Toolibin Lake Catchment Recovery Plan 2015–35

GOVERNMENT OF
WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

PARKS AND
WILDLIFE
SERVICE

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Accessibility
This document is available in alternative formats on request.

Cover photos
Top left Snail orchid. *Photo – DBCA*
Top right Pink eared ducks. *Photo – Roz Barber*
Main Toolibin Lake. *Photo – DBCA*
Back cover Road reserve within the catchment. *Photo – DBCA*

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Summary

Toolibin Lake is a **Ramsar**[1]-listed wetland that lies within a system of class 'A' nature reserves featuring wetlands that are managed by the Western Australian (WA) Parks and Wildlife Service at the Department of Biodiversity, Conservation and Attractions (Parks and Wildlife Service; DBCA; the department). The lake is part of the Toolibin Lake catchment (also referred in previous literature as the Toolibin Lake **Natural Diversity Recovery Catchment**), an area with significant value due to its remarkable variety of natural flora and fauna, some of which are rare and/or threatened.

This includes the critically endangered '*Melaleuca strobophylla-Casuarina obesa*' **threatened ecological community** (TEC) that is associated with the lakes within the catchment. These wooded freshwater wetlands are some of the last examples of a once-widespread vegetation type.

The Toolibin Lake catchment is a vital community asset not only for supporting important flora and fauna, but also for the educational and recreational opportunities that it provides and its contribution to the healthy functioning of a broad system of land uses.

A recovery plan for Toolibin Lake was released in 1994 that has guided the management of the lake and its surrounding **natural biota**. Many successful actions have been implemented since the inception of the original recovery plan, particularly addressing issues related to altered hydrology, which threatens the **biological elements** of the catchment.

These actions have resulted in the recovery of key vegetation elements in the catchment, and waterbirds using the lakes when they fill. These successes can, in part, be attributed to:

- the channels and other conveyance infrastructure that now divert highly saline surface water away from several nature reserves and lakes;
- a groundwater pumping system that has been operating in Toolibin Lake since 1994; and
- cooperation from private landholders to undertake revegetation and other works throughout the catchment.

Recovery actions to date have successfully contributed to protecting the catchment's wildlife and reducing declines in wetland vegetation. However, managing key **threatening processes**, such as altered hydrology, will require ongoing effort.

This *Toolibin Lake Recovery Plan 2015-35* builds on the previous plan's recovery actions, and adopts a planning approach that concentrates recovery activities on maximising the values people can derive from the biological elements in the catchment (Wallace 2012). Based on a prioritisation of these values, the management goal for recovery of the catchment is:

[1] There is a glossary of important terms at the end of this plan. These terms are highlighted in **bold** at first use in this document.

To maintain or improve the knowledge/heritage and education; productive use; and philosophical/spiritual contentment values provided by the specified biological elements for the next 20 years.

The priority biological elements identified to deliver these values are principally Toolibin Lake in its entirety, then the waterbirds and vegetation of the adjacent nature reserves and wetlands.Key recommendations involve the management of threats posed by altered hydrology, problem species and inappropriate fire regimes to protect priority biological elements.

By implementing the actions recommended in this plan, it is anticipated that the condition of the various biological elements, and consequentially the human values derived from the catchment, will be maintained or improved. The recommended monitoring program will enable the timely identification of changes within the catchment to inform adaptive management and better protect Toolibin Lake and the adjacent nature reserves.

1. Introduction

DBCA is responsible for managing the State's biodiversity and conservation reserve system, under the *Conservation and Land Management Act 1984* (CALM Act), *Wildlife Conservation Act 1950* and *Biodiversity Conservation Act 2016*[2]. The department's mission is to promote biodiversity and conservation to enrich people's lives through sustainable management of Western Australia's species, ecosystems, lands and the attractions in the department's care. DBCA's Parks and Wildlife Service is regionally focused and relies on the relationships built and maintained with neighbours, visitors, volunteers, partners, individuals, organisations, and local communities to achieve its mission.

Western Australia supports many significant wetlands, and various monitoring and management programs have been implemented to ensure these important areas are understood and protected. Programs, such as the Natural Diversity Recovery Catchment Program (NDRC), have been integral in helping recover and protect significant biological communities, particularly wetlands, from altered hydrology at a catchment scale within southern agricultural areas. Management plans also identify key actions required to protect natural assets, including conservation reserves and Ramsar wetlands. The previous Toolibin Lake Recovery Plan, prepared by the Toolibin Lake Recovery Team and Toolibin Lake Technical Advisory Group in 1994, outlined strategies for a ten-year period from its endorsement, and stated that it would continue as the endorsed guide for management until re-written, as has been the case. The development of this recovery plan aligns with the Parks and Wildlife Service's strategic direction, focusing on parks, wildlife, fire, managed use and people.

The planning process used to develop this plan involved a series of workshops and reviews over six years involving stakeholder representatives from the community, government and non-government groups, including the recovery team and **technical advisory group** (TAG) and followed the framework detailed in Wallace (2012). The provision of funds to undertake the recommended actions identified in this recovery plan is subject to availability, and may be affected by budgetary and other constraints.

In this plan, recommended actions are introduced throughout the document and are highlighted by ***Arial italicised*** font, and are also summarised in Section 6. To maximise the readability of the plan, important terms are defined within the text, in footnotes, or in the glossary of important terms in Section 7. These terms are highlighted in **bold** at first use in the main document. The recovery plan has additional supporting information which is provided in two separate documents. The supporting information document contains appendices that are referred to throughout this plan, and a five-year works plan details the activities and resources for the recommended actions.

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[2] Relevant provisions under the *Biodiversity Conservation Act 2016* had not yet been proclaimed at the time of publishing this plan.

Monitoring and management of the Toolibin Lake catchment is undertaken within an adaptive management framework. Management planning is therefore an iterative and ongoing pursuit that will be subject to regular review of the recommended recovery actions and outputs and, with new information and techniques, may result in updated management strategies and activities over time.

1.1. Description of the Toolibin Lake catchment

Catchment overview

The Toolibin Lake catchment lies about 180 kilometres south-east of Perth within the Avon Wheatbelt IBRA[3] bioregion (subregion AVW02, Katanning) of Western Australia (; Supporting Information Appendix 2). The catchment covers an area of 48,977 hectares and consists largely of long-established agricultural country, with land first cleared for farming in the late 1890s (Northern Arthur River Wetlands Committee 1987). Today about 12 per cent (6,024 hectares) of the catchment's original vegetation remains.[4] Much of that remnant vegetation is now protected in class 'A' nature reserves[5] vested with the Conservation and Parks Commission (a statutory authority), and managed by DBCA's Parks and Wildlife Service.

Toolibin Lake is located in the Toolibin Nature Reserve (24556) at the headwaters of the Northern Arthur River. The Arthur River joins the Blackwood River further south, and collectively the whole catchment is referred as the Blackwood River Basin. Dulbining Nature Reserves (9617 and 27286) are located to the north, Dingerlin Nature Reserve (15266) to the north-west and Walbyring Nature Reserve (14398) to the south; 5(1)(h)[6] un-named reserves 46407 (Chadwick's Reserve) and 52018 (Miller's Reserve) to the north, constitute the major focus of the department's management of the catchment. The wandoo woodland biological element, located on private property, and Taarblin Lake Nature Reserve (9550), located just outside the catchment boundary, are also of management interest.

Toolibin Lake

Toolibin Lake is the primary water body for recovery within the catchment. It is listed as a Wetland of International Importance under the Ramsar Convention, meeting four of the nine criteria. The site is of international importance as it encompasses occurrences of a threatened ecological community (see below), contains the last large *Casuarina obesa* dominated wetland that was once common in the inland agricultural area of south western Australia, and supports more breeding waterbird species than most, if not all, other wetlands in south-western Australia, including the freckled duck (*Stictonetta naevosa*), cormorants,

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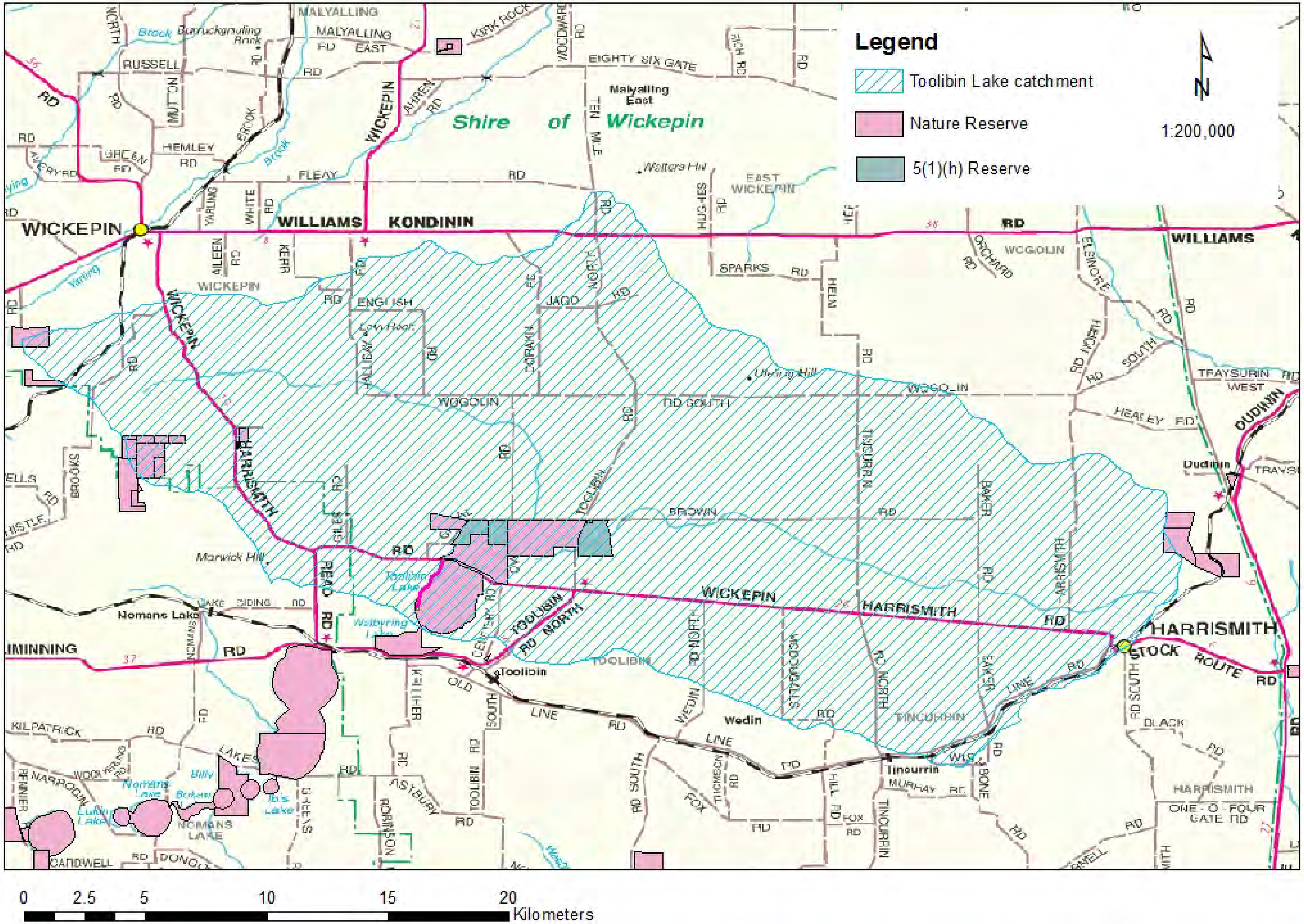
[3] Interim Biogeographic Regionalisation for Australia.
[4] Calculations from the Remnant Vegetation dataset (custodians: Department of Agriculture and Food WA; DAFWA and the department) by Geographic Information Services Branch, Department of Parks and Wildlife, Kensington, June 2011.
[5] Conservation reserves can have an extra classification applied to them and become a class 'A' reserve, meaning that they receive a higher level of protection.
[6] Reserves set aside (reserved) under the *Land Administration Act 1997* for various purposes.

egrets, night herons and spoonbills which are otherwise scarce or absent in the region.[7]

It is one of the last large (≈300ha) ephemeral and reasonably intact *Casuarina obesa* and *Melaleuca strobophylla*-dominated wetlands in the inland agricultural area of south-west Western Australia. The lake is bordered to the north and east by woodlands and shrublands of eucalypts, melaleuca, acacia, sheoaks and, on the sandy sites, by banksia. There was little remnant natural vegetation to the west and south of the lake and so land purchased in the 1980s was revegetated to buffer the lake from the surrounding agricultural lands. These lots are included in the Ramsar site.

[7] For more information on the Ramsar listing go to http://www.environment.gov.au/cgi-bin/wetlands/ramsardetails.pl?refcode=37. The lake's ecological character description can be found at https://rsisdev.ramsar.org/ris/483

Figure 1: Location of the Toolibin Lake catchment



Threatened Ecological Communities

Toolibin, as well as Walbyring and Dulbining lakes and two unnamed lakes of a similar type, all support the Toolibin Lake TEC (). The Toolibin Lake TEC, listed in full as 'Perched wetlands of the Wheatbelt region with extensive stands of living swamp sheoak (*Casuarina obesa*) and paperbark (*Melaleuca strobophylla*) across the lake floor', has been listed and endorsed by the WA Minister for Environment as critically endangered. Threatened ecological communities were not protected specifically under WA legislation at the time of publishing this plan[8], but this community is indirectly protected under state legislation through the *Environmental Protection Act 1986* and Environmental Protection (Clearing of Native Vegetation) Regulations 2004. The Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*[9] (EPBC Act) also recognises this '*Melaleuca strobophylla-Casuarina obesa'* TEC as endangered. These community occurrences are some of the last examples of a once-widespread vegetation type.

During the development of this recovery plan, the 'Eucalypt woodlands of the Western Australian Wheatbelt' community was listed nationally as a critically endangered threatened ecological community under the EPBC Act. This vegetation community was once extensive across the Wheatbelt but now occurs as mostly small remnants scattered across the Wheatbelt. The nationally listed woodlands only include patches that are large and remain in good condition, several of which may be located within the Toolibin Lake catchment, pending an assessment. The TEC status of this vegetation type was not specifically considered during this planning process; however, this should be considered in prioritising management actions in future recovery plans for the catchment.

Wildlife

When the lakes in the catchment fill with water for at least six months, they provide breeding and feeding habitat for migratory waterbirds, including the freckled duck (*Stictonetta naevosa*), which has a very small breeding population in south-west WA. The lakes also support breeding colonies of cormorants, egrets, night herons and spoonbills that are otherwise scarce or absent in the inland agricultural area of south-west WA.

The Toolibin Lake catchment boasts more than 300 natural plant species and 18 natural mammal species as well as a wide diversity of insects, reptiles, amphibians and terrestrial birds.

As one of the last substantial remnants of a formerly common wetland type, Toolibin Lake and the surrounding wetlands are a vital part of the natural diversity of the inland agricultural area of south-west WA.

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[8] The *Biodiversity Conservation Act 2016* does have provisions for the listing of TEC's. however these provisions had not yet been proclaimed at the time of publishing this plan.

[9] http://www.environment.gov.au/cgi-bin/sprat/public/publicshowcommunity.pl?id=15&status=Endangered.

Toolibin Lake
Photo – Lyn Alcock

Cultural heritage

The catchment has important cultural heritage values, and is located within the area of the Wilman Aboriginal language group. An Aboriginal heritage site on the western boundary of Toolibin Lake is listed with the Department of Planning, Lands and Heritage (Lake Torrbarn site ID: 4434). This unregistered artefact site is recorded as a camp.

The ability to carry out customary activities on country is an important part of Aboriginal culture and connection to the land. CALM Act managed lands and waters within the catchment provide for Aboriginal people to carry out customary activities.

