Toolibin Lake Catchment Recovery Plan 2015–35
Supporting Information

GOVERNMENT OF WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

PARKS AND WILDLIFE SERVICE

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Note

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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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Contents

Appendix 1. The Natural Diversity Recovery Catchment program 1

1.1. Background 1

1.2. Priority setting for salinity actions 1

Appendix 2. The Toolibin Lake Catchment 4

1.1. Planning area 4

1.2. Catchment overview 4

1.3. Climate 5

1.4. Social and economic characteristics 5

1.5. Historical background 5

Appendix 3. Terms of reference for the recovery team and technical specialist advice 7

3.1. Background 7

3.2. Role and composition of the Toolibin Lake catchment recovery team 8

3.3. Membership of the recovery team 8

3.4. Technical advisory group and technical specialist advice 10

3.5. Recovery team operating procedures 11

Appendix 4. Toolibin Lake catchment values ranking procedure 12

4.1. Introduction 12

4.2. Classification of values 12

4.3. Methods 12

Identification and involvement of stakeholders 12

Elicitation 12

4.4. Results and discussion 14

Appendix 5. Estimating the importance of values derived from biological elements 18

5.1. Introduction 18

5.2. Methods 20

Five steps to linking biological elements to human values 20

5.3. Results 26

Application of the approach 26

Summary of the model outcomes 28

5.4. Discussion *30*

Appendix 6. Description of the 2013 biological elements 33

6.1. Introduction *33*

6.2. Vegetation elements *33*

6.3. Waterbirds *42*

6.4. Terrestrial birds *46*

6.5. Aquatic invertebrates *48*

6.6. Natural mammals, reptiles and amphibians *52*

6.7. Conservation codes for WA flora and fauna *54*

Specially protected under Schedules 1 to 4 of the *Wildlife Conservation Act 1950* 54

Rankings 54

Priority Flora and Priority Fauna Lists rankings 55

Appendix 7. Identification of the biological elements for Toolibin Lake catchment 57

Appendix 8. Quantifying the properties 59

8.1. Richness *59*

8.2. Rarity *59*

8.3. Size *59*

8.4. Intactness *60*

Appendix 9. Expert assessment of value of the biological elements 62

9.1. Introduction *62*

9.2. Workshop description *62*

9.3. Results *62*

Appendix 10. Risk factor analysis 67

10.1. Description of the risk factor analysis *67*

10.2. Brief summary of key risk factors *67*

Altered hydrology 67

Disease, especially relating to *Phytophthora* spp. outbreak 67

Fire management 67

Lack of light 68

Appendix 11. Weed species 79

Appendix 12. Fire-sensitive plant species 81

Appendix 13. Benefit analysis 82

13.1. Introduction 82

13.2. Methods 82

13.3. Results 86

13.4. Discussion 89

Appendix 14. Surface water flow actions and monitoring 91

14.1. Surface water flow actions and monitoring to investigate when conceptual model complete 91

14.2. Monitoring 91

Appendix 15. Management guidelines for the hydrological infrastructure 94

Appendix 16. Standard operating procedures for groundwater monitoring 96

Appendix 17. Standard operating procedures for – ephemeral (fill) event 101

Appendix 18. Monitoring of vegetation elements 106

18.1. Methods 106

Establishment of a photo-point monitoring site 106

Photo-point monitoring steps 110

Analysis steps 112

Site selection and frequency of monitoring 112

Data software and recording process 112

Data management 116

Appendix 19. Monitoring protocol for *Melaleuca strobophylla* 117

19.1. Background 117

19.2. Methodology used to generate distribution maps for Toolibin Lake 117

Appendix 20. Plant genera with species known to be affected by *Phytophthora* species 122

References.. 123

Personal communication 129

Figures

Figure 1: Management hierarchy for Toolibin Lake catchment recovery actions 9

Figure 2: Simplified visual characterisation of several key planning terms and their relationship to each other 19

Figure 3: Comparison of the estimated value of each biological element by the property-value model and by directly elicited estimates from a technical advisory group 29

Figure 4: Example used to train the experts to rank the importance of each biological element with respect to the key values 64

Figure 5: Example of the interval agreement approach for three source intervals (e.g. from three experts) 64

Figure 6: Aggregated estimates of the knowledge/heritage and education value of each biological element 65

Figure 7: Aggregated estimates of the productive use value of each biological element 65

Figure 8: Aggregated estimates of the philosophical/spiritual contentment value of each biological element 66

Figure 9: Example of the predicted change in overall value utility for a vegetation element as a function of species richness 85

Figure 10: Expected relationship between species richness and utility for each priority biological element 87

Figure 11: Aerial view of the camera and star picket set up 111

Figure 12: Example of a monitoring photograph 111

Figure 13: Photo-point monitoring software front page 113

Figure 14: Reference sheet form 114

Figure 15: Compare sheet 115

Figure 16: Summary statistic page 116

Figure 17: Areas of Toolibin Lake where live (black) and dead (grey) Melaleuca strobophylla were mapped in 2013 (left map) and areas of Toolibin Lake where regenerating M. strobophylla was mapped in 2013 (right). 118

Figure 18: Different classes of M. strobophylla 120

Figure 19: Explanation of the methodological approach to map M. strobophylla 121

Tables

Table 1: Selection criteria for recovery catchments ... 3

Table 2: Overview of the Toolibin Lake catchment planning area ... 4

Table 3: Stakeholder representative group ... 10

Table 4: Values from natural biota – Toolibin Lake catchment ... 15

Table 5: Relevant stakeholder groups and their responsibilities for the Toolibin Lake catchment ... 17

Table 6: Stakeholder ranking of the values from their stakeholder perspective ... 17

Table 7: Stakeholder ranking of the values from their personal perspective ... 17

