
HOPETOUN
BREMER BAY
N
20 0 20 40 Kilometers
FBG
FITZGERALD
LEGEND
Town
Sub-regional Boundary
Pre-European Vegetation:
Bare areas, salt lakes (125)
Shrublands; mallee scrub, E. longicornis and E. sheathiana (1075)
Bare areas, freshwater lakes (126)
Bare areas, rock outcrops (128)
Bare areas, drift sand (129)
Medium woodland; York gum and salmon gum (142)
Medium woodland; York gum (352)
Shrublands (S.lands); scrub-heath in the Mallee Region (2048)
Shrublands; scrub-heath on sandplain (380)
Shrublands; scrub-heath in the Esperance Plains incl. Mt Ragged scrub-heath (4048)
Shrublands; tea-tree scrub (41)
Shrublands; mallee and acacia scrub on south coastal dunes (42)
Shrublands; tallerack mallee-heath (47)
Shrublands; dwarf scrub on granite (south coast) (50)
Shrublands; mallee scrub, black marlock (516)
Shrublands; mallee scrub, Eucalyptus eremophila (519)
Shrublands; Casuarina acutivalvis and calothamnus (also melaleuca) thicket on greenstone hills (552)
Shrublands; Dryandra quercifolia and Eucalyptus spp. thicket (691)
Medium woodland; salmon gum and gimlet (8)
Low forest; moort (E. platypus) (929)
Medium woodland; yate (931)
Shrublands; mallee scrub Eucalyptus nutans (934)
Medium woodland; salmon gum (936)
Medium woodland; York gum and yate (938)
Succulent steppe with woodland; York gum, sparse tea-tree scrub and samphire (939)
Mosaic: S.lands; mallee scrub, black marlock /S.lands; tallerack mallee-heath (940)
Mosaic: Med. w.land; yate / Shrublands; mallee scrub, black marlock (942)
MAP INFORMATION
Datum: GDA 1994.
Source/ Acknowledgements: Pre-European Vegetation Theme (Beard, Hopkins, Beeston and Harvey) Department of Agriculture WA (2002).
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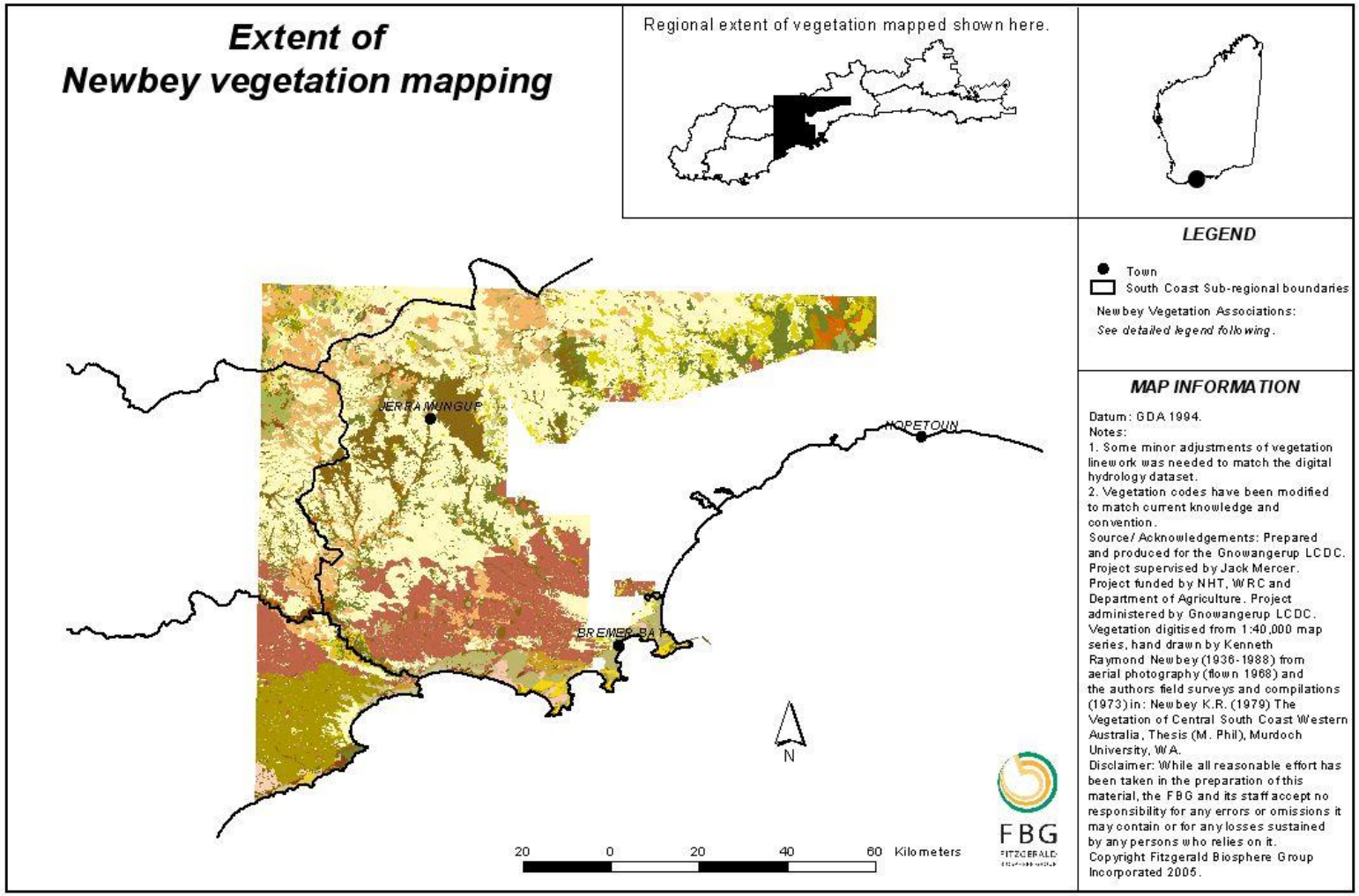
Disclaimer: While all reasonable effort has been taken in the preparation of this material, the FBG and its staff accept no responsibility for any errors or omissions it may contain or for any losses sustained by any persons who relies on it.

Map 7


Extent of
Newbey vegetation mapping
Regional extent of vegetation mapped shown here.
LEGEND
Town
South Coast Sub-regional boundaries
Newbey Vegetation Associations:
See detailed legend following.
MAP INFORMATION
Datum: GDA 1994.
Notes:
1. Some minor adjustments of vegetation linework was needed to match the digital hydrology dataset.
2. Vegetation codes have been modified to match current knowledge and convention.
Source/ Acknowledgements: Prepared and produced for the Gnowangerup LCDC. Project supervised by Jack Mercer. Project funded by NHT, WRC and Department of Agriculture. Project administered by Gnowangerup LCDC. Vegetation digitised from 1:40,000 map series, hand drawn by Kenneth Raymond Newbey (1936-1988) from aerial photography (flown 1968) and the authors field surveys and compilations (1973) in: Newbey K.R. (1979) The Vegetation of Central South Coast Western Australia, Thesis (M. Phil), Murdoch University, WA.
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JERRAMUNGUP
NORTOWN
BREMER BA
N
20 0 20 40 60 Kilometers
FBG
FITZGERALD

