# Meelup Regional Park

# Research Proposal

# 2014 – 2024

A report to the Meelup Regional Park Management Committee and the City of Busselton, Western Australia.

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May 2014


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# Acknowledgements

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The project was supervised by David Coates from the Science and Conservation Division of the Department of Parks and Wildlife.

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# Summary

The Meelup Regional Park research proposal was developed for the management committee to provide a strategic basis for future planning, prioritising and budgeting of research projects over the next ten years. Research was required to understand the natural and cultural environment, and to understand the impacts of threatening processes, management activities and visitor use on conservation values. The term 'research' in this report includes scientific research, consultant reports, surveys and monitoring.

A wide range of research questions can and have been posed through the Management Plan and other documents, but it is important to know which questions need answers to improve management decisions as part of the adaptive management process. Other research can provide interesting information that is useful for description or interpretation of cultural and conservation values, but these were considered of lower importance.

Potential research questions were identified from a workshop of committee members and from an extensive review of existing knowledge about Meelup Regional Park including management plans, annual reports, surveys and associated research and references. This also included communications with research organisations to determine the current state of knowledge and research about relevant conservation values and management issues in a broader context. Research questions were grouped according to whether they were about cultural or ecological values, and then according to their values and/or management issues.

Projects were prioritised and the thirteen highest priority projects were then described with background information, suggested methodology, environmental, social and economic benefits and indicative costs. These projects were:

- Soil erosion and track maintenance
- Impacts of fire on Threatened and Priority flora and fire sensitive communities
- Impacts of fire on Threatened and Priority fauna and their habitats
- Impacts of tree decline on vegetation communities and fauna habitat quality
- Understanding the susceptibility of plants to Phytophthora disease
- Monitoring the impacts of introduced predators on western ringtail possums and southern brown bandicoots
- Conservation of Meelup Mallee (*Eucalyptus phylacis*)
- Conservation of Threatened orchids
- Research into the taxonomy and genetics of Priority and disjunct flora
- Determine the sustainable visitor capacity of Meelup Regional Park
- Reduce visitor impacts on vegetation
- Reduce visitor impacts on hooded plovers and other shorebirds
- Trends in stream water flow and quality

Sources of funding have been suggested for different projects, although some projects may need to be adjusted to align with criteria for each funding body. Many of the projects can be partly or wholly funded from existing funds budgeted from the City of Busselton for managing Meelup Regional Park. A schedule of research projects is provided over ten years with the more urgent projects and those that can be undertaken by contractors and consultants

scheduled in the first few years while those that may take some time to develop and secure funding are scheduled in later years.

As with any research, there are many questions and many ways that a question can be answered. The projects developed in this proposal can be expanded or reduced according to availability of funding and other resources, and opportunities that may arise from time to time for collaborative partnerships with other agencies and research organisations. Most projects have at least some opportunity for volunteers to be involved to reduce overall costs and provide a meaningful connection with the Park.

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# 1.0 Introduction

Meelup Regional Park is an attractive area of near pristine natural vegetation, scenic landscapes, rock outcrops and sandy beaches that extends along Geographe Bay from Dunsborough to Bunker Bay. This area is also valued for its range of passive and creative recreational opportunities and its educational and research values for present and future generations. Meelup Regional Park was created in 1993 as a class 'A' reserve and is vested in the Shire of Busselton for conservation and recreation. Recreation and other uses are allowed only to the extent that they are compatible with and do not impair the inherent natural values of the park.

The Meelup Regional Park ('Park') is managed by the Meelup Regional Park Management Committee ('Committee') on behalf of the City of Busselton. The *Local Government Act* and City of Busselton Local Laws provide regulations for the daily operation of the Park, while the State Planning Policy 6.1 Leeuwin-Naturalist Ridge provides strategic planning framework for the next 30 years (Western Australian Planning Commission, 1998). Management specific to the Park is guided by the Meelup Regional Park Management Plan (2010) ('Management Plan') that was prepared as a requirement for the *Land Administration Act 1997.* The Management Plan outlines specific conservation, cultural and recreation values of the Park, threats and issues, strategic goals, management strategies, objectives, guiding principles and directions for operational management. A number of other plans and policies are associated with the Management Plan, including the Fire Management Plan, the Coastal Nodes Master Plan and the Interpretive Signage Plan.

Scientific research is considered to be highly important aspect of the Park with a stated goal to "seek a better understanding of the natural, cultural and social environments, and the impacts of visitor use and Park management". The management objective is to foster scientific and research uses that increase understanding of the Park and the environments whilst ensuring that the research itself does not conflict with Park values. A number of surveys and studies have been completed, while other research topics have been identified as high priorities in the Management Plan. The Park has been used for research by other groups and agencies, such as the South West Whale Ecology Study group, the Dunsborough Coast and Landcare Inc. and the Department of Parks and Wildlife ('Parks and Wildlife').

Management issues usually arise from a lack of knowledge, capacity or funding. Research is undertaken to meet the knowledge gaps and provide direction for overcoming the issues. The highest priority is for research into matters that cause the greatest environmental degradation and loss to the highest conservation values in the Park to provide guidance to the committee through the process of adaptive management.

# 2.0 Scope of project

The research program will provide a strategic base for the Meelup Regional Park Management Committee for future planning, prioritising and budgeting of research projects. The main focus of the research is to:

- Gain a better understanding of the natural and cultural environment, and
- Understand the impacts of management activities and visitor use on conservation values.

Specifically, this project has reviewed the literature, surveys and reports provided on the Meelup RP website and accessed other relevant information to gain a clear understanding of the Park, its environment, values and threats and the management undertaken and planned for the future. Based on this information, gaps in knowledge and management were identified which guided the development of an integrated research program for the park with a schedule of potential projects and activities over a ten year period from 2014 to 2024.

This research program schedule includes the following aspects:

- Research questions and objectives,
- Indicative methodology,
- Relation to previous and other research,
- Priority and sequencing relative to other projects,
- Benefits to park management, the scientific community and/or wider public,
- Suitable organisations that could undertake the research,
- Indicative costings, and
- Suggested funding sources or strategies to minimise costs to the City of Busselton.

Two consultation sessions were conducted after an initial scoping meeting on the 21st January, 2014. The first session was a workshop with the Committee on 11th February to outline the project and seek input from the committee members about their priorities for research. The second session was conducted electronically by asking the committee members to rank the highest priority research questions according to their intuitive assessment of values and risks. Discussions were held with staff from the Department of Parks and Wildlife, the Botanic Gardens and Parks Authority (BGPA), universities and other research organisations.

The indicative budget from the City of Busselton for research in the Meelup Park 10 year financial plan is in the order of $50,000 per annum. This funding could either be used to conduct the research or preferably as seed capital to attract further funding from other sources. Other research that uses sites within the Park, and that does not require a capital contribution from the Committee, is encouraged.

This report uses available information to determine knowledge gaps and develop priorities for research. During an initial meeting, Committee members expanded the term ‘research’ to include scientific research, surveys and monitoring, which provide different types of information and meet different management requirements. The Committee also aspired to include the community as volunteers in research projects wherever possible.

# 3.0 Conservation values

## 3.1 Flora and vegetation

Flora and vegetation communities were assessed in earlier broad scale surveys (Keating and Trudgen, 1986; Lyons *et al*., 2000; Keighery *et al*., 2011). More recently, Webb (2013) surveyed the Park in detail and noted the location of all the currently listed Threatened (Declared Rare Flora), Priority (rare and poorly known flora of conservation significance) and disjunct species in the Park (Smith, 2012). It is unlikely that additional surveys will result in new populations of currently known Threatened or Priority flora being discovered in the Park (A. Webb, personal communication). However, appropriate genetic and morphological investigations of the disjunct populations within the Park may result in the recognition of new species/subspecies that are highly likely to be ranked as Priority or even Declared Rare status. Known populations of Threatened and Priority flora will still need to be monitored on a regular basis by Parks and Wildlife to ensure their future conservation.

### 3.1.1 Threatened flora

There are four listed Threatened flora species (Declared Rare Flora under the Wildlife Conservation Act 1950) within the Park boundary, being *Caladenia excelsa* (1 of 30 populations), *Caladenia caesarea* subsp. *maritima* (5 of 6 populations), *Caladenia viridescens* (2 populations and 2 sub-populations of 8 populations) and *Eucalyptus phylacis* (1 sub-population of 1 population). The habitats of other populations in adjoining road reserves and private property extend into the Park and need to be managed accordingly. These populations are monitored annually by officers from the Department of Parks and Wildlife. Three of these Threatened species have an Interim Recovery Plan (IRP) that summarizes the threats and management actions required for each species, including priorities for research, i.e *E. phylacis* (Patten, 2004); *C. viridescens* (Patten *et al.,* 2005); and *C. caesarea* subsp. *maritima* (Department of Environment and Conservation, 2007).

- *C. viridescens, C. caesarea* subsp. *maritima* and *C. excelsa*. These orchid species are threatened by weed invasion, grazing and digging by kangaroos, rabbits and southern brown bandicoots, inappropriate fire, poor recruitment, recreational impacts (trampling, picking flowers and soil compaction), road and track construction and maintenance and dumping of rubbish. These species are surveyed at least once every three years.

Research has been conducted at several orchid populations to develop appropriate fire regimes but there has not been a satisfactory response to these trials. Caladenia species depend on mycorrhizal fungi for germination, which depend on surface litter, so maintaining the litter layer is important for the growth and survival of orchids (K. Dixon, personal communication). Prescribed burning between December and March during the dormant season has been recommended for orchids, on a 10-15 year rotation, but more specific guidelines are required for each species. Low to mild intensity burning of *C. excelsa* during late flowering in spring (late October 2007) resulted in good regeneration the following year with many new plants found in burnt areas (A. Webb and Simon Martin, unpublished data), while flowering of *C*. *caesarea* subsp. *maritima* was not adversely affected by burning in May (TPFL, 2014). However, trial burns in December, March and May have not resulted in regeneration of *C. viridescens* (Patten *et al*., 2005; TPFL, 2014).

Caladenia species are known to germinate without fire and flower more prolifically in years with good rainfall, but research is needed into the effects of litter cover, shading and weed competition on seed germination and growth of their tubers and associated mycorrhizal fungi. Other recommended research from the IRPs include seed viability and baiting for translocations; distribution, diversity and specificity of mycorrhizal fungi; pollinators and pollination biology; impacts of grazing on flowering and seed production; and effective methods for controlling weeds and grazing by animals in orchid habitats. *Caladenia excelsa* grows in banksia woodland, which is susceptible to *P. cinnamomi* disease, and would be at risk if the dominant banksia canopy deteriorated.

- *E. phylacis*. This endemic, relictual population is considered to be a clonal hybrid between *E. decipiens* and *E. virginea* (Nicolle and French, 2012) that has limited genetic diversity and produces very few viable seeds (Rosetto *et al*., 1999). It is threatened by bark borers and fungal canker disease with associated severe stem splitting (Scott, 2003; Robinson and Spencer, 2004). The canker and borer species have been identified (Patten, 2004) but are considered to be secondary causes of deterioration and death of older stems already stressed by a declining rainfall (Robinson and Spencer, 2004). *E. phylacis* may also be threatened by inappropriate fire regimes and road maintenance activities, which have in the past destroyed one part of the population (Patten, 2004). Individual ramets of this population have been surveyed in detail and eight are monitored annually by the Park committee members and DPaW staff.

A few seeds of *E. phylacis* were collected and germinated in 2003 (A. Cochrane, personal communication) and grown at the BGPA nursery but their fate is unknown. Other seed collections are warranted to study the genetic diversity and to produce material for translocating plants to more protected sites. Further work is required to clarify the phenology, pollinator activity and breeding biology and to find ways to overcome the low fecundity (Rossetto *et al*., 1999; Patten, 2004). Several plants have been propagated from *in vitro* cultures by BGPA, and some of the cultures are kept in cryostorage to ensure viable genetic material is kept in case the parent stock dies or is destroyed (Bunn, 2001; Patten, 2004). BGPA are continuing with this work and plan to have plants ready for possible translocation in 2015 (E. Bunn, personal communication). Funding has been sought from SGIO to cover some of the costs of this translocation, including vermin proof fencing and a watering system (M. Polley, personal communication).

Fire is likely to have maintained the mallee habit over thousands of years and may be required on a more frequent basis than currently experienced to maintain the ramets in a younger stage of growth (Robinson and Spencer, 2004). One ramet that was coppiced in 2001 produced new healthy growth that was more resilient to fungal cankers and stem borers. Ongoing monitoring is required to follow the growth patterns and health of coppiced stems to determine when they become susceptible to canker and borers, the time to first flowering of coppiced stems and the best time of year for coppicing (winter or spring). The response of ramets to fire and coppicing need investigating to determine an appropriate regeneration management strategy.

*Phytophthora cinnamomi* pathogen was isolated from the soil within the *E. phylacis* population, which could pose a serious threat (Robinson *et al.,* 2004). The susceptibility of *E. phylacis* to *P. cinnamomi* needs to be evaluated to determine if current hygiene management is adequate.

### 3.1.2 Priority flora

There are seven Priority flora within the Park boundaries, including some that are disjunct populations from the main occurrences (Webb, 2013). All Priority species are monitored every three years by Parks and Wildlife to check on their demographic status and assess the severity of threatening processes.

- *Thelymitra variegata* has not been recorded in Florabase since 1965 and may be locally extinct. It is prized by orchid enthusiasts and the general public and may have been over collected as in other populations, although many other factors can affect flowering and survival. Closer monitoring of this population and its habitat may be warranted, especially in higher than average rainfall years.
- *Boronia tenuis* and *Eucalyptus virginea* are significantly disjunct populations that may have been separated from other populations during past fluctuating climatic changes and are likely to have undergone genetic divergence (Webb, 2013). The population of *E. virginea* in the Park was only discovered in 2008 and is a considerable distance from the other occurrence near Denmark. Further study is required to determine their genetic and taxonomic status as they may be rarer than first thought and in need of greater protection.
- *Calothamnus graniticus* subsp. *graniticus* is only known from the Meelup and Sugarloaf Rock areas on exposed granite outcrops. Plants from these two areas differ in leaf hairiness so further genetic analysis is required to determine their genetic and taxonomic status (Keighery *et al*., 2011). This sub-species is the dominant shrub of the endemic Threatened Ecological Community (TEC) ('*Calothamnus graniticus* heaths on south-west coastal granites'). It is distinctive from the related subspecies (*C. g. leptophyllous*) found on the Darling Scarp (Webb, 2013).

- *Acacia latericola* - glaberous variant (P3), *Meionectes tenuifolia* (P3) and *Eucalyptus rudis subsp. cratyantha* (P4) are the other Priority species requiring ongoing population monitoring.

### 3.1.3 Other significant flora

Webb (2013) lists a further 15 flora species that are disjunct from their typical areas of occurrence, poorly recorded and/or at their range ends that are worthy of further taxonomic and genetic investigation to clarify their status to see if they have been subject to genetic divergence and speciation. Of particular interest are the species *Schoenus* aff. *subflavus, Johnsonia acualis* (Busselton form) and *Stylidium affine* that require further collection and study, the first two being new and unnamed taxa (Webb *et al.,* 2009; A. Webb, personal communication). Other genetic studies have been conducted on local orchids and marri with results still to be published (D. Coates, personal communication).

### 3.1.4 Vegetation communities

The '*Calothamnus graniticus* heaths on south-west coastal granites' TEC occurs in seven locations within the Park between granulite boulders and on exposed slopes near headlands and occupies about 40ha. This distinctive heath community has high species diversity and includes species that are adapted to shallow soils and patterns of very wet and dry periods. The TEC is being threatened by weed invasion and too frequent fire (Pryde, 2010), but is not currently being impacted by *P. cinnamomi* (A. Webb, personal communication). The response to fire and susceptibility to *P. cinnamomi* of individual species within the TEC are not well known. Other threats include grazing by rabbits and kangaroos, and damage to plants by maintaining tracks, creating new tracks and recreation impacts.

Vegetation surrounding granite outcrops that is dominated by annually renewed herbs has also been recognised as significant in the Park (Webb, 2013). This vegetation community is only found here and at one location near Augusta, and is associated with shallow clay-loam soils and seasonal waterlogging. The flora includes species that are found in claypans elsewhere but were first recorded in the Leeuwin block landform by Webb (2013), including eight *Schoenus* species and the Priority species *Meionectes tenuifolia*. They occur low in the landscape and are prone to weed invasion and degradation from walk trails and recreation impacts (Webb, 2013).

The other significant vegetation community in the Park is the woodland surrounding and intermingling with the granitic heath community, which warrants recognition as a TEC (Webb, 2013). This community is very diverse and supports most of the Park's Threatened and significant flora, and occurs almost exclusively within the Park. The granite vegetation communities in the Park are quite different to those in other granite outcrops on the Leeuwin Naturalist Ridge and Margaret River Plateau (Webb, 2013). Further surveys and analysis is required in these other areas to determine the floristic patterns and whether they should be recognised as different Threatened or Priority ecological communities (A. Webb, personal communication).

## 3.2 Fauna

Terrestrial fauna surveys were conducted in the Park from 1994 to 1997 (Hart *et al*., 1995, 1996 and 1997). These surveys found a high diversity of fauna species including Threatened and Priority fauna species and two reptiles with significant range extensions, one of which is a Priority species. These surveys recorded eight native and four introduced mammal species, nine frog species, 16 lizard species and three snake species. Other informal fauna

surveys have been conducted by the Dunsborough Coast and Landcare Inc. and the Busselton Naturalists Club.

A search of the Parks and Wildlife database, NatureMap, which includes records from WA Museum, Birdlife Australia and other databases, based on a 10km circle centred on the Park, found many more native terrestrial species that have been recorded from this general area and could be present in the Park. This search found records for 22 mammal species, 122 bird species, 27 reptile species, 10 amphibian species and 13 invertebrate species.

### 3.2.1 Threatened fauna

Threatened and Priority fauna recorded from the NatureMap 10km search that could be present in the Park are listed in Table 1. This list does not include cetaceous, marine or pelagic species that do not come directly under the management of the Park, while shorebirds that are protected under international agreement and that may use the beach to rest, feed and/or breed are included.

There are recovery plans for five Threatened species listed in Table 1 and one interim recovery plan. Recovery plans are also available for two other Threatened species (forest red-tailed black cockatoo and chuditch) that have been recorded in the 20km radius of the Park. These plans summarise what is known about the species and provide guidance for managing the species, including priorities for research. The recovery plans most likely to be of relevance to the Park are for the western ringtail possum (Department of Parks and Wildlife, 2014), Carnaby's cockatoo (Department of Environment and Conservation, 2012), Baudin's cockatoo (Department of Environment and Conservation, 2008a) and possibly the Dunsborough burrowing crayfish (Department of Environment and Conservation, 2008b).