Table 8: Some generally important properties of biota in terms of their human value ... 23

Table 9: The four properties of the biological elements used in the value-delivery analysis ... 24

Table 10: Species of flora that have, at some point, been listed as occurring in eight vegetation elements ... 35

Table 11: Waterbirds observed at Toolibin Lake from 1965 to 2011 ... 42

Table 12: Resident and non-resident terrestrial birds in the management area ... 46

Table 13: Aquatic invertebrate species ... 48

Table 14: Natural mammal species known or likely to occur in the catchment ... 52

Table 15: Natural reptile species known or likely to occur in the catchment ... 53

Table 16: Natural amphibian species known or likely to occur in the catchment ... 53

Table 17: Property data for each biological element ... 61

Table 18: Summary based on centroid values for experts' ratings of value delivery by biological element ... 63

Table 19: Proximal risks that may cause goal failure in the Toolibin Lake catchment ... 68

Table 20: Results and qualifying comments from the 'simpler' analysis ... 69

Table 21: Weed species ... 79

Table 22: Indicator plant species ... 81

Table 23: Management options relating to addressing the key threatening processes ... 84

Table 24: Biological element level benefit expected for each management option ... 88

Table 25: Overall expected benefit for each management option ... 88

Table 26: Recommended high priority surface water monitoring sites 91

Table 27: Recommended moderate priority surface water monitoring sites 92

Table 28: Recommended 'snapshot' sites for surface water monitoring................................. 92

Table 29: Photo-point monitoring sites.. 107

Table 30: Plant genera with species known to be affected by Phytophthora species 122

Appendix 1. The Natural Diversity Recovery Catchment program

1.1. Background

The Natural Diversity Recovery Catchment (NDRC) program was developed in 1996 under the *Western Australian Salinity Action Plan* (Government of Western Australia 1996) with the following objective:

> *To develop and implement a coordinated Wetlands and Natural Diversity Recovery Program targeting at least six key catchments over the next 10 years to ensure that critical and regionally significant natural areas, particularly wetlands, are protected in perpetuity*

Through the NDRC program, government and community collaboratively focus their actions to manage the impact of salinity on natural biota in the south-west agricultural region. In designated catchments, the program aims to conserve representative biological communities and their related physical diversity, together known as 'natural diversity'.[1] At the catchment scale, the focus of the program has been on selecting biological elements that represent the range of biological diversity threatened by salinity.

1.2. Priority setting for salinity actions

To guide resource allocation to protect high value biological elements threatened by salinity, the WA State Salinity Council commissioned the development of the Salinity Investment Framework in 2000. This study recognised that given the extent and consequences of salinity and the very high cost of management it is crucial for governments to have a rigorous framework for ranking salinity investments. Two reports describe the recommended approach to priority setting: *Salinity Investment Framework: Interim Report Phase I* (Department of Environment 2003) and *Salinity Investment Framework Phase II* (Sparks et al. 2006). The elements evaluated were: native biota, agricultural land, water resources, rural infrastructure and social amenities.

In 1996, three NDRCs were established under the *Western Australian Salinity Action Plan* (Wallace et al. 2011). These were Toolibin Lake, Lake Warden and the Muir-Unicup Wetland Complex. A further three NDRCs have been established since the inception of the program: Lake Bryde, Buntine-Marchagee and Drummond.

The first three NDRCs were selected prior to the completion of the Wheatbelt biological survey (Keighery et al. 2004). It was deemed important to identify and begin

1 This document is concerned with the conservation of natural biological diversity rather than domesticated species and other biological diversity arising from human actions.

to manage areas where biota values were high and coincided with significant threats from altered hydrology, particularly salinity. The preliminary results of the Wheatbelt biological survey (Keighery et al. 2004) informed the later selection of the Lake Bryde, Buntine-Marchagee and Drummond NDRCs.

The following criteria were developed for identifying recovery catchments (Table 1):

- biological values at risk from altered hydrology
- biogeographic representation
- opportunities for research and development or demonstration
- tenure of land at risk
- representation of hazard
- potential for success (note that local community support was an important element assessed in this regard)
- socio-political considerations.

An analysis using data generated by the Wheatbelt biological survey (Keighery et al. 2004) was used to determine which other areas of the Wheatbelt might best complement the existing NDRCs (Walshe et al. 2004). This information, along with the results from the Salinity Investment Framework, were used to select potential recovery catchments for the future.

Table 1: Selection criteria for recovery catchments

Criterion	Comment
Biological diversity values at risk	This is the primary criterion for selecting recovery catchments for natural diversity. Recovery catchments will contain very high nature conservation values at risk. The assessment of catchments will involve the following attributes: ○ how representative the catchment biota is of important natural communities ○ presence of threatened communities and species ○ species and community richness ○ whether the catchment provides an important biological corridor (e.g. connecting Lake Magenta Nature Reserve and Fitzgerald River National Park), or other significant ecological service ○ international or national significance of the area (e.g. Ramsar Convention, Directory of Important Wetlands in Australia).
Biogeographic representation	It is desirable to have recovery catchments that represent a range of situations. For example, as many IBRA regions as practicable will be represented, consistent with other criteria.
Opportunities for research and development or demonstration sites	Research and development or demonstration sites, particularly those with state, national or international significance, might include special management techniques for: ○ nature conservation ○ farm economics ○ cultural change or improved social interaction ○ landcare.
Tenure of land at risk	While conservation lands that are the focus of recovery catchments for natural diversity should be vested with the Conservation and Parks Commission, the department may consider for selection as recovery catchments other land tenures if they are sufficiently important for nature conservation and threatened by salinity.
Representation of hazard	The greater the hazard to an important site, the greater the urgency for action. However, recovery catchments that will be selected will represent a range of hazard situations including those that are threatened in the longer term by salinity, but are at present in good condition.
Potential for success	In the main, catchments that are likely to lead to recovery success will be selected. This will involve, for example, taking into consideration: ○ 'physics' of pressure (e.g. is hydrological pressure overwhelming?) ○ area of catchment (bigger catchments are generally more difficult to recover) ○ degree of threat ○ level of landcare community support, knowledge and enthusiasm ○ potential to use prospective commercial species in revegetation ○ current area and distribution of remnant vegetation (the more the better).
Socio-political considerations	There will be demands from a plethora of sociopolitical stakeholder groups ranging from catchment groups to federal agencies and politicians that will need to be taken into consideration.