Map 8

Newbey Vegetation Associations - Legend

- Acacia cochlearis (Acco)
- Acacia lasiocalyx (Aclax)
- Agonis flexuosa (Agfl)
- Allocasuarina campestris (Alca)
- Allocasuarina huegeliana (Alhu)
- Banksia heath (BH)
- Banksia attenuata (Batt)
- Banksia baxteri (Bbax)
- Banksia verticillata (Bver)
- Coastal granite (CG)
- Coastal limestone (CL)
- Chenopodium spp. (Chp)
- Cladium spp. (Cld)
- Casuarina obesa (Cobe)
- Calothamnus quadrifidus (Cqua)
- Swamp - fresh (D)
- Swamp - saline (DS)
- Dryandra complex (Dry)
- Dune (Dune)
- Eucalyptus annulata (Eann)
- Eucalyptus astringens (East)
- Eucalyptus buprestium (Ebup)
- Eucalyptus calophylla (Ecal)
- Eucalyptus conglobata (Econ)
- Eucalyptus cornuta (Ecor)
- Eucalyptus decipiens subsp. adesmophloia (Edec)
- Eucalyptus eremophila (Eere)
- Eucalyptus falcata (Efal)
- Eucalyptus floctoniae (Eflo)
- Eucalyptus gardneri (Egar)
- Eucalyptus grandiflora (Egra)
- Eucalyptus incrassata (Einc)
- Eucalyptus kondininensis (Ekon)
- Eucalyptus lehmannii (Eleh)
- Eucalyptus loxophleba (Elox)
- Eucalyptus marginata (Emar)
- Eucalyptus newbeyi (Enew)
- Eucalyptus occidentalis (Eocc)
- Eucalyptus oleosa (Eole)
- Eucalyptus phaenophylla (Epha)
- Eucalyptus platypus (Epla)
- Eucalyptus pleurocarpa (Eple)
- Eucalyptus preissiana (Epre)
- Eucalyptus salmonophloia (Esal)
- Eucalyptus staeri (Esta)
- Eucalyptus wandoo (Ewan)
- Eucalyptus xanthonema (Exan)
- Flat (F)
- Granite (G)
- Granite/ E. phaenophylla (GE)
- Sand (H)
- Coastal heath (HC)
- Lake (L)
- Laterite (LA)
- Limestone (LI)
- Mud flat (MF)
- Melaleuca cuticularis (Mcut)
- Melaleuca complex/ M. elliptica (Mel)
- Melaleuca nesophila (Mnes)
- Melaleuca pentagona (Mpen)
- Melaleuca uncinata (Munc)
- Olearia axillaris (Oaxi)
- Quartizite (Q)
- River/ Rush (Rr)
- Spongolite (S)
- Saline flat (SF)

10.4 Fitzgerald River National Park

Thirteen "mountain" peaks of the south coast, including Thumb Peak in the Barren Range were surveyed by Barrett (1996), and included a quadrat-based flora survey. Other local surveys and studies within the Fitzgerald River National Park include unpublished papers on aspects of the flora of an area near Twin Bays (Clavin 1983) and at West Mount Barren (Dodd 1977), a description of the vegetation and flora around Roes Rock (Newbey 1981), and a pre-burn survey of the Marningerup section as part of a planned fire ecology study in 1985 (Newbey 1985a).

The bryophyte species occurring in the National Park were listed by Hammersley (2002).

Newbey (1976) mapped and described the vegetation of the Tooregullup dune system north-east of Bremer Bay as part of a submission to the Mining Warden's Court in response to a proposal for sand mining.

Hopper *et al* (1978) and McQuoid and Hopper (2002) described hybridisation occurring in *Eucalyptus* species within the National Park.

Sites in the Barren Range were used for a series of studies comparing ecosystems here with those in similar environments in South Africa (Milewski 1979, 1981a, 1982, 1983, 1984; Milewski and Cowling 1985; Cowling & Witkowski 1994; Cowling *et al* 1994).

In association with long-term studies on the biology and ecology of the Honey Possum, *Tarsipes rostratus,* in the Park, there have been several studies on aspects of the ecology and regeneration of *Banksia* species, including *B. attenuata, B. baxteri, B. media* and *B. nutans* (eg Wooller & Wooller 2001, 2002, 2003, 2004; Wooller *et al* 2002). The floral characteristics of eight Proteaceous species, and the daily patterns of nectar production and anthesis of six species, were examined by Saffer (1998, 2004) in studies of bird and mammal pollination.

Itzstein-Davy (2003a, 2003b) measured modern pollen rain using moss polsters at 5 sites within the Fitzgerald River National Park, one site in Lake Magenta Nature Reserve, 7 sites in Stirling Range National Park and 5 sites in Lesueur National Park and Coomallo Nature Reserve north of Perth, and related them to the surrounding vegetation as part of a calibration for fossil-pollen studies on Eocene, Pliocene and Quaternary sediment.

10.5 Ravensthorpe Range

Bennett (1987) investigated the ecology of vegetation associations along two transects near Mt Desmond in the Ravensthorpe Range and related the associations to geology and soils. Chapman and Newbey (1995) described fifteen vegetation types and assembled a flora list as part of a fauna survey of the Ravensthorpe Range. Craig (1995) documents 150 of the more recognisable species occurring in the Ravensthorpe area.

10.6 Other areas

Witkowski *et al* (1991) looked at the seed bank dynamics of *Banksia baxteri, B. speciosa* and *B. coccinea* co-occurring in patch-burnt scrub heath just to the east of the Park. The effects of plant age, granivory by cockatoos, senescence and inter-fire establishment for the three species were described. At a site further east at the edge of the Biosphere, Witkowski *et al* (1992) compared leaf demography, sclerophylly and ecophysiology for *Banksia petiolaris* and *B. baueri.*

10.7 Other ecological studies

Burbidge *et al* (1979) identified the pollen loads on Yellow-winged Honeyeaters near Quaalup in the Fitzgerald River National Park, and Wooller *et al* (1983) looked at seasonal variation in the pollen carried by Honeyeaters and Honey Possums. Other studies that looked at the use of foodplants by native fauna include Craig *et al* (2002) at Bandalup Hill and Evelegh and Cockerton (2003), who surveyed for potential pollinators of *Kunzea similis* at East Mount Barren and Bandalup Hill.

10.8 Economic uses of native plants

The conservation status and economic uses of two *Banksia s*pecies of importance to the wildflower industry, *B. coccinea* and *B. baxteri,* were studied by Robinson (1991). Woodall and Robinson (2003) described the distribution and host species range of naturally occurring *Santalum spicatum* within several river catchments across the Biosphere and the potential for profitable revegetation, particularly of areas that may be otherwise affected by salinity. Woodall (2003) described another potentially profitable native plant, *Platysace,* which produces edible tubers. Aspects of the salt tolerance, rhyzobial symbionts and nutritional value of several *Acacia* species that occur in the Ravensthorpe-Hopetoun area are discussed by Craig in her 1989 thesis, and by Craig *et al* (1990, 1991, 1991). Cannon et al (1969) isolated and identified tropane alkaloids with potential commercial uses from *Anthocercis* species that occur in the Fitzgerald River National Park.

10.9 Environmental degradation

There have been few detailed studies on the effects of detrimental environmental changes on plant communities or species within the Biosphere. Carey (2004) examined the effects of hydrological change on communities associated with flat-topped yate (*Eucalyptus occidentalis*) within the Gairdner River catchment and discussed the implications for management of increasingly saline landscapes. There have been some studies on the impacts of plant pathogens, including *Phytophthora, Armillaria* and *Cryptodiaporthe,* on plant species in the area and these are described further in Section 12 of this report. Jeffery (1999) produced an unpublished report on the distribution of Victorian Tea Tree and some other environmental weeds in the Shire of Jerramungup.