#### 3.2.1.1 Mammals

Western ringtail possum (*Pseudocheirus occidentalis*) - The Dunsborough to Bunbury region is now recognised as one of three key management areas for the western ringtail possum (Jones, 2004; Jones *et al.*, 2007; Wayne *et al*., 2012). Their distribution has recently contracted to the cooler coastal fringes, due to a drying climate and associated impacts on stream flows in the south-west (Silberstein *et al*., 2012). Western ringtail possums (WRP) are susceptible to heat stress (Yin, 2006) and require dense myrtaceous shrubs and trees to provide shade and shelter. They prefer mature peppermints (*Agonis flexuosa*) in coastal areas for browsing, building dreys and protection from predators, but use a range of other native species including melaleucas and kunzeas. WRP can attain high densities in urban and semi-urban areas in and around Dunsborough and Busselton and appear to benefit from having access to drinking water and garden plants with enhanced nutrient quality (Shedley and Williams, 2014). Within the Park, there is about 60ha mapped as high quality habitat (class 4) mainly along the Meelup and Dolugup Brooks and two smaller creeklines. WRP were reported to be common but in restricted areas in the Park, along the coastal strip where peppermint grows and along Meelup Brook (Hart *et al.*, 1996, 1997) and probably occur in the banksia and peppermint woodland north of Dunsborough.

Threats to WRP include habitat loss from clearing, tree decline and intense fires that remove habitat protection and food resources for a number of years. Clearing to provide additional tracks, firebreaks or infrastructure in the Park should be minimised in known fauna habitats. The threat of habitat loss and associated increased predation following large-scale wildfires can be minimised by implementing the Meelup fire management plan (2007). This plan identifies peppermint woodlands and melaleuca thickets as vulnerable habitats that should be excluded from prescribed burning and that require special attention during wildfires (see Section 5.2). Tree and canopy decline is a serious threat for WRP and many peppermints have suffered from drought in recent years with mild to severe canopy decline evident in the Park. Peppermints are also particularly susceptible to myrtle rust disease, and although this

disease is not yet present in Western Australia, it would be a significant threat to peppermints and other myrtaceous species on which WRP depend (Dumbrell, 2011). Other threats include predation by foxes, cats, dogs and native predators and direct kill by vehicles. Foxes and cats are routinely baited and trapped in the Park, which may explain some of the recent increase observed in the WRP population (R. Glencross, unpublished data). Many WRP are killed by vehicles each year and the location of such incidents has been recorded where possible by the Busselton Naturalists Club (BNC, unpublished data). This could be useful data to determine the most suitable location to install rope bridges if these are to be used in future.

Key areas for research for the WRP include establishing long term monitoring sites to determine the total population, detect population changes and monitor other variables (e.g. fox density, tree canopy decline, vehicle fatalities and fire) that may contribute to a decline in the WRP population. Improved understanding of WRP browsing preferences and patterns of movement and dispersal within the Park and in adjoining areas is required to assist fire planners determine the appropriate scale for prescribed burns. The impacts of tree decline on WRP could be addressed by the Centre for CCWFH, while monitoring sites could be selected and registered for early detection of myrtle rust disease. Research is required to determine the reliance of WRP on urban structures, water supplies and non-native garden plants for providing food, shelter and habitat connectivity.

Southern brown bandicoots (*Isoodon obesulus* subsp. *fusciventer*) - require dense scrubby habitat with low ground cover along watercourses and wetlands, and is susceptible to declining groundwater and rainfall (Wilson *et al*., 2012). Bandicoots forage by digging in soil and can displace several tonnes of soil per year, which is likely to be a critical component off soil ecosystem processes (Valentine *et al*., 2012). Hart *et al.* (1996, 1997) found runways and diggings of the southern brown bandicoot along the coastal vegetation and in wetter areas, but the actual habitat areas occupied in the Park is unknown and needs to be mapped. The population may be declining in the Park due to fox predation and could suffer local extinction if the entire coastal area was burnt in one fire (Hart *et al.*, 1997), although the impacts of fire on bandicoots and their habitat are not well known. Monitoring of this Priority species is required to determine current population size and to detect changes in population numbers over time. Parks and Wildlife is currently undertaking a genetic study of bandicoots throughout its range and need volunteers to submit tissue samples from roadkill (Ottewell, 2013).

Other Threatened and Priority mammals - There have only been two recorded sightings of the western brush wallaby (*Pseudocheirus occidentalis*) in and near the Park in recent times. Southern brush-tailed phascogales (*Phascogale tapoatafa* subsp. *tapoatafa*) have been reported near Cape Naturalist, Injidup and Augusta, while chuditch (*Dasyurus geoffroii*), have been sighted in the Leeuwin-Naturalist National Park and both of these Threatened species could be present in the Park (Hart *et al*., 1997). Further surveys for these species are required to determine if viable populations exist in the Park. These species depend on ongoing fox control and appropriate fire management for their survival.

#### 3.2.1.2 Birds

Black cockatoos – Carnaby's cockatoo (*Calyptorhynchus latirostris*) and Baudin's cockatoo (*Calyptorhynchus baudinii*) have been recorded in the 10km radius of the Park, while forest red-tailed black cockatoo (*Calyptorhynchus banksii* subsp. *naso*) was recorded in the 20km radius (NatureMap, 2014). They all depend on marri seed as their main food source, with jarrah seed used when available. These cockatoos also use a variety of other native species including banksia, dryandra, hakea, allocasuarina seeds, and are likely to forage in the jarrah-marri open forest and woodland vegetation in the Park. Carnaby's cockatoos would also forage in the heath vegetation on a wider range of proteaceous species. Cockatoos all need access to fresh water each day and will drink at artificial water sources if necessary

(Department of Environment and Conservation, 2008a; Department of Environment and Conservation, 2012).

These Threatened and endemic species have been seriously impacted by loss of habitat through clearing in the south-west so vegetation in the Park is important habitat. Suitable nesting hollows are scarce and this is seen as one of the main threats, which is exacerbated by competition from Australian wood ducks, Australian shelducks, galahs, native and introduced corellas and feral European honey bees. Other threats include illegal shooting when they damage fruit crops (Baudin's cockatoo), pine plantations (Carnaby's cockatoo) and bluegum plantations (forest red-tailed cockatoos), road kills and further loss of nesting trees through forest harvesting and clearing of foraging vegetation (Department of Environment and Conservation, 2008a; Department of Environment and Conservation, 2012). Drought and tree decline are likely to impact on eucalypt seed availability as well as a reduction in natural water supplies.

Roosting sites are being mapped for Carnaby's cockatoos in the Swan Coastal Plain, and maps have been produced for that area and the adjacent jarrah forest for indicative breeding, roosting and feeding habitats (Glossop *et al*., 2011). As well, an online resource tool is available that provides information on the plants used by Carnaby's cockatoos, which is available on the Parks and Wildlife website (Groom *et al.,* 2010). Surveys are required to identify and map potential habitat for feeding, nesting, roosting and watering of cockatoos in the Park and adjacent areas to assist with conservation planning. Targeted surveys for the three cockatoo species to determine their patterns of movement, observations of cockatoo behaviour in public places, and records of any cockatoos killed on roads would assist with future management decisions in the Park. Fire management may need to consider cockatoo feeding areas as recent research has shown that banksias on which Carnaby's cockatoos feed requires 20 – 30 years without fire to maximize the number of seed cones (Valentine *et al.,* 2011). Identification and retention of any trees with suitable nesting hollows is also a high priority. Provision of artificial nest boxes has greatly assisted breeding success, particularly for Carnaby's cockatoos (Department of Environment and Conservation, 2012). The design of these boxes has been studied and is available for community groups to use if required, but the boxes do need to be maintained and monitored. Involvement in the Great Cocky Count and the Cockatoo Care projects is encouraged.

Barking owl – records of the barking owl (*Ninox connivens* subsp. *connivens*) from Commonage Rd in June 2000 and February 2002 are of great interest (NatureMap, 2014). This Priority species is rarely observed in the south-west, and apart from one sighting near Augusta in 1999, the nearest other observations have been nearly 200km away at Dryandra State Forest from 2005 to 2008 (NatureMap, 2014). This nocturnal species is usually detected by its call which is quite distinctive. It uses large hollows to nest and roosts in shady trees by day, usually in forest or woodland vegetation near water, and occupies a large territory (>1,000ha). It is similar to the smaller and more common southern boobook (*Ninox novaeseelandiae*) and could be mistaken for this species. The presence of barking owls depends on the availability of suitable prey, although it feeds on a wide variety of small animals, birds and insects. Availability and competition for nest hollows is another limitation to its distribution. Regular night time surveys using playback calls may help to detect its presence.

Peregrine falcon – this is a widespread but uncommon bird of prey that is specially protected due to its vulnerability to being shot or illegally collected for falconry. There have been a few recent sightings in the area from Yallingup to Dunsborough. Peregrine falcons (*Falco peregrinus*) nest on cliff faces, and sometimes in large tree hollows and buildings, so could be nesting in this area. They feed mostly on medium sized birds which they take at great speed in the air. These birds are usually reported from opportunistic sightings rather than from targeted surveys.

Hooded plover – hooded plovers (*Thinornis rubricollis*) were consistently recorded at Bunker Bay from 2000 to 2010, but none have been seen in the last four years. A few hooded plovers have been sighted at Eagle Bay from 2008 to 2013, and at Cape Naturalist from 1993 to 1996, but none were seen in 2014 (M. Signor, unpublished data). The Dunsborough Coast and Land Care Inc. group has helped to monitor four sites in the Meelup Beach to Bunker Bay area and expressed concerned about the dog and vehicle damage to nest sites in the Eagle Bay north site, where hooded plovers had been sighted since 2008 (R. Glencross, unpublished data). Highest numbers are generally found on wide beaches where they feed on small invertebrates, shellfish and crabs in washed up seaweed. Hooded plovers lay their eggs in a small scrape in the sand or in the foredunes and so are very vulnerable to disturbances from dogs, people and vehicles on the beach. Most of the beaches in the south-west are surveyed each year as part of the hooded plover annual surveys coordinated by Birdlife Australia. Monitoring sheets and registration details can be downloaded from their website. Monthly or quarterly surveys would be useful to monitor the breeding success of any pairs present at Eagle Bay and Bunker Bay. Management options include closing that section of the beach to dogs and vehicles during breeding times in summer, providing nesting shelters and erecting temporary signs to make people aware of the situation.

Other shorebirds – All shorebird species are counted at nominated sites on an annual basis as part of the Shorebirds 2020 project coordinated by Birdlife Australia. This project aims to detect any changes in populations at a national level and gather data that may explain any changes in populations. Eight shorebird species that are protected under international agreement have been recorded within 10km of the Park (Table 1), with another five species recorded within 20km (NatureMap, 2014). Regular monitoring of these species would contribute to the knowledge of the distribution and abundance of these species and their annual migration patterns.

#### 3.2.1.3. Reptiles

The southern carpet python (*Morelia spilota* subsp. *imbricata*) was not recorded by Hart *et al*. (1996, 1997) but there have been numerous records between Cape Naturalist and Cape Leeuwin (NatureMap, 2014). Carpet pythons occupy crevices in limestone and granite in undisturbed habitat similar to that present in the Park, and are thought to be threatened by foxes and altered fire regimes. It is a specially protected species to guard against illegal capture and unnecessary killing by people thinking it is a venomous snake. Targeted surveys are required to locate these pythons in suitable habitat and to protect that habitat from wildfires where possible.

There were many reptile species recorded from the Park during the fauna surveys (Hart *et* al., 1996), which is not so surprising with the multitude of rocky habitats. Two reptile species that were recorded by Hart *et al*. (1997) were significant extensions away from their known ranges and are of great interest. These species were the southern delma (*Delma australis*) and Dell's ctenotus (*Ctenotus dellii*), which is a Priority species. Another Priority species, the coastal plains skink (*Ctenotus ora*) was also recorded within 10km of the Park (NatureMap, 2014). Further surveys are warranted to determine the distribution and abundance of these species and to identify suitable habitat areas so they can be managed appropriately during prescribed burning operations.

#### 3.2.1.4 Invertebrates

The Dunsborough burrowing crayfish (*Engaewa reducta*) is a Threatened species currently ranked as Endangered that has been found in seepage areas at the headwaters of several rivers south of Dunsborough (e.g. the Carbunup River and Mary Brook) in very dense heathland growing on organic-rich sandy soils (Department of Environment and Conservation, 2008b). The earliest record from 1960 is near Dunsborough but the exact location of this record is not known. Given that there are seepage areas within the Park, it

might be worthwhile to survey these areas for the distinctive chimneys that the burrowing crayfish build. This species is under threat from clearing of habitat areas, soil compaction and hydrological changes due to water extraction, dam construction, inundation and a drying climate. Building access tracks and burning may also affect their habitat. Fire retardant chemicals used during fire suppression can contaminate soil and water and may be toxic to burrowing crayfish (Department of Environment and Conservation, 2008b).

Carter's freshwater mussel (*Westralunio carteri*) is the only large freshwater bivalve in Western Australia and is listed as a Priority species. There are numerous records in the south-west including the Vasse River and in rivers along the Darling Scarp and south coast, but only one record near Dunsborough in 2010 (NatureMap, 2014). This species is sensitive to water salinity greater than 3g/l and requires the presence of freshwater fish to host the larval stages of the mussels (Klunzinger *et al*., 2012). They generally occur in slower moving streams and rivers with sediment and leaf litter. A survey of Meelup Brook may be warranted.

Granite rocks often harbour a range of millipedes, spiders, insects and land snails with many species being short range endemics. Recent research by the WA Museum identified high levels of species richness and endemism in millipedes along the south coast from Walpole to Esperance (Moir *et al*., 2009). Species richness was greater where there were large differences in topographic relief and high rainfall. Surveys to identify short range invertebrate species and their habitats in the Park may assist with conservation planning to determine areas needing special protection. Research is also required to understand the impacts of fire and increasing aridity on invertebrates, particularly those species that are currently confined to moist refugia.

**Table 1**. A list of Threatened and Priority terrestrial fauna recorded in NatureMap (2014) within a 10km radius of Meelup Regional Park. Conservation status: T – Threatened/rare or likely to become extinct, X – presumed extinct, P – Priority (P1 – P5), S – specially protected, IA – protected under international agreement. (* unusual or historical record)

| Common name | Scientific name | Conservation status | Recovery Plan |
|---|---|---|---|
| **Mammals** | | | |
| Southern brush-tailed phascogale* | *Phascogale tapoatafa* subsp. *tapoatafa* | T | |
| Western ring-tail possum | *Pseudocheirus occidentalis* | T | Interim RP |
| Quokka | *Setonix brachyurus* | T | State RP |
| New Zealand fur seal | *Arctocephalus forsteri* | S | |
| Australian sea lion | *Neophoca cinerea* | S | |
| Water-rat | *Hydromys chrysogaster* | P4 | |
| Western brush wallaby | *Macropus irma* | P4 | |
| Southern brown bandicoot | *Isoodon obesulus* subsp. *fusciventer* | P5 | |
| Tammar wallaby* | *Macropus eugenii* | P5 | |

| | | | |
|---|---|---|---|
| **Birds** | | | |
| Baudin's cockatoo | *Calyptorhynchus baudinii* | T | State RP |
| Carnaby's cockatoo | *Calyptorhynchus latirostris* | T | State RP |
| Cape Barren goose* | *Cereopsis novaehollandiae* subsp. *grisea* | T | |
| Malleefowl* | *Leipoa ocellata* | T | National RP |
| Rufous bristlebird* | *Dasyomis broadbenti* subsp. *litoralis* | X | |
| Rainbow bee-eater | *Merops ornatus* | IA | |
| Common sandpiper | *Actitis hypoleucos* | IA | |
| Eastern great egret | *Ardea modesta* | IA | |
| Sharp-tailed sandpiper | *Calidris acuminata* | IA | |
| Sanderling | *Calidris alba* | IA | |
| Whimbrel | *Numenius phaeopus* | IA | |
| Grey-tailed tattler | *Tringa brevipes* | IA | |
| Common greenshank | *Tringa nebularia* | IA | |
| Marsh sandpiper | *Tringa stagnatilis* | IA | |
| Peregrine falcon | *Falco peregrinus* | S | |
| Barking owl | *Ninox connivens* subsp. *connivens* | P2 | |
| Hooded plover | *Thinornis rubricollis* | P4 | |
| **Reptiles** | | | |
| Carpet python | *Morelia spilota* subsp. *imbricata* | S | |
| Coastal plains skink | *Ctenotus ora* | P1 | |
| Darling Range heath ctenotus* | *Ctenotus delli* | P4 | |
| **Invertebrates** | | | |
| Dunsborough burrowing crayfish* | *Engaewa reducta* | T | State RP |
| Carter's freshwater mussel | *Westralunio carteri* | P4 | |

Other Threatened and Priority species that were recorded within the wider 20km radius of the Park included forest red-tailed black cockatoo (*Calyptorhynchus banksii* subsp. *naso*), lesser sand plover (*Charadrius mongolus*), eastern curlew (*Numenius madagascariensis*), Cape Leeuwin freshwater snail (*Austroassiminea letha*) and scorpionfly (*Austromerope poultoni*), as well as five other shorebird species protected by international agreement (NatureMap, 2014).

### 3.2.2 Other common fauna of interest

Short-beaked echidna diggings and sightings were reported by Hart *et al.* (1997), who also found the grey-bellied dunnart (*Sminthopsis griseoventer*), the common brush-tail possum (*Trichosurus vulpecular* subsp. *vulpecular*) and the honey-possum (*Tarsipes rostratus*). Honey possums were present in most of the sites but the other mammal species were scarce. Other native mammals species recorded in a 10km radius (NatureMap, 2014) included the western pygmy-possum (*Cercartetus concinnus*) and the Gould's wattled bat (*Chalinolobus gouldii*). Targeted surveys to determine the presence and abundance of these species would be useful to help guide management priorities, including the protection of important food resources and breeding sites. The impacts of fire, foxes, dieback and tree decline on these species needs further investigation.

The common western grey kangaroo (*Macropus fuliginosus*) is also present and abundant in all habits (Hart *et al*., 1997) and is possibly threatening the habitat of some other fauna species due to trampling, selective and over grazing and reducing the density of native vegetation (Clay and Webb, 2006). Ongoing monitoring of their abundance and damage to vegetation is needed to determine if control measures are required. Research into interactions between kangaroos and other fauna would also be useful to know what, if any, impact they are having on the habitats of other fauna species in the Park. Research would also be required into the most effective means of controlling this species near semi-urban areas, where they can breed rapidly under favourable conditions, particularly where grassy paddocks adjoin native vegetation. Although kangaroos cause numerous vehicle accidents and damage to agricultural and horticultural crops, controlling their abundance by direct kill close to a population centre would be problematic.

## 3.3 Geology, landform and soils

The Meelup Regional Park is on the Margaret River Plateau that has formed on the laterised granitic and gneissic basement rock of the Leeuwin Block (Tille and Lantzke, 1990; DAFWA, 2007). The main land systems in the Park are Cowaramup Uplands and Wilyabrup Valleys. These systems are further subdivided into map units and phases based on landscape position, soil type, slope and other criteria relevant to land capability (Tille and Lantzke, 1990; DAFWA, 2007). These landforms provide the unique character of the Park. A detailed geological survey of the Park may provide interesting information that can be used in interpretive materials to enhance the visitors' experience.