Appendix 2. The Toolibin Lake Catchment

2.1. Planning area

The Toolibin Lake catchment is located largely in the Shire of Wickepin with a small area of the catchment extending into the Shire of Narrogin. Table 2 provides an overview of the Toolibin Lake catchment planning area including land tenure composition.

Table 2: Overview of the Toolibin Lake catchment planning area

Land classification	Organisation
Local government shires	Shire of Wickepin Shire of Narrogin
DBCA administrative region	Department of Biodiversity, Conservation and Attractions Wheatbelt Region
Land tenure	Freehold (94%) DPaW-managed land (3%) Other tenure (3%)

Note: Percentages shown are the proportion of the catchment in a particular administrative region.

2.2. Catchment overview

The Toolibin Lake catchment covers an area of 48,977 hectares and is located approximately 180km south-east of Perth, with the northern boundary of the catchment 3km south of the Wheatbelt town of Wickepin. The town of Narrogin is located approximately 40km west of the catchment. The catchment spans about 19km from north to south and 40km from east to west. The Toolibin Lake catchment is comprised of multiple sub-catchments and is within the Avon Wheatbelt biogeographic region.

The catchment is a long-established agricultural area with land first taken up for farming in the late 1890s (Northern Arthur River Wetlands Committee 1987). Large-scale clearing occurred after World War I and most of the heavy clay soils were under cultivation by 1934 (Northern Arthur River Wetlands Committee 1987). Clearing of the light sandy soils occurred during the late 1940s and early 1950s. By 2011, approximately 12 per cent (6,024 hectares) of the Toolibin Lake catchment area remained as remnant vegetation.[2]

Toolibin Lake itself has been a main management focus within the Toolibin Lake catchment. The lake is an ephemeral wetland filling on average every three years (during the time period 1960s–90s), with this cycle of wetting and drying allowing for the formation of the paperbark and sheoak wooded wetland across the floor of the lake. In recent decades, coinciding with a period of low rainfall since 1996, Toolibin

[2] Calculations from the Remnant Vegetation dataset (custodians then DEC and Department of Agriculture and Food WA; DAFWA) by Geographic Information Services Branch, then DEC, Kensington, June 2011.

Lake has only partially filled on a few occasions; in 2006, 2008, and 2012[3]. The maximum depth of water when fully inundated is about 2m, after which the lake overflows into other wetlands downstream of the Northern Arthur River. While wetlands of this type were formerly widespread, the woodland in most of this type of wetland has been degraded or lost due to secondary salinisation associated with the agricultural development of the catchment.

Much of the remnant vegetation in the catchment lies directly to the north of Toolibin Lake. The few large vegetation remnants that remain throughout the catchment continue to be important for the delivery of the biological diversity values.

2.3. Climate

The Toolibin Lake catchment experiences a Mediterranean climate, with mild wet winters and hot dry summers. The average maximum temperature is 31°C in January, the hottest month (Jones et al. 2009). Pan evaporation averages 4.5mm per day over the year and ranges from 1.5mm per day in June to 8.7mm per day in January (Jones et al. 2009).

A Bureau of Meteorology rainfall station is located in the north-west of the catchment, about 4kms south-east of Wickepin and 14km north-west of Toolibin Lake. The average annual rainfall recorded from 1912 to 2012 was 408mm[4] with about 70 per cent of the rain falling between May and September (Jones et al. 2009). Rainfall in the catchment has shown a declining trend over time.

2.4. Social and economic characteristics

The Toolibin Lake catchment is largely freehold agricultural land (Table 2) 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).

2.5. Historical background

The late 1950s–60s were extremely wet with most of the south-west lake systems full and duck numbers highly dispersed. Numbers of ducks increased at specific lakes when others dried out. When Taarblin was full there were accounts of high numbers of ducks at the lake – up to 30,000 (unpublished information).

In the 1960s a local farmer (honorary warden) raised concerns that the level of duck shooting was high and duck numbers at Toolibin had decreased. A dramatic decline in duck numbers occurred after this and, anecdotally, numbers in the district never

[3] A fill event was recorded in February 2017, dring finalisation of the *Toolibin Lake Catchent Recovery Plan 2015–35*.
[4] http://www.bom.gov.au/climate/data: station 10654 Wickepin 32.81S, 117.53E

recovered from these levels. This was probably due to a generally low rainfall period and the habitat decline in the early 1960s. A debate on the need to protect the freckled duck (*Stictonetta naevosa*) at Toolibin continued in 1966–67 (unpublished information).

Following the early signs of salinity, the local community and State Government agencies instigated a process for the conservation of Toolibin Lake. This was only established after the neighbouring farmer cleared vegetation (1976–77) above Dulbining Nature Reserve despite lobbying beforehand to protect the bush. It wasn’t until it was cleared that the then Department of Fisheries and Wildlife offered and were successful in the purchase of the land (unpublished information).