Toolibin Lake and surrounds are recognised on the Australian Heritage Database (Registered Place Id 18116) and the State Government of Western Australia's Department of Planning, Lands and Heritage (Heritage Place Number 7312). Regarding non-Aboriginal heritage, the Wickepin area has become culturally important for its association with well-known Australian author Albert Facey, who lived near the lake in the 1920s and 1930s.

Social and economic use

The Toolibin Lake catchment is largely freehold agricultural land comprising about 31 landholders (Munro and Moore 2005). In 2004, farm sizes ranged from 131 hectares to 5,000 hectares with an average size of 1,536 hectares (Munro and Moore 2005). Property ownership ranged from two to 75 years and averaged 32 years (Munro and Moore 2005), indicating that the majority of farms in the catchment were worked by longer term owners. Broadacre agriculture is the main industry, consisting of cereal, pulse and oilseed crops and sheep (wool and meat production).

The nature reserves of the catchment, particularly Toolibin Lake, are valued by members of the community for recreation and nature appreciation. They are also highly valued for education and research, as they represent the natural heritage of the region.

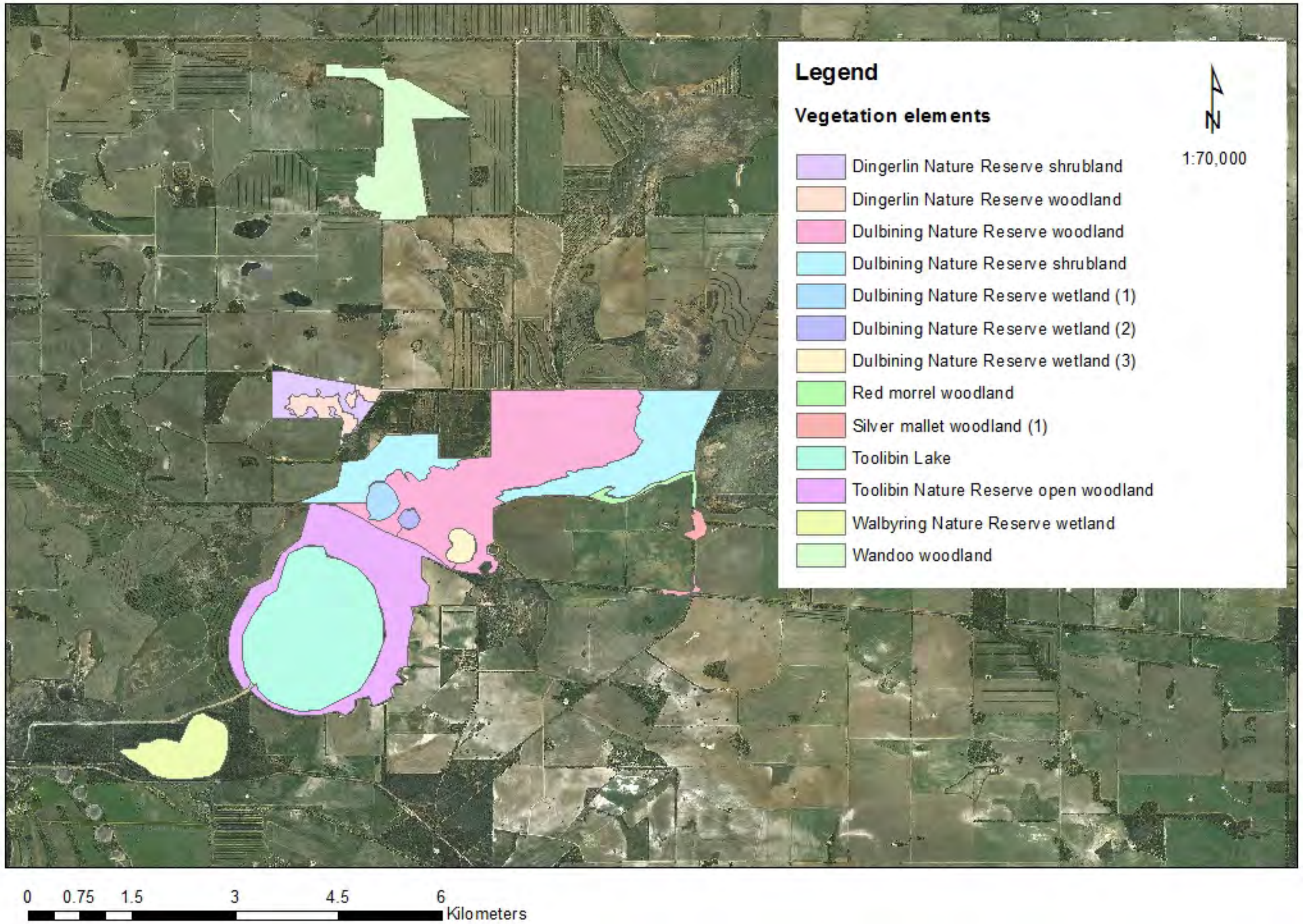

Figure 2: Location of the Toolibin Lake catchment vegetation biological elements

1.2. Achievements of the previous recovery plan period

Natural Diversity Recovery Catchment program

In 1996, the Toolibin Lake catchment was included in the Natural Diversity Recovery Catchment (NDRC) program, developed under the Salinity Action Plan for Western Australia (Walshe et al. 2004, Wallace et al. 2011). This was in recognition of the importance of the biological elements[10] associated with the catchment and the threat to these elements posed by altered hydrology.

The aim of the Salinity Action Plan was to protect regionally significant, high priority biological elements such as those found in and around Toolibin Lake. As the emphasis on catchments implies, the NDRC program focused on areas threatened by catchment-scale modification of the region's hydrology, particularly where this led to secondary salinisation.

Broadscale clearing of natural vegetation and its replacement with crops and pastures that use less water has led to changes in the water balance and accelerated salt loads, resulting in secondary salinisation of the catchment's lands and wetlands. To ameliorate these impacts particularly at Toolibin Lake and other downstream wetlands, a number of measures have been put in place. These include: revegetation with natural species to manage surface water flows and connect the conservation reserves; the installation of infrastructure to manage the water balance at Toolibin Lake through diverting surface water flows and pumping of groundwater; and monitoring of groundwater and surface water hydrology, to monitor how water and salt move in the catchment and assess the performance of the management systems, and biodiversity.

A number of other threatening processes have been identified in the catchment resulting from human modification of the environment, that also require management. These include problem species, such as kangaroos, rabbits and environmental weeds, and the frequency and intensity of natural processes, such as fire regimes, that have changed substantially since colonial settlement. This recovery plan addresses a variety of management actions required to ameliorate these threats to conserve the biodiversity and natural processes associated with the Toolibin Lake catchment.

Management outcomes

The management of the Toolibin Lake catchment under the NDRC project was reviewed in 2004 (Wyland 2004) and 2012 (Higbid, Coleman and Trimming 2012). Findings from the reviews were that:

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[10] Biological elements are the natural living things that people value. They are artificially classified subsets of the overall group of biological organisms that occur in the system (e.g. the mammals or the waterbirds). The elements are the things we want to remain in place over the management period and they have been assigned a spatial boundary. In the case of this plan, this is the area thought to generally be under threat from secondary salinisation. Of note, the organisms that characterise an element will commonly also occur outside of the area spatially delimiting the element. The definition of a biological element excludes ecosystem processes and the non-living (or abiotic) system components.

- There has been measurable improvement in the survival and regeneration of key plant species on the Toolibin Lake floor and in the surrounding area.
- With favourable weather conditions, waterbirds are still likely to visit and breed at Toolibin Lake and the surrounding wetlands as observed during previous fill events.
- The implementation of the surface water management infrastructure has regulated surface water such that high saline flows are now diverted away from the lake and its surrounding nature reserves.
- Groundwater levels have decreased, which coincides with the commencement of pumping in 1997 and an extended period of low rainfall.
- In 2002 the Toolibin Lake recovery team and technical advisory group (TAG) were recognised and awarded the Engineers Australia (IEAust) National Salinity Prize for innovation in dealing with salinity.

As a result of these management interventions, and aided by a drying climate in recent decades, the broad conservation values of Toolibin Lake and the surrounding reserves have been maintained despite severe pressure from altered hydrology.

Opening of diversion gates at Toolibin Lake
Photo – Gary Mills/DBCA

2. The planning framework and the recovery plan

This recovery plan has been developed in accordance with the framework detailed in Wallace (2012) and Pourabdollah et al. (2014) (Figure 3). The following sections of the plan are structured according to this framework, and the relationship map in section 3 provides a summary.

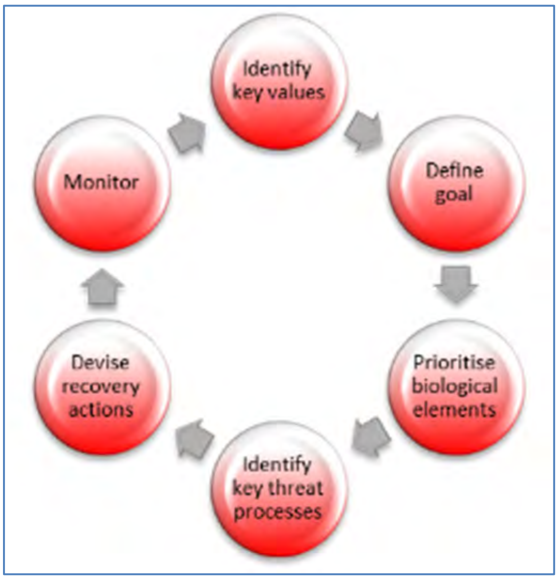

Figure 3: Framework used for the recovery plan

In consultation with stakeholders, the planning process yielded the following outcomes:

- Three key **human values** were identified for the catchment: 1) knowledge/heritage and education, 2) productive use, and 3) philosophical/spiritual contentment. A goal was developed to maintain these values.[11]
- 21 biological elements in the catchment were identified as important due to their effect on the three key human values.
- These biological elements were rated on their contribution to delivering the identified human values, which facilitated the prioritisation of management focus areas. The highest priorities were management of Toolibin Lake wetland vegetation, several additional vegetation biological elements, and waterbirds.
- 'Key **properties**[12]' of the biological elements that need to be managed to ensure the

[11] The wise use of wetlands is the key concept orienting the work of the Ramsar Convention. 'Wise use of wetlands' is defined as "the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development". Wise use therefore has at its heart the conservation and sustainable use of wetlands and their resources, for the benefit of people and nature. http://www.ramsar.org/document/the-fourth-ramsar-strategic-plan-2016-2024.

[12] In this planning process the key properties identified are species composition (richness and abundance), structure, intactness, rarity and size. It is the properties that determine, in relative terms, the provision of human value. Properties are measured at a point in time and within specified spatial boundaries and allow us to rate the biological element.

biological elements deliver on the human values were identified as **species composition (species richness** and **species abundance)**, **structure**, **intactness**, **rarity** and **size**.

- Through risk analyses, the key threatening processes that require management to maintain species richness were identified as altered hydrology, problem species and inappropriate fire regimes.
- A series of possible recovery options were compared and then prioritised relative to their expected benefits (in terms of human value). Altered hydrology rated the highest, followed by problem species and then inappropriate fire regimes.
- A series of recommended actions were proposed and then assessed in terms of efficiency. This included further hydrological research to guide management.
- An adaptive monitoring program was developed to allow managers to monitor the status of the biological elements and the threatening processes over the management period. This adaptive monitoring program was based around **limits of acceptable change (LoAC)** for species abundance and key threatening processes. It aimed, firstly, to garner important management and recovery information and, secondly, to trigger new recovery responses should they be required.

This recovery plan incorporates input from stakeholder representatives from the community, government and non-government groups through the Toolibin Lake recovery team (refer to Supporting Information Appendix 3) and technical advisory groups (TAG; also referred to as **technical specialist advice**). Both the recovery team and technical specialists are involved in the ongoing planning and implementation of management actions.

Landholder support for the conservation of the biological elements is critical, with 94% of the catchment comprising private property. Recovery actions will need to take into consideration local aspirations, including the need for landholders to continue their agricultural business through economically viable, sustainable land use. Land management practices will continue to evolve over time. Future landholders in the catchment will likely be living and working with modern farming systems, in a drying climate and in some cases may take a different approach to conservation. Recent land management practices have focused on broadscale natural species revegetation across the catchment including in and around the lakes, mallee belt planting in surrounding agricultural areas (Mendham et al. 2014) and other revegetation initiatives.

Recovery actions that meet the requirements of all partners will be those that best integrate land use and catchment recovery activities. Realising the goal to maintain or improve the values of the Toolibin Lake catchment will require consideration of a diverse set of land-use issues and collaboration with many stakeholders. The implementation of this plan will provide opportunities for stakeholders to:

- access new knowledge relating to the management of catchment-scale hydrology
- attract funds for on-ground works identified in this recovery plan, to integrate sustainable agriculture with the conservation of biological elements
- contribute to identifying and implementing solutions to land degradation
- conserve natural biota for future generations.

In this context, management of the Toolibin Lake catchment makes an important contribution to improved land management in the south-west agricultural zone.

Mallees planted in 1993 at Chadwick's property
Photo – Peter White/DBCA

2.1. Identify key values

For effective natural resource planning and management, it is important to clarify the key human values expected from a management area's biological elements and to use those values to drive decision-making (Wallace 2006). Supporting Information Appendix 4 outlines a complete description of the steps taken to elicit the key values arising from the catchment's biological elements.

Stakeholder representatives and technical expert groups identified a total of 21 biological elements (14 vegetation and seven fauna) as the basis for assessing human values (Table 1; Supporting Information Appendix 5). Stakeholder groups only considered the biological elements most susceptible to the impacts of altered hydrology, given the significance and catchment-wide impacts of this threatening process.

The three key values identified are detailed below.

Knowledge/heritage and education[13]

A wide range of educational groups, including primary, secondary and tertiary students, use the Toolibin Lake as a living classroom and research area. As the last extensive area of this type of wetland, the lake and environs represent an important piece of our disappearing heritage. The knowledge arising from continued research in the catchment makes an important contribution to understanding how these systems function, which in turn will contribute to our improved learning of environmental change and its management requirements throughout south-western Australia.

Productive use

Productive use refers to the benefits derived either from direct commercial harvesting or indirectly through enhancing the production of commercial goods. These include food and fibre, structural materials (e.g. wood products), energy in the form of biofuels or bioenergy, medical and other oil products (e.g. from mallee) and consumptive use. Stakeholders identified the value of productive use arising from two sources. Firstly, the presence of biological elements of high community interest (e.g. waterbirds) potentially attracts funds for work on private property to ameliorate hydrological issues. Although the primary driver supporting this funding is protection of natural biological elements, an ancillary benefit to managing water balance is productive use of farmland that provides an income for landowners. Secondly, the biological elements contribute directly to productive land use by lessening the downstream impact of salinity and other processes degrading agricultural soils. This second interpretation of productive use was used in the analysis of priority elements, recognising that this restricts the biological elements of interest to natural vegetation. The

[13] Note, originally this value was titled 'knowledge and education'. However, with development of the planning approach the title was updated to 'knowledge/heritage and education' to better reflect the related and important heritage value of the catchment.

first interpretation of productive use is believed to be captured by the philosophical/spiritual contentment value.

Parks and Wildlife Service staff conducting a tour for tertiary students
Photo – Maria Lee/DBCA

Philosophical/spiritual contentment

Stakeholders considered a biological diversity ethic (or conservation ethic) as important and a strong driver for conservation management. Human activity has significantly affected the Toolibin Lake catchment and the remaining biological elements are representative of systems that were once widespread, but which have now largely disappeared. There is an ethical responsibility to protect these remnant systems for present and future human generations.