10.10 Remnant vegetation

Shepherd and True (1995) surveyed remnant mallee vegetation throughout the wheatbelt area. Native vegetation remnants in the Bremer River catchment was surveyed by Heller and Brown (1996).

10.11 Management plans

Further information on the vegetation and flora is included in various management plans that have been developed for parts of the Biosphere. These include an integrated vegetation management plan for the Biosphere (Robinson, 1997); the management plan for the Fitzgerald River National Park (Department of Conservation and Land Management, 1991a); planning and project report documents associated with the Fitzgerald Biosphere Group's project on revegetation of the Fitzgerald River corridor (Mercer 1999, 2003a; Department of Conservation and Land Management 2003; Fitzgerald Biosphere Group 2003); management plans for the Cocanarup Timber Reserve (Forests Department 1980) and for the Corackerup Nature Reserve (Jones 1998); and various coastal management plans (eg Craig 1994a, Newbey 1988).

10.12 Aquatic and marine vegetation and flora

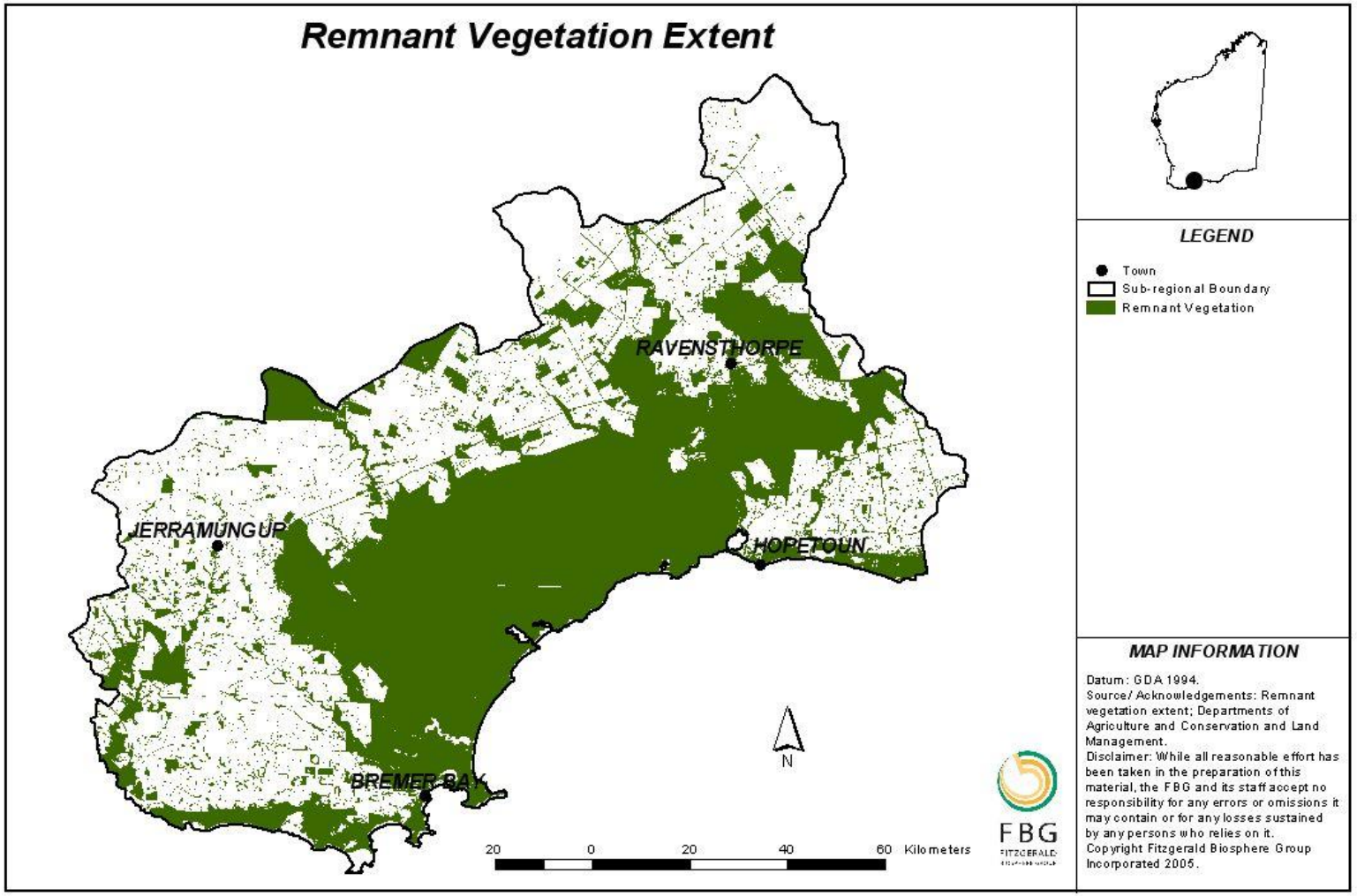
Congdon and McComb (1986) described the vegetation of the Wellstead Estuary and Gordon Inlet and looked at the impact of increasing salinity on species of aquatic macrophytes in Gordon Inlet. Benthic vegetation and its value as habitat for invertebrate fauna was examined by Forbes (2004) and comparisons made between Wellstead Estuary and Wilson Inlet. The series of studies on south coast estuaries by Hodgkin and Clark (1987, 1988, 1990) included discussion of the vegetation. An unpublished report by Smit *et al* (2000) of the UWA Botany Department for the Water and Rivers Commission used macrophytes to measure eutrophication status and may have included Wellstead Estuary, but the report was unable to be located during this study.

Also unavailable was a 1996 study by the Southern Western Australian Seagrass Study, compiled by Murdoch University for the Australian Heritage Commission, which was cited by Colman (1998) as identifying two areas in the Biosphere for proposed listing on the Register of the National Estate "on the basis of extensive meadows of perennial, deep-rooted species such as *Posidonia* and *Amphibolus*". The areas were Hassell Beach, and the area from Bremer Bay and Doubtful Islands Bay to Red Island.

Colman (1998) summarises the previous knowledge of the marine environment of the south coast and describes marine surveys off the Fitzgerald River National Park. Marine flora and fauna occurring in the area are listed. Data gathered from a survey of major benthic habitats between Red Island and Starvation Boat Harbour (Bancroft and Davidson 2000; report not available in this project) was used by Wernberg *et al* (2003) to compare the structure of kelp-associated macroalgal assemblages in this region with two west coast regions, Marmion Lagoon and Hamelin Bay.

NOTE: While the major botanical survey and study efforts have been mentioned here, there have been innumerable other collections throughout the Biosphere for taxonomic purposes (Green 1982, for example). The resources of this project did not allow for a collation of taxonomic studies, and databases such as the Department of Conservation and Land Management's "Florabase" should be consulted for further information (https://florabase.dbca.wa.gov.au/). Similarly, information on the Biosphere's 250[15] threatened, rare or priority plant taxa can be obtained through the Department of Conservationa dn Land Management and the WA Herbarium.

[15] Of the 250 taxa, 26 are Declared Rare Flora and 224 are Priority species. Sarah Comer (June 2005, pers comm.)