The Cowaramup Uplands occur on the plateau in the north-west of the Park up to 100m above sea level and consist of gently undulating plains with flat to gentle slopes and yellow-brown gravelly duplex and pale grey mottled soils, which support jarrah and marri forest and woodland. The Wilyabrup Valleys dissect the plateau further south and east with major creeklines including the Meelup and Dolugup Brooks flowing in narrow valleys. The valley sides have gentle (5-10%) to moderate (10-15%) slopes with low hills and yellow-brown gravelly duplex and red-brown gradational soils, which support jarrah and marri woodlands and forests. Shallower rocky soils occur south of Dolugup Brook that also support jarrah and marri woodland. Granite outcrops and rocky slopes occur closer to the coast and are exposed to strong winds off the ocean. These outcrops are fringed with shallow saprolitic soils that support heath with some stunted woodland vegetation. Along the beaches and

foredunes at Meelup Bay, Eagle Bay and Bunker Bay are the Kilcarnup Dunes formed from calcareous sands with fringing vegetation of acacia and peppermint scrub (Tille and Lantzke, 1990; DAFWA, 2007).

Soils that are more prone to wind and water erosion include the exposed shallow soils over granite, the coastal sandy dunes and soils on steeper slopes. Any removal or degradation of vegetation on these areas by clearing, trampling, overgrazing, illegal camping, vehicle incursions, wildfires or frequent burning will result in increased erosion and loss of soil, as well as increased runoff that will have additional impacts further downslope. It is noted that the trail master plan map in the Meelup interpretation plan (Ecoscape, 2006) includes a new trail connecting the whale lookout to Meelup Beach Rd that traverses shallow rocky soils and, although this generally follows the contour around Dolugup Brook, may contribute to erosion of these soils.

In addition, the fire management plan includes recommendations for establishing new internal firebreaks, fire lines around fauna habitat areas and new tracks as buffers in each fire cell. There are also recommendations to maintain low fuel buffer strips along roads, tracks and firebreaks that would expose vulnerable soils to increased erosion. Further research is needed into the location of these additional tracks and buffer strips with regard to their potential to exacerbate soil erosion and spread of *Phytophthora* disease. Laying crushed limestone is an appropriate management tool that can reduce surface soil erosion on paths, and will be used on some of the firebreaks. Existing tracks and firebreaks need to be carefully monitored for evidence of erosion and action taken before there is damage to vegetation and significant loss of soil. Similarly, water runoff from sealed and unsealed access roads on steeper slopes can create erosion gullies and these also need to be monitored. Beach erosion due to storm water overflows from some coastal car parks needs to be ameliorated and monitored.

Areas that have been eroded and degraded should be rehabilitated using locally sourced planting material and best management practices. Many areas including foredunes, an old gravel pit, the lookout carpark, walk trails and several drainage lines have already been revegetated by the Park committee and other volunteers (Annual reports 2009/10 to 2012/13). This has required ongoing weed control, planting, brushing, mulching and tree guarding. Following a workshop in 2010, deep dune planting techniques were employed with great success.

Large disused gravel pits in the southern end of the Park by the golf course have required major works to re-contour the slopes and revegetate to combat soil erosion and prevent the spread of *Phytophthora* spores and infected soils (Meelup Regional Park management plan, 2010). These areas lacked topsoil, which reduced plant growth and some older areas were planted with exotic species that will need to be removed. Additional areas have been identified for revegetation in the coastal nodes master plan to formalise existing car parks and walk trails (William James landscape architects, 2013). Further research into ways to improve the efficiency of revegetation, weed control and selection of appropriate species to reconstruct natural plant communities across the range of soil types in the Park may be worthwhile.

## 3.4 Water resources

The Meelup and Dolugup Brooks are the main creeklines flowing through the Park, with other minor drainage lines also flowing in a north-easterly direction towards the coastline. Dolugup Brook has its catchment entirely within the Park whereas Meelup Brook has a significant proportion of its catchment area beyond the Park boundary. The Jingarmup Brook has a much larger catchment but this creekline only traverses a narrow strip (125m) of the

Park at Eagle Bay. A characteristic of smaller streams in Geographe Bay is that they tend to end behind the foredunes.

There is a natural spring along one of the minor drainage lines that flows into Eagle Bay. The water from this spring is harvested into an underground water tank on the firebreak, which gravity feeds a fire hydrant in Reidle Park. The importance of this spring water to native fauna and invertebrates is unknown but should be investigated. Meelup Brook enters a small dam near Meelup Beach that was probably a natural spring, but which is now often stagnant and polluted. Large dams have also been built on the upper reaches of Meelup Brook by the neighbouring winery. There is concern that these dams and associated winery and vineyard operations may have affected the flow (volume and duration) and quality (chemical contamination and nutrient enhancement) of water in the brook.

Most fauna, including birds, require daily access to fresh water at sites that are relatively protected from predation pressures. Western ringtail possums in particular are very sensitive to heat stress so any reduction in water availability or decline in canopy density of habitat trees due to reduced stream flow would affect their survival during summer months. Similarly, southern brown bandicoots prefer moist habitats around wetlands and creeklines so the area of suitable habitat for bandicoots may have been impacted by reduced stream flows. Cockatoos also need safe access to drinking water during summer, while Dunsborough burrowing crayfish require damp soil with a relatively shallow water table, and freshwater mussels and other macro-invertebrates require permanent fresh water.

The south-west has already suffered large reductions in annual rainfall due to climate change so further limitations to water availability are likely to have significant impacts on fauna and reduce the conservation values of the Park. Research is needed to quantify the above changes to stream flow and water quality and to assess the impacts that these changes may have had on vulnerable fauna, their habitats and fringing vegetation. The feasibility and likely benefits of addressing these impacts should also be investigated.

Water resources are required for the Park visitor facilities, for drinking, washing and toilets as well as for fighting fires and irrigation of grassed areas. The Bunker Bay pipeline provides some of this water, but as visitor numbers increase, there will be increased need for water supplies. As indicated in the management plan, all new developments need to use scheme water, or tank and roof supplies, rather than accessing springs or creeklines. A water resource management plan is required to address this issue.

# 4.0 Cultural values

The Meelup Regional Park is valued for its recreational and tourism opportunities, its unique beauty and its conservation significance (William James Landscape Architects, 2010). A visitor survey in 2012 reported that the most desirable features of the Park were the beaches, nature, beauty, peaceful and its undeveloped pristine nature (Polley, 2012). Some of the discrete values expressed by the committee and the visitor survey included its natural character, flora and fauna, beautiful beaches, coastline and walk trails, peaceful and clean, best mountain bike trails, uncrowded, privacy, unspoilt by commercial activities, recreational activities that don't detract from the natural environment, east facing beaches protected from sea breezes and for moon rise viewing, and opportunities for fishing, swimming and whale watching (William James Landscape Architects, 2010). Other popular uses include surfing, sailboarding and sailing in the bays.

The cultural heritage values that have been identified in the Meelup Regional Park Management Plan (Meelup Regional Park Management Committee, 2010) and the Meelup

Regional Park Interpretation Plan (William James Landscape Architects, 2006) characterise the unique sense of place for Meelup.

## 4.1 Aboriginal cultural heritage

Aboriginal people lived mainly around wetlands, swamps, rivers and estuaries around Bassendean sands and Pinjarra plains on the Swan Coastal Plain, living in semi-permanent camps in summer and dispersing in winter to hunt in smaller mobile groups in the forested uplands and less dense woodlands further inland (Hallam, 1979; Hallam, 1986; Lilley, 1993). The Wardandi people are one of the Noongar tribes or language groups and are the traditional custodians for the area from Bunbury to Augusta. Earliest evidence of aboriginal occupation in the south-west comes from charcoal, bones and stone artefacts in a limestone cave at Devil's Lair near Margaret River with dates ranging from 47,000 years before present to 6,500 years before present (Dortch, 1979; Dortch, 2002; Turney *et al*., 2001).

It is known that Meelup is an aboriginal word meaning the place of moon rising, because the full moon sometimes rises up from the sea, while the aboriginal name for Dunsborough is Quedjinup which means place of women. The word ngari (pronounced 'nyari') is the word for salmon and is acknowledged in the naming of the Ngari Capes Marine Park. Traditionally, salmon were an important seasonal source of food for the Noongar people. They made use of rocky headlands in Geographe Bay to spear salmon that passed close to the rocks using gidgees (Department of Fisheries, 2014). Aboriginal camp sites were noted above Meelup Beach and Curtis Bay in the site analysis map for the Meelup park interpretation plan (Ecoscape, 2006), but the age of these camps and the origin of this information is unknown. To date, no systematic archaeological survey has been undertaken in the Park.

A number of aboriginal heritage sites are registered for the Dugalup Brook and Dunsborough foreshore area on the Department of Indigenous Affairs (DIA) sites register according to a recent aboriginal heritage survey of several sites in Dunsborough (Goode and Harris, 2007). These include an extensive artefact scatter site (mostly quartz) dated between 8,000 and 12,000 years, camping grounds, a ceremonial ground, mythological sites, scar trees and rocks, but this survey did not include any sites within the Park.

The aboriginal heritage survey report for Dunsborough (Goode and Harris, 2007, and referenced cited therein), provides some background knowledge to local aboriginal culture and early interactions with European, and is paraphrased below:

*There is some evidence of encounters between aboriginal people and early Dutch and French sailors from the mid 1650's, as well as with survivors of shipwrecks, sealers and whalers, and those searching for fresh water. The Wardandi people initially helped the early settlers in the Vasse area in the 1830's to find water and were employed on farms in exchange for flour, sugar and tobacco. Many of the tracks created by the Noongar people were used by early settlers to explore the land. The land around Vasse produced better pastures for grazing stock than around Augusta, but was also prime hunting ground for the Wardandi people who were quickly displaced. Tensions increased in 1837 when several aborigines were killed for slaughtering a cow for food, which was followed by reprisal killings. Widespread attacks by the settlers in 1841 after a spearing left many dead aboriginal men, women and children. Nevertheless, aborigines were seen as a convenient source of labour for farming, domestic help, whaling and forestry on which the settlers depended.*

*The Wardandi did not camp at Quedjinup (Dunsborough) or along the coast all the time, but visited certain locations to take advantage of the fish runs. Fish traps around Quedjinup were used to harvest the abundant salmon runs to feed large groups of aboriginal people who came together for ceremonies during the summer season. However, settlers destroyed many of these traps to discourage the gatherings and a law was passed in 1899 prohibiting the building and use of fish traps. The traditional lifestyle of the Wardandi people may have ended as early as the 1860's as they became more dependent on European food supplements. Later, the government passed laws to remove aboriginal people to mission camps and to control their way of life. A summer recreational camp was established at Dunsborough for the children of the Roelands Mission from the 1940's to the late 1960's and many local Wardandi people have strong memories of these camps. The local Noongar representatives and members of the stolen generation have requested that this camping area be acknowledged as an important place of historical significance.*

Clearly, the area around Dunsborough has cultural and historical significance for the Wardandi people from thousands of years before European settlement through the early occupation period until the present. A search of the literature and aboriginal sites register, archaeological surveys and consultations with local Wardandi elders are all required to understand the historical aboriginal culture and significance of areas within the Park. Any developments within the Park, particularly around the foredunes, and near the creeks and springs should be preceded by a heritage survey as required under the Western Australian Aboriginal Heritage Act (1972).

## 4.2 Early European cultural heritage

Early Dutch and French explorers sailed around Western Australia in the 1600s to map the coast and landed at various sites in search of fresh water. In 1622 the Dutch named the southern corner Leeuwin's Land, after their ship. Following on from James Cook's expeditions in the 1770s, Nicolas Baudin lead a large French scientific expedition, including zoologists, botanists, astronomers, gardeners and painters, to Australia in two ships named the Géographe and the Naturaliste, to more accurately chart the western and southern coastlines and collect scientific specimens. They reached the Western Australian coast and landed somewhere near Eagle Bay in May 1801 in search of water (Marchant, 1998). Baudin's expedition continued up the east coast of Australia and around to Mauritius, where Baudin died of tuberculosis. Their landing site at Eagle Bay has a lookout memorial built in the form of ship's bow and mast but there seems to be little acknowledgement, other than a small plaque, of the historical significance of this site. Further research into the early Dutch, French and British explorers could provide more interesting details about sites visited, their activities and scientific findings on-shore and interactions with local aboriginal people.

Castle Bay was used as a whaling camp by early American whalers and was the location of the Castle Bay Whaling Company, also known as "The Fishery", which operated from 1845 until 1872. Although whales were abundant, Castle Bay was isolated and supplies had to be obtained from Vasse by row boat, however fresh water was always available from a spring at Castle Bay and at nearby Meelup Beach. Whales were harpooned and brought to shore where they were cut up and the blubber boiled down for oil in try pots and the whale bones and other products were extracted for various commercial uses. Wardandi people were often employed around the whaling camps and were keen lookouts and likely took advantage of discarded whale carcases. The whaling season was from June to November and mainly operated between Castle Bay and Bunker Bay. An informative account of the whaling can be found on the Meelup regional park's website in an anonymous report based on the diary of Frederick Seymour, who was the chief headsman of the Castle Bay Whaling Company. A cairn above the beach marks the position of the company's kitchen, while a few bricks mark the whale lookout on Lookout Hill. Quandong trees grow near the lookout and it is thought

that these may have grown from seeds dropped by whale spotters (Meelup Regional Park Management Committee, 2010), but this aspect has not been confirmed. Quandongs were an important source of carbohydrates for aborigines who ate the sweet fruit and fatty kernels (Brand-Miller and Holt, 1998).

New Zealand fur seals were completely wiped out from the western coast of Australia by sealers who killed them for their thick furry skins more than 150 years ago. Small numbers of them reappeared on a small rock near Dunsborough about 15 years ago and they have since spread north to Rottnest Island and the Beagle Islands north of Jurien Bay Marine Park (Department of Environment and Conservation, 2013). Historical information about seals and the sealing industry should be investigated to add to the knowledge base for the area.

Meelup Beach has been a popular picnic and swimming beach for about the last 150 years, with camping permitted until the 1970s (Meelup Regional Park Management Committee, 2010). Other early European culture relating specifically to the Park is not readily available. It would be worth investigating some of the older family historical accounts from the relevant historical societies and other sources to gain further insights to enrich the visitor experience.

## 4.3 Current cultural values

### 4.3.1 Fishing

Beach fishing has been a popular in the Park for many years due to the sheltered waters and easy access from rocky outcrops (Meelup Regional Park Management Committee, 2010). Near the Baudin memorial is the site of an old fish factory that operated in the mid-1900s, with a shed, kitchen and processing area, but there is little other information about the early fishing industry. Dhufish, salmon, blue groper, snapper, tailor, skippy, western rock lobster and abalone are popular targets. Fishing is now not permitted south of Gannett Rock, including Meelup Beach, due to the gazetting of the Eagle Bay sanctuary zone within the Ngari Capes Marine Park, but is permitted along Eagle Bay due to a special purpose zone for shore based activities (Department of Environment and Conservation, 2006). Licensed commercial fishermen can apply to have vehicle access to Castle Bay, Meelup Beach and Bunker Bay during the salmon season during late summer and autumn, but otherwise vehicle access is prohibited.

### 4.3.2 Whale watching

Whale watching is a popular tourist activity with many commercial boat tours and opportunities to view humpback whales, southern right whales, and the rare blue and minke whales on both their northern and southern migrations as they come close to the shore around Cape Naturaliste. Blue whales are the largest animal on the planet and are thought to breed in Geographe Bay, while humpback whales appear to use this area as a nursery. Whales can also be sighted from Castle Rock and Point Picquet on the coast and from the old whale lookout on Lookout Hill, accessed by a track that goes up the hill from the Curtis Bay to Castle Bay walking track. Other informal viewing points for whale watching, or just appreciating the views, are the carpark along Meelup Beach road and in the gravel pit areas above Curtis Bay near the Golf Course, which is accessed by a walking track from Dunsborough. A whale viewing platform has been proposed for Point Picquet by the Dunsborough Coast and Land Care Inc. group, which raised funds for a survey and construction plan, including an access path and interpretive signage.

A group of volunteers from the Dunsborough Coast and Land Care Inc. has monitored whale movements in Geographe Bay from Point Piquet since 2006 as part of the Western Whale Research group's activities. Numbers of humpback, blue and southern right whales are recorded during late winter to early summer each year. This monitoring indicates that the

numbers of whales are slowly increasing (R. Glencross, unpublished data). The Western Whale Research group also works with the Centre for Marine Science and Technology at Curtin University on a theodolite tracking program for whales and investigates the vocalisations of humpback and blue whales migrating through Geographe Bay. The Curtin University research group uses a higher monitoring point behind Point Picquet. This is an excellent example of how local people can be involved in meaningful research conducted by other agencies, but which will provide useful information to improve conservation outcomes in the area.

Commercial tour boats, recreational boats and watercraft are increasingly interacting with whales and dolphins with the likelihood of greater impacts due to physical disturbance by boats, direct strikes, entanglement in litter and fishing gear, illegal feeding, ingestion of marine litter etc., which can interfere with the natural behavior of these animals (Department of Environment and Conservation, 2013). Commercial tour operations require a licence from Parks and Wildlife and have to abide by a code of conduct while other restrictions apply to recreational boats, including staying more than 100m away from whales (Department of Environment and Conservation, 2013). Monitoring of these interactions and impacts is being undertaken by the Western Whale Research group and results could be used to determine if greater management controls are needed. Reducing the amount of litter along the beaches and discarded by boats can improve the marine environment and is something that should be facilitated as part of the Park management responsibilities.

### 4.3.3 Mountain bike riding

Mountain bike riding is evidently very popular in Dunsborough with two active clubs based on courses around the Dunsborough golf course and zone 6 at the southern end of the Park. Mountain bikes currently need to use the existing roads in the Park as there are no authorised bike tracks. However, cyclists are using the coastal walk trail and causing a hazard to walkers and damaging the trails, and some unauthorised tracks have been created in the southern end of the Park that need to be either formalised or removed. The Cape Mountain Bikers Inc. is currently working with the Busselton City and the Committee to amend the property Local Law to allow bikes on designated trails within the Park.

The Cape Mountain Bikers group has developed a trail master plan (Dirt Art, 2013) for Zone 6 near the Dunsborough Golf Club, which they refer to as the Zone 6 Mountain Bike Park. About 7.3km of new trails will be constructed and sections of the existing tracks will be redesigned to improve drainage and reduce erosion, or closed and rehabilitated. Many of the proposed works require clearing of vegetation, soil movements and the use of excavators. While much of Zone 6 is disturbed and infested with dieback, it borders on other dieback free areas in the Park. Another mountain bike club, the Dunsborough Cycle Club, uses trails around the edges of fairways at the Dunsborough Golf Course, and has proposed extensions to this trail network which are designed to link up with Meelup Regional Park and the Zone 6 Mountain Bike Park. Flora and vegetation surveys (Eco Logic Environmental Services, 2011) and dieback surveys (Dieback Treatment Services, 2012b) have been completed for this trail extension project with appropriate recommendations for managing impacts and reducing the spread of disease.