It is acknowledged that value preferences may change over time and indeed can be influenced by recovery activities. For example, stakeholders ranked the recreational value of the Toolibin Lake catchment fourth. This value may become more important with increased use of the area derived from an improvement in the key properties of biological elements that affect knowledge/heritage and education and philosophical/spiritual contentment values.

Delivering knowledge/heritage and education and philosophical/spiritual contentment values will require the dissemination of information about the biological elements, recovery activities and outcomes, and the development and fostering of partnerships and engagement activities with stakeholders. Engagement and communication methods include a biannual newsletter, excursions for secondary and tertiary institutions and other interest groups, and presentations at conferences and regional shows. Opportunities to involve the community and educational institutions in the collection of data also ensure the values are upheld. A consultative approach has been devised to engage stakeholders in the monitoring and management of the Toolibin Lake catchment.

The goal for the Toolibin Lake catchment (Section 2.2) and recommended recovery actions aim to maximise the human values derived from the biological elements of the catchment.

Dingerlin Nature Reserve woodland
Photo – Peter White/DBCA

Table 1: Summary of the catchment's biological elements

Note: the scores provided for the number of species in the vegetation elements are based on estimates generated from the most recent vegetation survey data and used in the modelling in Section 2.3. However, the descriptions of the vegetation biological elements in Supporting Information Appendix 6 may include more species. This is because the lists contain previously detected species and species thought likely to occur in the element that may not have been recorded in the most recent surveys.

Element	Estimated number of species	Number of individual species of known conservation concern
Amphibians	8	0
Aquatic insects	185	0
Dingerlin Nature Reserve shrubland	146	2 (P3)
Dingerlin Nature Reserve woodland *	110	1 (P4)
Dulbining Nature Reserve shrubland	124	1 (P4)
Dulbining Nature Reserve wetland (1)	10	0
Dulbining Nature Reserve wetland (2)	37	0
Dulbining Nature Reserve wetland (3)	25	0
Dulbining Nature Reserve woodland *	65	0
Mammals	8	2 (1xT-EN, 1xT-VU)
Non-resident terrestrial birds	37	1 (IA)
Red morrel woodland*	10	0
Reptiles	22	1 (S)
Resident terrestrial birds	31	1 (T-VU)
Silver mallet (1) woodland*	10	0
Silver mallet (2) woodland*	10	0
Toolibin Lake wetland	37	0
Toolibin Nature Reserve open woodland*	100	1 (P3)
Walbyring Nature Reserve wetland	37	0
Wandoo woodland *	30	0
Waterbirds	50	1 (T- EN); 8 (IA)

Description of the codes

T: Threatened species – Specially protected under the Wildlife Conservation Act 1950*, listed under Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice for Threatened Fauna.*
EN: Endangered
VU: Vulnerable
IA: Migratory birds protected under an international agreement – Specially protected under the Wildlife Conservation Act 1950*, listed under Schedule 3 of the Wildlife Conservation (Specially Protected Fauna) Notice*
S: Other specially protected fauna – Specially protected under the Wildlife Conservation Act 1950*, listed under Schedule 4 of the Wildlife Conservation (Specially Protected Fauna) Notice*

P3: Listed as Priority 3 (Poorly-known species)
P4: Listed as Priority 4 (Rare, Near Threatened and other species in need of monitoring)
For a complete list of conservation codes and their definition see Supporting Information Appendix 6

**Denotes elements to be assessed for protection as a nationally threatened ecological community (TEC).*

2.2. Define goal

The goal is constrained in space (the catchment) and time (20 years). The temporal scale for this recovery plan is a compromise between the long duration of some natural cycles (in some cases over 100 years) and our ability to plan with reasonable certainty. In addition, it is expected that while incremental positive outcomes from recovery works will occur in the short term (less than three years), major improvements will take much longer to achieve.

Based on the values arising from the analysis of the biological elements by stakeholders, and endorsement by the recovery team, the recovery catchment goal is:

To maintain or improve the knowledge/heritage and education; productive use; and philosophical/spiritual contentment values provided by the specified biological elements for the next 20 years.

Aerial view of Toolibin Lake
Photo – Peter White/DBCA

2.3. Prioritise biological elements

The approach

Effective management requires the allocation of resources to focus on managing the highest priority biological elements. Prioritisation should favour the subset of biological elements that are the most important to realising the priority values. An assumption of this approach is that, by successfully managing the highest priority biological elements (a subset of the overall natural biota), we will deliver a greater proportion of the key human values than if resources were, for example, equally distributed across all biological elements. Appendices 7 through 10 and Smith et al. (2016) detail the process to identify biological elements, define and quantify their properties, and assess their values and risks.

Priority biological elements

Whilst all biological elements are valued, there will be variations in why, how and to what extent they are valued. The biological elements were grouped based on their contribution to delivering the priority human values (**Table 2**). These groupings were derived from:

1) modelling of the relationship between the properties of the biological elements (i.e. species composition, structure, intactness, rarity and size) and the values that are derived from them (property-value modelling); and
2) ratings of biological elements based on their contribution to delivering the human values, as elicited from the technical advisory group (TAG-elicited ratings).

The process of identifying and rating the biological elements and quantifying their properties is described further in Supporting Information Appendices 7 through 9.

Table 2: Biological element groupings for the Toolibin Lake catchment based on their contribution to the key human values.

Group 1 *(Highest priority)*	The Toolibin Lake wetland rated very highly in both the property-value modelling and TAG-elicited ratings, particularly due to its knowledge/heritage and education, and philosophical/spiritual contentment values. The overall value of the Toolibin Lake wetland was also very high (Figure 4) and, consequently, this is recognised as the highest priority biological element.
Group 2 *(High priority)*	Waterbirds, all nature reserve vegetation, and the remaining wetland vegetation rated (grey group; Figure 4).
Group 3	Terrestrial birds, wandoo woodland, amphibians, mammals, reptiles and aquatic

(Moderate priority)	invertebrates[14] (green group; Figure 4).
Group 4 *(Lowest priority)*	Red morrel woodland and the two Silver mallet woodland biological elements (blue group; Figure 4).

Red-capped robin at Dulbining Nature Reserve
Photo – Deanna Rasmussen/DBCA

[14] Because productive use is a priority value that was not treated as deliverable by the biological fauna elements, it is important to note that several of the biological fauna elements were predicted to be particularly important for philosophical/spiritual contentment value (mammals, waterbirds, terrestrial birds) and knowledge/heritage and education value (waterbirds, aquatic invertebrates, terrestrial birds).

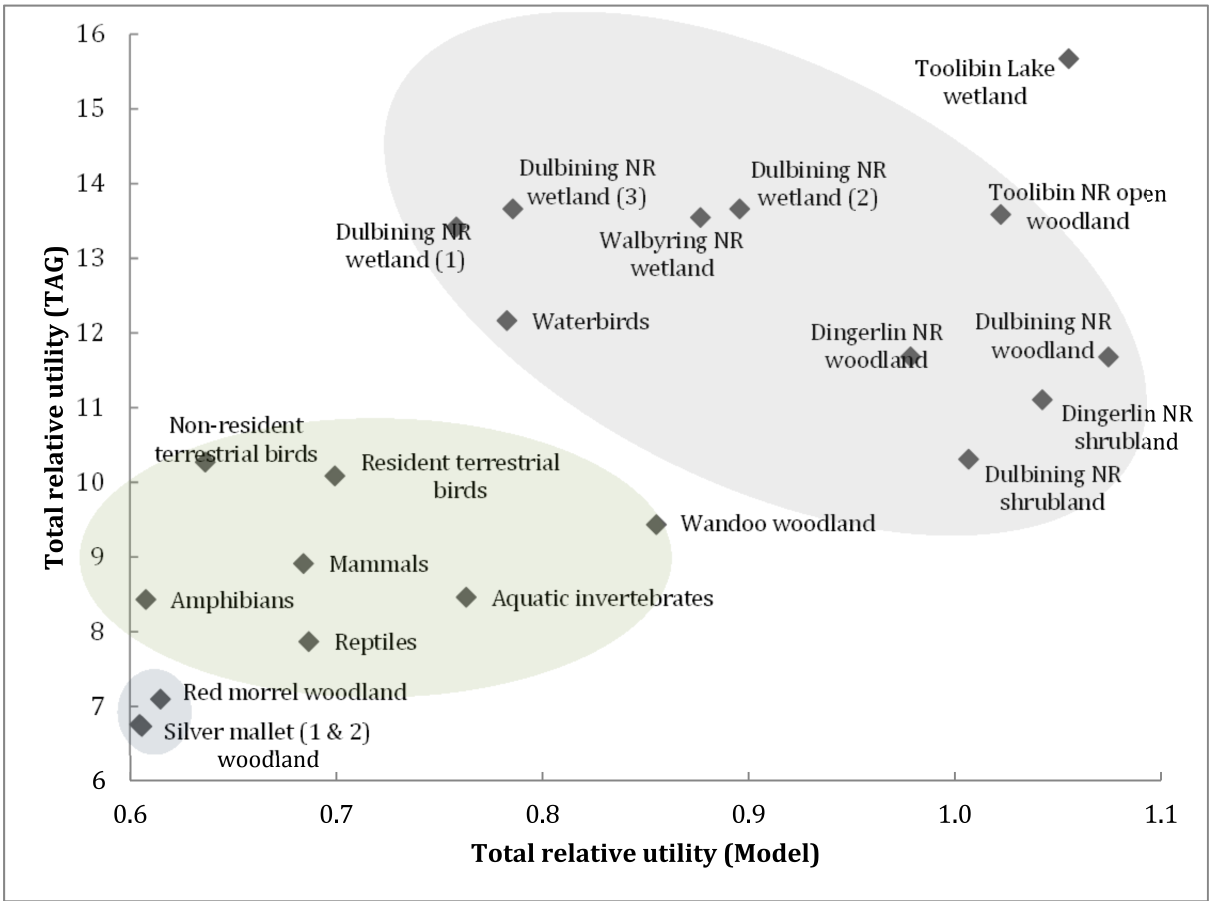

Figure 4: A comparison of utility (or overall value of a biological element) estimated by the technical advisory group of experts and the property-value modelling

Note: Utility estimates are relative, unit-less scores. Dulbining Nature Reserve is comprised of three separate wetlands (denoted as wetland 1, 2 and 3).

Based upon expert opinion and the property-values analysis, many of the biological elements associated with the wetlands are of particular importance. This result accords well with the hydrological focus of recovery activities in the catchment, the targeting of wetland conservation by the NDRC program (Supporting Information Appendix 1), and the Ramsar status afforded to Toolibin Lake.

Of note, whilst Dulbining Nature Reserve wetland (2) and (3) vegetation are not listed as occurrences of the *M. strobophylla-C. obesa* TEC, the vegetation is comparable to that at Toolibin Lake, Walbyring and Dulbining (1) wetlands, therefore also scored highly.

Broadening the management focus in terms of biological elements listed in the 1994 recovery plan is also important because aquatic and terrestrial systems within a broader management area overlap and can be expected to interact ecologically (Moreno-Mateos et al. 2012). Consequently, we can expect that the values derived from the biological elements will be similarly complex and interactive.

Dulbining Nature Reserve wetland (2)
Photo – Maria Lee/DBCA

Based on this analysis, while the Toolibin Lake wetland should remain the primary focus of management, all the biological elements listed in group 2 are also important. The biological elements in these two groups will therefore be the focus of recommended management actions. In practice, effective management of groups 1 and 2 should also contribute to maintaining the human values associated with most of the group 3 biological elements.

The accuracy of the assessment process would be significantly improved with better data on species composition, structure, size, rarity and intactness.

2.4. Identify key threatening processes

Identifying the key processes affecting the likelihood of achieving the goal (i.e. a risk factor analysis) was an essential step towards describing the actions required for management success. The steps used to identify the key processes affecting management were to:

1) Specify the goal in more detail in the form of management targets for important properties.
2) Analyse the risk factors controlling the management targets to describe the key threatening processes.

Section 4 provides a summary of management targets and limits of acceptable change for priority biological elements.

Management targets

To allow for effective management targets to be set, it was necessary to conduct a risk analysis and focus on the properties of the priority biological elements that affect the way people value them. Due to the iterative nature of planning activities since 2009, there has been some variation in the sets of biological elements and related targets used in the various risk analyses. The TAG recommended that management targets focus on species composition (specifically richness) due to its influence on the key values, and this property has been used for most of the priority biological elements. Activities that improve element intactness and size (where appropriate) will also have positive benefits in achieving the values, as described in Supporting Information Appendix 5. As knowledge increases, future iterations of the planning approach could include additional properties of the biological elements.

The focus areas of vegetation and waterbirds broadly encompass the biological elements of highest priority in groups 1 and 2.

Biological element - Vegetation

Management target:

To maintain the species composition of the priority biological vegetation elements (groups 1 and 2) over the management period, and specifically:

(a) minimise the decline in the size (area occupied) and abundance of *C. obesa* and *M. strobophylla* in the lake bed vegetation.

Biophysical limits

Within the context of the management target for the biological vegetation elements, initial biophysical limits are:

- acceptable variation in the abundance of individual species (e.g. with ecological succession and seasonality and within LoAC[15]).

Biological Element - Waterbirds

Management target:
To maintain the species composition of the waterbird element (Group 2) over the management period by maintaining appropriate waterbird habitat, and specifically:

(a) retaining the six indicator species listed in Table 3.

It must be recognised that factors outside of the catchment, such as seasonal conditions, more suitable habitat elsewhere and wider population declines caused by impacts outside of the catchment[16], can have a strong influence on waterbird use of the Toolibin Lake catchment for breeding.

The six indicator waterbird species were selected as they were recorded in reasonable numbers in 1981 to 1985 and 1996 surveys (Halse et al. 2000),

Biophysical limits
The species listed in Table 3 encompass a range of feeding habits and life histories. To provide suitable conditions for all six species, the wetland or lake would need to meet the following criteria:

- When the seasonal conditions are conducive (e.g. wetland and lake surface water ≈2.0m in the deepest sections and reasonably fresh [e.g. lower than 2000 µS/cm@25°C]), the indicator waterbird species should occur in numbers comparable to those from previous surveys and there should be evidence of successful breeding (e.g. fledglings) in some of the indicator species.

Table 3: Indicator waterbird species used to assess management targets

Common name	Scientific name	Abundance range from previous surveys
Australian shelduck	*Tadorna tadorniodes*	74–200
Pink-eared duck	*Malacorhynchus membranaceus*	134–154
Grey teal	*Anas gracilis*	194–1162
Freckled duck	*Strictonetta naevosa*	25–600

[15] LoAC are defined in Section 2.6 and are set around abundance and reproduction, as these two 'sub-properties' can be monitored to provide timely warning of significant change in richness.
[16] This is particularly relevant to migratory shorebirds, where population declines may be caused by impacts throughout the flyway, and cannot be attributed solely to local catchment changes. Waterbird abundance at a local level must therefore be assessed on a case-by-case basis and in the context of wider population trends.

Black-winged stilt	*Himantopus himantopus*	19–51
Eurasian coot	*Fulica atra*	201–370

Pink-eared duck
Photo – Hayden Cannon

Risk analysis

To ensure consistent assessment of risk, the risk analysis considered those environmental sources of risk (hazards), such as salt toxicity, grazing and drought stress, that directly affect the capacity of priority biological elements to survive and reproduce at a sufficient rate to maintain populations. These factors– termed 'direct hazard factors' – must be managed to protect the biological elements and thus meet management targets (Metcalf and Wallace 2013). The direct hazard factors relate to the threatening processes, as listed in Table 4.