The Northern Arthur River Wetlands Rehabilitation Committee (NARWRC) was established in 1977 to recommend measures to protect Toolibin Lake and rehabilitate other downstream wetlands (NARWRC 1987). In 1987, the committee released a report entitled *The Status and Future of Lake Toolibin as a Wildlife Reserve* (NARWRC 1987) that provided background information, described the studies undertaken and proposed recommendations for the conservation and management of Toolibin Lake. Many of these recommendations were incorporated into the subsequent *Toolibin Lake Recovery Plan* 1994 (Toolibin Lake Recovery Team and Toolibin Lake Technical Advisory Group 1994).

Appendix 3. Terms of reference for the recovery team and technical specialist advice

3.1. Background

Toolibin Lake is a Ramsar-listed wetland that lies within a system of class 'A' nature reserves featuring wetlands that are managed by the Western Australian (WA) Department of Biodiversity, Conservation and Attractions (DBCA; the department; Parks and Wildlife Service). The lake is part of the Toolibin Lake catchment (previously known as the Toolibin Lake Natural Diversity Recovery Catchment (NDRC)). Since 1996, the department has coordinated management actions within the Toolibin Lake catchment, which has been in protecting a range of high-value public assets (with associated biological elements) threatened by changed hydrology, particularly salinity.

Since the mid 1970s the department has mostly focused on management operations on and adjacent to Toolibin Lake itself. This asset has and will continue to be a primary focus for recovery works in the Toolibin Lake catchment; however, over time there is increasing scope to apply actions to other priority biological elements in the catchment, particularly those threatened by altered hydrology. Scientists, specialists and other stakeholders have consistently provided advice and support.

The inaugural recovery team meeting was held on 9 September 1993, with the original team comprising stakeholders and technical specialists. The recovery team finalised a recovery plan in 1994. The technical advisory group (TAG) was established later to work with the recovery team on scientific and technical aspects of the recovery process.

Since about 2006, the recovery team's involvement has declined. This is partly due to dwindling availability of the members and partly because the department is now implementing many of the recovery actions identified in the *Toolibin Lake Recovery Plan* (1994) as day-to-day operations. However, with the preparation of a new recovery plan that follows the revised planning approach of Wallace (2012), the appointment of an updated recovery team and technical and specialist advice (TSA; the term now used to describe the TAG – see section 3.4) is required.

The current planning approach focuses on managing biological elements for their key human values and, consequently, the recovery team should represent these values. It is also important to ensure that stakeholders directly affected by management in the catchment are represented. The new recovery plan will provide the direction for management over the next 20 years and, and a recovery team, with clearly defined roles, will assist in the effective delivery of, and support for, recovery actions. Technical specialist advice will also be important to ensure management decisions are well informed and consider up to date knowledge.

These terms of reference have been developed with the aim of achieving an effective recovery team and specialist group to oversee the development and implementation of the new recovery plan.

3.2. Role and composition of the Toolibin Lake catchment recovery team

The recovery team will aim to meet twice a year; however, this will depend on the need for a meeting as determined by the chairperson. The role of the recovery team is to advise the department on the following:

1) Development and review of the recovery plan for the Toolibin Lake catchment
2) Implementation of recovery actions, particularly as representatives of a range of stakeholders
3) Development of priorities for recovery action
4) Dissemination of information on the progress of recovery
5) Development of progress reports.

The department's regional manager – Wheatbelt Region will be the recovery team chairperson.

Figure 1 describes the reporting and decision-making framework for the Toolibin Lake catchment. The recovery team has no decision-making powers and meets as an advisory group only. The department considers advice from the team at these meetings in relation to the department's statutory responsibility and, if necessary, seeks approvals for a specific recovery action following the hierarchy described in Figure 1.

3.3. Membership of the recovery team

The recovery team will consist of up to 13 representatives from key stakeholder groups who represent the values derived from the biological elements within the Toolibin Lake catchment, or who represent those directly affected by management of Toolibin Lake (Table 3). The position or representation by the group is listed, not individual people. It is the responsibility of the person nominated as the group representative to arrange for alternative representation if they are unable to attend. To ensure equity of representation, only one individual from each stakeholder group will be nominated. The department's Executive Director Science and Conservation division endorses recovery team membership.