Although the main threats associated with dieback and impacts to vegetation have been addressed, some ongoing monitoring of soil erosion may be warranted. Where trails are planned to go near or through dieback free areas, then appropriate surfacing techniques need to be used. These may include hardening with limestone or gravel, rock paving and boardwalks. Other methods, including the use of plastic hard surfacing products (e.g. Jakmat and Diamond grid) are being trialled by Parks and Wildlife at William Bay National Park for the Munda Biddi cycle track. These methods enhance soil stability and drainage and should reduce the spread of dieback. The committee should investigate the outcomes of these trials

and consider undertaking similar trials for vulnerable sections of walk and cycle trails in the Park.

### 4.3.4 Dogs

Walking with dogs is not permitted in the park, other than on Eagle Bay beach. The presence of dogs in the Park is managed by signage and by the twice yearly baiting for foxes with 1080, a poison that will also kill dogs. Some locals have requested additional areas designated for exercising dogs but the impacts of dogs on native fauna can be great (Banks and Bryant, 2007; Lenth *et al.*, 2008). Dogs are known to have a strong negative effect on hooded plover breeding on popular sandy beaches (Weston, 2003; Maguire, 2008) and are may impact the western ringtail possums and southern brown bandicoots living in denser vegetation around creeklines and the Meelup Beach car park. They may also disturb bush birds (e.g. cockatoos) and other fauna (e.g. echidna) in the Park simply by their presence. Western ringtail possums and bandicoots do survive and breed in urban environments where dogs are prevalent, but their survival may depend on having safe access to protective shelters and habitat trees. The use of artificial nesting shelters, and closing or fencing off known nesting beaches during the hooded plover breeding season, has resulted in increased breeding success (Maguire *et al*., 2011). Further research may be warranted on the impacts of dogs on native fauna and birds in the Park and along the beaches, and on ways to improve attitudes of dog owners and their compliance with Park regulations.

### 4.3.5 Beaches

The scenic and sheltered beaches at Meelup Bay, Bunker Bay, Eagle Bay, Castle Bay and Curtis Bay are key recreational areas for swimming, snorkelling, picnics, nature study, walking and generally passive activities. Surfing is permitted along the Point Picquet coast but is discouraged in other areas. Camping and the use of 4WD vehicles, trail bikes, mountain bikes, water skiing and spear fishing are not permitted. These restrictions help to create a restful ambience that is appreciated by most visitors to the Park. BBQ and picnic facilities are provided at several beaches along with rubbish bins and toilet facilities. Trees and vegetation growing close to the beach is an unusual feature and an important aspect of the natural landscape that is highly valued by visitors. The Coastal Walkway running along the coast just inland of the foredunes and rocky headlands allows access to the beaches and a connection to the Leeuwin Naturaliste National Park.

## 4.4 Events management

Several large sporting events take place in the Park and these can enhance visitor satisfaction, raise the profile and awareness of the Park and its conservation and aesthetic values, and provide funds to assist with Park management. However, these events are likely to have increasing impacts on the conservation and wilderness values of the Park as their popularity grows. Tracks used during the events are not closed to the public and some events may also conflict with existing Park users or management objectives. Most visitors to the Park come to relax, swim or participate in other passive activities (Polley, 2012) whereas the sporting events are inherently high impact activities. The capacity of the Park to withstand and recover from these additional visitor impacts is currently unknown.

All commercial events must abide by the Meelup Regional Park management plan requirements, associated policies and guidelines and have specific approval under the City of Busselton's Local Law relating to Reserves and Foreshores. The management plan states that events will not be held in conservation and protection areas (i.e. Zones 7, 8, 12 and 18) and requires event proponents to provide an environmental management plan including dieback management, and pay a bond to cover the cost of rehabilitation if required.

Some of the events include:

- Anaconda Adventure race
- X-Adventure Dunsborough
- Vintage car Meelup Hill climb
- Cape to Cape Mountain Bike event
- Mountain Bike Enduro event
- Annual school leavers' day at Meelup Beach.

These events attract large numbers of competitors and spectators over a few days each year, which can result in high intensity impacts such as trampling of vegetation, illegal parking on road verges, erosion and widening of tracks, littering, spread of dieback and disturbance to fauna. The high number of people present in the Park during these events, their noise, traffic congestion, lack of parking, and excessive demand on amenities can also impact on existing and casual visitors and may detract from the natural and peaceful values of the Park.

The most pressing research requirement in regards to event management appears to be how to determine the upper limit for the number of events and/or the number of people per event, beyond which the risk of damage to conservation and other values in the Park are unacceptable. Some events exceed 1500 competitors, and combined with spectators, this represents a considerable escalation of pressures over normal visitor impacts. Factors to consider in determining an upper limit include the duration, intensity and timing of activities. For example, are the impacts of 1500 visitors over two days greater than 30 visitors over 100 days? The environmental impacts of various events need to be monitored using effective ecological indicators (Buckley, 2003).

Ecological indicators that could be investigated include track and vegetation condition, and abundance of common and Threatened fauna in the Park. Monitoring the number of visitors and bikes would be required to correlate with track and vegetation condition and to provide metrics for determining capacity limits. These would require baseline data before and after an event, or paired sites could be selected in event areas and non-event areas. Fauna surveys were conducted in the Park (Hart *et al.,* 1996; 1997), but only one site (TS1) was sampled in 1994 in Zone 6. These fauna surveys could be redesigned in future to include sample sites in Zone 6 specifically to monitor changes in fauna species and abundance in this area compared with other areas.

# 5.0 Threats to cultural and conservation values

Many of the threats and associated impacts have been discussed under the ecological or cultural values, but they often apply across groups of values and are best managed at a Park level rather than a species level.

## 5.1 Plant diseases

### 5.1.1 *Phytophthora* dieback

Dieback caused by *Phytophthora cinnamomi* is one of the main threats to the vegetation and fauna habitats in the Park. Dieback is prevalent in many areas in the Park, particularly adjoining the urban areas, in Zone 6, around the golf course near Eagle Bay, along the main internal roads and several tracks (Meelup Regional Park Management Committee, 2010). Surveys in 1994 showed that 28% of the Park was infested (Helyar, 1994), a figure that was increased to 34% following surveys along boundaries tracks by Parks and Wildlife. More recent surveys in 2009 and 2013 have refined the areas and shown that about 25% of the Park is infested, 61% is uninfested, 7% is uninfested but unprotectable and 7% can't be

interpreted and is unprotectable (Dieback Treatment Services, 2013). All of the uninfested areas are surrounded by infested vegetation so it is critical that effective measures are taken to prevent this disease impacting on other vulnerable vegetation. Disease expression was generally low with few new deaths of indicator species. However, new spot infestations were observed in 2009 and 2013 along a road side drain, the car rally track, and along the north-west boundary and existing disease edges (Dieback Treatment Services, 2013).

Regular monitoring along roads, track, drainage lines and watercourses in uninfested and interpretable areas is required where dieback is likely to spread due to foot traffic, vehicles, mountain bikes and water flows. Annual spring and autumn inspections of vegetation health along these vector pathways is recommended, particularly downslope of known infested areas and in moisture gaining sites (Dieback Treatment Services, 2012a). This could be done by volunteers with some training, who could report any suspicious deaths to a dieback consultant to take samples and organise laboratory identification. Regular dieback surveys by a trained consultant need to continue every four to five years as planned.

Areas of susceptible vegetation (particularly *Xanthorrhoea preissii, Banksia attenuata* and *B. grandis*) near and downslope of infested areas have been treated with phosphite to manage this problem. This treatment should be monitored to determine if it is achieving the desired outcome. Similarly, the outcomes of other management actions, such as stem injections, tyre/boot cleaning stations, vehicle wash down facilities, limestone hardening of footpaths, modification of drainage, restricting public access and installing interpretation signage need to be assessed in terms of reducing the spread of the disease and increasing visitor awareness and appropriate behaviour. This is particularly important with respect to event management and the mountain bike tracks in and around zone 6, due to the significantly greater potential for disease spread.

### 5.1.2 Other fungal diseases

Another disease species (*Phytophthora cryptogea*) was identified in the wildlife corridor in a separate survey in 2012, which was associated with older deaths of *Xanthorrhoea preissii* (Dieback Treatment Services, 2012a). This species has also been isolated from marri roots and trials are underway to determine its pathogenicity (Centre for Excellence for Climate Change, Woodland and Forest Health, 2013). The extent of this disease in the Park is currently unknown. Other partial deaths of *X. preissii* were noted in the 2013 survey where only the very centre of the plant was alive (Dieback Treatment Services, 2013). This symptom was not typical of *Phytophthora* dieback and samples taken were shown to be negative for this disease. Further research is required to identify the causal agent(s).

The incidence of *Armillaria luteobubalina* was noted in the 2009 dieback survey near the gate at the entrance off Sheens Road (Dieback Treatment Services, 2009). About 16% of the Park is infected with this fungus, which can infect many woody species (Meelup Regional Park Management Committee, 2010). Although this is a natural fungal pathogen, it has a much lower impact than that of *P. cinnamomi*, and is generally only a problem in disturbed areas. It would be useful to map the occurrence of fruiting bodies of this fungus during autumn for future reference.

Aerial cankers are a major threat to the *Eucalyptus phylacis* population, as previously noted in section 3.1.1. Research is required to understand how this disease is spread and other predisposing factors that determine the severity of the disease in susceptible eucalypt species.

### 5.1.3 Tree decline

There is increasing concern about tree decline that is affecting mainly the peppermints and marri in the Park. These are important tree species on which a number of fauna depend,

including western ringtail possums and the red and white tailed black cockatoos. They also provide abundant nectar for other birds and insects, and shade for fauna and people. The possible causes of this decline include drought, ongoing climate change with increasing temperatures and decreasing rainfall, reduced mycorrhizal function, nutrient depletion, insect borers and leaf defoliators, reduced soil turnover by fauna, stem cankers and *Phytophthora* dieback. It is likely that these factors interact to hasten the decline.

Researchers at Murdoch University in the Centre for Excellence for Climate Change, Woodland and Forest Health ('Centre for CCWFH') are investigating various aspects of tree decline that will be relevant to this area and are open to new projects, particularly where industry can provide seed funding. Funding has been sought from the City of Busselton to conduct a GIS spectral analysis of the Park to quantify the extent of tree decline, particularly for peppermints, over the last ten years (M. Polley, personal communication). This data would be very useful for identifying affected sites for further investigations.

## 5.2 Inappropriate fire regimes

There is much written about fire management planning and appropriate fire regimes for maintaining native vegetation and fauna habitats (Abbott and Burrows, 2003). Most of the local vegetation in the Park is able to tolerate fire and many plant species require fire or some other disturbance to stimulate recruitment or flowering. However, some fire regimes are detrimental to some plant and animal species. Inappropriate fire regimes may result in changes in vegetation structure and composition, and local extinction of fire sensitive species. Species vary considerably in their responses to fire and no one fire regime is suitable for all.

Fire regime refers to the frequency (number of fires per unit time), interval (number of years between successive fires), season, intensity and extent of fire. These factors are related for example, summer fires are generally very intense and cover large areas. While cooler spring fires are easier to manage and leave some unburnt patches that protect fauna, they may not generate enough heat to stimulate germination of soil stored seeds. This may result in a lack of hard seeded leguminous species that add nitrogen to the ecosystem.

Plant species that have a long juvenile period, or time to first flowering after fire, are most sensitive to frequent fire as they do not have time to produce another seed crop between fires. Species with canopy stored seed (e.g. banksias and hakeas) release all their seeds after fire and these seeds either germinate or die within 12 months, as they are not stored in the soil. Knowing how different species respond to fire can help to determine the best fire regimes for different plant communities.

Fires also need to be managed to conserve fauna and their habitats in the Park. Some species benefit from the fresh growth after fire but others depend on food resources or nesting sites that only build up in long unburnt vegetation. Intense fires that consume mature trees with hollows have a significant impact on many species, including parrots, cockatoos, owls and possums. Even moderate fires that remove dense shrubs can leave many fauna species vulnerable to predation or to loss of food resources and starvation. Small birds (e.g. honeyeaters and fairy-wrens) are unable to find suitable nesting substrates (e.g. grasses, fine sticks and cobwebs) for several years after fire. On the other hand, kangaroos, possums and quokkas preferentially graze the fresh new growth soon after fire and may damage the regenerating vegetation in small burnt patches.

Fire can also increase the spread of weeds as they are fast growing and take advantage of open patches of ground with little initial competition from the slower growing native plants.

The ash left after fires also increases the nutrients available for weed growth. Dieback may also spread more rapidly after fire as water runs off more readily over the open ground carrying the dieback propagules. These management issues need to be addressed during fire planning and fire operations with appropriate mitigation strategies.

The fire management plan developed for the Park provides direction for prescribed burning and management of wildfires, including protection of assets, neighbouring properties and areas with significant conservation values (Meelup Regional Park Management Committee, 2007). Fire history in the Park was recorded from 1982 and digitised for 1996–2006, with one major wildfire in April 2005 that burnt 230ha in the southern half of the Park. Arson was considered to be a significant risk and may be the main cause of fires in the future. The fire management plan covers many aspects including fire fighting resources, firebreaks, access tracks, water sources, maintenance of low fuel buffers, visitor safety and education. The plan is based on the creation of 12 cells of varying size based on the main vegetation types, with each cell being burnt on an 8–10 year cycle, with two spring burns, one autumn burn and one no burn interval. However, this cycle does not take into consideration the fire responses of key fire sensitive species within those vegetation types.

Some issues that need further research have been flagged in the list of recommended actions in the fire management plan. Subjects for fire research include:

Highest priority

- A study of likely fire sensitive plant species to determine their fire responses, juvenile periods and other life attributes as a basis for recommending minimum fire intervals and ecological fire regimes;
- Mapping and description of fire sensitive fauna habitats (particularly southern brown bandicoots, western ringtail possums and honey possums) to determine areas that need special protection from fire, or specific fire regimes;
- Mapping of fire sensitive flora species and communities as a basis for defining burn boundaries;

Medium priority

- Monitor the impacts of frequent burning and slashing in the buffer areas on regeneration of plants and soil erosion as a basis for managing these areas;
- A study of the effects of frequent burning in low fuel buffers on species composition and vegetation structure;
- Study the effect of fire on reptile and bird species abundance and composition, and on food availability for black cockatoos in particular;
- Monitor the impacts of fire on the spread of weeds and dieback in the Park;

Lower priority

- Study the likely impacts of climate change on flammability of vegetation and soil dryness index;
- Investigate whether foxes and cats are more prevalent after fire and whether they preferentially use the firebreaks and access tracks;
- A study of factors associated with arson and illegal camping fires to predict where and when these incidents may occur and what measures can be taken to reduce their occurrence.
- Survey visitors about their level of understanding about the impacts of fire on cultural and conservation values as a basis for developing an education program;

## 5.3 Weeds

A survey of weeds was conducted in August and September 2011 and found that about 75% of the Park was in pristine condition (Fisher, 2011). Most of the exotic plants occur along roadsides, creeklines, tracks, firebreaks, car parks, boundaries and disturbed areas in zone 6. These are areas where weed propagules are transported by humans and vehicles, but

some weeds are spread by wind, surface water flows, birds, foxes and native animals. Dumping of garden rubbish is another common and preventable means of weed dispersal. Weed surveys and maps provide valuable data for assessing changes in weed abundance and distribution and early detection of new outbreaks. They also provide a means of assessing the effectiveness of management operations and so should be continued on at least a five yearly basis.

Declared weeds in the Park are cape tulip (*Moraea flaccida*), arum lily (*Zantedeschia aethiopica*), apple of Sodom (*Solanum linnaeanum*), bridal creeper (*Asparagus asparagoides*), doublegee (*Emex australis*) and nodding thistle (*Carduus nutans*). Arum lilies are prolific around Point Picquet and Meelup Brook and need continual control efforts. Other weeds are present including woody weeds, broadleaf herbs and annuals, some of which cover significant albeit localised areas. The most important of these weeds are watsonia (*Watsonia meriana*), gladiolus (*Gladiolus undulatus* and *G. caryophyllaceus*), freesias (*Freesia refracta*), dolichos pea (*Dipogon lignosus*), deadly nightshade (*Solanum nigrum*), fumaria (*Fumaria muralis*), various wattles (Acacia spp.) and Pittosporum.

Control methods are available for most of these plants but it requires ongoing efforts to manage the existing populations with few resources. A contractor is employed to spray weeds on an annual basis and volunteers are encouraged to help with identifying new outbreaks and controlling weeds were possible. Preventing the introduction and spread of weeds into new areas and early detection and control of new outbreaks are key management actions.

Clearly regular monitoring and mapping of weed abundance and distribution is a high priority for developing a strategic weed management plan and improving management outcomes. GPS mapping of weed population boundaries and estimating cover of each weed species within those boundaries provide quantitative measures of changes in weed abundance and extent. Monitoring is also required to assess the effectiveness of various control measures and any impacts on native vegetation. A study of how the various weeds are spread may provide direction for more effective education and control measures, including preventing the dumping of garden rubbish, insisting on contractors having weed free machinery and educating visitors about the risks of spreading weeds along walking and cycling tracks. Fire can exacerbate weed spread but it also provides an opportunity for controlling weeds more effectively when they are young and regenerating.

## 5.4 Feral, domestic and pest animals

Feral animals are likely to impact on native fauna within the Park. Feral foxes and feral cats are very efficient killers of small native animals and are a major threat to the western ringtail possum, quokka, water rat and southern brown bandicoot in the south-west of Western Australia. Other fauna at risk include the common brushtail possum, honey possum, echidna, southern brush-tailed phascogale and a wide range of bird and reptile species. Domestic cats and dogs that are allowed to roam in the Park from the urban neighbourhood are also likely to disturb native fauna and disrupt their normal patterns of feeding and breeding (see Section 4.3.4).

Foxes are baited twice a year in spring and autumn with 1080 poison, while cats are trapped every autumn to control numbers in the Park. However, there needs to be some way of monitoring whether this level of control is effective. Fauna surveys provide data on the abundance and distribution of each species but don't provide any information about why these may be increasing or decreasing. Surveys of fox and cat abundance would be very useful to know if they are causally linked to changes in native fauna populations, and also test the effectiveness of the feral animal control program. Remote cameras installed along

boundaries, firebreaks and other tracks can provide data on movements of feral and domestic animals that is readily accessed and relatively low cost. One disadvantage is the possibility of the cameras being stolen so they would need to be placed in inaccessible places and well camouflaged. An alternative method for monitoring feral animals is to use sand pads across tracks but these pads need to be regularly monitored and maintained. Incidental and spotlight surveys do not provide reliable information for these species.

Rabbits compete with native fauna for food and spread many annual weeds, which are often more prevalent around their dung heaps and warrens, and are baited each year in the Park in autumn. Rabbit abundance should be monitored using remote cameras as for foxes and cats, or by surveying warren activity to assess the effectiveness of the control program.

Western grey kangaroos are abundant in the Park and are considered by some to be pest animals due to their selective grazing and trampling of vegetation (see Section 3.2.2). Control of kangaroos within the Park is probably not feasible but their abundance and impacts should be monitored. Remote cameras can provide some data on kangaroo abundance, especially at known access and watering points. Kangaroo activity can also be monitored by assessing the abundance of their tracks, scats and resting hollows under grasstrees and large shrubs. Impacts on grazing native plants can be readily monitored by installing fencing enclosures, (usually 5m x 5m) and measuring changes in plant cover, species composition and recruitment.