Table 4: Direct hazard factors that may cause goal failure in the Toolibin Lake catchment

Threatening process categories	Direct hazard factor
Physical and chemical factors	pesticides/herbicides acidity/alkalinity heavy metals nitrogen toxicity phosphorus toxicity physical damage toxins ground water salinity surface water salinity
Resources	lack of food lack of oxygen

Threatening process categories	Direct hazard factor
	lack of/too much light lack of water
Disease/predation/grazing etc.	disease predation/grazing
Reproduction	lack of mates lack of genetic diversity lack of reproduction

Risk was assessed by means of an expert analysis of the probability, under current management, that the set of direct hazard factors will cause management target failure for the biological elements (refer to Metcalf and Wallace 2013 and Supporting Information Appendix 10). The risk assessment considered the spatial extent of the hazard factors within the mapped boundary of each element () and constrained them in time to the duration of the recovery plan (i.e. 2015 to 2035).

For the highest priority element – the Toolibin Lake wetland[17] – Metcalf and Wallace (2013) conducted a detailed and structured analysis of the risk of losing species. Their detailed analysis was only conducted on the risk factors mediated by hydrological change that were assessed by their expert group to have a probability of causing 'goal failure' in excess of five per cent.

A more rudimentary risk analysis for the majority of the biological elements in group 2 (Dulbining Nature Reserve wetland (2), Toolibin Nature Reserve woodland, Dulbining Nature Reserve woodland and shrubland and waterbirds) was undertaken by the TAG. The risk analysis involved working through element-hazard factor combinations and estimating (using expert judgement), the probability that the particular risk factor would cause goal failure under current management. Risk factors with probabilities of less than five per cent were not considered.

Table 5 summarises the findings of both risk analyses. Further information about the justifications for the scores and details of the other results of the second analysis can be found in Supporting Information Appendix 10.

Due to the iterative nature of the process, the TAG did not specifically address in their risk analyses the biological elements of Dingerlin Nature Reserve (woodland and shrubland), although these are recognised as high priority biological elements (group 2). Dingerlin Nature Reserve is showing signs of secondary salinisation and, consequently, altered hydrology is seen as a major threatening process for this element. Problem species and fire management are also likely key significant threatening processes.

[17] Metcalf and Wallace (2013) also assessed the risk of losing aquatic invertebrate species.

Recommended action:

1. *Conduct a risk factor analysis for all element-risk factor combinations for Dingerlin Nature Reserve.*

Table 5: Summary of the key threatening processes and their consequences

Note: several risk factors that were not rated as a problem but are currently managed are included as it is assumed they would become significant if current recovery activities were to cease. These risk factors are denoted by an asterisk.

Threatening process	Threat description	Direct risk factors	Major consequence	Biological elements	Probability of target failure
Altered hydrology	Increased surface water salinity	Root zone anoxia and salt toxicity	Mortality in natural plant species	- Toolibin Lake wetland	0.41
				- Dulbining NR wetland (2)	0.05
Altered hydrology	Increased groundwater salinity	Root zone anoxia and salt toxicity	Mortality in natural plant species	- Toolibin Lake wetland	0.23
				- Other NR wetlands	0.2
				- Dulbining NR woodland	0.4
				- Dulbining NR shrubland	0.4
				- Toolibin NR woodland	0.4
Altered hydrology	Lack of water	Drought stress	Mortality in natural plant species	- Toolibin Lake wetland	0.34
				- Dulbining NR wetland (2)	0.29
				- Dulbining NR woodland	0.5
				- Dulbining NR shrubland	0.5
				- Toolibin NR woodland	0.5
Altered fire regimes	Change in fire frequency, intensity, season or extent	Senescence	Senescence in serotinous obligate seeder natural plants	- Dulbining NR woodland	0.2
				- Dulbining NR shrubland	0.2
				- Toolibin NR woodland	0.2
Problem species	Introduction and proliferation of competitively superior weed species	*Lack of light due to competition with weed species	Mostly relating to competition with weed species reducing germination, growth and reproductive success and causing mortality in natural plant species. Potential	- Dulbining NR woodland (particularly relating to snail orchid)	0.2
				- Dulbining NR shrubland (particularly	0.2

Threatening process	Threat description	Direct risk factors	Major consequence	Biological elements	Probability of target failure
			link to fire regimes	relating to snail orchid)	
				- Toolibin NR woodland (particularly relating to snail orchid)	0.2
Problem species	The proliferation of problem grazing species	*Grazing and predation	Grazing by kangaroos and rabbits decreases reproductive success and causes mortality in natural plant species	- Toolibin Lake wetland*	0.05
				- Other NR wetlands*	0.05
				- Dulbining NR woodland*	0.05
				- Dulbining NR shrubland*	0.05
				- Toolibin NR woodland*	0.05
Problem species	Introduction and proliferation of pathogens	Disease	*Phytophthora* infestation causing mortality in natural plant species	- Dulbining NR woodland	0.2
				- Dulbining NR shrubland	0.2
				- Toolibin NR woodland	0.2

Key threatening processes

The key threatening processes emerging from the analyses of risk factors outlined above are:

1) Altered hydrology
2) Competition and predation by problem species
3) Altered fire regimes and related processes

These key threatening processes are recognised to affect natural systems widely across Western Australia (Bell 2001, Burrows and Abbott 2003, Fitzpatrick et al. 2008, Halse et al. 2003, Hancock et al. 1996, Hester and Hobbs 1992, Shearer et al. 2007).

Altered hydrology

The management of factors affecting hydrology in Toolibin Lake has contributed to preventing species loss. Groundwater rises and increased surface water flows in the Toolibin Lake catchment are typical of those commonly seen in the Wheatbelt region. Between the 1920s and 1970s the replacement of deep-rooted perennial natural vegetation with shallow-rooted, low water use annual crops and pastures resulted in catchment-scale changes to the water balance (Froend et al. 1987, George et al. 2005). This change created a water surplus, which manifests as persistent surface water run-off and groundwater recharge (Figure 5). Both processes provide more water, and water with generally higher salinities, to the biological elements within wetland systems.

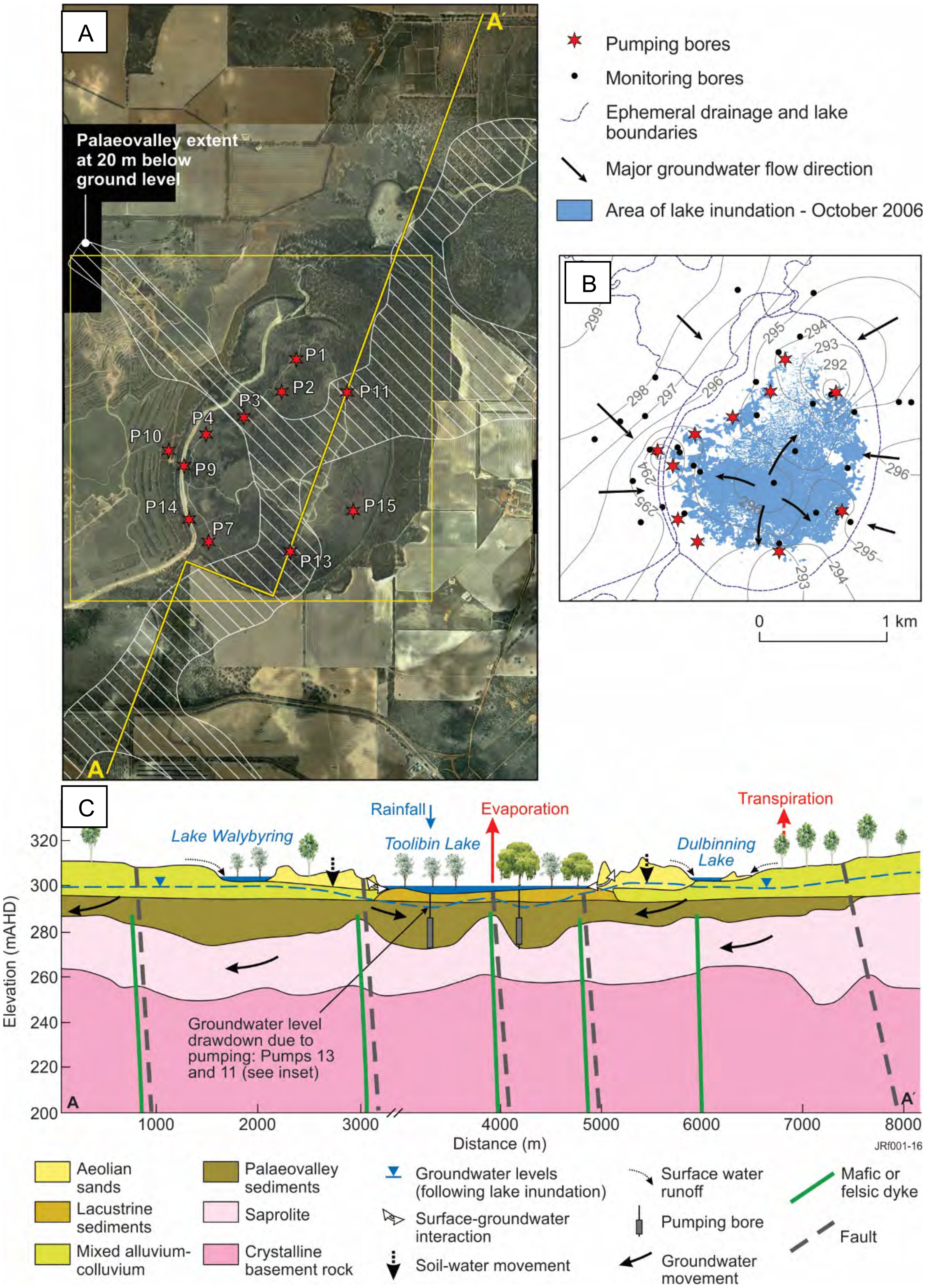

Figure 5: Toolibin Lake conceptual hydrological model

Note: (from Rutherford (in prep); (a) May 2015 orthophoto showing the location of Toolibin Lake pumping bores in relation to the extent of palaeovalley sediments mapped by airborne geophysics (b) Spatial distribution of regolith materials and water balance dynamics along cross section A-´A and (c) October 2006 groundwater gradients during lake inundation event (note the drawdown from groundwater pumping is sustained with >0.5m of lake water and major gradients are moving groundwater both towards the lake as well as from the central area of the lake towards the margins)

Intensive groundwater and surface water investigations of the lake and catchment commenced in the 1970s when the average rainfall levels were higher and both shallow groundwater and surface water inflows were first identified as threats to biota. In the late 1990s, hydrological management systems were installed in the Toolibin Lake catchment to manage the excess groundwater and surface water to minimise the decline of the fringing and lake bed vegetation, and to maintain a functional bird habitat at Toolibin Lake. This included installation of a groundwater pumping system and surface water diversion within Toolibin Lake and enhancement of a number of ephemeral up-gradient drains. Groundwater and surface water monitoring systems were also put in place to increase understanding of how water and salt were moving in the catchment, and to assess the performance of the management systems.

Reductions in average rainfall in the early 2000s changed hydrological conditions. This occurred before sufficient data could be collected to fully understand and characterise the surface water hydrology during the wet climate cycle. The drier climate changed some aspects of groundwater and surface water behaviour, which has presented significant challenges that require ongoing research and adaptive management strategies. A key research challenge in a drier climate is the need for a better understanding about which landscapes generate run-off and flow that will either benefit or threaten natural biota.

Decadal changes have produced challenges for surface water that include water flows being less frequent, shorter lived, poorly connected and harder to measure with respect to flow rates and water quality (Cattlin et al. 2004, Callow et al. 2008, Muirden and Coleman 2014). As a result, less water (fresh or saline) is being delivered to the biological elements and, as a consequence, the frequency, intensity and duration of lake hydroperiods (the period in which a soil area is waterlogged), for Toolibin and other lakes, have changed.

In the same period, groundwater levels have continued to rise in deeper aquifers in some areas of the catchment (Richard George pers. com., Rutherford et al. (in prep)). Up-gradient of the valley floor, seasonal shallow aquifers develop less often, and many bores drilled to depths of less than five metres in the uplands and valley margins have been dry since the early 2000s (Rutherford et al. (in prep)). These changes have reduced groundwater recharge as well as soil moisture levels. Beneath Toolibin Lake, groundwater levels are lower due to groundwater abstraction through pumping. However, when the pumps are turned off for extended periods, groundwater levels rebound to levels close to the ground surface. This means it is likely that groundwater levels are near the surface within lakes that occupy the valley floor in nearby reserves (e.g. Dulbining and Walbyring lakes).

Reductions in average annual rainfall and soil moisture have caused drought stress to deep-rooted perennial vegetation over the past 10 to 15 years. Some vegetation death has occurred but this has been difficult to quantify spatially due to the sparse canopy of many species. Colletti et al. (2015) modelled water use of deep-rooted perennial natural species, calculating transpiration rates and changes in biomass during lake inundation. Results suggest that under a drier climate, competition for water between species increases. Therefore, a robust understanding of the local and broader water balance is required to design revegetation plans that enable maximum plant water use with minimal vegetation loss. The effects of pumping were also examined and results indicated that this can cause additional stress to some species (e.g. *Melaleuca strobophylla*) (Colletti et al. 2015). Drake et al's (2012) work on understanding the relationship between soil water and plant survival and reproduction requires further research to determine whether the observations of this study are replicated when an inundation event is preceded by a wet period as opposed to an extended dry period.

Understanding the effectiveness of the groundwater pumping and surface water diversion management systems and their associated monitoring programs is essential to guiding ongoing management actions. Data collected in the mid-2000s has demonstrated that management actions have been effective in preventing further deterioration of biological elements, and it is anticipated that refinement of management strategies may lead to an improvement and ultimately a recovery of the catchment.

Since the late 1980s the effectiveness of groundwater and surface water management of the Toolibin Lake catchment has been reported based on hydrological assessments of the water balance (Rutherford et al. 2015). Most studies have been modest, incorporating only part of the large amount of hydrological data and information collected over the past 40 years. Colletti et al. (2015) undertook the most recent study, attempting an update of the lake and catchment assessment undertaken by Dogramaci et al. (2003).

Work by Coletti et al. (2015) did not use or interpret all available data and focused mainly on surface water hydrology, acknowledging that groundwater hydrology and broader scale surface-groundwater interactions needed further research. A hydrology TAG meeting in December 2014 considered these knowledge gaps to be critical, and recommended modelling of valley floor groundwater and surface-water hydrology, including Toolibin Lake hydrogeology, to better assess and manage pumping and other engineering options (see recommended actions 2 and 3).

Problem species

The development of regional areas and an increased human population in the surrounding areas resulted in the introduction and spread of weeds, additional food and water sources for natural and pest animals, and the opening up of natural bushland to foot, vehicle and rail traffic and the potential introduction and spread of diseases.

i. Weeds

Globally, the negative effects related to invasion by weed species is now well understood and documented (e.g. Lawes and Grice 2010). Within the catchment, agricultural weeds, escapees from gardens, and weeds transported along roads and railways pose a serious risk for primary producers as they can impact on agricultural production, both in crops and pastures. Agricultural practices provide significant avenues for weed and disease introduction. Many weed species from agricultural and horticultural activities have and will continue to pose a threat to natural ecosystems. Given its location in the lower part of the catchment, and that it is surrounded by agricultural lands, Toolibin Nature Reserve and the priority biological elements that it supports are exposed to weed invasion from surrounding areas.

Much of the remnant vegetation in the Wheatbelt has a high perimeter-to-area ratio, making it more vulnerable to the processes that facilitate weed invasion. Soil from surrounding agricultural lands, enriched with nutrients such as nitrogen and phosphorous from fertilisers, can be deposited within the edges of the region's nature reserves by wind erosion or rainfall run-off. These additional nutrients, particularly phosphorous, favour the establishment of weeds over natural species. Weed seeds and other propagules can be transported into the reserves by water flowing through the catchment, blown in by the wind from neighbouring properties, or carried in by animals and humans (including via vehicles and machinery). Physical soil disturbance by machinery or vehicles can also favour weeds where they are already present. While fire can also promote weeds where they already occur, it can also be used as a management tool to reduce weeds and encourage the regeneration of natural species.