Remnant Vegetation Extent
RAVENSTHORPE
JERRAMUNGUP
HOPETOUN
BREMER BAY
N
20 0 20 40 60 Kilometers
FBG
FITZGERALD
LEGEND
Town
Sub-regional Boundary
Remnant Vegetation
MAP INFORMATION
Datum: GDA 1994.
Source/ Acknowledgements: Remnant vegetation extent; Departments of Agriculture and Conservation and Land Management.
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Map 9

11. FAUNA

Knowledge of the fauna of the Biosphere is addressed through broad summaries and surveys of the south coast region, more detailed surveys or studies particularly within the Fitzgerald River National Park, and one-off surveys in defined locations often associated with mining or other development proposals. The most comprehensive and long-term studies of the ecology and behaviour of a particular species have been the work conducted over more than 20 years by Wooller and colleagues associated with Murdoch University on the honey possum (see below).

Gilfillan (2000) reviewed the available information on the south coasts' fauna in a supporting document to the South Coast Management Group's *Southern Shores* coastal planning strategy. Sanders (1996) describes a study within the Biosphere buffer and transition zones (the "zone of cooperation") that included biological surveys at ten sites.

Within the National Park, the most comprehensive surveys were conducted as part of the 1985-87 biological surveys by Chapman and Newbey (1995), which included birds (Part 5), terrestrial mammals (Part 6), amphibians and reptiles (Part 7) and inland fish (Part 8). Chapman and Newbey (1988, 1994) also surveyed parts of the National Park burnt by wildfire in 1985 to assess recolonisation by vertebrate fauna.

Other surveys in or adjacent to the National Park include the survey of mountain peaks by Barrett (1996) which describes the outcome of pit-fall trapping for vertebrates and invertebrates and use of mammalian hair tube sampling at a number of sites in the south coast region, although only opportunistic sampling of invertebrates was conducted at the one Biosphere site, Thumb Peak in the Barren Range. Taylor and Baynes (1970) described a brief survey of the Park by the University of WA's Zoology Department, conducted at the time that land release and mining proposals were threatening the Park and little documented biological information was available to support the opposition to these moves. Chapman (1988) provided a preliminary list of vertebrate fauna observed in an area then proposed as the Kybulup Reserve, on the northeastern edge of the Park. Clavin (1983) studied the flora and fauna of Twin Bays near the centre of the Park (coast between Thumb Peak and Mid Mt Barren) but this report was not able to be located during this project. Lullfitz (1994) conducted trapping at a location on (then) Crown land on the north-western edge of the Park in 1994 in an attempt to determine whether dibblers occurred in the area; no dibblers were captured but 5 mammals (the common dunnart *Sminthopsis murina*; the honey possum *Tarsipes rostratus*; bush rat *Rattus fuscipes;* the southern brown bandicoot *Isoodon obesulus* (gazetted rare); and the common house mouse) were trapped.

As part of the Western Shield project, the Department of Conservation and Land Management undertakes bi-annual (spring and autumn) fauna trapping at two locations within the Fitzgerald River National Park and in other Nature Reserves in the Biosphere. The results for the period 1997-2004 have been summarised in an unpublished report by Collins and Comer (2005).

Some ecological aspects of the fauna, including reptiles, birds and invertebrates, of the Barren Range are included in a series of papers by Milewski (1981, 1982, 1984)

and Milewski and Cowling (1985) in comparisons with the Caledon Coast in South Africa and related to climatic and edaphic influences.

Chapman and Newbey (1998) also surveyed the Ravensthorpe Range area and recorded fourteen mammals, including the tammar wallaby (*Macropus eugenii),* Short-nosed bandicoot (*Isoodon obesulus*), Western mouse *(Pseudomys occidentalis)* and Heath rat (*P. shortridgei)*; 89 species of birds; and two species of inland fish. Bradby and Chapman (1987) surveyed several sites in the Range that were proposed for gravel extraction by the Main Roads Department and made recommendations on their management. Surveys on sites proposed for mining have been conducted by Biota Environmental Services and Moloch Fauna Consultants (2000), Craig (1992) and Craig and Chapman (1998) but were unavailable to this project.

Heller (1996) produced a fauna list for the Bremer River catchment based on observations during his thesis studies in the area. Leighton and Watson (1992) surveyed fauna at sites on the Corackerup Creek and the Fitzgerald River as part of a regional survey of river reserves.

11.1 Terrestrial invertebrates

As is the case for many areas, invertebrates have received limited attention compared to vertebrate species despite their integral roles in the ecological processes such as pollination, food chains, nutrient cycling and other soil processes. Invertebrates were not included in Chapman and Newbey's (1995) survey of the National Park, and while Barrett's (1996) survey of mountain peaks included invertebrate surveys of peaks in the Stirling Range, Porongorups and elsewhere, only opportunistic collections were made at Thumb Peak in the Barren Range.

Based on observations near East Mount Barren, Scott (1979) suggested that ants may play a protective role in protecting *Banksia media* flowers from attack by the larvae of Lepidoptera and Curculionidae, and hence assist in improving seed set.

Evelegh and Cockerton (2003) observed and collected insects visiting *Kunzea similis* at sites at Bandalup Hill and at East Mount Barren as part of investigations to identify potential pollinators of the species.

Milewski and Bond (1982) compared the interactions between plants and ants at sites in the Barren range with similarly sandy sites on the Caledon Coast in South Africa and suggested that the low nutrient status of soils was related to the high incidence of seed dispersal by ants. Further comparisons between the sites and the bird-ant-plant relationships are described by Milewski (1982, 1983, 1984, 1986) and Mileski and Cowling (1985).

Abensperg-Traun and Milewski (1995) compared the abundance and diversity of wood-eating and litter-harvesting termite species in burnt and unburnt vegetation in the Barren Range two years after the 1989 wildfire. Van Heurck and Abbott (2003) have reviewed the relationships between fire and terrestrial invertebrates throughout the south-west of Western Australia.

Gilfillan (2002) described the results of a study for the Department of Conservation and Land Management in which locations that could potentially harbour Gondwanan relictual invertebrates were identified through a GIS-based site assessment incorporating factors such as altitude and aspect. Sites in the Barren Range were among those identified but systematic survey has not yet occurred.

Other information on terrestrial invertebrates, including taxonomic studies (eg Jennings et al 2004) is held by the WA Museum. Several of the other fauna surveys described in this report have reported that opportunistic invertebrate samples have been lodged with the Museum, but that resources for identifying and publishing the results are very limited.

11.2 Terrestrial mammals

Of the 20 species of native terrestrial mammals that occur in the Fitzgerald River National Park (more than any other conservation reserve in south-west WA, according to Chapman and Newbey 1995b), few have been studied extensively within the Park or in its surrounds. Most work has been based on rare species, including the dibbler and the heath rat, although the continued studies on the honey possum by Ron and Sue Wooller and their students from Murdoch University over more than twenty years has yielded valuable understanding of this species, as well as better understanding of many aspects of the *Banksias* and other plant species that provide its main food source.

The pilot field studies on honey possums *Tarsipes rostratum* were initially conducted in an area further west of the Biosphere in the late 1970s (Wooller et al 1981, Renfree et al 1984, Richardson et al 1986) and identified morphological and behavioural adaptations to the seasonal availability of nectar sources, such as *Banksia nutans.* The pollen loads carried by honey possums were compared to those carried by honey-eater birds and suggestions made as to the importance of vertebrate pollinators for some species (Wooller et al 1983).