## 5.5 Visitor impacts

Many of the impacts associated with Park visitors have been discussed in earlier sections including the impacts of mountain bikes (see Section 4.3.3). With increasing visitor numbers there is an increasing demand for facilities and access and an expectation of more interactive experiences. Visitor impacts include soil erosion along tracks, creation of illegal tracks, trampling of vegetation, spread of weeds and dieback by tyres, bikes and shoes, disturbance to native fauna, illegal camp fires, arson and littering. Visitors also have increasing impacts on the enjoyment of other visitors and it is important to manage such conflicts. Visitor impacts can be largely managed by careful planning of events, controlling access of people, bikes and vehicles into and around the Park, and by appropriate education and signage. A variety of options for managing existing impacts are covered in the management plan.

A visitor survey conducted in 2010 was useful to characterise the visitor profiles, their activities and perceptions of the Park (Polley, 2012). Other than the water based activities, most visitors in 2010 were engaged in passive activities, such as relaxing, sightseeing, bushwalking, photography or picnics. Environmental issues of most concern were litter, rubbish dumping and wildfire. This survey needs to be repeated every few years to assess the effectiveness of management actions and to assess changes in visitor profiles. Other surveys should be undertaken during some of the larger events as these visitors may have different expectations and perceptions.

Research is required into the type, volume, timing and location of litter throughout the Park so that management actions can be more targeted (Polley, 2012). Management of litter can include the provision of bins, signage and education on websites and pamphlets and the issuing of infringement notices. The effectiveness of any management actions to increase public awareness and to reduce littering should be monitored by surveys of people's attitudes and of litter left during peak periods.

Other visitor impacts, and management actions taken to alleviate these impacts, can be monitored in a variety of ways. For example, the effectiveness of new signage to educate

visitors on the risks of spreading dieback can be monitored by surveying people's level of understanding about dieback spread and assessing any change in behaviour, and by surveying the rate of spread along tracks from known infested sites (see Section 5.1.1). In this way, both the cause and effect are being monitored.
One of the main concerns of the management committee is how to determine the maximum sustainable number of visitors that the Park can accommodate before having unacceptable impacts to the cultural, ecological and aesthetic values that are so much appreciated by visitors. An impact analysis is needed to resolve this issue by analysing whether visitor impacts are direct or indirect, whether impacts increase with the number of visitors, and whether the impacts are immediate (e.g. trampling of vegetation) or time delayed (e.g. spread of weeds and dieback). Impacts should be assessed on the type, source, severity and extent under various visitor number and management scenarios. An impact analysis using environmental, economic and social criteria will help to clarify the key risks, while a sensitivity analysis can assess how these impacts may vary with the number and type of visitors. For example, one visitor can ignite a wildfire that results in considerable damage to vegetation, fauna and property, while hundreds of visitors involved in a well-managed mountain bike event confined to disturbed areas of zone 6 may have little impact. A cost-benefit analysis of different visitor activities should form part of this research and lead to a decision support system to help the committee manage visitor expectations while protecting the core values of the Park.

## 5.6 Climate change

Impacts of climate change on Threatened flora, vegetation and fauna habitats is of concern as a large proportion of the Park is situated on shallow granitic soils with limited soil moisture availability. A drying climate could have significant impacts on the hydrology and stream flows in particular, which could affect riparian vegetation and the fauna (e.g. western ringtail possums and southern brown bandicoot) that rely on these moist habitats. Lower rainfall also leads to increased periods of soil dryness and greater flammability of the vegetation that need to be considered in planning burns and for wildfire risk analysis.

Some aspects of climate change impacts on vegetation are included in the research programs on tree decline in the Centre for CCWFH, but there is less known about the impacts of climate change on fauna and their habitats.

# 6.0 Priorities for research

## 6.1 Prioritisation process

It was evident from the assessment of research requirements for each of the ecological and cultural values that a lack of knowledge was the over-arching management issue whether that related to species biology, population trends, ecological processes, threats, managing visitors, or historical and cultural information. Better information leads to more efficient management and better use of resources and is an integral part of adaptive management.

An initial list of 142 basic research questions was compiled from the knowledge gaps and management issues identified for each ecological and cultural value in the foregoing literature review and entered into a spreadsheet. The wording of the questions was not critical at this stage but suggested a general line of enquiry. These projects were all considered to be feasible and within the capacity of the committee and City of Busselton to manage either internally or by outsourcing to other research agencies or consultants. Some projects were considered where sites within the Park could be included in broader existing

research programs that could produce relevant management recommendations, such as the work on tree decline.

Research questions and objectives were listed according to the category (ecological or cultural), type (aboriginal, geology, flora, fauna, hydrology etc), value (black cockatoos, western ringtail possums, Priority flora, soils etc), management issue and research method (research, survey or monitoring). Some questions sought to increase knowledge of ecological or cultural values while others were about increasing knowledge of various threats and impacts to those values to improve management effectiveness.

The list of research questions was sent to the Meelup Regional Park Management Committee members and to their environment officer, which resulted in two separate priority assessments (P) based on 'expert' knowledge of the Park and its environment. All research questions were ranked from very low (1) to very high (5) priority and the total scores from these assessments (2 to 10) were used to identify their highest priority areas for research. One additional research question on the impacts of climate change was added at this stage.

Research questions were also assessed personally according to the current level of knowledge (K) and urgency of the management issues (U), which were multiplied (K x U) to provide a priority index from 1 to 9:

- K - current level of knowledge (Low, Medium or High, and scored 3, 2 or 1);
- U - perceived urgency of the management issue (High, Medium or Low, and scored 3, 2 or 1).

The current level of knowledge (K) was informed mainly by what is currently known within the Park based on the literature review and also by what is known in a general sense about the value or management issue. A few research questions were rated with a high level of knowledge and a high level of urgency (e.g. nesting success of hooded plovers; population trends of Threatened orchids), as although they are currently being monitored every year, they are under a significant level of threat and require ongoing monitoring data (knowledge) to ensure they are being effectively managed.

The level of urgency (U) was informed by the likelihood, timeframe, scope and potential impact of the threat on the ecological and cultural values, based on the literature review and by the priority given to these management issues by the Park committee during the initial consultation workshop. Thus some research questions could have a low level of knowledge and a high level of urgency (e.g. the population trend of western ringtail possums; the sustainable visitor capacity of the Park), while others could have a low level of knowledge and a low level of urgency (e.g. population trend of barking owls; early European history).

The questions were then ranked as Very High, High, Medium or Low priority based on the average score from the two assessment processes (i.e. [P + (K x U)]/2) described above:

- Very High – scores 8.5 to 9.5;
- High – scores 7 to 8;
- Medium – scores 5.5 to 6.5;
- Low – 3.5 to 5.

Research questions were then grouped together according to similar themes based on values and/or management issues. This grouping recognised that several questions could be addressed within one research project, which would make more efficient use of resources and funding. Some research questions were reworded slightly to accommodate multiple species or activities being addressed (Appendix 1). One project (#23) was split into two separate projects as the questions related to different types of research.

The 31 broad research projects that resulted from this grouping were ranked according to the associated questions that had the highest score within each project. From this process, 13 projects with very high or high scores were included in the 10 year research schedule (Table 2). Some lower priority questions were included in projects where there were obvious synergies. Project numbers in Table 2 differ from those in Appendix 1 due to the way some questions have been grouped.

**Table 2**. Research projects that were assessed as very high priority (Score 8.5 to 9) for the Meelup Regional Park based on the ranking process (adapted from Appendix 1). Some projects have more than one component.

| Project No. | Research Project | Topic | Management Issue | Research questions |
|---|---|---|---|---|
| **1** | Survey soil erosion | Soil erosion and track maintenance | Erosion | How can fire and firebreaks be managed to minimise soil erosion? |
| **2** | (a) Research fire response flora | Impacts of fire on Threatened flora and other communities | Fire | What is the appropriate fire regime to conserve Threatened species? |
| | (b) Research fire response Meelup Mallee | Appropriate coppice regime for Meelup Mallee | Fire | What is the appropriate fire/coppice regime to conserve species? |
| **3** | Research fire response fauna | Fire and Threatened mammal habitat use | Fire | Does fire affect habitat quality and use? |
| | | Fire and reptile habitat use | Fire | Does fire affect habitat quality and use? |
| | | Fire and invertebrate habitat use | Fire | Does fire affect habitat quality and use? |
| **4** | Research tree decline impacts | Impacts of tree decline | Tree decline | What vegetation communities are affected by tree decline? |
| | | Fire and Threatened mammal habitat use | Tree decline | Is tree decline reducing food availability? |
| | | Black cockatoo population trend | Tree decline | Is tree decline reducing food availability? |
| **5** | (a) Survey of dieback susceptible species | Dieback susceptibility of flora | Dieback | Is this species susceptible to dieback? |
| | (b) Research of dieback susceptibility | Dieback threat to flora | Dieback | Is this species susceptible to dieback? |
| **6** | Monitor feral and pest animals | Predation of Threatened mammals | Disturbance | Do dogs disturb their feeding or breeding activities? |
| | | Predation of Threatened mammals | Predation | Is fox or cat predation a major cause of mortality? |
| **7** | Research tissue culture and translocation | Conservation of *Eucalyptus phylacis* | Rehabilitation | What site preparations are needed for translocation? |
| | | Conservation of *Eucalyptus phylacis* | Poor recruitment | Can more plants be propagated by tissue culture? |
| **8** | Research orchids | Recruitment of Threatened orchids | Poor recruitment | Does germination or pollination biology limit recruitment? |
| **9** | Research taxonomy and | Taxonomy and genetics of Priority | Taxonomy / genetics | Are these taxa taxonomically/genetically |

| | | | | |
|---|---|---|---|---|
| | genetic analysis | and disjunct flora | | significant? |
| **10** | Research sustainable visitor capacity | Sustainable visitor capacity | Sustainable capacity | What is the sustainable visitor capacity of the Park? |
| | | Sustainable visitor capacity | Economics | What are the costs and benefits of running different events? |
| **11** | Monitor visitor impacts on vegetation | Impacts of visitors on vegetation | Disturbance to flora | Are human activities causing significant loss of habitat? |
| **12** | Monitor visitor impacts on hooded plovers | Impacts of visitors on hooded plovers | Poor breeding success | Are dogs affecting nesting success of hooded plovers? |
| | | Impacts of visitors on hooded plovers | Poor breeding success | Do visitors disturb their feeding or breeding activities? |
| **13** | (a) Research hydrology and water requirements | Impacts of past and current water use | Water supply and quality | How has water quality and supply been affected by on and off site damming and water extraction? |
| | (b) Monitor surface and groundwater | Adequate water supply for future | Water supply and quality | Is there sufficient water supply for ecological and human needs into the future? |

## 6.2 Priority research projects

Thirteen high priority research projects, based on Table 2 are described in more detail below, along with the indicative methodology, estimated time involved, benefits and costings. The listing of projects does not imply any order of priority. Some of the projects require longer term monitoring to obtain useful data, which needs to be coordinated by the environmental officer of the management committee. Possible organisations that could undertake more discrete research projects are suggested. Volunteers and/or students can reduce the costs of projects where their involvement is appropriate.

Cost estimates for one project can vary widely depending on how the project is undertaken and so should not be relied upon. These cost estimates are based on salary levels appropriate for the project tasks, plus some vehicle expenses but do not include all overheads. They also assume some materials are available or can be shared between projects. Some projects are costed using approximate rates to engage a consultant or undertake contract research, but the time required to complete these project was not fully investigated. Detailed quotes would need to be obtained before decisions are made to undertake the projects.

**Project #1 – Soil erosion and track maintenance.**
Background: There are thirteen internal firebreaks and access tracks that define the fire management cells, while other tracks have been proposed to exclude vulnerable fauna habitats and sensitive vegetation types from regular prescribed burns. Some of these firebreaks are bitumen roads, but others are gravel, sand or limestone tracks that are prone to erosion as they occur on shallow soils over granite and/or on steep slopes. Most tracks have a locked gate to prevent illegal vehicle access, but heavy use during events and every day walking leaves the surface soils prone to erosion. Some tracks have already been hardened with limestone rubble that is effective in reducing runoff and minimising the spread of dieback. Parks and Wildlife is trialling some of the alternative track hardening products, such as Jakmat and Diamond Grid, and should be consulted before undertaking this project.

Project description: A survey of internal firebreaks and access tracks is required to determine their current state of repair and to recommend areas that need to be stabilised or redesigned to reduce erosion water runoff and the most effective means of hardening tracks.

Benefits:

- *Environmental* – Erosion gullies are not formed on tracks and adjoining vegetation;
  – The spread of dieback is minimised;
- *Social* – Tracks are safer to walk on;

– Tracks are less hazardous for vehicles and fire fighters during fire operations;

- *Economic* – Stabilized tracks are less expensive to maintain;

– Additional firebreaks can be designed to minimise soil erosion and have lower maintenance costs.

Indicative costs:
This survey and report is expected to take about 3 months, and with vehicle costs included, would be around $25,000 to $30,000. This project could be undertaken by an environmental officer or by a track design consultant. Volunteers could help with the track condition surveys to help reduce the costs.

**Project #2 – Impacts of fire on Threatened and Priority flora and fire sensitive communities.**

Background: The fire management plan recommends that cells are burnt every 8 to 10 years, with two burns in spring followed by a burn in autumn and one no burn interval, over a period of 32 years. This rotation is designed to maintain forest fuel loads at an acceptable level that assists wildfire suppression operations, ensures that prescribed burns can be burnt at moderate intensity that results in a mosaic of burnt and unburnt patches, and enables recruitment of a wide range of plant species. However, this fire regime is based on jarrah and marri forest vegetation growing on deep lateritic soils and is unlikely to be suitable for vegetation associated with outcropping granite. Vegetation complex mapping indicates that about 70% of the vegetation in the Park is associated with outcropping granite, including the jarrah and marri woodland and low open forest vegetation associations (Webb, 2013). Studies of granite outcrops in the south-west have shown that about 75% of species are obligate seeder species (Hopper, 2000; Yates *et al*., 2003). These species are slow maturing and require longer fire intervals to produce enough viable seeds to maintain their populations (Burrows *et al*., 2008; Burrows, 2013). Most seeder species regenerate better after autumn burns rather than spring burns, while orchids are particularly vulnerable to burning during their active growing season from May to October.

Meelup Mallee (*Eucalyptus phylacis*) appears to require fire or coppicing on a regular basis, possibly every 7-10 years, to maintain healthy stems. Fire response information is available for some species from Parks and Wildlife, including some rare and Threatened species, but the response of many species is unknown. Appropriate fire management guidelines are required for all fire sensitive flora and communities to ensure their long term survival.

Project description: Research is required to determine the life attributes and fire responses of fire sensitive plant species and communities, so that more appropriate fire regimes can be developed based on the ecological requirements of key indicator species. Trial burns may be required for some species to generate the required fire response information, but most fire responses can be determined by monitoring plants for several years following prescribed burns or wildfires. A separate trial (Project #2b) will determine the most appropriate method and frequency for regenerating endangered Meelup Mallee ramets by fire and/or coppicing to improve stem vigour.

Benefits:

- *Environmental* – Fire regimes for Threatened and Priority flora species are based on their ecological requirements to ensure their long term survival;
– *Calothamnus graniticus* heath Threatened Ecological Community is managed according to the fire responses and ecological requirements of key fire sensitive indicator species;
– Meelup Mallee is regenerated at regular intervals to reduce the level of canker and borer damage;
– Orchids, including Threatened species are managed according to their ecological requirements;
– Fire sensitive species are identified in other plant communities, including Threatened fauna habitats, and used to develop appropriate fire regimes.
- *Social* – Important flora values in the Park are protected for future generations to enjoy;
- *Economic* – The cost of maintaining Threatened and Priority species and communities will be reduced if they are healthy and are able to regenerate naturally.

Indicative costs:
Project #2a – This research will require surveys of plants before burning and for at least six years after burning to determine fire responses and time to first flowering and seed set. Quadrats would be established in representative areas of vegetation and in Threatened and Priority species populations to obtain quantitative data on plant growth. This project would need to fit in with the program of prescribed burning, or have smaller trial burns conducted in representative areas. Plant monitoring and data analysis may take about two months each year with more frequent monitoring in the first year after fire to capture seedling regeneration. Both resprouters and reseeders should be monitored to help develop fire guidelines for each plant community as well as for the key fire sensitive plant species. Cells are burnt at different times so not all vegetation types can be monitored at the same time. Therefore, this research needs to be an ongoing commitment until all vegetation communities and Threatened and Priority species and communities have been assessed. Any proposal for burning Threatened or Priority flora and Threatened Ecological Communities requires approval from Parks and Wildlife and would need to be conducted in conjunction with their staff.

An indicative cost for this research and reporting, including the cost of setting up quadrats and vehicle use, would be around $100,000 to $125,000 over about six years, although the cost is likely to decrease over time. This project requires a person to be able to accurately identify flora species, including Threatened flora species, and be able to measure, collate and analyse fire response data and prepare fire management guidelines. It would be appropriate for a botanist/fire ecologist consultant or a flora officer within Parks and Wildlife with assistance from skilled volunteers for monitoring the plants.

Project #2b – The response of Meelup Mallee to coppicing or burning should be investigated by treating two or three ramets out of the 27 ramets in the population every three years and monitoring the growth, time to first flowering, seed set, borer and canker damage and stem splitting. This would require approval from the south-west region Threatened flora and communities recovery team in Parks and Wildlife, and would need to be undertaken by their scientists, but volunteers can assist with monitoring the time to flowering and health of the ramets. The Meelup Mallee regeneration trials and follow up monitoring could cost about $12,000 per year every three years.

**Project #3 – Impacts of fire on Threatened and Priority fauna and their habitats**
Background: Western ringtail possums and southern brown bandicoots are restricted to riparian vegetation, peppermint woodlands and dense coastal shrublands that need to be protected from inappropriate fire regimes. Burning these habitats increases the risk of predation as these species have few alternative areas of suitable habitat in the Park. Other

fauna, including honey possums and southern carpet pythons, may also be affected by large fires that reduce their food resources. Several fauna surveys have been conducted in the Park, but the habitat zones of Threatened and Priority and specially protected fauna have not been mapped. An assessment of habitat quality as well as habitat area is required. While the general habitat requirements for these fauna species is known, the specific habitat zones within the Park need to be delineated to manage them appropriately during prescribed burning and wildfire suppression.

Project description: Research is required to determine the habitat zones of Threatened and Priority fauna, and to study the response of their specific habitat vegetation to fire so that appropriate fire regimes can be developed. The fire response of habitats specific to southern carpet pythons and short range endemic and Priority invertebrates should be included in this project.