Weeds compete with natural vegetation for nutrients, sunlight and water, can have an allelopathic effect on natural plants, or can be toxic to natural animal species (e.g. slender ice plant). Natural vegetation is already under pressure from a range of threatening processes and the impact of weed invasion can have a compounding effect on the quality of natural vegetation and habitat. Competitively superior weed species present a threat to many of the natural plant species once they are able to establish. The size of this threat depends on the extent to which they may cause a loss of natural species.

Managing problem weeds cannot be done in isolation, and will require an integrated management approach with other key threatening processes. Fire-dependent species require fire for regeneration, but introducing fire into the woodland in the absence of a weed control program may trigger an explosion of weeds.

In previous decades, when the hydroperiods were frequent and the lakes remained full for longer, inundation also controlled weeds on the floors of the lakes. The drying climate has also provided opportunities for *Eucalyptus* species not normally associated with the lake floor vegetation to successfully establish. In the context of the management targets these could potentially be considered problem species.

The variety of the weed species is uncertain at Toolibin Lake due to the extended periods of dry experienced over the last few decades. It is likely that if periods of more frequent inundation return, like those typical of previous decades, the issue of aquatic weeds will also need to be addressed.

The other key threatening processes – altered hydrology, excessive grazing and inappropriate fire regimes – may all contribute to creating disturbances that can facilitate establishment of weed species. Supporting Information Appendix 11 lists the important weed species known to occur in the general area and identifies those species that have been recorded within the vegetation-based biological elements.

ii. Grazing animals (kangaroos and rabbits)

Kangaroos and rabbits are key problem species in the catchment when they occur in high densities. The numbers of western grey kangaroos have declined across the Wheatbelt landscape as habitat loss and fragmentation have increased with clearing for agriculture (Arnold et al. 1995). Locally, numbers fluctuate depending on seasonal conditions; wetter years lead to an increase, while drier years result in population declines. When conditions are favourable kangaroos tend to concentrate in natural areas for food and refuge and extensively graze on agricultural lands.

The high perimeter-to-area ratio of many Wheatbelt reserves maximises the opportunity for kangaroos to move between reserves and paddocks and, as a result, they may damage fences, infrastructure, crops and natural vegetation. Western grey kangaroos appear to preferentially graze and browse in natural vegetation but, depending upon seasonal conditions, may spend a portion of their time in adjoining paddocks. While kangaroos have been observed browsing on *Casuarina obesa*, it is unclear whether they are responsible for widespread damage to seedlings; however rabbits, even at very low densities (<1/ha), are known to heavily browse and eliminate *Allocasuarina* species seedlings in south-eastern Australia (Bird et al. 2012). Heavy browsing has resulted in stunted *C. obesa* that are less than 50cm tall when four or five years old and are unlikely to reach reproductive maturity. Ungrazed individuals are up to two metres tall at the same age. When Toolibin Lake fills, these stunted trees may not survive the prolonged inundation. Kangaroos are also known to ringbark the base of mature *C. obesa* trees looking for moisture. The constant browsing stress on vegetation can also increase susceptibility to other diseases.

While the western grey kangaroo is a declared pest under the *Biosecurity and Agriculture Management Act 2007* (BAM Act), the *Wildlife Conservation Act 1950* protects and regulates the taking of all natural fauna. In the Toolibin Lake catchment, regulations require landholders to apply for a permit to destroy kangaroos. The recognition of kangaroo grazing as a threatening process creates an interesting juxtaposition of values given the importance attributed to the natural mammals as a biological element. It is important to note that the aim is not to reduce the richness of the natural mammals, but to manage the abundance of kangaroos.

Rabbits are also having a significant impact on the regeneration of natural vegetation and seedlings planted for revegetation projects throughout the catchment. They compete with natural animals for grazing resources, and have been demonstrated to suppress populations of kangaroos in south-eastern Australia (Bird et al. 2012). Agricultural crops also provide a food source for rabbits, and under the BAM Act they are a declared pest. Rabbits can also disperse viable weed seed through their scats, and their latrines and warrens provide productive sites for weed establishment.

***Heavily grazed* Casuarina obesa**
Photo – Ray McKnight/DBCA

iii. Disease[18]

Disease, if undetected and not managed, is likely to cause loss of natural species in the Toolibin Lake catchment. Dieback, caused by the pathogen *Phytophthora cinnamomi* and other related species, is of concern.

Dieback is an introduced plant pathogen that is widely distributed throughout south-west Western Australia, particularly in higher rainfall areas. Dieback can irreparably change the

[18] Disease currently relates to biological vegetation elements

structure and composition of some vegetation by eliminating susceptible plant species, and reducing its suitability as fauna habitat. Traditionally the Wheatbelt has been considered a low risk area due to its drier climate.

Dieback can remain dormant in the soil for long periods, but becomes active in warm, moist conditions, and infects and kills the roots of susceptible plant species. It can be easily moved in its dormant or active state through the movement of contaminated soil, but also spreads through direct contact between infected and uninfected plants. Up to 40 per cent of natural plants, and many species of horticultural and agricultural importance, are susceptible to the disease, particularly banksias, grevilleas and hakeas in the Proteaceae family, some Eucalypts such as jarrah, and grasstrees (*Xanthorrhea* species). Several hundred threatened plant species in the south-west are at risk of extinction from the impact of dieback.

Since the inception of the previous recovery plan, continual revegetation works have occurred on private property and conservation estate throughout the catchment. Major earthworks to manage altered hydrology have also contributed to mass movements of soil, as well as to the import of basic raw material into the catchment. It is important to ensure that any works undertaken do not introduce or spread diseases and pathogens.

Based on a soil and propagule testing program and incidental observation, dieback has not been detected at Toolibin Lake, although other species of *Phytophthora* have been detected. *P. inundata* has been detected from the Toolibin Lake floor, with *P*. aff. *humicola* and a *Phytophythium* sp. being found in the Miller's Reserve revegetation site (Peter White pers. comm.). These are newly identified species of *Phytophthora* and the extent of their impact on natural vegetation is currently unknown. Significant summer rainfall events over the last decade, and the introduction of these new species, have challenged the notion of Toolibin Lake being a low risk area for dieback.

Fire regimes

The Toolibin Lake catchment lies within the Southwest Biodiversity hotspot[19], and the biological vegetation elements support a high richness of plant species. The evolution of this diversity is a result of several factors – a geologically ancient and stable landscape, nutrient-poor soils, variable climatic conditions, highly specialised pollinators, and natural fires. Natural fires have influenced the flora of the south-west for nearly 90 million years. Fire-adapted traits such as resprouting, hard-seededness, heat release of canopy-stored seed and synchronous post-fire flowering are common in the south-west flora.

Historically, the vegetation within the Toolibin Lake catchment was influenced by fires ignited by lightning. These fires spread through large areas of contiguous vegetation until reaching areas with low fuel, areas that had been recently burnt, saline drainage systems, freshwater

[19] http://www.environment.gov.au/biodiversity/conservation/hotspots

lakes, or until they were extinguished by weather conditions. Aboriginal people used fire as a land management tool, lighting fires regularly to ensure the availability of food as they travelled.

However, the historical clearing of vegetation for agriculture and the movement of Aboriginal people from across the Wheatbelt had a profound effect on fire regimes. The landscape is now largely cleared of natural vegetation, and bushfires are actively suppressed to protect life and property, so natural fires are unable to spread. The time between successive fires on many small Wheatbelt reserves now exceeds the life cycle of many plant species dependent on fire (Parsons & Gosper 2011).

Managing altered fire regimes, which are considered a significant threat to the natural biological diversity in the area, is a particularly complex issue. Different species vary in their sensitivity to changes in the frequency, timing and intensity of fires according to their life history traits, and no single fire regime is likely to be optimal for all species (Gosper et al. 2013, Tulloch et al. 2016 and Supporting Information Appendix 12). An understanding of the fire response of most species is limited, with knowledge gaps including germination triggers, age to maturity, life span, and rate of seed bank accumulation and decline. There are also gaps in knowledge relating to the impact of changing climate on key life stages, the relationship between significant climatic events and changing fire regimes, and the effect fire may have on other threatening process such as rising water tables and land salinisation.

Summary

Due to the nature of these key threatening processes, and the corresponding probabilities of target failure identified in

Table 5, even with the maintenance of current management there is still a reasonable likelihood of a loss of natural species (i.e. goal failure). Therefore additional management actions are required to achieve the management goals to protect the biological elements, and consequently the human values, of the Toolibin Lake catchment. Finally, this plan focuses on the key threatening processes known to currently impact the catchment. However, new or latent threats may emerge during the life of this plan, therefore monitoring approaches (described in Section 2.6) are proposed to indicate emerging issues.

2.5. Devise recovery actions

Management of key threatening processes

As outlined in section 2.4, additional management of the key threatening processes is required to reduce the likelihood of species loss, and thus maintain or improve the properties of the biological elements and deliver priority human values. A suite of recovery actions to address the key threatening processes were then identified and prioritised based on an assessment of the benefits (**benefit analysis**) expected from managing each threatening process both on an individual basis (taking into account all of the currently feasible actions required to successfully manage each process), and in combination with each other. This was undertaken by a technical advisory group (TAG). Supporting Information Appendix 13 explains in detail the benefit analysis of recovery actions. All management actions that were deemed socially acceptable and technically feasible were considered.

Benefit analysis of actions

The eight management options in Table 6 represent actions to address the key threatening processes in isolation or in combination.

Table 6: Management options for the key threatening processes

Note: A tick indicates which processes are targeted in the management option.

Management option	Problem species	Fire regimes	Altered hydrology
1			
2	✓		
3		✓	
4			✓
5	✓	✓	
6	✓		✓
7		✓	✓
8	✓	✓	✓

The four options that included management of altered hydrology were expected to result in the maintenance or improvement of species richness. In order of rating, the top four options were to manage:

1) All key threatening processes (option 8)
2) Altered hydrology and problem species (option 6)

3) Altered hydrology and inappropriate fire regimes (option 7)
4) Altered hydrology alone (option 4).

A loss in species richness was expected from all other management options. The 'walk away' option (i.e. no management, option 1) was predicted to result in the worst loss, followed by managing problem species only (option 2) which was predicted to provide the least benefit.

The management of all three key threatening processes (option 8) was predicted to result in the best outcome. This involves management of:

1) altered hydrology (specifically relating to the quantity and quality of water available to the biological elements).

2) problem species:
   a. Manage weed species.
   b. Control kangaroos and rabbits with target densities established through the monitoring.
   c. Establish protocols to reduce the risk of disease introduction and spread, and monitor appropriately.

3) fire as a tool for regeneration of biological elements which require it, and for asset protection.

Managing altered hydrology

Hydrological monitoring and assessment programs are currently in place in the Toolibin Lake catchment. A major review of hydrological monitoring was undertaken in 2014 and 2015 that confirmed that the current water management infrastructure was appropriate and achieving the intended outcomes, and led to the rationalisation of both the surface water and groundwater monitoring programs. The first review by Muirden and Coleman (2014) details the surface water procedures, including measurement of ephemeral flows (volume and water quality) and lake levels. The second review by Rutherford and others (in prep) details a rationalised groundwater monitoring program. The monitoring program is provisional and will be finalised on completion of the conceptual and numerical models (currently in progress). The following recommendations are based on these review findings:

2. *Develop a quantitative conceptual model that details how and when water and salt moves.*
3. *Construct numerical models of groundwater and surface water, focusing on department-managed estate, which will be used to apply management levers and develop monitoring programs.*
4. *Maintain and where feasible improve current hydrological infrastructure.*

Groundwater and surface water management activities will be developed within five-year operational plans using outputs from the monitoring and conceptual and numerical models. Activities will include improving the effectiveness of current infrastructure to move poor quality surface water away from the biological elements.

Surface water actions to manage flow (Supporting Information Appendix 14) under a wetter climate cycle have been developed (Rutherford et al. 2015) and their relevance needs to be tested in a conceptual and numerical model.

Specific groundwater management recommendations include:

5. *Rationalise and/or improve groundwater pumping program based on the results of the hydrological numerical model.*

Finally, for the management of both ground and surface waters:

6. *Optimise management of the affected biological elements, through development of refined diversion gate and pump management guidelines informed by analysis of monitoring data and modelling results.*

Maintenance of electric submersible pump
Photo – Maria Lee/DBCA

The various hydrological management options need to be assessed in terms of feasibility and significance with respect to meeting the vegetation and waterbird management targets. Additionally, there is a clear set of steps to be taken for the management of hydrology infrastructure (Supporting Information Appendices 15 through 17) that should be followed. These standard operating procedures and guidelines should be assessed and refined over time, especially when informed by the findings of tests of the infrastructure during fill events.

Revegetation is an important management action to manage the water and salt balance. Further, it influences the important biodiversity properties of species richness (and associated abundance), rarity, size and intactness, providing scope to increase the values of managed biological elements. Completing the conceptual and numerical models will enable the development of new, and refinement of existing, revegetation plans for the catchment and lake systems (encompassing the TEC's). This will consider current and predicted future climate to identify optimal locations for planting. Given the whole catchment cannot be revegetated, identifying and revegetating key areas is anticipated to result in lowering the water table, though large areas may need to be revegetated to achieve this (Hodgson et al. 2001, Kinzig et al. 2006).

Recommended action:

7. *Develop a revegetation plan for the catchment to primarily address altered hydrology processes, to facilitate other aspects of wildlife management and to meet other human values.*

Planting of natural species at Miller's Reserve
Photo – Maria Lee/DBCA

Managing problem species

Weeds, pests and disease are managed in accordance with departmental policies and procedures. Activities relating to the management of problem species will be triggered by findings through the monitoring program as described in Section 2.6.

i. Weeds

A weed management program is in place for Toolibin Lake and adjacent nature reserves. In accordance with the department's Weed Management Policy No. 14[20] and other departmental guidelines[21], chemical and physical methods are used in priority areas. These include the day-use recreation area, along fire access tracks, and at revegetation sites pre-planting and post-planting until seedlings are established and can survive the competition from weeds. Weed control provides many benefits including reducing fuel loads in visitor areas and access tracks.

A photo-point monitoring program is in place that focuses on monitoring the introduction and spread of weed species in order to instigate a management response to control or remove species that pose a threat to priority biological elements. The management of particular infestations requires prioritisation and case-specific control mechanisms, whether they are biological, chemical or physical.

Issues such as chemical resistance and persistence of chemicals in the environment will need to be addressed, as well as the potential use of natural plant species for weed management (i.e. competitive exclusion, negative allelopathy). Integrated management across other key threatening processes will provide the greatest benefit, and will increase knowledge on management of priority biological elements (e.g. introducing fire to stimulate regeneration of banksia woodlands may also provide an opportunity for some weed species to flourish). The decision analysis tool provided by Zimmerman et al. (2011) provides an example of a detailed approach to making decisions about weed management.

The current weed management program for Toolibin Lake and adjacent nature reserves has proven to be effective in minimising the impact of weeds on natural vegetation in revegetation areas, and maintaining fire breaks for reserve management, and should be continued. However a review of the program and development of a weed management plan will assist in setting effective long-term weed management strategies to protect high priority conservation areas within the reserves.