Those sites were subsequently cleared, and the Murdoch University group moved its study sites to the western end of the Fitzgerald River National Park where investigations have continued and have included studies on factors influencing the abundance of honey possums, such as annual rainfall (Wooller et al 1998). The effect of dietary constraints, particularly the availability of nectar and pollen of *Banksia* and *Dryandra* species, on reproduction rates was described by Wooller et al (1999). Wooller et al (2000) further examined the reproductive behaviour of the honey possum and the influence of nutrient and energy sources using data collected over a twelve-year period.

In her PhD thesis, Saffer (1998) examined the foraging behaviour of honey possums and nectar-feeding birds on eight species of *Banksia, Dryandra, Lambertia* and *Adenanthos* in relation to floral characteristics and temporal patterns of nectar availability. Further studies on the role of honey possums and honey eaters in pollination of *Banksia nutans* were described by Wooller and Wooller (2003).

Garavanta (1997) used mark-recapture techniques in her thesis to examine the social organisation of honey possums, including observations on their range and dispersal ability. The movement patterns were also described by Garavanta et al (2000).

Another Ph D thesis examined the effect of fire on the honey possum (Everaardt 2003, 2005) by comparing capture rates in vegetation of varying age post-fire and showed the dependence of the species on access to unburnt patches of vegetation containing mature food plants.

Friend (1992) drew on the Murdoch University work and provided an article on the potential threats to conservation of the honey possum because the spread of *Phytophthora cinnamomi* dieback and its impacts on the Proteaceae and Myrtaceae that include most of the honey possum's food sources.

Much of the work undertaken through the Murdoch University research team was also summarised for a chapter in "The Biology of Australian Possums and Gliding Possums[16]" (Wooller et al 2004).

The dibbler, *Parantechinus apicalis,* was thought extinct in Western Australia after not being collected since 1884 but was re-discovered in 1967 at Cheyne Beach to the west of the Biosphere area, and then in the Jerdacuttup area in the 1970s (Woolley 1977, 1980). A recently dead specimen was found within the Fitzgerald River National Park in 1984 (Muir, 1985). Since then, surveys within the Park have consistently found dibblers in long unburnt heathland. The dibbler is gazetted as endangered and is subject to a Recovery Plan developed by the Department of Conservation and Land Management (Friend, 2004). Under WA and Australian government programs for the recovery of endangered species, surveys have continued at known locations for the species both within the Fitzgerald River National Park and in the other surviving (wild) populations on Boullanger and Whitlock Islands near Jurien Bay. Results from these studies are reported by Baczocha and Start (1997), Start (1997, 1998) and Friend (2001). Lynam (1987) completed an Honours thesis on inbreeding and juvenile dispersal in the dibbler and the Grey-bellied dunnart *Sminthopsis griseoventer* on the two islands but included a comparison with the Fitzgerald River National Park populations. The recovery program for the dibbler recommended genetic studies on the island and mainland populations and Mills and Spencer (2003) report on the characterization of polymorphic microsatellite loci used to investigate population parameters.

Friend and Friend (1992?) reported on an Endangered Species Program study on the Red-tailed Phascogale (*Phascogale calura)* which mainly reported on the results on investigations at Tutanning Nature Reserve (outside of the Biosphere area) but includes some information on the location of Phascogales near Calyerup Creek adjacent to the Fitzgerald River National Park.

Another species believed to be extinct before its rediscovery in the Fitzgerald River area is the Heath Rat *Pseudomys shortridgei.* Baynes et al (1987) reports that its rediscovery followed the 1984 finding by Keith Bradby of remains in an owl pellet of

[16] R. Goldingay and S. Jackson (Eds): *The Biology of Australian Possums and Gliding Possums.* Surrey Beatty and Sons, Chipping Norton, 2004.

undetermined age, and the subsequent finding by Andrew Chapman of apparently fresh remains, also in an owl pellet, in 1987. Baynes then re-examined specimens collected by Chapman in 1983 in the Ravensthorpe Range and initially identified as *Rattus fuscipes* and determined that these were in fact *P. shortridgei.* Butler and Merrilees (1971) had previously described mammal remains, presumably from accumulated disintegrated owl pellets, found in sand dunes near the Hunter River. Reptiles, fish and shells of the land snail *Bothrimbryon* were also identified.

The Heath Rat also occurs in Victoria, and Cooper et al (2003) described and compared the eastern and western populations of this species. Quinlan et al (2004) used the Heath Rat as a case study in the use of remote sensing to identify target habitat types for trapping programs, with most of the field trial occurring in the Lake Magenta Nature Reserve to the north of the Biosphere area. The Heath Rat is the subject of an Action Plan under the Australian Government's Endangered Species Program (Department of Environment and Heritage 2001).

Papers by Kitchener and Halse (1978) and Kitchener and Coster (1981) describe reproduction by female bats (*Eptesicus regulus* and *Chalinolobus morio* respectively) from specimens in the WA Museum collection that had been collected within the Biosphere area as well as elsewhere in WA.

11.3 Birds

As for the terrestrial mammals, the available information on birds falls mainly into two types: general surveys and discussions of bird fauna, and references on individual species, generally those that are threatened or rare.

The 1985-87 biological survey of the Fitzgerald River National Park (Chapman and Newbey 1995b) includes a section describing bird surveys undertaken at various locations within the Park, including at some of the estuaries. The observations in this survey formed the basis for bird lists published for the Park. Newbey and Newbey (1987) record some aspects of bird dynamics in remnant roadside vegetation near Ongerup which, although just outside the Biosphere area includes habitats similar to many of the roadsides within the Biosphere. Burbidge's (2003) review of birds and fire in south-west Western Australia includes observations drawn from the National Park after wildfires.

As part of a series of papers comparing aspects of the ecology of the Barren Range with the Caledon Coast in South Africa, Milewski (1986) compared the bird-plant relationships.

The Western Ground Parrot *Pezoporus wallicus flaviventris* is a critically endangered species with one of the few remaining populations occurring within the Fitzgerald River National Park. Birds Australia, the World Wildlife Fund and the Department of Conservation and Land Management have all participated in recovery projects funded through the Australian and Western Australian Governments and several reports have subsequently been published on the conservation status of the species (Burbidge et al 1989, 1990; Watkins and Burbidge 1992), research and management plans (Cale and Burbidge 1993), or on surveys (eg Watkins 1985). Newbey et al (1983) produced a

short note on observations of individuals seen feeding at a roadside in the Park, and Burbidge (1998) discussed possible effects of a wildfire on the remaining population.

Other species for which the Biosphere, and the Fitzgerald River National Park in particular, provide important habitat include the Western Whipbird *Psophodes nigrogularis nigrogularis* and the Western Bristlebird *Dasyornis longirostris*, both of which are also threatened. Early reports of the occurrence of the Western Whipbird in the Park and at Hopetoun are given by Ford (1975) and Robinson (1975) respectively, and Smith and Moore (1977) reported on the occurrence of the Western Whipbird in the National Park.

Smith (1977) discussed the effects of fire, agricultural clearing and climate on six rare bird species including the Western Whipbird and Western Bristlebird, and in a later paper (Smith 1985) discussed in more detail the possible fire effects on the distribution of both the Western Whipbird and Western Bristlebird (and the Noisy Scrub Bird which occurs in the Two Peoples Bay – Waychinicup area west of the Biosphere). The ecology of the Western Whipbird was discussed by Smith (1991), although most of this paper was based on observations made at Two Peoples Bay but also includes habitat and population observations from the Fitzgerald area.