Benefits:

- *Environmental* – Fire regimes for Threatened and Priority fauna species are based on the ecological requirements of their habitat to ensure their long term survival;
- – Peppermint woodlands and riparian vegetation are burnt using appropriate fire management guidelines;
- – Coastal shrublands are burnt using appropriate fire management guidelines;
- – Other fauna species occupying these habitats will benefit from a greater level of protection from fire;
- – The risk of losing Threatened and Priority fauna species is minimised;
- *Social* – Important fauna values in the Park are protected for future generations to enjoy;
- – Peppermint woodlands and coastal vegetation near popular beaches are retained for shade and amenity;
- *Economic* – The cost of planning prescribed burns will be reduced if fauna habitat maps are available and the fire response information is known.

Indicative costs:
This research requires detailed surveys and mapping of Threatened and Priority fauna and other fire sensitive fauna, and their habitats. Research into the fire responses of the plant species making up their habitats is also needed, which could be carried out in conjunction with the previous research project. The project would be expected to take about three years, with fauna surveys and mapping of fauna habitat over two months of each year, plus data analysis and reporting. Some materials may need to be purchased such as remote cameras, batteries, fauna traps, spotlights etc. depending on their current availability, and there would be some vehicle expenses. Monitoring of fire responses of Threatened fauna habitat species could be included in the previous project, otherwise an additional two weeks per year should be allowed for this part of the project.

The total cost is expected to be around $60,000 – $65,000 over three years. An ecologist with fauna survey skills and an appropriate licence would be required to survey and map the fauna habitat zones of threatened and fire sensitive species. However, the response of fauna habitats after fire could be monitored by an environmental officer as this is mainly studying the response of common plants and changes in vegetation structure, which could reduce the overall cost of the project. This project could replace the fauna surveys that are planned every five years for this ten year time frame.

**Project #4 – Impacts of tree decline on vegetation communities and fauna habitat quality.**

Background: Tree decline in the south-west of Western Australia is being studied at the Centre of excellence for climate change, woodland and forest health (CCWFH) based at Murdoch University. A number of causes of tree decline have been identified, such as

decreased rainfall and increased incidence of insect damage and fungal infection, but the extent of this decline and the impact on vegetation communities in the Park are unknown. Tree decline affects several important species in the Park including marri (*Corymbia calophylla*) and peppermint (*Agonis flexuosa*), and has the potential to impact on food resources for some of the Threatened fauna including western ringtail possums that feed on peppermint foliage and black cockatoos that feed on marri nuts. Decline in the health of peppermints around Meelup Beach and Meelup Brook are of particular concern. Tree decline is also relevant to the health and survival of the ancient and critically endangered Meelup Mallee (*Eucalyptus phylacis*).

A project proposal to use remote sensing imagery to detect past changes in tree canopy health has been developed with the remote sensing section of Parks and Wildlife. The project proposed here will assist with the interpretation of the remote sensing imagery by surveying tree health on the ground at numerous sampling sites and investigating possible causes, such as dieback, insect defoliation and drought stress. This will provide calibration of the imagery and also provide a baseline for ongoing assessments of canopy health and changes in availability of food resources for western ringtail possums and black cockatoos. This project will also complement the existing marri decline research project conducted by CCWFH, in which volunteers and others can register sites and record incidence and severity of cankers on marri trees via the Marri App, and conduct simple trials to treat affected trees. Changes in the health of tree canopies will affect the food resources and nesting opportunities for many other fauna species (e.g. bush birds, honey possums, brushtail phascogales) and can be related to changes in fauna abundance.

Project description: Research is required to determine which woodland and forest communities in the Park are being affected by tree decline, the possible causes and the impacts that that this decline may be having on Threatened fauna habitats.

Benefits:

- *Environmental* – The rate of tree decline in different vegetation communities is known;
  – The possible causes of tree decline are evaluated;
  – The health of western ringtail possum habitat (peppermint woodlands) is monitored;
  – Food resources for black cockatoos (marri nuts) are monitored;
- *Social* – Important fauna habitats in the Park are managed for future generations to enjoy;
- *Economic* – management decisions to treat affected trees and important fauna habitats are based on reliable information.

Indicative costs:

This research requires surveys of woodland and forest communities to determine whether they are being affected by tree decline. The survey sites should be coordinated with the remote sensing project to assist with ground truthing of the LandSat imagery. Once the tree decline imagery has been processed and calibrated, additional images for the same areas can be processed at lower cost to monitor trends into the future. Canopy health can be monitored visually using standardised scoring and diagrams (e.g. leaf density, canopy cover, canker presence and severity). Hemispherical camera lens and associated software can also be used to assess changes in leaf area. It is likely that trees growing on shallow soils will be most affected due to the greater influence of drought, but comparative sites are also needed in other areas to gain a greater understanding of the factors causing tree decline. For example, tree decline in sites mapped as being infested with dieback disease may be compared with uninfested sites. The cost of this project will depend on the number of sites visited, but has been estimated at $50,000 to $60,000 over 10 years, with the one-off calibration of canopy health costing around $30,000 and on-going image analysis and canopy health surveys conducted every four years.

It would be appropriate for part of this project to be undertaken at the CCWFH by Murdoch University students, or by the remote sensing section in DPaW, to calibrate the canopy health with the remotely sensed data when this is available. The ongoing surveys of marri and peppermint canopy health and food resources for western ringtail possums and cockatoos could be coordinated by an environmental officer with assistance from volunteers.

**Project #5 – Understanding the susceptibility of plants to Phytophthora dieback.**
Background: Phytophthora dieback is a significant threat to many plant species and communities in the Park, and also to the fauna that depend on these communities. Four dieback surveys have been conducted in the Park and currently about 25% of the Park is infested, with new infestations recorded each time the Park is surveyed. Various management actions have been taken to minimise this risk, including limiting access, improving disease hygiene standards, hardening of tracks, installing drains, signage and treating affected trees. However, the susceptibility of numerous plant species to dieback remains unknown. The susceptibility of Meelup Mallee is unknown but can be investigated when sufficient clonal plant material is available from tissue culture. In particular, some of the Priority species and species growing in the *Calothamnus graniticus* heath TEC and nearby fringing vegetation need to be tested for their susceptibility to dieback. Knowing which species and communities are most prone to infestation will help to direct resources for phosphite spraying to protect vulnerable species, and for developing a dieback management strategy for the Park.

Project description: Research is needed into the susceptibility of species within the Park to determine priorities for managing the spread of the disease and for treating affected plants with phosphite. This research would search the existing dieback databases as the susceptibility of many species is already known, and sample the soil and/or roots of plants showing signs of dieback within infested areas. A separate project (Project #5b) would grow seedlings with unknown responses to dieback and artificially inoculate them with the pathogen under controlled shade house conditions to determine their susceptibility to this disease.

Benefits:

- *Environmental* – The susceptibility to dieback of Threatened and Priority flora plant species are known, so that management actions can be more targeted to protect the most vulnerable species;

– Vegetation communities and fauna habitats that have susceptible species can be managed appropriately during events and other activities.

- *Social* – The natural environment is protected for future generations, and people using the Park know that is being managed appropriately;
- *Economic* – management of dieback spread is more targeted, which should reduce the cost of treating susceptible plants, vegetation communities and fauna habitats.

Indicative costs:
Project #5a – The cost of this project will depend on the number of samples and species tested in the laboratory or cultured in green house conditions. Soil and plant samples can be tested in several commercial laboratories to isolate the disease from cultures but the samples should be collected by experienced dieback interpreters. This service may cost around $110 – $130 per sample plus the cost of collection. The Centre for Phytophthora Science at Murdoch University (CPSM), the Department of Agriculture and Food, and Parks and Wildlife have diagnostic and research laboratories, while there are several dieback consultants available locally who could collect the samples, including Dieback Treatment Services who have previously mapped dieback in the Park. The total cost of this part of the project, including a search of species already in the dieback databases, could be around $10,000.

Project #5b – Determining the susceptibility of other species to dieback would take much longer as seeds need to be collected and grown in a greenhouse for at least 10 months before inoculation, and then grown for another 10 months to assess the response. At least 50 – 100 seedlings per species are required. The Vegetation Health Service at Parks and Wildlife does this research for Threatened and Priority species, but they could assist another researcher to run these trials for other species if required as a separate project. The cost of this project over two years could be around $200,000 including salary, use of greenhouse and materials, inoculum and travel. The project could be suited to a PhD student, perhaps under the direction of scientists at CPSM. Other aspects could be included in a PhD project such as studying the impacts of dieback on plant composition and nectar resources, or the phytotoxic effects of phosphite spray on flowering and seed production in native plants.

**Project #6 – Monitoring the impacts of introduced predators on western ringtail possums and southern brown bandicoots.**

Background: Foxes and feral cats are known to occur in the Park, but their impacts on resident western ringtail possums and southern brown bandicoots are unknown. Research over many years in inland forests has shown that introduced predators can have a significant impact on populations of these Threatened mammals and that fox baiting helps to reduce this threat. Possums and bandicoots live along Meelup Brook, around Meelup Beach and in the denser coastal dune vegetation. Many also live in adjoining urban gardens where shade, shelter, plant nutrients and moisture may be enhanced, often in the presence of domestic dogs and cats. Foxes and feral cats are regularly baited in the Park, but it is not known whether this management action is reducing the impact of these predators. Domestic dogs are permitted at Eagle Bay and can access the Park if allowed to roam and may disturb the feeding or breeding activities of native fauna.

Project description: The presence and activity of dogs, foxes and cats in the Park would be monitored around known habitat zones of western ringtail possums and southern brown bandicoots, and along entry and access tracks and the urban interface. Covert remote sensing cameras would be placed at baited sites (using lures and/or poison baits) along tracks to detect the presence of dogs, foxes and cats in the area and to monitor the effectiveness of control methods. Other cameras would be installed in known fauna habitats (e.g. in peppermint trees for western ringtail possums or near active runnels or diggings for southern brown bandicoots) to observe any interactions between predators and native fauna.

Benefits:

- *Environmental* – Presence and activity of foxes, feral cats and domestic dogs are observed at different times of year;
- – Fox and cat control programs are evaluated;
- – Disturbances caused by feral predators and dogs to native fauna are assessed;
- – Relative abundance may be estimated if individual markings can be observed
- *Social* – Visitors will be reassured that predators are being effectively managed;
- – Iconic native fauna will be protected for the enjoyment of future generations;
- *Economic* – cost effective predator control programs are employed.

Indicative costs: Remote sensing cameras placed at baited sites or in fauna habitat areas need to be well hidden to avoid them being stolen. Covert cameras should be used as they do not make any sound or have a flash that would give away their location to animals or people. The actual number of cameras and locations selected will depend on the contractor, the design of the study and the availability of suitable sites, but around 20 cameras may be required. Cameras need to be placed where they are not continually triggered by movements of grass or swaying branches and this can take some time to get right. They can be purchased for around $300 each, and several sets of batteries and rechargers are

required, costing a total of around $10,000. Remote cameras can be left in place for several months and data can be downloaded remotely if required. An experienced contractor or conservation officer would be required to manage this monitoring program and install the cameras, although trained volunteers can assist greatly with viewing and screening the images, charging and replacing batteries and checking that cameras remain in place. The time required to review the thousands of images can also be reduced by using filtering software.
The project is expected to be run over three years to obtain sufficient data to allow for seasonal variations. Monitoring should be undertaken for at least 6 weeks per year (i.e. three weeks in autumn and spring). A contractor would be required for two weeks each season to install and remove the cameras, review the images and record the data, with two weeks to prepare an annual report, or about 5 months in total. Volunteers could assist by checking cameras and screening the images for positive sightings. Depending on the experience level of the contractor engaged to conduct the project, and the contribution from volunteers, the total cost is estimated be around $60,000. Parks and Wildlife officers are experienced in setting up these cameras and could provide advice on selecting sites, installing cameras and interpreting the images if required. This project could fit into the existing feral animal baiting program to reduce overall project management costs.

A code of ethics may be required if remote sensing cameras are used in areas where members of the public may inadvertently be captured. Licensed contractors must be used if cameras are used in conjunction with poison baits as part of the fox control program.

**Project #7 – Conservation of Meelup Mallee (*Eucalyptus phylacis*)**
Background: Conservation of the critically endangered Meelup Mallee (*Eucalyptus phylacis*) is primarily the responsibility of Parks and Wildlife and is managed according to the Interim Recovery Plan (2004–2009), while conservation actions are coordinated by the south west region Threatened flora and communities recovery team. *E. Phylacis* is known from a single clone estimated to be more than 6,000 years old and grows on a hill crest with loamy granitic and lateritic soils. It is being impacted by bark borers, fungal pathogens and bark splitting, which are likely to be associated with increasing drought and/or site effects. Volunteers and staff have assisted research efforts by monitoring the health and growth of stems while the City of Busselton removed the old carpark and rehabilitated the area to reduce impacts on the population. *E. phylacis* is believed to be a hybrid between *E. virginea* and *E. decipiens* and although it regenerates from the lignotuber and basal buds with increased vigour after fire or coppicing, it produces very few viable seeds. Tissue culture has produced some plants, but the process has been problematic and very few plants are available for establishing another translocated population to reduce the risk of extinction. Parks and Wildlife is preparing a translocation plan for establishing the few plants currently available at BGPA and aims to supplement this with additional plants when they are propagated. A suitable translocation site has been identified in an old gravel pit over the road from the known population.

Project description: This project will fund further research into tissue culture for *E. phylacis* by the Botanic Gardens and Parks Authority (BGPA) to establish sufficient advanced material to plant out in a new translocated population and for long term cryostorage of tissue cultured material. Monitoring of stem health and growth will continue to determine the time to first flowering after fire or coppicing, and the age at which stem splitting and senescence is reached.

Benefits:

- *Environmental* – Tissue culture techniques will be improved and sufficient planting material will be available for a translocated population;

– Tissue cultured material will be available for long term cryostorage;

– Time to stem splitting and senescence will be known to assist with management decisions about burning and coppicing.
– Several recovery actions will be addressed from the Interim Recovery Plan
- *Social* – Important natural values in the Park will be protected and enhanced for future generations;
- *Economic* – A second viable and secure population of *E. phylacis* may allow the promotion of this species as a tourist attraction.

Indicative costs: The tissue culturing of sufficient material is likely to cost around $10,000 to $15,000 to generate and nurture at least 50+ plants for the translocation. Preparation of the translocation site and care of plants over two to five years may cost around $5,000 to $10,000 including testing for dieback, ripping the soil, and fencing the site. Watering may be required in the early years to ensure establishment of plants. Stem health and time to flowering and stem splitting could be monitored during autumn (Feb–Mar) when monitoring the translocated population.

**Project #8 Conservation of Threatened orchids**

Background: Several Threatened orchid species are present in the Park, which are managed by Parks and Wildlife through the south west region Threatened flora and communities recovery team. Poor recruitment, weeds, trampling and grazing are significant threats to populations of *Caladenia caesarea* subsp. *maritima* and *C. viridescens* in the Park. Recovery actions in the Interim Recovery Plans include obtaining biological and ecological information on the pollination biology, pollinator activity (thynnid wasps) and seed viability, and studying the effects of grazing by rabbits and kangaroos on the survival, flowering and recruitment of these orchids. Trials are also needed to determine the most appropriate herbicide to control annual weeds that compete with *C. caesarea* subsp. *maritima*. Spraying early in the growing season with Fusilade was effective in controlling grasses in other orchid populations.

Project description: Research is required into the pollination biology of *C. viridescens* to understand the causes of low recruitment. This may include artificial hand pollination and monitoring of pollinator activity and seed production, and using remote sensing cameras to record pollinators such as thynnid wasps. Grazing impacts on *C. caesarea* subsp. *maritima* by rabbits and kangaroos can be investigated using exclusion plots with different mesh sizes and/or remote sensing cameras. Individual plants will need to be tagged and carefully monitored during the growing period from May to December. Trials with grass selective herbicides (e.g. Fusilade®, Verdict®) are needed to determine the appropriate timing and rates that will provide effective control of weeds in several populations of *C. caesarea* subsp. *maritima* growing in shallow soil pockets around granite outcrops and along walk trails, especially where rabbits disturb the soil and encourage weeds.

Benefits:
- *Environmental* – Causes of low recruitment in *C. viridescens* is understood;
– Grazing impacts on *C. caesarea* subsp. *maritima* associated with rabbits and kangaroos are known and can be managed;
– Impacts of people trampling orchids may also be determined;
– Appropriate methods for controlling annual weeds in populations of *C. caesarea* subsp. *maritima* are available for managing this threat;
- *Social* – People can enjoy seeing the flowering orchids;
- *Economic* – Management of Threatened orchids can be more targeted and cost effective if the causes of poor recruitment are known;

Indicative costs: Hand pollination and monitoring of flowering and seed production in orchids can be conducted by scientists within Parks and Wildlife or BGPA, or by a university Honours student under appropriate supervision, although it should be continued for several

years to study annual variations, which would not fit in with an Honours project timetable. The cost of this research may be around $5,000 to $10,000 including the cost of several remote sensing cameras and travel. More in depth studies of pollen and seed viability could be considered for a three year PhD project. The cost of constructing several enclosures with rabbit and/or kangaroo proof netting and monitoring the impacts of grazing on *C. caesarea* subsp. *maritima* may cost around $6,000 in the first year and $4,000 per year for three years, totalling $14,000. Some enclosures may need to encompass a whole rock outcrop to effectively enclose a population growing around the fringes. This study could be done by the DPaW flora officer with assistance from committee volunteers. Herbicide trials could be done by the DPaW flora officer or the coordinator of Threatened species (Andrew Brown) who has some experience with using herbicides in orchid populations. The cost of these herbicide trials and monitoring could be around $5,000 to $10,000 over three years.

**Project #9 Research into the taxonomy and genetics of Priority and disjunct flora**
Background: Eighteen flora species and/or subspecies in the Park, including three listed as Priority 4 species, are recognised as significant and in need of further research in a recent survey by Andrew Webb (Webb, 2013). These species either differ morphologically from their typical form, or are isolated populations at some distance (disjunct) from other populations and may have evolved differently since they were separated. These unknown or poorly described taxa are in need of further morphological examination or genetic analysis to determine their taxonomic and conservation status.

Project description: The taxonomy of the eighteen Priority and disjunct species and subspecies will be examined to assess the morphological variations between populations. Collections of plant material within the Park and in other locations on the Leeuwin Naturaliste Ridge and elsewhere will help to define the species and their ranges. Genetic DNA analysis will be undertaken to assess genetic diversity and conservation status of these species. This study involves sampling the populations within the Park and up to ten other populations of each species within their main area of occupancy.

Benefits:

- *Environmental* – Priority and disjunct species will have their taxonomic and genetic status determined.
- *Social* – Important conservation values are protected for future generations;

– The determination of any new species will confer greater conservation significance to the Park.

- *Economic* – Disjunct taxa will be managed according to their taxonomic status;

– Tourism appeal may increase if the conservation significance of the Park is increased through taxonomic research.