Recommended actions:

8. *Continue with current weed management priorities.*
9. *Develop and implement a weed plan to identify and prioritise ongoing weed management.*

ii. Grazing animals (kangaroos and rabbits)

A pest management program is in place for kangaroos and rabbits for the Toolibin Lake catchment. This program is in accordance with the department's Pest Management Policy

[20] The department's management of weeds policy can be found at pws.dbca.wa.gov.au/about-us/36-policies-and-legislation
[21] pws.dbca.wa.gov.au/plants-and-animals/plants/weeds/155-how-to-control-weeds

No. 12[22] and other associated guidelines[23] and the Good Neighbour Policy[24], in recognition of the coordinated approach working with neighbours that is essential for the management of pest animals.

At present, rabbits are baited annually (or possibly up to three times per year in revegetation sites) over the summer period when alternative food sources are scarce. Baiting is undertaken in the day-use recreation area and at revegetation sites pre-planting and post-planting until seedlings have established and can survive grazing by rabbits. Opportunistic warren ripping is also undertaken to prevent young rabbits re-invading from other areas. The widespread nature of this issue across the region makes it unlikely that rabbits will be eradicated over the management period, however populations can be managed within the planning area to reduce their impacts, as per the current management program.

Kangaroo abundance is monitored twice per year using the spotlighting method. Data collected over a decade has shown that the average numbers of kangaroos observed on the reserve system has tripled. In recognition of this rapid population increase, ongoing approval was granted in 2011[25] to cull and remove western grey kangaroos on Toolibin Lake and the surrounding reserve system using a professional kangaroo shooter. Culling is considered the most effective way to manage the threat at Toolibin Lake, believed anecdotally to have minimised grazing pressure within the reserve. Owners of neighbouring freehold property are required to apply for a permit before shooting kangaroos, and are encouraged to do so.

While the spotlighting program effectively monitors the abundance of kangaroos on the lake floor, instigating a management response to control or remove grazing species requires determining the LoAC for the biological elements susceptible to overgrazing and monitoring to determine exceedances. This involves monitoring the abundance of kangaroos and rabbits while simultaneously monitoring the level of impact on populations of plant species susceptible to overgrazing.

Recommended actions:

10. *Continue with pest management for kangaroos and rabbits.*
11. *Define the LoAC for elements susceptible to overgrazing (process), and identify the abundance or density of rabbits and kangaroos that is consistent with maintaining the properties of the biological elements within their LoAC.*

iii. Disease

Preventing introduction and spread is a key strategy in managing diseases. The department's

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[22] The department's management of pest animals policy can be found at pws.dbca.wa.gov.au/about-us/36-policies-and-legislation
[23] & pws.dbca.wa.gov.au/plants-and-animals/animals/kangaroo-management-in-western-australia
[24] pws.dbca.wa.gov.au/about-us/36-policies-and-legislation

[25] In 2011, the Director General of the former Department of Environment and Conservation (now the Department of Biodiversity, Conservation and Attractions) granted approval for the culling and removal of western grey kangaroos on Toolibin Lake.

Corporate Policy No.3[26], and existing **standard operating procedure** (SOP) and management guidelines direct the management of *Phytophthora*.[27] A precautionary approach towards disease management is essential, and vigilance is required through the maintenance of disease hygiene practices to prevent the introduction or spread of diseases (including rusts and cankers) in the catchment.

Activities within the catchment that involve the movement or introduction of soil or plant material, including earthworks and revegetation, are subject to standard procedures to detect the presence of *Phytophthora* species. Soil and vegetation propagules are sampled in susceptible species that are dead or in poor health. Dieback poses the greatest threat to the *Banksia* species in the Toolibin Nature Reserve woodland and the Dingerlin Nature Reserve shrubland. The current status of dieback in these reserves is unknown and dieback interpretation and mapping of these two areas is a priority.

As per other problem species, this plan outlines a monitoring approach to detect potential disease infestations and trigger a management response (Section 2.6). Recommended actions for the management of disease should be updated as new information and approaches are identified. The current status of disease in the biological elements is unknown.

Recommended actions:

12. *Undertake dieback* (P. cinnamomi) *interpretation of Dingerlin Nature Reserve shrubland and Toolibin Nature Reserve woodland.*
13. *Continue with hygiene management.*
14. *Investigate evidence of* Phytophthora *expression in susceptible genera.*
15. *Monitor and investigate deaths or decline in vegetation elements that may be attributed to other diseases.*

Managing fire regimes

The time since the last major bushfire in the catchment is estimated to be at least 50 years. This may be approaching the interval at which species dependent on fire for regeneration may be lost within the bushland reserves. However, the relatively small areas of the reserves within the Toolibin Lake catchment means the plant and animal species may be more susceptible to grazing, predation and weed competition, and there is the potential for temporary increases in water tables after a fire.

Maintaining biota is important to delivering the key human values, and introducing fire in a managed way will help maintain biodiversity. Re-introducing fire will require a greater

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[26] The department's management of *Phytophthora* disease policy can be found at
[27] pws.dbca.wa.gov.au/management/pests-diseases/129-phytophthora-dieback

understanding of how the biological vegetation elements respond to fire, including the level of senescence, the impacts of prescribed fire. It is generally accepted that when managing bushland, application of the same fire regime over a large area should be avoided.

Banksia stands at Toolibin Nature Reserve
Photo – Deanna Rasmussen/DBCA

A fire management plan is recommended, to be developed in consultation with technical specialists, and in accordance with the department's Fire Management Strategy 2017 – 2021[28] . The primary aim should be to reduce bushfire risk and, including loss of vegetation and infrastructure. Secondarily, fire should be introduced as required, in an informed and managed way, to maintain or improve vegetation health where it will deliver on key values and promote biodiversity. The plan should be adaptive and updated as knowledge improves.

[28] https://dpaw.sharepoint.com/Key%20documents/Parks%20and%20Wildlife%20Fire%20Management%20Strategy.pdf

Recommended action:

16. Develop and implement a fire management plan to address:

(i) protection of infrastructure

(ii) protection and maintenance of biological elements.

2.6. Monitor

Limits of acceptable change

To develop meaningful limits of acceptable change (LoAC) it is important to identify the main threatening process to the properties of the biological elements. This can be difficult as symptoms may be similar across threats, or a combination of threats may have caused cumulative stress and the introduction of an additional threat trigger the death of the element.

For the Toolibin Lake catchment, LoAC have been set around species composition and structure, as these two element properties can be monitored to provide timely warning of significant change. For species composition, the LoAC is described in terms of the abundance of key individuals of the natural species that characterise each element. As long as the LoAC are not exceeded (i.e. abundances do not change significantly), key natural species will not be lost.

Based upon LoAC, the recommended monitoring framework for the Toolibin Lake catchment is outlined in

Table 7 and, following from the previous section, focuses on monitoring species composition (richness; the key property) such that individual species abundances do not exceed LoAC over the management period. To provide information to assist in the management of the biological elements, information relating to the processes targeted by the recovery activities should also be monitored (identified in Section 2.5). Specifically, activities are undertaken to manage threatening processes that alter the properties of the biological elements that maintain key human values. If changing a recovery activity does not resolve a problem, the likely outcome is management target failure and, ultimately, goal failure.

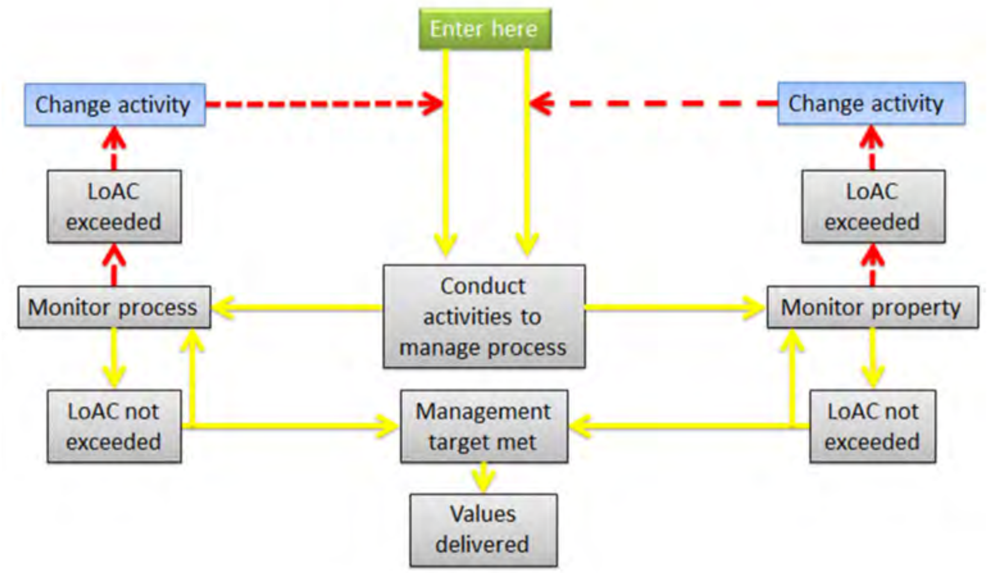

Figure 6: Monitoring framework

Table 7: Recovery response framework

LoAC = limits of acceptable change

		Element property	
		LoAC not exceeded	LoAC exceeded
Process	LoAC not exceeded	No recovery response triggered; however, activities and LoAC can be adapted with new information	Recovery response triggered; LoAC for process and/or element may need to be reviewed
	LoAC exceeded	Recovery response triggered; LoAC for process and/or element may need to be reviewed	Recovery response triggered; LoAC for process and/or element may need to be reviewed. Modify control program

Adaptive monitoring and evaluation

The following example explains how the LoAC monitoring approach (Figure 6; Table 7) is used to monitor the impact of grazing by kangaroos on natural vegetation.

The abundance (a property) of a number of natural plant species (relative to a set LoAC) is monitored at a number of sites in a vegetation element. At the same time grazing by kangaroos (a process) is monitored to ensure the density of kangaroos in the same area doesn't exceed 2 kangaroos/ha (a LoAC). If the kangaroos exceed the LoAC (more than 2/Ha) but the plant species abundance does not decline below the acceptable level, then several recovery responses are possible; the LoAC for kangaroo density per hectare could be increased, the LoAC for plant species abundance could be reviewed (in light of new information), or both LoAC left unchanged. If the LoAC for plant species abundance is exceeded (but not the process LoAC), and there is evidence that this is a direct response to kangaroo grazing, the control program will need to be modified (including the LoAC). If both the process and property LoAC are exceeded, the probable recovery response would be to modify the kangaroo control program. If the vegetation LoAC is exceeded but there is no evidence it is related to the kangaroos, other processes should be assessed. It is an implicit assumption of the framework that recovery responses are defined.

This section follows the framework outlined in Figure 6 and Table 7 outlining the recommended monitoring program separated out for the element properties, processes and values. However the various activities outlined below should be treated as part of a larger, more integrated approach. Where appropriate, the biological element property monitoring should be conducted concurrently and within the same spatial context as the process monitoring, so that any correlation between a change in process and element property can be investigated and, if deemed important, used to support management decisions.

The relationship between the properties of the biological elements and human values are not currently monitored, nor have any survey or monitoring approaches for the values been developed. It is therefore assumed that, until a monitoring protocol for the values is developed, a change in a property will reflect a change in value as predicted by the modelling described in Section 2.3 and Supporting Information Appendix 5.

Monitoring species composition

There are two major components to the data collection for properties. Firstly, detailed information (e.g. on composition) will provide a strong basis to rate the currently defined biological elements on their contribution to the key human values. As outlined in section 2.3, detailed biological information is required for each element to improve the current values and risk analyses. Secondly, monitoring change in properties (e.g. species richness) within the context of the management targets, LoAC, management triggers and the key risk factors is imperative, but may not require as detailed information as the values analyses. The accuracy of the assessment process would be significantly improved with better data on species composition, intactness, size, structure and rarity.

Recommended actions:

17. *Identify and assess patches of the 'Eucalypt Woodlands of the Western Australian Wheatbelt' in the catchment, and document eligible TEC occurrences under the EPBC Act.*
18. *Conduct a comprehensive survey[29] of species composition, intactness, size and structure of each currently defined biological element[30], and then update the values-delivery analysis.*

Given the variable nature of funding and availability of management resources, an approach to monitoring the properties of biological elements and processes that can be adapted to suit the available resources is required (e.g. variable level of detail, site number and/or sampling frequency). Although the focus of this section is monitoring, data can often have multiple uses and so it is noted where data collection for monitoring will provide additional information for future values-delivery analyses.

A low intensity monitoring approach (e.g. lower cost, less data collection and lower resource requirements) is initially recommended, such as photo-point and automatic camera-capture monitoring. Collected properly, photographic information will provide quantitative data on change in the abundance and reproductive status of the key individuals, allowing recovery responses to be triggered.

A more detailed monitoring program can then be instigated should additional resources become available, or if photo-point and camera-capture monitoring identifies additional monitoring or research requirements or proves to be inadequate. This may include vegetation quadrats and intensive fauna monitoring. Specific monitoring guidelines may become available for TECs and should be applied where resources permit. Also, detailed research to quantify relationships between properties of biological elements and processes (e.g. salt tolerances for key species) may be required.

The disadvantage of using the less intensive approach is that fewer species (and individuals) will be detectable for monitoring. Consequently, changes in the abundance of the undetected species may be missed, with the increased risk of missing critical triggers for management. Missing management triggers increases the risk of reducing the values associated with the biological elements.

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[29] In this plan, *surveying* is defined as an initial cataloguing or quantifying of property information (e.g. composition) or process state and *monitoring* as ongoing (over the management period) assessment of change in the initial catalogue. The survey information is critically important because the entire planning approach relies on identifying biological elements that, via key properties, deliver human value. This task is significantly undermined by poor and/or insufficient data. Additionally, robust monitoring of management targets (which determine the success of management) relies upon well-defined and appropriately quantified properties, such as natural species composition.

[30] The survey should include fungi and terrestrial invertebrates which were not defined as biological elements due to significant data deficiencies.

Monitoring elements

Vegetation

Randomly located photo-point monitoring sites have been established to collect information on the properties and processes for each vegetation element. Randomising site location is critical to avoid selection bias and improve causal inferences, better enabling information to be generalised to the entire element and to capture the overall impacts of the various threatening processes.

> *Provisional limits of acceptable change for vegetation elements*
>
> *For each vegetation element, the abundance (measured as per cent cover) of any key indicator natural species should decrease by no more than 25 per cent in no more than 25 per cent of monitoring sites (in relation to the initial reference estimates) during the management period.*

Specific software has been developed to facilitate the management of the photo-point data and the monitoring of LoAC (Supporting Information Appendix 18). Additionally, data from the photographs may allow other properties such as intactness to be quantified for future values-delivery analyses and will allow for the subjective assessment of aspects of the vegetation such as condition and reproduction.

Recommended action:

19. *Continue monitoring vegetation elements to define LoAC (property).*

Melaleuca strobophylla is a key indicator species for the management of altered hydrology in Toolibin Lake (Bell and Froend 1990). In 2013, a survey was undertaken to quantify the abundance of regenerating shrubs and both live and dead trees (Supporting Information Appendix 19). The survey found that *M. strobophylla* has regenerated in parts of the lake over the past two decades, providing some evidence that current management has been successful (although the exact causes of the patterns of regeneration are not known). The survey provides baseline vegetation data for measuring the effectiveness of management at Toolibin Lake. Ongoing monitoring of *M. strobophylla* will provide a measure of management effectiveness or indicate new emerging threats to the system. Monitoring of the other key TEC species, *Casuarina obesa*, would further aid in understanding the requirements of, and pressures on, this community.