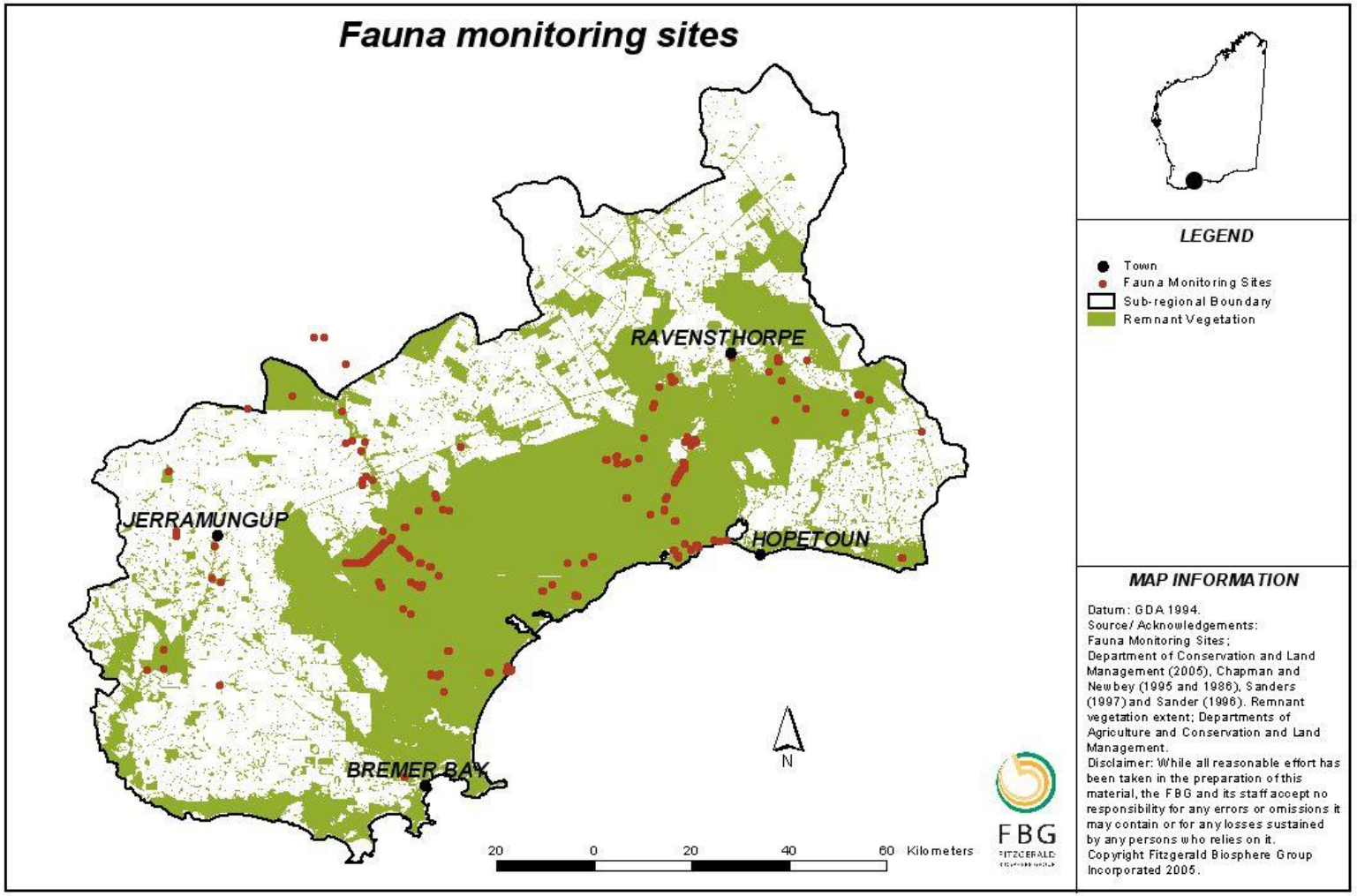
McNee (1986) reported on surveys of the Western Whipbird and Western Bristlebird throughout their range on the south coast and includes information on their historical distribution. McNee and Newbey (1998) surveyed the Western Bristlebird in parts of the Fitzgerald River National Park that had been burnt in a wildfire the previous year.

Various references to the role of birds in pollination of native plant species have already been discussed under "Vegetation and Flora" (eg Saffer 1998, 2004; Wooller et al 1983; Wooler & Woller 2001, 2002, 2004). Burbidge et al (1979) also looked at pollen loads on Yellow-winged Honeyeaters within the National Park. To the east of the Park, near Hopetoun, Witkowski et al (1991) looked at various factors affecting the seed bank dynamics of three *Banksia* species including feeding by cockatoos.

Malleefowl are found throughout the Biosphere area and most of the work on this species has been coordinated by or has otherwise involved the Malleefowl Preservation Group based at Ongerup. Harold and Dennings (1998) summarised the work of the group, including their survey work and predator control, for the period 1992-1997.

The wetlands, including the estuaries, of the Biosphere provide important habitat for several waterbird species and were included in a series of annual waterbird counts that were conducted across the south-west of the State. Reports on annual counts for the years from 1988/89 to 1991/92 have been published by the Department of Conservation and Land Management (Halse et al 1990, 1992, 1994, 1995). Halse et al (1993) reviewed some of this work and related the waterbird use to wetland characteristics.

Newbey (1996) reported on a survey and the conservation status of the Hooded Plover at both inland and coastal sites throughout Western Australia, including several sites within the Fitzgerald River National Park and some other locations in the Biosphere as part of an Australia-wide project for the RAOU.


Fauna monitoring sites
RAVENSTHORPE
JERRAMUNGUP
HOPETOUN
BREMER BAY
N
20 0 20 40 60 Kilometers
FBG
LEGEND
Town
Fauna Monitoring Sites
Sub-regional Boundary
Remnant Vegetation
MAP INFORMATION
Datum: GDA 1994.
Source/ Acknowledgements:
Fauna Monitoring Sites;
Department of Conservation and Land Management (2005), Chapman and Newbey (1995 and 1986), Sanders (1997) and Sander (1996). Remnant vegetation extent; Departments of Agriculture and Conservation and Land Management.
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Map 10

11.4 Introduced species

The Western Shield program extends across the National Park and the Nature Reserves in the Biosphere and, as mentioned above, Collins and Comer (2005) have summarised native fauna trapping conducted as part of the monitoring of the effects of the baiting program.

As part of the program within the National Park for the conservation of the Western Ground Parrot, Onus et al (2004) assessed the feral cat population and determined that feral cats were moderately abundant across the Park and that Bush Rats *Rattus fuscipes* were common in the diet of those trapped animals for which stomach analyses were conducted.

Twigg et al (2003) tested the longevity of 1080 egg-baits in a trial at Corackerup Nature Reserve, monitoring the uptake of baits by non-target (native) species.

11.5 Aquatic fauna

The series of reports by Hodgkin and Clark on estuaries of the south coast include fish, birds and some macroinvertebrate lists for the Wellstead, Beaufort and Gordon Inlets, and the estuaries and lagoons within the National Park as well as the Jerdacuttup Lakes (Hodgkin and Clark 1987, 1988, 1990).