Indicative costs: The cost of taxonomic studies of disjunct and poorly known flora species can vary greatly depending on whether additional plant material needs to be collected and whether a formal published description or informal assessment and report is required. Due to the high cost and time required to formally describe and publish new taxa, it is suggested that the informal process be taken. This usually involves collecting additional material from the field and making morphological measurements in the herbarium to compare with other known populations. If there is reason to believe that the taxa is different, the collection is given an appropriate phrase name and a form is completed and the taxa is placed on the priority list for further formal investigation. The cost of this work is reduced if multiple collections of different taxa are sampled in the same field trip, but this is not always possible due to different flowering times. An experienced botanist may require a week to assess the taxonomic status of plant material from one species and prepare a report, costing about $2,500, or about $50,000 for the eighteen species with uncertain taxonomic status, including the cost of several field trips. This cost may increase depending on the level of variations with the species, but can be reduced if fewer species are included in the research project.

Taxa that appear to be different from taxonomic studies or occur in populations that are significantly isolated from the usual range are good candidates for DNA analysis. The cost of genetic analysis is approximately $10,000 per species including the time taken to collect suitable plant material from the population within Meelup Park and from about 10 other comparable populations within its known range ($5,000/species), and the cost of laboratory DNA analysis ($5,000/species). Costs can be reduced by collecting material and/or analysing DNA for several species at the same time. The genetics laboratory in the Science and Conservation Division at Parks and Wildlife is established to run these analyses, and the analysis takes about 2 weeks per species. Dr David Coates can assist with developing this project further if required. If ten species were selected for DNA analysis, this would cost around $80,000 to $100,000.

**Project #10 Determine the sustainable visitor capacity of Meelup Regional Park**
Background: Visitor numbers are steadily increasing in Meelup Regional Park and are having an increasing impact on the conservation values and facilities provided. Events attract large crowds that can provide funding for managing the Park, but can cause significant damage over a short time period, some of which can be take many years to repair. The cumulative effects of these impacts on the ecological, cultural and aesthetic values in the park are unknown, but it is anticipated that a threshold may be approached beyond which the level of damage is unacceptable. Some impacts can be managed by controlling access and appropriate signage, while other impacts are more insidious such as the spread of dieback and weeds, and disturbance to native fauna, which often have a time delay. Increasing numbers of visitors also has an impact on the enjoyment of existing visitors and local residents who have enjoyed the peaceful natural environment for many years. The cost of improving facilities, such as parking areas, toilets, shelters, walk trails and picnic areas needs to be borne by the committee and City of Busselton, and so a benefit to cost analysis of running events is required.

Project description: An impact assessment of visitor numbers on the ecological and cultural values in the Park is required, as well as a benefit to cost analysis of various events. The impact assessment would consider qualitative and quantitative impacts gained from observations by stakeholders through desktop study of available research and survey or workshop processes. Individual and group activities would be treated separately. Tables would be developed with criteria showing the 'maximum number of annual visitors (group size, frequency, time of year etc) before there is an impact on values' and the 'minimum number of annual visitors before there is an unacceptable impact on values' for each activity and each value. These tables would be summarised into a synopsis matrix to provide recommendations of sustainable visitor numbers for each activity.

A benefit to cost analysis would be conducted on each event to assist management decisions around the running of future events. A simple approach is to use an expert panel to rate the indicative benefits and costs of running events on a scale of 1 (low) – 10 (high). Environmental, social and economic benefits and costs could be rated separately and averaged to calculate the Benefit Cost Index (BCI), which would be ranked to determine priorities. Negative values can be used to indicate impacts rather than benefits. Other aspects to consider include the feasibility of running large events, socio-political constraints and availability of funding. Event organisers may be required to provide their own benefit cost analysis for future events based on the criteria developed during this project, in a similar way that an environmental impact assessment is required for development projects.

Benefits:

- *Environmental* – Impacts of visitors on ecological and cultural values are properly assessed for each activity and event;

– Limits on visitor numbers are determined above which unacceptable impacts may be expected for activities and events.
- *Social* – The sustainable capacity of the Park is known and accepted by the committee and can be enforced;

– The maximum number of visitors is understood by the public and respected.
- *Economic* – Events are managed sustainably and only those events with a high BCI are approved;

– The management committee has a transparent process to determine what they charge event organisers to cover the costs of damage to ecological or cultural values.

Indicative costs: This research would need to be undertaken by an experienced economist with considerable input from the committee members and stakeholders during workshops. Additional data on visitor numbers and vehicles may be required but often an expert panel can provide useful estimates of the relative impacts, benefits and costs. As always, more reliable estimates generate more useful outcomes, and this will depend on the nature of the relationships involved. Estimating the relationship between visitor numbers and level of rubbish may be fairly straight forward, but assessing impacts of increasing visitor numbers on the behaviour of Threatened fauna is not. One consultancy contacted (Dr Liz Petersen of Advanced Choice Economics) has appropriate experience and capacity to undertake this project. Using a consultant rate of $900 per day, and including several workshops with stakeholders volunteering their time and using existing data, an indicative cost could be around $60,000. If additional data or surveys are required, then the cost could increase depending on the nature of those surveys. The following two projects on visitor impacts would provide useful information for the sustainable visitor capacity.

**Project #11 Reduce visitor impacts on vegetation**

Background: Visitors walk in the Park on tracks and along the beach and usually have minimal impact on the vegetation. However, some people walk through the vegetation, park illegally outside parking areas, ride mountain bikes along tracks and cut corners or widen the walking tracks. Visitor impacts on vegetation include direct trampling and damage to shrubs, herbs and fauna habitats, compaction of soils that affects root growth, erosion of tracks that leads to increased water runoff on steep slopes and spread of weed propagules and dieback disease, and sand blasting of vegetation on eroded dunes. The impacts on some species (e.g. orchids) and some vegetation types (e.g. fringing vegetation around granite outcrops and vegetation on foredunes) are more pronounced than others. Access tracks and signage help to manage these impacts but in summer and during events when visitor numbers are high, these impacts can be significant.

Project description: Surveys are required to assess the condition of vegetation along tracks on a regular basis and particularly before and after major events. Simple transects and photopoint monitoring would be adequate in combination with surveys for weeds, dieback and track condition. Photopoints would be sited in areas known to be affected by vehicles and people, and in sensitive vegetation such as coastal foredunes and around granite outcrops and lookouts. Casual observations and photos recorded by volunteers during events would help to identify parking issues and areas of greatest impact. Recommendations from the surveys will assist with planning vehicle and people movements during events and peak holiday periods, and help to determine sustainable visitor numbers to reduce future impacts on vegetation.

Benefits:
- *Environmental* – Damage to vegetation will be reduced in heavy traffic and pedestrian areas;

– Damage to sensitive vegetation will be reduced;
– Lower risk of spreading weeds and dieback into vegetation.
- *Social* – People will benefit from more appropriate parking and access tracks;

– People can enjoy seeing vegetation in good condition.
- *Economic* – Lower rehabilitation costs;
– Less weed and dieback spraying;
– Information is made available to help determine sustainable visitor numbers.

Indicative costs: Photopoints and transects would be set up in the first year and monitored during spring and autumn for five years to determine the rate of vegetation decline. At least twelve permanent photopoints should be established in places expected to have high (4), medium (4) and low (4) impacts. Temporary photopoints can also be established in areas used during events (e.g. Zone 6) to capture information before and immediately after an event. Each photopoint could be marked with a painted wooden peg level with the ground surface in the middle of a track, with accurate GPS coordinates and a field map showing their locations. Photopoints should cover a quadrat or transect that is at least 5m wide by 10m long and preferably straddling a walk track or vegetation boundary. The cost of monitoring sites is simply the time taken to set up and mark the sites, take photos and then monitor each quadrat or transect to collect data on vegetation cover, health or condition score, presence of weeds and condition of track or soil surface, and preparing annual reports. This project should cost around $4,000 per year over five years, or $20,000, although this could be undertaken by trained volunteers if required.

**Project #12 Reduce visitor impacts on hooded plovers**

Background: Hooded plovers were regularly seen and monitored during November to March at Bunker Bay and Eagle Bay beaches but they were absent in the 2014 survey. A survey report in 2013 expressed concern about dog and vehicle damage to nest sites in the Eagle Bay north site where hooded plovers had been seen since 2008. The hooded plover is a Priority 4 species that is in decline across Australia largely due to disturbances by people, vehicles and dogs. Eggs are laid in a small scrape in the sand above the high water mark and in the foredunes and can be easily damaged by people and 4WD vehicles or eaten by dogs. Eggs and chicks are also taken by silver gulls, ravens, foxes and other predators, but breeding success has been improved in other areas by using temporary signage and roping off known breeding sites (Onton, 2009). This action reduces the disturbance to adult hooded plovers during nesting and provides some protection to eggs and chicks. The signage also raises public awareness about on-ground conservation efforts.

Project description: This project will monitor hooded plovers over ten years at Bunker Bay and Eagle Bay and install temporary fencing and signage as required to improve their breeding success, using standard procedures and monitoring forms developed by BirdLife Australia. Remote sensing cameras can be used to monitor disturbances in the nesting area if they can be suitably camouflaged.

Benefits:

- *Environmental* – Hooded plover abundance and activities will be known and recorded in the BirdLife Australia database and in the DPaW hooded plover database;
– Hooded plovers are better protected and breeding success may improve;
– Presence of other shorebirds in the area will be recorded;
- *Social* – People appreciate the conservation efforts to protect hooded plovers;
– 4WD vehicles and dogs are restricted on beaches creating safer swimming beaches;
– People are educated about beaches being habitats for animals as well as places of enjoyment for people;
- *Economic* – Hooded plovers are managed in a cost effective way.

Indicative costs: Trained BirdLife Australia volunteers would be encouraged to assist with monitoring the beaches for hooded plovers and erecting the rope fence if required. There is

a significant risk that these activities can disturb the birds more than if nothing was done so they must be carried out by trained people using standard protocols. The Dunsborough Coast and Landcare group has helped to monitor hooded plovers over recent years and may be available to assist with this project. About 15–20 recycled plastic garden stakes (1.6m tall) and two signs are needed per site with about 60m of rope. Signage can be purchased through BirdLife Australia by contacting the hooded plover community coordinator. Kim Onton and Marcus Signor are the contact people for hooded plover projects and can be contacted through BirdLife Australia WA Branch. The cost of materials for this project is expected to be around $500 for materials and $500 if a remote sensing camera and batteries are used. A community education program may be required to inform people about the project and plight of the hooded plovers. This may require newspaper articles, radio interviews, static displays and stakeholder workshops with a cost of around $2,000. The total cost of the project over ten years, including training of volunteers, replacement signs and data entry may be around $5,000. However, if there are no nesting records, then the cost is only to coordinate and/or train volunteers to monitor the beaches and record observations.

**Project #13 – Trends in stream water flow and quality**

Background: Water resources in the Park are limited and will be in greater demand in the future with increasing visitor numbers and a drying climate. Water is required for visitor facilities (e.g. drinking, washing, toilets, watering grassed areas), fighting fires as well as for ecological needs. Meelup Brook and Dolugup Brook are the main creeklines that flow through the Park, with some other natural springs and minor drainage lines. Scheme water is provided for drinking and fire hydrants while several tanks and small dams provide additional stored water capacity. Meelup Brook has been dammed on a neighbouring vineyard and winery which limits the flow of water in the Park and there is concern that the quality of water in this brook may have been contaminated from this off-site industry. Water has also been extracted from natural springs that may have impacted on ecological values. The management plan outlines a number of actions to maintain natural surface water flow rates and groundwater levels and to ensure that surface and groundwater quality is not adversely affected by on-site or off-site activities.

Surface water in Meelup Brook and Jingarmup Brook have been monitored fortnightly for water quality since 2006 by Geocatch NRM group for the water quality improvement plan for Vasse-Wonnerup and Geographe Bay. Currently, the nitrogen and phosphorus levels in the Dunsborough streams (including Meelup Brook) are below the targets set by Geocatch in their report cards (Total N< 1mg/l, Total P <0.01mg/l), but the total nitrogen level in Jingarmup Brook is above the target. However, numerous individual water samples taken from Meelup Brook itself exceeded these levels, with up to 5mg/l total N and nearly 0.1mg/l total P. Nutrient loads have been estimated from models while surface water flows have been modelled for Jingarmup Brook but not for Meelup Brook. There are no gauging stations, monitoring bores or data on groundwater levels in the area. There have been no investigations into the adequacy of current water resources to meet future water requirements for the Park, its visitors and the environment, or into the management of nutrients and potential contaminants to protect water quality.

Project description: This project will study the hydrology of the Park and assess the impacts of past and current water extractions on stream water flows, seepage and groundwater levels and water quality. Current water resources and requirements will be investigated in a so that this limited resource is appropriately managed into the future. A separate project (Project #13b) will monitor ongoing trends in water supply and water quality of surface and ground water so that shortfalls in supply or contamination issues can be identified and managed accordingly.

Benefits:

- *Environmental* – The natural catchment hydrology, stream flows, ground water levels and their annual variations will be known;
  – Stream and ground water levels and water quality will be monitored;
  – Ecological water requirements for vegetation and fauna will be evaluated.
  *Social* – Current and future water requirements will be known;
  – Alternative water resources will be identified for future requirements;
  – The quality of drinking water will be protected;
  – Fire fighting water resources will be assured;
  – Meelup Brook and dam will be attractive places to relax and enjoy.
- *Economic* – Water resources will be managed in a cost effective manner;
  – The impacts of visitors on water resources will be known to help determine sustainable visitor numbers;
  – Future water requirements will be known and the cost of delivering these supplies can be planned.

Indicative costs:
Project #13a – This project involves a hydrological study of current water resources, the impacts of damming and extraction on stream flows and groundwater levels, and an assessment of current and future water requirements for the Park. A consultant hydrologist would be required to undertake this study using existing information (desktop study plus measurements of capacity, flow rates and extraction amounts), in association with the Water Corporation, Department of Water, Geocatch, the City of Busselton and the committee. The Water Corporation may be able to assist by conducting a review of existing water sources and future requirements for public use, and the Department of Water could supply existing models of surface water flows and nutrient loads for these streams. The cost of this part of the project would depend on the actual project brief, but could be around $60,000.

Project #13b – Surface and ground water monitoring would need to be continued for at least five to ten years to determine longer term trends. Water would be monitored each month for eight months (April to November) each year, although more frequent monitoring is better able to detect peak nutrient loads. Data is entered into the Department of Water's databases and can be accessed through their Water Information Reporting (WIR) tool. The cost of analysing water samples using the Geocatch protocols for various nitrogen and phosphorous fractions, conductivity, salinity, pH, dissolved oxygen and total soluble solids is about $83 per sample. Analysing for various contaminants would be an additional cost and hasn't been included in this estimate.

Several piezometers could be installed near natural seepage areas or other sites determined by the hydrologist. Few areas would be suitable for monitoring groundwater due to the shallow depth to rock. A local water boring contractor (e.g. Dunsborough Water Boring) can install the piezometers (test wells) at a rate of about $1,400 each, which would be drilled to about 6m or to bedrock as required, and the 100mm PVC pipe installed, backfilled and sealed so the cost of installing four piezometers in the first year, if justified, would be $5,600. The cost for monitoring ground water levels and sampling four piezometers on a monthly basis, plus data entry might be around $5,000 per year, plus $3,000 for freight and analysis of samples, or $80,000 over ten years.

The cost of monitoring surface water quality in three sites (e.g. upper Meelup Brook, Dolugup Brook, seepage area near firebreak) that are additional to the Geocatch monitoring sites, plus measuring stream flow rates in Meelup, Jingarmup and Dolugup Brooks could be around $5,000 per year if monitored on a monthly basis, plus $2,500 for analysis of water from three sites, or $75,000 over ten years.

## 6.3 Sources of funding and resourcing strategies

Various sources of funding are available from time to time and depending on the nature of the projects. The committee would need to examine the funding guidelines in detail and may need to adjust some projects to align them more closely with the priorities for each funding body. Some of the more accessible funding options are suggested below.

- Lotteries West grants program (LW) – several relevant programs such as Conserving Natural Heritage, Projects and Research would be relevant to most of these projects, including the hydrology study, fire response study, Meelup Mallee propagation and translocation, research on taxonomy and genetics, and possibly the feral animal and soil erosion projects.
- SGIO Community Grants Support (SGIO) – under their Environment category with grants up to $5,000 for local communities to preserve natural assets, for water reduction and for raising awareness about reducing carbon emissions. This would be suitable for part of the hydrology project (water monitoring) and the tree decline and dieback projects, as maintaining a healthy vegetation cover would reduce carbon emissions.it may also be suitable for the feral animals and soil erosion projects.
- Tourism Western Australia (TWA) – has a policy under Eventscorp Division of attaining sustainability and projects are funded by the Royalties for Regions program. Several programs such as Environmental Community Support and Coast West Community support would be relevant to the sustainable visitor numbers project, track erosion and the hydrology study, as these are about making Meelup Park a sustainable tourism destination while conserving the environment.
- State NRM (NRM) – a new round of Natural Resource Management funding is being offered to community groups and local government by the WA Government for three years from 2015/16, based mainly on Royalties for Regions funding. This would be a good opportunity to fund several projects including the hydrology research and water monitoring, and the impacts of feral animals on Threatened fauna. Closing dates for round one has closed but there will be a second round of applications.
- Western Australian Planning Commission (WAPC) – funds the Coastwest grants program with grants up to $50,000 for community groups for projects to address issues related to climate change and population growth, and that seek to improve the condition and amenity of coastal environments. This funding source would be suitable for most of the projects, but particularly for the tree decline impacts, the hydrology research and monitoring, the sustainable visitor numbers study and impacts of visitors on vegetation.
- Birdlife Australia (BA) – has limited funding but can support the hooded plover monitoring project as it comes under an existing project that they manage called Beach Nesting Birds project, which is funded mainly by donations to the organisation.
- Australian Biological Resources Study (ABRS) – funds taxonomic and genetic research into a taxonomic group that is poorly defined or the conservation status of undescribed species under their Environmental Information and Research Program. This would be relevant to the taxonomy and genetic research project, in partnership with Parks and Wildlife and/or the Botanic Gardens and Parks Authority and/or as a post graduate research project through Murdoch University or the University of Western Australia. This project may need to be expanded to include a wider taxonomic group.
- University post graduate scholarships and grants (UNI) – The major universities can support post graduate research projects (PhD) with Australian Post graduate Awards or University Research Scholarships with a stipend of around $25,000 per year. These projects need to be of high scientific value and are usually, but not

always part of an existing research program that has been planned and prioritised over several years. Projects would need to be developed in close collaboration with the particular research group within the university and they would then try to attract a suitable applicant, which could take several years lead up time. Industry top up funding or in-kind support is well regarded and can be used as seed funding to attract other funding. PhD projects are a useful way of conducting more detailed research at a reasonable cost, but the project may not be so tightly defined as if the project were conducted by a consultant or contract research scientist.