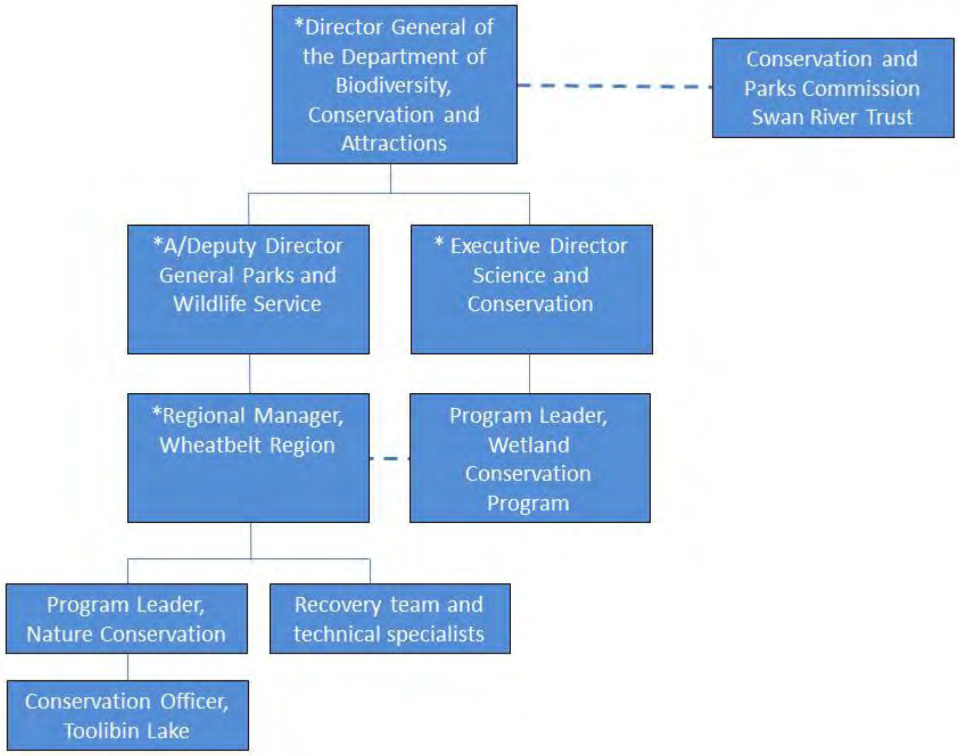


Figure 1: Management hierarchy for Toolibin Lake catchment recovery actions

*Note: * denotes key decision-maker based on departmental approvals matrix*

Table 3: Stakeholder representative group

Stakeholder/organisation	Sector/group	Position
Department of Biodiversity, Conservation and Attractions	Government	Regional Manager
	Wetland Conservation Program	Program Leader
Shire of Wickepin	Shire	Councilor
Wickepin community	Wickepin landholders and business person	Landholder
	District community and Wickepin ratepayer	Community member
Dryandra Country Visitors Centre	Tourism	Manager
Central South Naturalist Club and Wildflower Society of Western Australia	Local environment	Member
South West Catchments Council	NRM group	Regional Officer
Department of Water and Environment Regulation	Water management	Manager
Department of Primary Industries and Regional Development (formerly Department of Agriculture and Food WA)	Agriculture	Project Manager Land and Water Assessment Program
Gnaala Karla Booja	Aboriginal custodians	Elder
Birdlife Australia	Fauna	Member

3.4. Technical advisory group and technical specialist advice

Technical specialists can advise the department and the recovery team on a range of technical, research and development issues related to the Toolibin Lake catchment. Prior to 2015, these specialists were referred to as the technical advisory group (TAG). They are now called the technical specialist advice (TSA). These terms are therefore interchangeable in these supporting documents.

A list of technical and research advisors is provided below. Expert advice will be sought as issues arise. This list is not exhaustive and relevant experts, both private and government, may be called to provide advice on recovery matters.

1) Hydrology – surface water and groundwater (DBCA/Department of Primary Industries and Regional Development [DPIRD], private)
2) Hydro-geology (DBCA)
3) Sustainable land use (DPIRD)
4) Engineering (DBCA, DPIRD, private)
5) Ecology (DBCA, private)

6) Botanist (DBCA, private)

7) Wetlands – physical and biological factors (DBCA)

8) Revegetation (DBCA)

9) Research/education (DBCA, universities, CSIRO)

10) Climate change (DBCA, universities)

11) Others as required.

3.5. Recovery team operating procedures

The Regional Manager Wheatbelt Region, or their representative, will be the chairperson for all meetings.

The role of the chairperson is to:

- schedule meetings, set and distribute the agenda and notify all members
- guide the meeting according to the agenda and the time available
- review, approve and distribute minutes of meetings
- invite specialists to attend meetings when necessary.

Other invited guests may attend meetings but they are not formal members. Generally the Conservation Officer and Technical Officer (Toolibin Lake) will attend meetings and take minutes.

If a member is unable to attend the meeting they should arrange a proxy.

Appendix 4. Toolibin Lake catchment values ranking procedure

4.1. Introduction

A brief summary of the process and results for the Toolibin Lake catchment values-ranking exercise is covered under three headings: classification of values, methods, and results and discussion. Note: a new method has been developed by Wallace et al. (2016) which can be used for future exercises.

4.2. Classification of values

The classification of values used for the Toolibin Lake catchment is provided in Table 4. The value set was based on that described by Lindenmayer and Burgman (2005) and was modified for three reasons. Firstly, to reduce redundancy among the categories to minimise double counting and, secondly, to increase the clarity and simplicity of the classification for use in a practical application where there are often time limitations. To the extent practicable, the classification reflected the ideas outlined in Wallace (2012).

4.3. Methods

Identification and involvement of stakeholders

The Western Australian State Government is responsible for managing the biological elements subject to planning in the Toolibin Lake catchment. Thus, the statutory functions of this agency mean that the biological elements are being managed on behalf of the State community of people, who are the stakeholders that need to be engaged. It is clearly not practicable to engage the whole State community, and so the department’s approach was to identify groups and organisations that might reasonably be expected to represent a broad set of community views.

Table 5 lists the groups invited to participate in the values exercise for Toolibin Lake catchment and identifies those who were represented. This group broadly formed the advisory group for management planning and was chaired by the then local District Manager (this role no longer exists, with the Parks and Wildlife Service Regional Manager now the relevant position).

Elicitation

The department undertook the values elicitation and ranking in November 2010, facilitated by the then manager of the Natural Resource Branch. Prior to the elicitation, it was emphasised to the workshop participants that the outputs were advisory, and that ultimately the nature reserves had to be managed consistent with the relevant State Government legislation. The elicitation was then conducted using the following steps.

1) The department offered definitions of the term 'value' and these were discussed with the workshop participants. The definition used for the exercise was that values are benefits for human well-being where this encompasses survival, reproduction and other key human needs. The facilitator then presented the proposed list of values (Table 4) and the participants discussed.

2) The group described the biological elements of the native biota at risk from altered hydrology in the Toolibin Lake catchment as:
    a) Toolibin Lake biological diversity
    b) a number of important vegetation communities dominated by species such as salmon gum (*Eucalyptus salmonophloia*), *Melaleuca* species, and wandoo (*E. wandoo*)
    c) priority and rare flora
    d) threatened fauna (other than waterbirds)
    e) waterbirds
    f) aquatic flora and fauna other than that associated with Toolibin Lake
    g) other flora and fauna.

5) The workshop participants and the facilitator discussed the values that may arise from the biological elements, and ensured that the group was comfortable with the values classification.