Recommended actions:

20. *Further develop the monitoring plan for TEC species* Melaleuca strobophylla *to improve reporting of ecological community health.*
21. *Develop a monitoring plan for TEC species* Casuarina obesa*.*

Monitoring site at Dulbining Nature Reserve woodland
Photo – Maria Lee/DBCA

Waterbirds

Although waterbirds were not deemed to be under any major risk at a local scale, largely due to the recovery actions taken over the past 20 years, waterbirds are still an important element to deliver the priority values and contribute to the Ramsar status of Toolibin Lake. A recommended action is:

22. *When conditions are conducive, monitor (following the methodology of Halse et al. 2000) the indicator waterbird species listed in Table 3 at all natural lakes and wetlands in the management area.*

> *Limits of acceptable change for waterbirds*
>
> *When conditions are conducive across the lakes and wetlands all indicator species are recorded as present. (Section 2.4)*

Additionally, while indicator species are the focus for the management targets, an understanding of how the wetlands are used by all waterbird species can indicate the health of the wetlands and may influence the abundance of the indicator species due to interspecies interactions (e.g. competition for resources and habitat). Therefore it is also recommended to:

23. *Monitor all waterbird species, including counts of abundance and reproductive effort (e.g. number of nests, fledglings) where possible for Ramsar reporting.*

Other fauna

Mammals (other than bats)

Although fauna elements other than waterbirds were not included in the two priority biological element groupings in terms of their influence on delivering the key values, they still provide important philosophical/spiritual contentment and knowledge/heritage and education values, and are beneficial in terms of many of the lower ranked values. Information will be collected on several other mammal species incidentally via the process monitoring program.

The additional information will also inform future values analyses and has the potential to play an important role in the delivery of knowledge/heritage and education and philosophical/spiritual contentment values, especially if community involvement in the data collection is fostered and encouraged. These kinds of approaches can have a broad appeal to the community.

Recommended action:

24. *Assess the feasibility of mammal surveying and monitoring and, if acceptable, develop LoAC and a monitoring plan.*

Terrestrial birds, bats, reptiles and amphibians

There is an opportunity to survey terrestrial birds using standard techniques (e.g. point sampling approach; Gregory et al. 2005) at each of the established vegetation photo-monitoring points. Whilst a LoAC for terrestrial birds needs to be developed, collecting terrestrial bird abundance and species richness data that aligns with the property and process information collected for other elements will provide a better picture of ecosystem health and provide the basis for future values-delivery analyses.

Recommended action:

25. *Assess the feasibility of terrestrial bird surveying and monitoring and, if acceptable, develop LoAC and a monitoring plan.*

Like birds, bats (Marckmann and Runkel 2010, Miller 2010) and frogs (Littlejohn 1988) communicate acoustically with species-specific vocalisations that can be captured by automatic recording equipment. Given resource limitations and, in the case of frogs, the variable nature of their breeding habits (e.g. different species breed in different seasons and are differentially influenced by the availability of surface water), automatic call recording equipment can provide a practical approach to surveying and monitoring, providing estimates of species richness and relative abundance classes.

Recommended action:

26. *Assess the feasibility of bat, amphibian and reptile surveying and monitoring and, if acceptable, develop LoAC and a monitoring plan.*

Aquatic invertebrates

Aquatic invertebrates have an important role in several ecosystem processes (e.g. food availability for some waterbirds), and they are also important in terms of knowledge/heritage and education values. Therefore, at some point during the management period they may require survey and monitoring.

There are several accepted monitoring techniques for aquatic invertebrates that represent a trade-off between effort, precision, cost and effectiveness (Meyer et al. 2011). Consequently, the actual survey approach employed for aquatic invertebrates will be determined to some degree by resource availability. However, previous sampling results and methods (Halse et al. 2000, Doupe and Horwitz 1995) should be considered in the development of new monitoring protocols to ensure consistency and comparability of results. A survey and monitoring program should be developed primarily for Toolibin Lake, and secondarily components of the aquatic invertebrate element for Dulbining (1, 2 & 3) and Walbyring wetlands. Surveying aquatic invertebrates of key wetlands will provide important information on species richness and abundance to be used in future values-delivery analyses.

An investigation to determine whether appropriate indicator species could be sampled and reared from sediment egg banks (Aquatic Research Laboratory 2009) should be considered. This would alleviate the need for water to be present in the wetlands for monitoring, enabling standardised, scheduled sampling throughout the year/seasons rather than reactive monitoring that is dependent on wetland conditions. However, the approach will rely upon appropriate and amenable species being present as well as there being facilities within which to rear eggs and larvae.

Recommended action:

27. *Assess the feasibility of aquatic invertebrate surveying and monitoring and, if acceptable, develop LoAC and a monitoring plan.*

Monitoring key threatening processes

Altered hydrology

A considerable amount of effort and resources have been dedicated towards monitoring and managing Toolibin Lake and its catchment over the past 40 years. Many management actions require decades to show their full impact, therefore it is important to maintain surface water and groundwater monitoring regimes to understand how these recovery actions are achieving management targets.

The current preliminary guidelines to manage the diversion infrastructure at Toolibin Lake are detailed in Drake et al. (2012) and Supporting Information Appendix 15. Muirden and Coleman (2014) put forward a number of management and monitoring options, listed in Supporting Information Appendix 14. These require assessment using the conceptual and numerical model (when available) to evaluate the expected benefits of implementation of these options.

Groundwater levels are likely to be close to the surface in Walbyring Lake and the three Dulbining wetlands. There is currently no infrastructure to actively measure groundwater, or to manage both groundwater and surface water, in these wetland systems.

A monitoring program has been developed to measure water quality and species richness of the associated biological elements, based around the current understanding of LoAC. The LoAC (which relate to changes in species abundance), once exceeded, triggers a management response. In the short term, and assuming full operation of the available infrastructure, the only adjustable management triggers are the operation of the groundwater pumps, the diversion gate and the sump pump at Toolibin Lake. Longer term actions need to be adaptive as knowledge of LoACs improve.

> *Limits of acceptable change for altered hydrology at Toolibin Lake (provisional pending the outcomes of hydrological model)*
>
> 1) *Groundwater should be at a minimum of 2 mbgl when the wetland is dry, but preferably at a minimum of 4 mbgl.*
> 2) *The salinity of surface water entering into Toolibin Lake should not exceed 2000 µS/cm@25°C at the diversion gate. However, inflow salinities could be relaxed to higher EC values (cf. Walshe et al. 2007) if the groundwater is 4 mbgl or lower.*
> 3) *Salt concentration should be monitored in the surface water and shallow ground water. At 2.5 mbgl root zone salinity is controlled by shallow groundwater salinity and so ground water levels should be kept below this threshold.*
> 4) *Water should never be forced into the lake when groundwater level is < 2.5 mbgl.*
> 5) *If groundwater is 4 mbgl, the surface water should not be in the lake for more than seven months. The pump takes four months to empty a full lake without additional water input. If groundwater is less than 4 mbgl[31] when the lake begins to fill, the sump pump should be turned on immediately as per management guidelines.*

Recommended actions:

28. *Continue current hydrological management and monitoring regime.*
29. *Utilise the hydrological model to develop predictive scenarios that can be developed to refine LoAC for altered hydrology (process).*

Problem species

i. Weeds

A weed monitoring program will help to determine which weed species are most likely to affect management targets (i.e. cause loss of natural species) and require control or eradication. Monitoring will focus primarily on perennial weed species, as the abundance of annual weeds tends to fluctuate with prevailing season rainfall.

[31] The ground water below Toolibin Lake will be heterogeneous in depth and so an average of 4 mbgl should be used.

Provisional limits of acceptable change for weeds

1) *For each vegetation element, the abundance (measured as per cent cover) of any extant and key introduced weed species should not increase by more than 25 per cent in more than 25 per cent of monitoring sites over the management period.*

Current control efforts and LoAC should be adapted as appropriate.

Recommended action:

30. *Continue with monitoring program to define LoAC for weeds (process).*

ii. Grazing animals (kangaroos and rabbits)

The monitoring program will help to determine which species are most likely to affect management targets (i.e. cause loss of natural species) and require control.

Recommended action:

31. *Continue monitoring and observation to define LoAC for grazing (process) by rabbits and kangaroos.*

iii. Disease

Investigation of mortality of plant genera known to be susceptible to *Phytophthora* (Supporting Information Appendix 20) within the vegetation elements should be undertaken in accordance with appropriate SOP's (i.e. Dieback Working Group and Threatened Species Network, 2008) as a priority. If *Phytophthora* or any other disease is confirmed within the vegetation elements, it will require mapping and monitoring and other management action as appropriate.

Limits of acceptable change for disease

Mortality in any dieback-susceptible species detected in vegetation elements should trigger management action.

Recommended actions:

32. *Continue with monitoring program to define LoAC for disease (process) and implement a monitoring plan for* Phytophthora *infestations.*
33. *Continue with monitoring program to define LoAC for other disease (process) and implement a monitoring plan for other diseases as required.*

Monitoring values

To measure the success of recovery activities, the extent to which the human values are being derived from the biological elements must also be assessed. This requires quantifying who is making use of the elements in the catchment and why.

What to measure?

Wallace et al. (2016) and Smith et al. (2016) respectively have developed updated stakeholder values elicitation and property-values elicitation approaches. These approaches can be used to reassess stakeholder value preferences and to set these as a new benchmark for subsequent assessments to monitor value changes.

i. Knowledge/heritage and education

Acceptable and measurable indicators of the knowledge/heritage and education value include:

- Applicable visitation rates by individuals, educational institutions, cultural groups and interest groups. This could be measured through appropriately designed surveys (paper and/or online).
- Production and dissemination rates of research and other information sources.

Ecophysiology experiment on plant water use at Toolibin Lake
Photo – Ray McKnight/DBCA

ii. Philosophical/spiritual contentment

Acceptable and measurable indicators of the philosophical/spiritual contentment value include:

- Applicable visitation rates by individuals, educational institutions, cultural groups and interest groups. This could be measured through appropriately designed surveys (paper and/or online).
- Other social surveys focused on specific stakeholder groups. This could be achieved through collaboration with tertiary institutions.

iii. Productive use

Measuring the delivery of the productive use value is particularly difficult. It is clear that salinity threatens the productivity of surrounding farmland, and the productive value of the 'mid-slope' agricultural land is particularly high when compared to the lower slope areas (A. Abadi pers. comm.) Thus, a key area of assessment of productive use relates to the management of altered hydrology and the likelihood of increased spread of salinity. It may be possible to analyse productive trends to identify areas of reduced production as the impetus to increase the use of perennials on those sites. Less productive sites could also be forgone to another land-use activity such as vegetation establishment for landcare or grazing. Additionally, given the importance of knowledge/heritage and education, it is recommended to:

34. *Continue with current tools of communication and formalise the communication plan for audiences (including written, spoken and electronic*

interaction).

35. *Consult with stakeholders midway through the term of the management plan to evaluate values and management outcomes.*

Management of data and statistical analysis

Appropriate collection, management and use of data are critical to effectively manage the biological elements and to assess target status. Data needs to be properly collected, housed and quality assured, and the amount of data collected should reflect the capacity of the organisation(s) to manage, use and disseminate it. Additionally, the data must be readily available, easily accessible and accompanied by appropriate metadata. The management of data relating to the catchment's hydrology is particularly important given its cost and volume.

Monitoring the status of management targets requires timely analysis of available data to inform the need for recovery response. Data management requires appropriate training for the responsible officers and should be organised and documented to ensure consistency and allow easy handover for staffing changes over time. Staff may also need training in database development and management.

Methods for data collection and analysis must be articulated clearly and followed consistently. If consultants are engaged to conduct data collection, analysis and/or reporting, they must be given and adhere to clear guidelines. The time investment required for correct data collection, analysis and management is routinely underestimated, to the detriment of entire programs. When making decisions about which data to collect, the realistic cost in time and resources must be taken into consideration.

Recommended actions:

36. *Develop standard operating procedures for recovery activities for consistency, training and for review and reporting on the recovery plan.*
37. *Continue managing all data and engage appropriate new technologies to further manage and disseminate data.*
38. *Manage historical and current records as evidence of government accountability and information for planning, analyses, decision-making and reviewing.*

Reporting and review

In addition to the required departmental budget and activity reporting, reporting activities should include:

1) Annual summaries of monitoring activities and results. It is important that the summaries are produced within the context of meeting the management targets.
2) Annual summaries of other recovery activities relating to the recommendations. Reporting should include a description of activities and resultant benefits in terms of the management targets. Reports should include assessments of potential activities that were deemed unfeasible (both in terms of funding and capacity) or unnecessary.
3) Ramsar reporting will be required every six years.

4) Continued reporting on TECs, for the department's annual report, and to funding bodies (where applicable) on the status of the Toolibin Lake catchment.
5) Reporting to the recovery team annually.

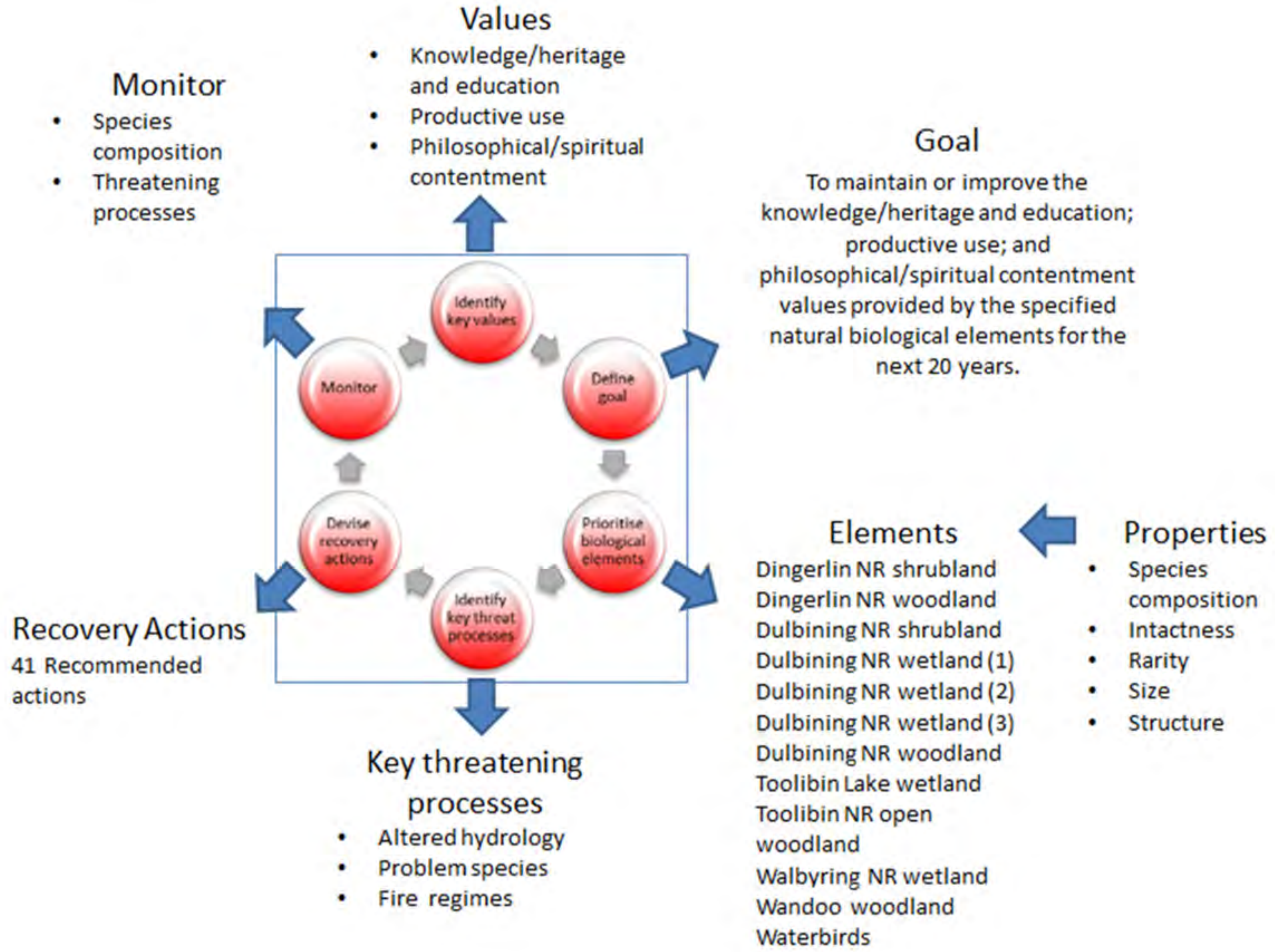
Recommended actions:

39. *Continue with annual reporting to recovery team, stakeholders and management.*
40. *Develop five-year works plan to provide a clear and temporally complete record of management activities.*

It is necessary to review this recovery plan to improve decision-making, enhance organisational learning and document achievement of targets for biological elements, and thus progress to achieving the plan's goal.