Lenanton (1974) surveyed rivers and estuaries across the south coast from the Hardy Inlet to Stokes Inlet, including Beaufort Inlet, the Pallinup River, Wellstead Inlet and the Bremer River within the Biosphere, for fish and crustacean species and listed them, as well as providing some discussion of the relationship between the opening of the estuarine systems to the sea and the recruitment of commercial species into these systems. A later paper (Lenanton 1984) expands on the strategies developed by commercial and recreational fish species to adapt to the different physical, chemical and biological conditions encountered in south coast estuaries which have varying connectivity with the ocean.

Young and Potter (2002) provide a detailed study the effects of opening of the Wellstead Estuary after a long period of bar closure and of high freshwater discharge on fish species.

One of the estuarine fish species that has been most extensively studied, mostly by researchers from Murdoch University, is the Black Bream *Acanthopagrus butcheri.* Work has included a number of comparative studies between the species at sites on the west (Moore and Swan River Estuaries and Lake Clifton) and south coasts (Walpole Nornalup and Wellstead Estuaries) and related to estuary characteristics. Sarre and Potter (1999) compared reproductive biology of Black Bream, Sarre et al (2000) compared dietary composition, while Sarre and Potter (2000) looked at population characteristics such as age composition and growth rates.

Heald (1984) conducted surveys of amateur net fishing in the Wellstead and Beaufort Inlets in the summer of 1980/81 to document usage, species caught and size composition of the catch in relation to catch effort and the size of mesh used.

Bennett and George's (1994) biological study of Culham Inlet sampled invertebrates (and nutrients and vegetation) to determine whether opening of the bar for a six-week period in 1993 had changed the status of the inlet's biology.

Forbes' (2004) thesis compared the invertebrates within four southwest estuaries with the major discussion comparing the ecologies of Wellstead Estuary and Wilson Inlet, and the roles played in these systems by benthic vegetation and benthic invertebrate fauna.

There are very few papers on the fauna of the rivers and wetlands, other than estuaries, of the south coast. Chapman (2003) studied the biology of the Spotted Minnow *Galaxias maculatus* at several sites on the south coast, including the Jerdacuttup River. Aquatic macroinvertebrates have been used as part of an Australia-wide monitoring of river health (AusRivAS), and several of the sites occur within the Biosphere area. Sutcliffe (2003) provides a further analysis of some of the AusRivAS information to discuss the conservation status of aquatic insects. Further information on the Monitoring River Health program can be found on the website http://eriss.erin.gov.au/water/rivers/monitoring.html

The River Action Plans for the Bremer, Phillips and Jerdacuttup Rivers (Water and Rivers Commission 2001; Department of Environment 2003, 2004) and the report on "State of the Waterways of the Fitzgerald River Catchment" (Water and Rivers Commission 2003) provide some information on aquatic macroinvertebrate monitoring in these waterways.

11.6 Marine fauna

The only marine flora and fauna survey of the south coast identified in the project was by the Department of Conservation and Land Management in 1996 (Colman 1998) which surveyed areas of estuaries and coasts adjacent to terrestrial nature reserves, to determine their suitability for reservation for marine conservation. An area adjacent to the Fitzgerald Biosphere Reserve was surveyed and benthic habitats mapped.

The waters off the south coast of WA, including those offshore from the Biosphere area, support diverse marine fauna including whales, Fur Seals and Sea Lions. The Doubtful Islands are particularly important sites for the latter two species, while the waters around them are used by Southern Right Whales for calving.

Abbott (1979) summarised the past and present distribution and status of Sea Lions and Fur Seals in WA. Gales (1990) reported on the abundance of Australian sea lions *Neophoca cinerea* on islands along the south-western and southern coasts of Western and South Australia, including the Doubtful Islands. Gales et al (1994) discussed the abundance and the breeding cycle of Australian sea lions based on their studies on islands in WA and SA between 1987 and 1992.

Shaughnessy et al (1994) reported on the distribution and abundance of the New Zealand fur seal *Arctocephalus forsteri* based on surveys on islands in WA and SA between 1987 and 1990. Gales et al (2000) discussed apparent increases in the population of New Zealand fur seals in WA.

Bannister (1990, 2001, 2002) reports on aerial surveys of Southern Right Whales off the south coast and the assembly of a photo-identification database by the WA Museum. Holst (undated) discussed possible reasons for the Doubtful Islands being one of two major calving areas for this species (the other area is Israelite Bay), including the orientation of the coastline relative to prevailing winds.

12. PLANT DISEASES

Shearer (1994) reviewed the major plant pathogens occurring in native ecosystems in south-western WA by drawing on extensive databases, reports and published information. *Phytophthora cinnamomi* poses one of the greatest threats to the biodiversity of the Fitzgerald Biosphere area but is only one of the plant pathogens occurring in the area. Others that have been identified as potential threats to some species include other *Phytophthora* species (eg *P. megasperma), Diplodina, Armillaria luteobubalina* and *Cryptodiaporthe melanocraspeda.*

An occurrence of *Phytophthora cinnamomi* on the Bell Track is the subject of monitoring and management measures, including phosphite application. Other *P. cinnamomi* infection sites within the South Coast are currently being mapped as part of a Natural Heritage Trust funded project through SCRIPT. Grant and Barrett (2003) provide an overview of the distribution and impact of *P. cinnamomi* across the south coast, with particular attention to the impacts within the National Parks and implications for conservation of threatened species and communities. Barrett (1999, 2003) discusses the results of monitoring aerial application of phosphite in the Stirling Range National Park and at the Bell Track location in the Fitzgerald River National Park.

Shearer and Crane (2003) looked at the influence of soil types from within the National Park on the mortality of *Banksia baxteri* infected with *P. cinnamomi.*