- Australian Research Council (ARC) – This is a highly competitive grant scheme for high level PhD candidates and is possibly an avenue for undertaking the research on the impacts of tree decline and/or fire on Threatened fauna and their habitats. Funds from the City of Busselton could be used as seed funding to attract a government or university scholarship.
- Centre for Excellence for Climate Change, Woodland and Forest Health (CCWFH) – This cooperative research centre based at Murdoch University has a number of programs that are relevant to the tree decline and dieback projects. They can supervise students or research but would need a partner to provide funding for salaries as their project funding has all been committed.
- City of Busselton (COB) – Part of the funding budgeted for managing Meelup Regional Park from the City of Busselton has been allocated to research projects under the Consultancies account (3260) in the 10 year financial plan. Project #2a could be partly funded using the $50,000 already allocated for time of seeding study, while Project #3 could be funded using the $50,000 allocated to the threats to bandicoot study. Considering that a detailed flora survey has only recently been completed, the $60,000 budgeted for flora surveys, plus the $20,000 budgeted to flora studies could be allocated to Project #9 (research taxonomy and genetics). Similarly the $80,000 funding for fauna surveys and fauna studies could be allocated to project #4 to study the impacts of tree decline on fauna.

  Other accounts in the Financial Plan have funds budgeted for operational activities that could be redirected to some of the high priority research projects discussed above. For example, some of the $100,000 funding budgeted for maintaining trails could be used for Project #1, while some of the $80,000 budgeted for other conservation and rehabilitation could be used for Project #7 and Project #11, and some of the $140,000 budgeted for baiting feral animals could be used for Project #6. Other sources of funding could be sought for top up funding using these budgeted amounts as co-contributions.
- Department of Regional Development (DRD) – administers the regional grants scheme and the country local government fund that are available through local governments and the SW development Commission, derived from Royalties for Regions funding. The SW Events program may be relevant for the sustainable visitor numbers project.
- Department of Parks and Wildlife (DPaW) – Many of these projects involve studies with Threatened and Priority flora and fauna, and as such would require collaboration or partnership with Parks and Wildlife, which has responsibility for the protection and conservation of these species. Staff from the South West regional office in Bunbury and the Blackwood district office in Busselton, as well as scientists and staff from the Threatened and Species and Communities Branch in Kensington would be able to assist in the planning and development of projects as well as identifying and monitoring the Threatened flora. In-kind staff time and some resources may be made available for approved projects where they align closely with current departmental priorities.

## 6.4 Schedule of research projects

The highest priority projects have been scheduled over a ten year period with those that can be implemented straight away or that are considered urgent by the committee, being scheduled in the earlier years (Table 3). The total estimated cost of these research projects is around $1.14 million dollars, or around $60,000 to $130,000 per year. A reasonable proportion of this cost can be covered by the budget already allocated to research and consultancies for the Meelup Regional Park from the City of Busselton, or could be reallocated from some the operational budgets. If external funding can be obtained, then some projects can be scheduled earlier than indicated in Table 3.

**Table 3**. A schedule of the thirteen highest priority research projects for the Meelup Regional Park over ten years. Projects are not listed in order of priority. Some of the potential sources of funding and in-kind support for each project are indicated by letter codes, which are explained in Section 6.3 above. DPaW* would be restricted to in-kind staff time.

| Project No. | Research Project | Total cost | Potential source of funds | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | Survey soil erosion on tracks and firebreaks | 30,000 | COB, TWA | | 30,000 | | | | | | | | |
| **2a** | Survey fire response of flora and TEC | 120,000 | LW, COB, DPaW* | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| **2b** | Meelup Mallee coppice regeneration | 36,000 | COB, DPaW* | | 12,000 | | | | 12,000 | | | | 12,000 |
| **3** | Research fire response fauna and habitats | 60,000 | COB, LW, ARC, UNI | | | 20,000 | 20,000 | 20,000 | | | | | |
| **4** | Survey impacts of tree decline | 60,000 | COB, SGIO, CW, ARC | 30,000 | | | 15,000 | | | 15,000 | | | |
| **5a** | Survey of dieback susceptible species | 10,000 | COB, CW | | 10,000 | | | | | | | | |
| **5b** | Research susceptibility of species to dieback | 200,000 | LW, COB, DPaW*, UNI | | | | | | | | 60,00 | 70,000 | 70,000 |
| **6** | Monitor feral and pest animals | 120,000 | COB, LW, NRM | | | | | | | 50,000 | 40,000 | 30,000 | |
| **7** | Research translocation Meelup Mallee | 25,000 | COB, DPaW* | | 10,000 | 5,000 | 5,000 | 2,500 | 2,500 | | | | |
| **8** | Threatened orchid recruitment trials | 30,000 | COB, DPaW* | | 10,000 | 10,000 | 10,000 | | | | | | |
| **9** | Research taxonomy and genetics of flora | 150,000 | COB, LW, UNI, DPaW*, ABRS | | | 50,000 | 50,000 | 50,000 | | | | | |
| **10** | Research sustainable visitor capacity | 60,000 | TWA, CW, DRD | 60,000 | | | | | | | | | |
| **11** | Monitor visitor impacts on vegetation | 20,000 | COB, TWA, CW | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | | | | | |
| **12** | Monitor visitor impacts on hooded plovers | 5,000 | BA, CW, COB | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 |
| **13a** | Research hydrology and water requirements | 60,000 | LW, TWA, NRM, CW | | | | | | 60,000 | | | | |
| **13b** | Monitor stream flows and groundwater | 155,000 | LW, DoW, NRM, CW | 20,000 | 15,000 | 15,000 | 15,000 | 15,000 | 15,000 | 15,000 | 15,000 | 15,000 | 15,000 |
| | **Total costs** | **1,141,000** | | **126,500** | **103,500** | **116,500** | **131,500** | **104,000** | **102,000** | **92,500** | **127,500** | **127,500** | **109,500** |

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Appendix I. List of research questions grouped into potential projects. The priority (P) rank of each question was determined by the management committee while the knowledge (K) by urgency (U) rank was assessed by the author. The average of these ranks [P+(KxU)]/2] was used as the final ranking score for each question, with scores assessed as Very High (8.5 – 9 Green), High (7 – 8 Blue), Medium ( 5.5 – 6.5 Yellow) and Low (3.5 – 5 Orange). Projects were then scored according to the question with the highest rank score within each project. Projects that were scored with very high priority (Green) were included in the research schedule for the next ten years.

| Project No. | Project type | P | K x U | [P+(KxU)]/2 | Topic | Issue | Research questions |
|---|---|---|---|---|---|---|---|
| **1** | Research Aboriginal heritage | 7 | 9 | 8 | Aboriginal history | Heritage sites | Are there any aboriginal heritage sites present? |
| | | 6 | 9 | 7.5 | Aboriginal history | Stories | What was the early aboriginal culture of the area? |
| | | 5 | 6 | 5.5 | Aboriginal history | Stories | What was the aboriginal experience during early European settlement? |
| | | 6 | 6 | 6 | Aboriginal history | Stories | Who are the people connected to this country? |
| **2** | Research archaeology | 8 | 6 | 7 | Archaeology | Heritage sites | What is the archaeological significance of the area? |
| **3** | Research European history | 6 | 4 | 5 | European history | Heritage sites | Where are the significant European historical sites? |
| | | 6 | 3 | 4.5 | European history | Stories | Who are the people connected to this country? |
| | | 5 | 2 | 3.5 | European history | Stories | How did the early settlers live? |
| **4** | Survey geology | 6 | 3 | 4.5 | Geology | Distribution | What and where are the main geological features? |
| **5** | Survey soil erosion | 9 | 9 | 9 | Soil erosion and track maintenance | Erosion | How can fire and firebreaks be managed to minimise soil erosion? |
| | | 5 | 6 | 5.5 | Soil erosion and track maintenance | Erosion | Can tracks be hardened and designed adequately to minimise erosion? |
| | | 4 | 4 | 4 | Soil erosion and track maintenance | Erosion | Which soil types are most susceptible to wind and water erosion? |
| **6** | Monitor rehabilitation | 7 | 6 | 6.5 | Effectiveness of rehabilitation | Soil erosion | How should different soil types be rehabilitated? |
| | | 6 | 6 | 6 | Effectiveness of rehabilitation | Rehabilitation | Are degraded communities being effectively rehabilitated? |
| | | 4 | 6 | 5 | Impacts of visitors on soils and vegetation | Trampling | How can visitor impacts be minimised? |
| **7** | Survey and map weeds | 6 | 9 | 7.5 | Impacts of weeds on threatened flora | Weeds | Are weeds affecting growth of threatened flora and communities? |
| | | 6 | 6 | 6 | Impacts of weeds on other vegetation | Weeds | Which weeds are spreading most rapidly or having greatest impact? |
| | | 6 | 4 | 5 | Impacts of weeds on other vegetation | Weeds | Which areas are being impacted most by weeds? |
| | | 6 | 4 | 5 | Impacts of weeds on other vegetation | Weeds | Are weeds being effectively managed? |
| **8** | Research fire response | 10 | 9 | 9.5 | Impacts of fire on | Fire | What is the appropriate fire regime to conserve species? |

| Project No. | Project type | P | K x U | [P+(KxU)]/2 | Topic | Issue | Research questions |
|---|---|---|---|---|---|---|---|
| | flora | | | | threatened flora | | |
| | | 10 | 6 | 8 | Impacts of fire on other vegetation | Fire | What is the appropriate fire regime to conserve species? |
| **9** | Research fire response fauna | 9 | 9 | 9 | Fire and threatened mammal habitat use | Fire | Does fire affect habitat quality and use? |
| | | 9 | 6 | 7.5 | Fire and reptile habitat use | Fire | Does fire affect habitat quality and use? |
| | | 9 | 6 | 7.5 | Fire and invertebrate habitat use | Fire | Does fire affect habitat quality and use? |
| | | 9 | 4 | 6.5 | Fire and bird habitat use | Fire | Does fire affect habitat quality and use? |
| **10** | Research tree decline impacts | 8 | 9 | 8.5 | Impacts of tree decline | Tree decline | What vegetation communities are affected by tree decline? |
| | | 9 | 6 | 7.5 | Tree decline and threatened mammal habitat use | Tree decline | Is tree decline reducing fauna habitat quality? |
| | | 9 | 6 | 7.5 | Tree decline and black cockatoo food resources | Tree decline | Is tree decline reducing food availability? |
| | | 9 | 4 | 6.5 | Impacts of tree decline | Tree decline | What environmental factors lead to tree decline and can they be managed? |
| **11** | Survey of dieback | 10 | 8 | 9 | Dieback threat to threatened flora | Dieback | Is this species susceptible to dieback? |
| | | 6 | 6 | 6 | Management of dieback spread | Dieback | How can tracks be managed to minimise spread of dieback? |
| | | 7 | 3 | 5 | Management of dieback spread | Dieback | Are events being managed to minimise the spread of dieback? |
| **12** | Monitoring grazing impacts | 8 | 6 | 7 | Impacts of western grey kangaroos | Grazing | Does grazing by kangaroos and rabbits affect vegetation composition? |
| | | 9 | 2 | 5.5 | Impacts of western grey kangaroos | Population | How is the kangaroo population changing over time? |
| | | 7 | 4 | 5.5 | Impacts of western grey kangaroos | Grazing | Does grazing affect vegetation growth and recruitment? |
| **13** | Monitor feral and pest animals | 9 | 9 | 9 | Disturbance of threatened mammals | Disturbance | Do dogs disturb their feeding or breeding activities? |
| | | 9 | 6 | 7.5 | Predation of threatened mammals | Predation | Is fox or cat predation a major cause of mortality? |
| **14** | Surveys of birds and habitat | 9 | 3 | 6 | Bird populations and habitat use | Population | How are the populations changing over time? |
| **15** | Surveys of invertebrates and habitat | 9 | 6 | 7.5 | Invertebrate populations and habitat use | Population | Are they present in the park? |

| Project No. | Project type | P | K x U | [P+(KxU)]/2 | Topic | Issue | Research questions |
|---|---|---|---|---|---|---|---|
| | | 9 | 6 | 7.5 | Invertebrate populations and habitat use | Habitat area | What is the area currently occupied? |
| **16** | Surveys of reptiles and habitat | 9 | 6 | 7.5 | Reptile populations and habitat use | Habitat area | What is the area currently occupied? |
| | | 9 | 4 | 6.5 | Reptile populations and habitat use | Population | Are they present in the park? |
| | | 9 | 4 | 6.5 | Reptile populations and habitat use | Population | Are populations changing over time? |
| **17** | Surveys of threatened mammals and habitat | 10 | 6 | 8 | Threatened mammal populations and habitat use | Habitat area | What area is currently occupied? |
| | | 9 | 6 | 7.5 | Threatened mammal populations and habitat use | Population | How are the populations changing over time? |
| **18** | Monitor black cockatoos habitat, nesting boxes | 8 | 6 | 7 | Black cockatoo population and habitat use | Habitat area | What food resources are available during the year? |
| | | 8 | 6 | 7 | Black cockatoo population and habitat use | Water | Is there adequate access to safe drinking water in habitat areas? |
| | | 9 | 4 | 6.5 | Black cockatoo population and habitat use | Population | How is the population changing over time? |
| | | 9 | 2 | 5.5 | Black cockatoo population and habitat use | Nesting | Would artificial nesting hollows assist breeding success? |
| **19** | Monitor birds | 9 | 3 | 6 | Population trends of other birds | Population | How are the populations changing over time? |
| **20** | Survey other fauna | 9 | 3 | 6 | Other fauna population and habitat use | Population | Are they present in the park? |
| | | 9 | 3 | 6 | Other fauna population and habitat use | Habitat area | What is the area currently occupied? |
| **21** | Research seed biology and translocation | 9 | 9 | 9 | Conservation of *Eucalyptus phylacis* | Rehabilitation | Can they be translocated to other areas of similar habitat? |
| | | 8 | 9 | 8.5 | Conservation of *Eucalyptus phylacis* | Habitat area | What other areas of similar habitat occur in the Park? |
| | | 8 | 9 | 8.5 | Conservation of *Eucalyptus phylacis* | Recruitment | What are the causes of low fecundity? Will in vitro cultures be viable? |
| | | 9 | 2 | 5.5 | Conservation of *Eucalyptus phylacis* | Population | How is the population changing over time? |
| **22** | Monitor threatened flora | 8 | 6 | 7 | Population trends of threatened flora | Population trend | How is the population changing over time? |

| Project No. | Project type | P | K x U | [P+(KxU)]/2 | Topic | Issue | Research questions |
|---|---|---|---|---|---|---|---|
| **23** | Research taxonomy, genetic analysis | 9 | 9 | 9 | Taxonomy of priority and disjunct flora | Recruitment | Does germination or pollination biology limit recruitment? |
| | | 7 | 9 | 8 | Taxonomy of priority and disjunct flora | Taxonomy/genetics | Are these taxa taxonomically/genetically significant? |
| **24** | Research sustainable visitor capacity | 8 | 9 | 8.5 | Sustainable visitor capacity | Sustainable capacity | What is the sustainable visitor capacity of the Park? |
| | | 8 | 9 | 8.5 | Sustainable visitor capacity | Economics | What are the costs and benefits of running different events? |
| | | 6 | 6 | 6 | Sustainable visitor capacity | Sustainable capacity | What are the patterns in visitor numbers? |
| | | 5 | 6 | 5.5 | Sustainable visitor capacity | Sustainable capacity | What are the patterns in vehicle numbers? |
| **25** | Survey visitor impacts | 6 | 6 | 6 | Managing visitors | Conflict with other users | Do mountain bikers conflict with other track users? |
| | | 6 | 6 | 6 | Managing visitors | Signage | Do event participants comply with existing signage and regulations? |
| | | 6 | 6 | 6 | Managing visitors | Conflict with other users | Do events have a significant impact on other visitors enjoyment? |
| | | 6 | 6 | 6 | Managing visitors | Fire | How can events be managed to minimise the risk of fire? |
| | | 6 | 6 | 6 | Managing visitors | Rubbish | How can litter from human activities be reduced? |
| | | 5 | 6 | 5.5 | Managing visitors | Conflict with other users | Does the noise during events exceed a socially acceptable level? |
| | | 5 | 6 | 5.5 | Managing visitors | Weeds | Are weeds increasing due to events? |
| | | 4 | 6 | 5 | Managing visitors | Facilities | Is there adequate parking for visitors during peak times and events? |
| | | 3 | 6 | 4.5 | Managing visitors | Signage | Do dog owners comply with existing signage and regulations? |
| | | 4 | 4 | 4 | Managing visitors | Facilities | Are facilities adequate to meet expectations during events? |
| **26** | Monitor visitor impacts on vegetation | 8 | 9 | 8.5 | Impacts of visitors on vegetation | Disturbance to flora | Are additional activities causing significant loss of habitat? |
| | | 7 | 6 | 6.5 | Impacts of visitors to threatened flora | Trampling | Do visitors disturb threatened plants and communities? |
| | | 8 | 4 | 6 | Impacts of visitors on vegetation | Rehabilitation | Which areas need to be rehabilitated to restore habitat loss? |
| **27** | Monitor visitor impacts on fauna | 9 | 6 | 7.5 | Impacts of visitors on threatened mammals | Disturbance to fauna | Do visitors disturb the feeding or breeding activities of threatened mammals? |
| | | 6 | 9 | 7.5 | Impacts of visitors on fauna | Disturbance to fauna | Do human activities disrupt fauna feeding, breeding or movements? |
| **28** | Monitor visitor impacts on hooded plovers | 9 | 9 | 9 | Impacts of visitors on hooded plovers | Nesting | Are dogs affecting nesting success of hooded plovers? |
| | | 9 | 9 | 9 | Impacts of visitors on hooded plovers | Nesting | Do visitors disturb their feeding or breeding activities? |
| | | 9 | 3 | 6 | Impacts of visitors on hooded plovers | Nesting | How many pairs breed successfully? |

| Project No. | Project type | P | K x U | [P+(KxU)]/2 | Topic | Issue | Research questions |
|---|---|---|---|---|---|---|---|
| | | 9 | 3 | 6 | Impacts of visitors on hooded plovers | Population | How is the population changing over time? |
| **29** | Monitor visitor impacts from whale watching | 4 | 6 | 5 | Impacts of visitors on whale watching | Population trend | Are visitor numbers increasing for whale watching? |
| | | 3 | 6 | 4.5 | Impacts of visitors on whale watching | Population trend | What factors are affecting whale populations in the bay? |
| | | 3 | 6 | 4.5 | Impacts of visitors on whale watching | Population trend | Are commercial tours affecting whale movements? |
| | | 4 | 4 | 4 | Impacts of visitors on whale watching | Population trend | How can visitor impacts be minimised? |
| **30** | Research hydrology and water requirements | 10 | 9 | 9.5 | Impacts of past and current water use | Water quality | Has water quality been affected by on and off site activities? |
| | | 10 | 9 | 9.5 | Impacts of past and current water use | Water supply | Are flows being affected by current use? |
| | | 10 | 6 | 8 | Impacts of past and current water use | Water supply | How have flows been affected by damming, extraction? |
| | | 7 | 9 | 8 | Impacts of past and current water use | Water supply | Is there sufficient water supply for ecological and human needs? |
| | | 4 | 9 | 6.5 | Impacts of past and current water use | Water supply | How can visitor impacts on water be minimised? |
| **31** | Research impacts of climate change | 6 | 4 | 5 | Impacts of climate change | Erosion | What effect will climate change have on beaches and sea levels? |
| | | 6 | 4 | 5 | Impacts of climate change | Habitat area | What impact will climate change have on the flora and fauna in the Park? |