6) The workshop participants formed into groups of three and discussed amongst themselves the values that may arise from the biological elements. The participants then reformed as a single group, and discussed the outputs of their deliberations. This ensured that all participants had a comprehensive and shared set of views concerning the values that might arise from the biological elements.

7) Workshop members individually and anonymously ranked values from their stakeholder group perspective and also from their personal perspective. It was expected that the rankings for the two approaches would differ, thus providing support for the notion that the stakeholders could put aside their personal feelings to represent their stakeholder group.

The facilitator then collated the results, which were presented to the workshop group for discussion and finalisation. The group did not express any concerns with the results. The top three ranked values were identified as the priority values for the recovery planning process. During the group discussion of the results the facilitators documented more detail about why values were important.

4.4. Results and discussion

Table 6 shows the results of the values elicitation when individuals ranked them from their stakeholder group perspective. Table 7 shows the ranking from personal perspectives. There is a distinct difference between the two sets of rankings, suggesting that stakeholders are clearly differentiating their personal views from those of the organisations they represent. Additional information provided by the group on the top three ranked values is provided below.

1) Knowledge/heritage and education

The information and data collected from the Toolibin Lake catchment will further contribute towards knowledge, including knowledge about the development and management of salinity. The recovery project assists in improving our understanding of the processes of salinity through the testing of innovative solutions in a real situation to protect public and private elements. The management of altered hydrology within the Toolibin Lake catchment has wider application for other areas of southern agricultural land impacted by salinity.

2) Productive use

The work to recover biological elements has an important positive impact on production values within the catchment. Stakeholders consider the protection of biological elements to provide a direct connection with production in the catchment, and the focus on the Toolibin Lake catchment increases the funding opportunities available to landholders. Reducing the widespread impacts of salinity throughout the catchment is seen to improve not only the condition of biological elements but also the agricultural land that provides an income for farmers.

When the productive use category was explored with the group, it was revealed that stakeholders saw this value arising from two sources. Firstly, the presence of biological elements of community interest attracted significant funding for work on private property to ameliorate hydrological processes, particularly salinisation. Although the primary driver for this work is protection of natural biota, an ancillary benefit is that productive use values can also be improved. This aspect of the productive use value is therefore dependent on other values, presumably philosophical/spiritual contentment and the knowledge/heritage and education value. Secondly, the stakeholder group considered that the biological elements contributed directly to productive land use by lessening the downstream impact of salinity and other soil conservation issues. For the analysis, we treat productive use as relating to the second interpretation, noting that this restricts the biological elements of interest to native vegetation. We consider the first interpretation of productive use to be captured by the philosophical/spiritual contentment value.

3) Philosophical/spiritual contentment

The biological diversity ethic is considered a particularly important part of the human moral framework in the catchment and is a strong driver for conservation. The

Toolibin Lake catchment has been significantly impacted by human activity, and the remaining biological elements are representative of systems that were once widespread. Stakeholders feel a moral responsibility to protect these remnant systems for their own intrinsic values and for future human generations.

Table 4: Values from natural biota – Toolibin Lake catchment

Values	Description of value and examples
Productive use	Are the values of biological diversity ones that are harvested commercially, or ones that contribute to the production of commercial goods? E.g.: ○ food (harvesting of kangaroos, hydrological protection from bushland) ○ potable water (role of native biota in sediment and nutrient stripping) ○ structural materials (fence posts, timber) ○ energy (firewood) ○ wild harvest of cut flowers and other plant products.
Consumptive use	Are the values of biological diversity harvested for domestic use and used without passing through a market? May include any of those above, e.g. farmers using trees from their properties for firewood or fence posts.
Recreation	The importance of biological diversity for leisure activities is well known. Includes passive recreation (e.g. birdwatching, nature photography) and more active recreation which may require significant construction works (e.g. extensive walk trails). Research links recreation in natural environments to both physical and mental health. There are strong links between recreation and amenity (aesthetic) values.
Health (physical environment)	Those values from biological diversity that contribute to the quality of our chemical and physical environment: ○ shade and shelter from remnant vegetation around yards and houses ○ biological diversity as indicators (i.e. 'the canary in the coal mine') ○ dust reduction through retained vegetation, with a positive effect on human health.
Health (protection from other organisms)	Biological diversity helps to maintain our health by protecting us from other organisms. Includes: ○ medicines (e.g. eucalyptus oil) ○ biological diversity as a form of disease suppression (epidemic prevention, e.g. by maintaining low populations amongst disease-carrying organisms).
Aesthetics	Scenic and other aesthetic values of natural landscapes, beauty of wildflowers and birds. Includes 'sense of place' values, although this could be incorporated into the next category.
Philosophical/spiritual contentment	All humans operate within either an explicit or implicit set of philosophical beliefs that: ○ establish and explain the role of humans in the world/universe, including birth and death ○ provide guidance for how we should live our lives and interact with other people, other organisms, and the inanimate world. Biological diversity is often an important part of our spiritual/philosophical

Values	Description of value and examples
	and moral framework. Intrinsic values are incorporated here given that they are a statement of beliefs.
Knowledge/heritage and education	Natural biological diversity is widely used for scientific and educational purposes. E.g. maintaining a set of representative, undisturbed soils and their related biota is essential if we wish to understand the changes brought about by various uses. Other examples include the widespread use of bushland to research natural processes, and as an educational resource by schools.
Opportunity	The conservation of biological diversity provides for a range of future opportunities in any of the above categories. Most obvious is the germplasm resource in native plants. Thus opportunity values are those values listed elsewhere in this table that are not currently realised. They will include maintaining the opportunity for: ○ discovery of currently unknown values in our native biota ○ currently known values to be used at some time in the future ○ future generations to make their own decisions concerning biological diversity values.