41. *Review recommended actions prior to development of the five-year works plan.*

3. Relationship map



4. Summary of management targets and limits of acceptable change for priority biological elements (property)

Element		Monitoring parameters	Management target	Biophysical limit	LoAC
Group 1	Toolibin Lake wetland	(a) Photo-point monitoring	To minimise the decline in the size (area occupied) and abundance of *Casuarina obesa* and *Melaleuca strobophylla* and to maintain the species composition of the priority biological element over the management period	(Initial biophysical limit) Acceptable variation in the abundance of individual species (e.g. with ecological succession and seasonality and within LoAC)	For each vegetation element, the abundance (or % cover) of any key indicator natural species should decrease by no more than 25% in no more than 25% of monitoring sites (in relation to the initial reference estimates) during the management period.
Group 2	Waterbirds	(a) Indicator waterbird monitoring (b) All waterbird species monitoring	To maintain the following species listed over the management period: Australian shelduck (*Tadorna tadorniodes*), pink-eared duck (*Malacorhynchus membranaceus*), grey teal (*Anas gracilis*), freckled duck (*Strictonetta naevosa*), black-winged stilt (*Himantopus himantopus*) and Eurasian coot (*Fulica atra*)	When the seasonal conditions are conducive (e.g. wetland and lake surface water ≈2.0m in the deepest sections and reasonably fresh [e.g. lower than 2000 µS/cm@25°C]), the indicator waterbird species should occur in numbers comparable to those from previous surveys and there should be evidence of successful breeding (e.g. fledglings) in some of the indicator species.	When conditions are conducive across the lakes and wetlands all indicator species are recorded as present.
	All vegetation biological elements for the nature reserves and wetlands	Photo-point monitoring	To maintain the species composition that is characteristic of the priority biological elements over the management period; and	(Initial biophysical limit) Acceptable variation in the abundance of individual species (e.g. with ecological succession and seasonality and within LoAC)	For each vegetation element, the abundance (or % cover) of any key indicator natural species should decrease by no more than 25% in no

Element		Monitoring parameters	Management target	Biophysical limit	LoAC
			minimal decline in the extent and degree of lake bed vegetation		more than 25% of monitoring sites (in relation to the initial reference estimates) during the management period.
Group 3	Wandoo woodland	Photo-point monitoring	To maintain the species composition that is characteristic of the priority biological element over the management period	(Initial biophysical limit) Acceptable variation in the abundance of individual species (e.g. with ecological succession and seasonality and within LoAC)	For each vegetation element, the abundance (or % cover) of any key indicator natural species should decrease by no more than 25% in no more than 25% of monitoring sites (in relation to the initial reference estimates) over the management period.
	Mammals (other than bats)	Assess the feasibility of mammal surveying and monitoring and, if acceptable, develop LoAC and a monitoring plan			
	Terrestrial birds, bats, reptiles and amphibians	Assess the feasibility of terrestrial bird, bat, amphibian and reptile surveying and monitoring and, if acceptable, develop LoAC and a monitoring plan			
	Aquatic invertebrates	Assess the feasibility of aquatic invertebrate surveying and monitoring and, if acceptable, develop LoAC and a monitoring plan			

5. Summary of limits of acceptable change for key threatening processes

Key threatening process	Monitoring parameters	Limits of acceptable change
Altered hydrology	Groundwater monitoring Surface water monitoring Ephemeral flow monitoring (volume, quality and lake levels)	Provisional pending the outcomes of hydrological model. 1) Groundwater should be at a minimum of 2 mbgl when the wetland is dry, but preferably at a minimum of 4 mbgl. Monitoring this reliably would require installation of additional shallow bores. 2) The salinity of surface water entering into Toolibin Lake should not exceed 2000 µS/cm@25°C at the diversion gate. However, inflow salinities could be relaxed to higher EC values (cf. Walshe et al. 2007) if the groundwater is 4 mbgl or lower. 3) Salt concentration should be monitored in the surface water and shallow ground water. At 2.5 mbgl root zone salinity is controlled by shallow groundwater salinity and so groundwater levels should be kept below this threshold. 4) Water should never be forced into the lake when groundwater level is < 2.5 mbgl. 5) If groundwater is 4 mbgl, the surface water should not be in the lake for more than 7 months. The pump takes 4 months to empty a full lake without additional water input. If groundwater is less than 4 mbgl when the lake begins to fill, the sump pump should be turned on immediately.
Weeds	Photo-point monitoring	Provisional pending the outcome of monitoring review. For each vegetation element, the abundance (or % cover) of any extant and key introduced weed species should not increase by more than 25% in more than 25% of monitoring sites over the management period.
Grazing	Photo-point monitoring	To be identified

Key threatening process	Monitoring parameters	Limits of acceptable change
Disease	Photo-point monitoring	Mortality in any dieback-susceptible species detected in biological vegetation elements should trigger management action.
Altered fire regimes	To be identified	To be identified

6. Summary of recommended recovery actions

It is anticipated that undertaking the recommended management actions outlined in this plan will result in the various biological elements persisting throughout the management period in such a way that the important human values continue to be delivered and thus achieve the main goal of this recovery plan. The monitoring program should enable important changes to be identified and understood in a timely manner, such that appropriate management responses can be devised and implemented. Importantly, there is also considerable scope to improve the values of the biological elements over the management period and this should be an additional goal for the recovery catchment.

The recommended actions are:

1. *Conduct a risk factor analysis for all element-risk factor combinations for Dingerlin Nature Reserve.*
2. *Develop a quantitative conceptual model that details how and when water and salt moves.*
3. *Construct numerical models of groundwater and surface water, focusing on department-managed estate, which will be used to apply management levers and develop monitoring programs.*
4. *Maintain and where feasible improve current hydrological infrastructure.*
5. *Rationalise and/or improve groundwater pumping program based on the results of the hydrological numerical model.*
6. *Optimise management of the affected biological elements, through development of refined diversion gate and pump management guidelines informed by analysis of monitoring data and modelling results.*
7. *Develop a revegetation plan for the catchment to primarily address altered hydrology processes, to facilitate other aspects of wildlife management and to meet other human values.*
8. *Continue with current weed management priorities.*
9. *Develop and implement a weed plan to identify and prioritise ongoing weed management.*
10. *Continue with pest management for kangaroos and rabbits.*
11. *Define the LoAC for elements susceptible to overgrazing (process), and identify the abundance or density of rabbits and kangaroos that is consistent with maintaining the properties of the biological elements within their LoAC.*
12. *Undertake dieback* (P. cinnamomi) *interpretation of Dingerlin Nature Reserve shrubland and Toolibin Nature Reserve woodland.*
13. *Continue with hygiene management.*
14. *Investigate evidence of* Phytophthora *expression in susceptible genera.*

15. *Monitor and investigate deaths or decline in vegetation elements that may be attributed to other diseases.*
16. *Develop and implement a fire management plan to address:*
    (ii) protection of infrastructure
    (ii) protection and maintenance of biological elements.
17. *Identify and assess patches of the 'Eucalypt Woodlands of the Western Australian Wheatbelt' in the catchment, and document eligible TEC occurrences under the EPBC Act.*
18. *Conduct a comprehensive survey of species composition, intactness, size and structure of each currently defined biological element, and then update the values-delivery analysis.*
19. *Continue monitoring vegetation elements to define LoAC (property).*
20. *Further develop the monitoring plan for TEC species* Melaleuca strobophylla *to improve reporting of community health.*
21. *Develop a monitoring plan for TEC species* Casuarina obesa*.*
22. *When conditions are conducive, monitor (following the methodology of Halse et al. 2000) the indicator waterbird species listed in Table 3 at all natural lakes and wetlands in the management area.*
23. *Monitor all waterbird species, including counts of abundance and reproductive effort (e.g. number of nests, fledglings) where possible for Ramsar reporting.*
24. *Assess the feasibility of mammal surveying and monitoring and, if acceptable, develop LoAC and a monitoring plan.*
25. *Assess the feasibility of terrestrial bird surveying and monitoring and, if acceptable, develop LoAC and a monitoring plan.*
26. *Assess the feasibility of bat, amphibian and reptile surveying and monitoring and, if acceptable, develop LoAC and a monitoring plan.*
27. *Assess the feasibility of aquatic invertebrate surveying and monitoring and, if acceptable, develop LoAC and a monitoring plan.*
28. *Continue current hydrological management and monitoring regime.*
29. *Utilise the model to develop predictive scenarios that can be developed to refine LoAC for altered hydrology (process).*
30. *Continue with monitoring program to define LoAC for weeds (process).*
31. *Continue monitoring and observation to define LoAC for grazing (process) by rabbits and kangaroos.*
32. *Continue with monitoring program to define LoAC for disease (process) and implement a monitoring plan for* Phytophthora *infestations.*
33. *Continue with monitoring program to define LoAC for other disease (process)*

and implement a monitoring plan for other diseases as required.

34. *Continue with current tools of communication and formalise the communication plan for audiences (including written, spoken and electronic interaction).*
35. *Consult with stakeholders midway through the term of the management plan to evaluate values and management outcomes.*
36. *Develop standard operating procedures for recovery activities for consistency, training and for review and reporting on the recovery plan.*
37. *Continue managing all data and engage appropriate new technologies to further manage and disseminate data.*
38. *Manage historical and current records as evidence of government accountability and information for planning, decision-making and reviewing.*
39. *Continue with annual reporting to recovery team, stakeholders and management.*
40. *Develop five-year works plan to provide a clear and temporally complete record of management activities.*
41. *Review recommended actions prior to development of the five-year works plan.*

7. Glossary

Automatic camera-capture monitoring: a specialised monitoring technique that uses purpose-built camera systems that detect heat and movement to capture photographs or video of animals. These images can be used to develop indices of activity, occupancy or abundance of animals, and detect changes or trends through time.

Benefit analysis: a systematic process for calculating and comparing benefits of a series of recovery options (or activities).

Biological element: any individual or groups of natural biota that provide human value. The elements are the things we want to remain in place over the management period and they have been assigned a spatial boundary.

Expert: a person who has skills, experiences, education, training or knowledge concerning the issues to be discussed or resolved (adapted from Burgman 2005).

Fill event: where a perceptible volume of water has entered the lake (usually implying surface flows).

Human values: any important penultimate state, such as health and recreation, that contributes to human well-being (Wallace 2012).

Intactness: the property of being sound, flawless, entire (adapted from OED). Scholes and Biggs (2005, page 45) describe their biodiversity intactness index as 'an indicator of the average abundance of a large and diverse set of organisms in a given geographical area, relative to their reference population'.

Limits of acceptable change (LoAC): a predetermined amount of change that can occur in a monitored property. Change that exceeds the limits of acceptable change will trigger a recovery response.

Management target: a target used to assess the risk that a process will cause goal failure. In the plan, the management targets are set around an unacceptable loss of a property over the 20-year management period.

Management triggers: An event that is the cause of a particular action, process or situation, which lies inside the boundaries of acceptable change and are intended to provide an early alert so that an adaptive management response can be implemented if required, prior to the limits of acceptable change being reached.

Natural biota: any living organism that is considered indigenous to the catchment.

Natural diversity recovery catchment (NDRC): the NDRC program was developed under the Western Australian Salinity Action Plan (Government of Western Australia 1996). The objective was to develop and implement a coordinated program targeting at least six key catchments over 10 years to ensure that critical and regionally significant natural areas, particularly wetlands, are protected in perpetuity.

Photo-point monitoring: a technique used to record and monitor change in the natural environment over time. It involves taking a series of images of a fixed area at regular time intervals, which can then be used to measure change at a given location.

Problem species: any species that poses a significant threat to meeting the management targets over the 20-year management period.

Processes: the physical, chemical and biological actions or events that link organisms and their environment (Source: GreenFacts).

Properties: attributes that can be used to describe biological elements (Wallace 2012).

Property-values analysis: a five-step approach to classify and rate the human values expected from the biological elements.

Ramsar: the Convention on Wetlands of International Importance, called the Ramsar Convention, is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.

Rarity: scarcity in numbers of a community with respect to a given geographic boundary; and any formal listing as a conservation concern within the context of the South-West Land Division.

Serotinous obligate seeder: a plant species that is killed by fire, and can only regenerate from seeds stored in woody capsules (cones) in the canopy. Many species require the heat from a fire to release the seeds from the capsules, particularly members of Proteaceae family such as *Banksia* and *Hakea*.

Size: the size of a biological element, in particular the area occupied (in hectares) was used as a property. Generally, the larger the area occupied by a biological element, the greater will be its expected contribution to particular human values.

Southwest Biodiversity hotspot: An area internationally recognised for its high diversity of endemic species that are not found or are rarely found outside the hotspot. Hotspots are characterised by containing at least 1500 endemic vascular plant species and have lost at least 70 per cent of their original habitat. The south-west of Australia is recognised as one of 36 international biodiversity hotspots.

Species abundance: the relative representation of a species within a biological element, usually measured by the number of individuals within a sample. It can also be measured as a relative abundance against all other species within the biological element.

Species composition: the richness and abundances of the organisms that make up a biological element.

Species richness: the number of different types (i.e. species) of organisms that make up a biological element.

Stakeholder representatives from community, government and non-government groups: a stakeholder is any person who has an interest in, is affected by, or can affect, the management of the biological elements in the given management area (based on Reed 2008). Planning is often undertaken on behalf of an agency, which typically represents a community (a city, province, state, country) and engagement will often focus on representatives of key communities of interest as defined by Harrington et al. (2008). In the management of conservation lands, communities of locality (e.g. local and regional government) and communities of practice (e.g. conservation groups and agencies, land-user groups and agencies, education bodies) will generally be important.

Standard operating procedure (SOP): a set of standardised step-by-step instructions to achieve a predictable, desired result. An SOP requires continual updating and regular review.

Structure: the three-dimensional distribution of all biological elements present (i.e. the spatial distribution of a given composition including height and canopy cover of vegetation, population age structure, presence of different life stages, etc.). Structure includes both natural and introduced species. Linkages between structure and values have been demonstrated (Nassauer 1995). For the Toolibin Lake catchment, the means of quantifying structure in relation to values requires further investigation before it can be applied.

Technical advisory group (TAG): a group of experts with the relevant skills, experiences, education, training or knowledge concerning the issues to be discussed or resolved. The terms of reference now refer to this as technical specialist advice (TSA).

Threatened ecological community (TEC): an ecological community that is a naturally occurring group of plants, animals and other organisms interacting in a unique habitat. The Western Australian Minister for Environment may list an ecological community as being threatened if the community is presumed to be totally destroyed or at risk of becoming totally destroyed. Some Western Australian communities are also listed under federal legislation, the *Environment Protection and Biodiversity Conservation Act 1999*.

Threatening processes: any process that threatens the delivery of the human values by the biological elements. In the plan, significant processes were those thought to have a risk of more than five per cent of causing the associated management target to not be met.

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