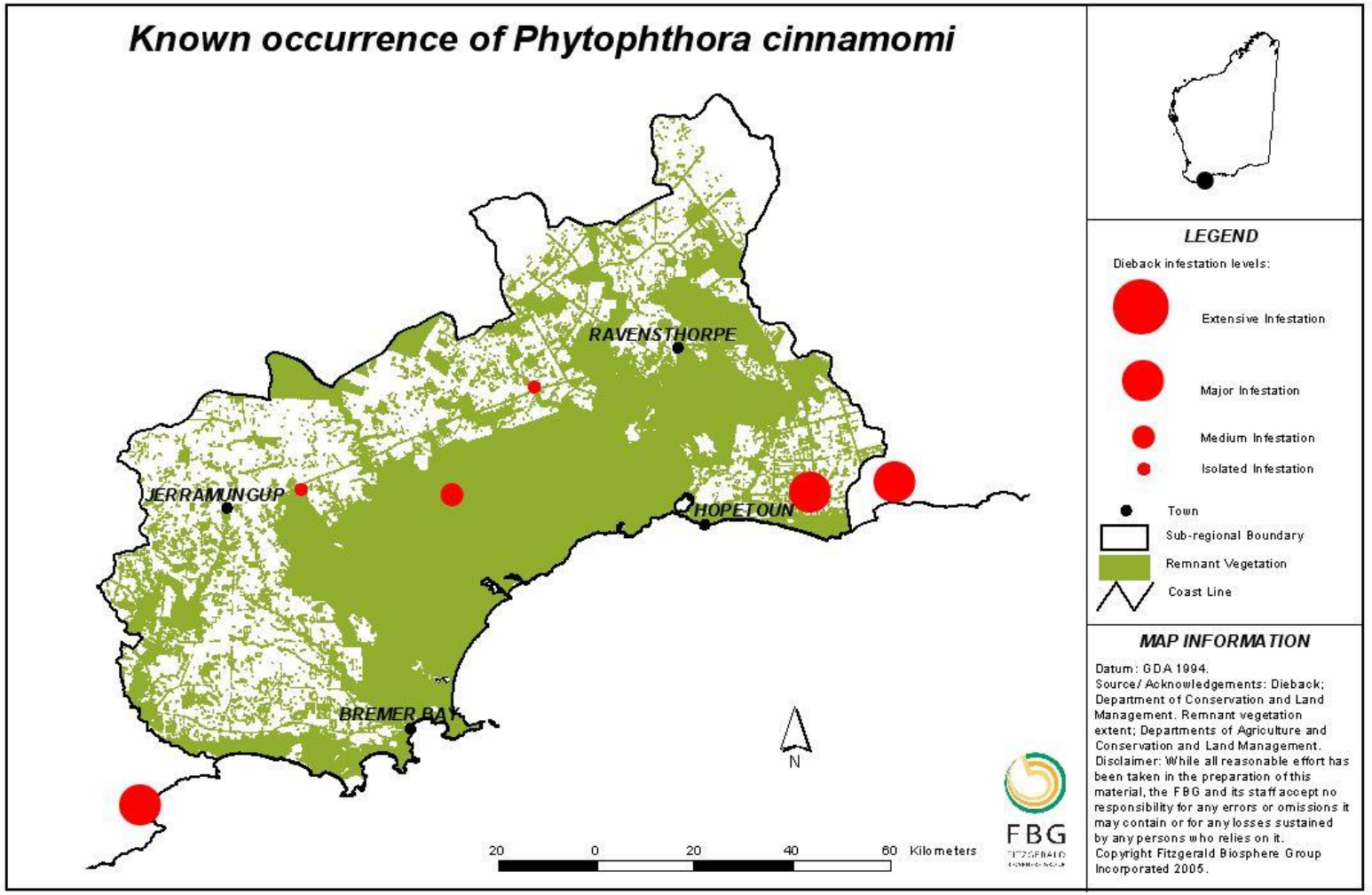
The threats from *P. cinnamomi* are not only to conservation of flora species; fauna is also at risk, particularly those species that are highly dependent on the nectar and pollen production from the Proteaceae. Friend (1992) describes the risks to the Honey Possum, for example. Robinson (1991) reviewed the conservation status and economic value of *Banksia coccinea* and *B. baxteri,* two species highly prized by the wildflower industry but potentially threatened by uncontrolled collection and disease spread.

Glevan Dieback Consultancy Services (2000) assessed areas near Ravensthorpe for the presence of *P. cinnamomi* for the Ravensthorpe Nickel Project. The Department of Conservation and Land Management has had a number of projects funded through the Department of Environment and Heritage (formerly Environment Australia), some of

which have used the Bell Track infestation as one of their study sites (Department of Conservation and Land Management 1997). The Department also produces 5-year protection plans for the South Coast outlining actions to be taken to contain or prevent further spread of the disease (e.g. Department of Conservation and Land Management 1994).

Phytophthora megasperma has been isolated around East Mt Barren, in western parts of the Park (Pt Anne, West Mt Barren and Quaalup) and near Hopetoun to the east of the National Park (Bellgard et al 1994) and has high impact on *Banksia speciosa* as well as some other *Banksia* and *Dryandra* species (Bellgard et al 2004).

Banksia coccinea is also susceptible to cankers caused by *Cryptodiaporthe melanocraspeda.* Shearer et al (1995) sampled dead and dying *B. coccinea* across its range, including sites in the National Park, and isolated several types of fungus from them but attributed the deaths to *C. melanocraspeda.* Shearer et al (1997) assessed sites along the coast for *Armillaria luteobubalina* and found that this pathogen resulted in changes in community structure and increased area of bare ground in disease centres, and that threatened taxa killed by the fungus include the rare and endangered *Banksia brownii, B. occidentalis* subsp *formosa* and *B. verticillata.* The relative susceptibilities of plants in coastal dune vegetation to killing by *A. luteobubalina* is described by Shearer et al (1998).


Known occurrence of Phytophthora cinnamomi
RAVENSTHORPE
JERRAMUNGUP
HOPETOUN
BREMER BAY
N
20 0 20 40 60 Kilometers
FBG
LEGEND
Dieback infestation levels:
Extensive Infestation
Major Infestation
Medium Infestation
Isolated Infestation
Town
Sub-regional Boundary
Remnant Vegetation
Coast Line
MAP INFORMATION
Datum: GDA 1994.
Source/ Acknowledgements: Dieback; Department of Conservation and Land Management. Remnant vegetation extent; Departments of Agriculture and Conservation and Land Management.
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Map 11

13. FIRE

References addressing fire and its effects on the biota of the Fitzgerald Biosphere are, for the most part, either part of wider reviews into the fire relationships of systems within south-western Australia, or opportunistic studies and surveys post-wildfire.

A recent publication reviewing knowledge on several aspects of fire and its impacts on ecosystems, *Fire in ecosystems of south-west Western Australia: Impacts and management* (Abbott and Burrows Eds, 2003) includes references to the Fitzgerald area in relation to birds (Burbidge 2003), terrestrial invertebrates (van Heurck and Abbott 2003), the fire environment (McCaw and Hanstrum 2003) and the pre-European fire history (Hassell and Dodson 2003).

McCaw, Maher and Gillen (1992) provided a detailed description of the fire weather conditions and fire behaviour of the wildfires that occurred in the Park in December 1989.

Hassell's (2000) thesis examined historical records, current vegetation structures, monitoring of post-fire recovery in marked plots, and charcoal and pollen preserved in estuarine sediments, to determine the changes that may have occurred in fire frequencies within the National Park. His thesis included discussion of some of the habitat requirements for flora and fauna species and consequent fire interval preferences. Everaardt's (2003) thesis provides detailed examination of the impacts of fire on one species, the Honey possum *Tarsipes rostratus,* and like Hassell, found that fire intervals in excess of 20 years favoured habitat for fauna.

Chapman and Newbey (1988, 1994) monitored areas burnt by wildfires in 1985 during the first year of the Fitzgerald River National Park Biological Survey (Chapman and Newbey 1995) for both recolonization by fauna and regeneration of flora. McNee and Newbey (1998) surveyed for Western Bristlebird populations in areas burnt by wildfire in 1997.

Witkowski et al (1991) looked at the seed bank dynamics of three *Banksia* species (*B. coccinea, B. baxteri* and *B. speciosa*) in patch burnt scrub heath 10 and 21 years post-fire and studied the roles of how plant age, seed removal by cockatoos and senescence affect establishment.

The abundance and diversity of wood-eating and litter-harvesting termite species in burnt and unburnt vegetation near the Barrens was compared by Abensperg-Traun and Milewski (1995). Burbidge (1998) suggested some impacts that a wildfire may have had on the Park's Western Ground Parrot population.

Bennett (1987) studied vegetation structures in relation to soil characteristics in the Ravensthorpe Range and had fire burn several of the vegetation quadrats during the course of the study. Her thesis includes monitoring of recovery and recruitment post-fire in these plots.

The Friends of the Fitzgerald River National Park hosted two fire symposia, at Gairdner and at Ravensthorpe, in 2002 and recorded the presentations and discussion sessions on two audio CDs (Friends of the FRNP, 2002).

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