Table 5: Relevant stakeholder groups and their responsibilities for the Toolibin Lake catchment

Note: stakeholders that were invited and participated in the meeting are indicated

Stakeholder group	Organisation (if relevant)	Invited	Attended
Landholders		Y	N
State government	Department of Parks and Wildlife (now DBCA)	Y	6
	Department of Agriculture and Food WA (now DPIRD)	Y	1
	Department of Water (now DWER)	Y	N
Local government	Shire of Wickepin	Y	N
Catchment management body	Facey Group	Y	1
Natural resource management council	South West Catchments Council	Y	1

Table 6: Stakeholder ranking of the values from their stakeholder perspective

Note: each column represents the ranking of an individual.

Norm = 1- (normalised mean rank)

Values	1	2	3	4	5	6	7	8	9	Total	Rank	Norm
Knowledge/heritage and education	6	1	1	2	2	1	1	3	1	18	1	1.00
Productive use	4	2	4	1	5	3	3	7	4	33	2	0.70
Spiritual/philosophical contentment	1	9	3	6	3	6	5	1	2	36	3	0.64
Recreation	8	5	2	5	4	5	6	2	5	42	4	0.52
Aesthetics	2	4	6	4	7	7	2	9	3	44	5	0.48
Opportunity	9	8	5	3	1	2	7	4	6	45	6	0.46
Consumptive use	5	3	9	9	6	4	4	8	8	56	7	0.24
Health (physical and chemical)	3	6	8	8	9	9	8	5	7	63	8	0.10
Health (protection from organisms)	7	7	7	7	8	8	9	6	9	68	9	0.00

Table 7: Stakeholder ranking of the values from their personal perspective

Note: each column represents the ranking of an individual

Norm = 1- (normalised mean rank)

Values	1	2	3	4	5	6	7	8	9	Total	Rank	Norm
Spiritual/philosophical contentment	1	4	3	6	1	1	1	1	1	19	1	1.00
Aesthetics	2	1	5	5	4	2	2	2	2	25	2	0.88
Knowledge/heritage and education	4	2	2	2	3	7	3	5	4	32	3	0.73
Recreation	6	3	1	3	7	4	5	7	5	41	4	0.54
Opportunity	7	9	4	4	2	3	7	6	6	48	5	0.40
Productive use	5	8	6	1	9	9	6	3	8	55	6	0.25
Health (physical and chemical)	3	6	8	8	5	6	8	9	3	56	7	0.23
Consumptive use	8	5	7	9	8	8	4	4	9	62	8	0.10
Health (protection from organisms)	9	7	9	7	6	5	9	8	7	67	9	0.00

Appendix 5. Estimating the importance of values derived from biological elements

5.1. Introduction

People's well-being relies on living natural resources[5] for many reasons (Millennium Ecosystem Assessment 2003). This highlights the importance of managing these biological elements to maintain or enhance their delivery of values and thus well-being. Yet, in spite of the considerable literature noting the importance of human values in natural resources management (Decker et al. 2001, Lindenmayer and Burgman 2005, Prato and Fagre 2005), and the existence of values-based frameworks (Keeney 1992), the department has not found any planning method that fully applies this knowledge in a logical and coherent manner (e.g. not mixing ends and means; Wallace 2007) to assess the comparative importance of the biological elements in terms of their value. Without such an assessment, natural resource managers will not be able to set management priorities to maximise the provision of values for their stakeholders.

Consequently, an important challenge for those planning the management of living resources is deciding how best to elicit priority values from stakeholders and how to then use this information to rank biological elements in terms of these values. Here the discussion focuses on the second of these tasks. This discussion aims, firstly, to show that properties of biological elements (such as structure and composition) determine, in relative terms, the provision of values. Properties can be thought of as attributes used to describe biological elements (or systems or processes). Figure 2 further illustrates these important concepts. Secondly, the discussion describes the evaluation of properties to rank biological elements for management importance. The approach described fits within the broader natural resource planning framework of Wallace (2012; also refer to Wallace, 2007). Within that context, an important additional contribution of the approach outlined here is that it will help managers, planners and decision-makers to integrate the various components of a natural resource management program (e.g. values, biological elements, properties) within a logical and coherent framework. As noted by Wallace (2007), this is not a task that natural resource managers, decision-makers and planners have always done well in the past.

The values that humans derive from a system's biological elements will vary, depending on the specific biological elements present and their particular properties (e.g. Ghilarov 2000, Serengil et al. 2007). Specifically, planning is concerned with

[5] Referred to in the plan as 'biological element'.

those properties that allow us to rate the biological elements. For example, using a range of experimental and field situations Lindemann-Matthies et al. (2010a, 2010b) found that people's aesthetic appreciation (a value) of grasslands (biological elements) increased with species richness (a property that links the biological elements to the value). They also found that perceptions of richness were affected by another property, the structural distribution of plants. Similarly, Ribe (2005) and Shelby et al. (2005) have shown that the appreciation of different forests (biological elements) for aesthetic and recreational value is affected by several properties, including stand structure, the age of trees, and the size of the trees.

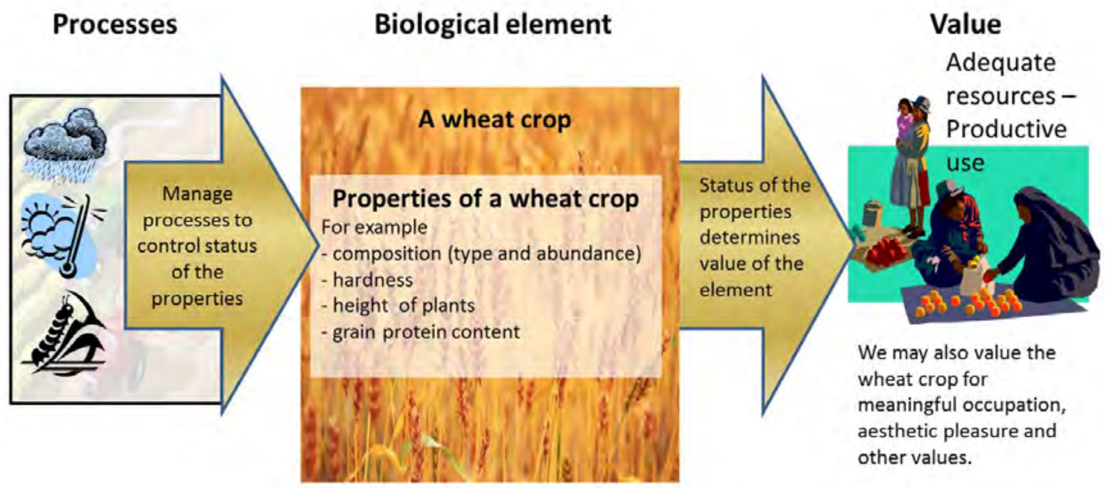


Figure 2: Simplified visual characterisation of several key planning terms and their relationship to each other

Note: In this example, the biological element is a wheat crop. We value the wheat crop for, among other things, a food resource (adequate resources – productive use). The wheat has several properties that determine its productive value, such as composition (in this case we may want a single species with high abundance), hardness (the harder the better), and grain protein content. The properties that determine the value of the crop are themselves influenced by numerous processes, some of which the farmer can manage (such as altered hydrology and pest species) and perhaps some the farmer cannot manage (frost damage relating to unseasonably cold temperatures). The farmer would want to manage the processes to influence the properties to maximise the value of the biological element. From an on-ground management perspective (as shown in the figure) we work from the processes to the values. From a planning perspective (the focus of this appendix), we start at the values and work towards the processes.

This appendix describes a five-step method to rate the relative values of biological elements in the management area through the quantification and combination of key properties. Specifically, the method:

1) Makes use of the classification of human values from Appendix 4.
2) Describes the set of biological elements.
3) Explores and ranks the importance of the values arising from the set of biological

elements.

4) Identifies, quantifies and models properties to predict the relative values of each biological element.
5) Is used to predict the overall relative value (or utility) of each biological element.

Importantly, a value is any desirable end state, such as health and recreation, which directly contributes to human well-being (Wallace 2012). An underlying assumption is that, by realising an appropriate mix and level of values, people will have a satisfactory quality of life. The values listed in

Table 4 (Appendix 4) are applicable to biological elements. These are a subset of the classification outlined by Wallace (2012), who consolidated a range of different value classifications to avoid redundancy and other definitional problems.

The 'Methods' section describes the approach in a general sense and this is then applied in the 'Results' section. The management of biological elements is the focus of this plan, but the approach also applies to abiotic elements (e.g. potable water). Despite the linear sequence of the steps presented above, the approach is iterative, and reapplication with new data may generate changes to the property scores, model structure, elicited estimates and model predictions. Data may come from empirical measurement or from expert opinion, or both. An expert is taken to be someone who has skills, experiences, education, training or knowledge concerning the issues to be discussed or resolved (adapted from Burgman 2005).

5.2. Methods

To garner expert information, elicitation processes are required. One characteristic of elicitation processes is that there is considerable scope for subjectivity and bias (cf. Kadane and Wolfson 1998). However, given that values inevitably drive the rating processes for biological elements (Wallace 2012), subjectivity is unavoidable and deeply embedded in all such processes. An important advantage of the approach described in this appendix is that all steps, including those that are subjective, are made explicit and documented. Techniques designed to reduce subjectivity and bias (Burgman 2005) can be applied when eliciting expert (or stakeholder) information (e.g. Al-Awadhi and Garthwaite 2006, Low Choy et al. 2009, O'Leary et al. 2009, Martin et al. 2011, Metcalf and Wallace 2013).

Five steps to linking biological elements to human values

I. Classify the human values to be used in the planning process

This step identifies the set of values that stakeholders derive from the biological elements. It is critical that this classification includes only values – not processes (e.g. pollination of plants), biological elements (e.g. natural freshwater fish) or properties (e.g. composition of the natural freshwater fish species or resilience – an example of a property of a system). To minimise bias and uncertainty in their judgments, all stakeholders involved in an elicitation (or their representatives) must hold similar knowledge concerning the values and their classification. Refer to Appendix 4 for a description of the values elicitation step.

II. Describe the set of biological elements

The living natural resources of an area can be thought of as biological elements. An important challenge is deciding how best to define the biological elements because this may affect the values elicitation. Readers are referred to Fauth et al. (1996) who provide a simple framework for defining biological subsets.

Importantly, properties of biological elements (e.g. species composition) are invariably used to underpin biotic classifications. Therefore, practitioners must take care to acknowledge this issue and to minimise bias in any classification of biological elements that will affect later steps in the analysis.

III. Explore and rank the importance of the values arising from the set of biological elements

A structured stakeholder elicitation process is suggested (e.g. Gregory and Keeney 1994, Borsuk et al. 2001, Gregory and Wellman 2001, Wallace et al. 2016) to rank the importance of the values expected from the biological elements specified in Step II. From this process, a priority subset of values for the management area will often emerge.

IV. Elicit, quantify and model properties to predict the relative value of each biological element

At this stage practitioners could simply construct a table of values by biological elements and then estimate the importance of each biological element to each value (perhaps with the help of experts and/or stakeholder representatives). This is an important point to reach as the managers will now have a clearer understanding of the values, the biological elements, and the expected values that may be derived from each biological element. However, for the subsequent steps to complete the planning cycle (e.g. identify threatening processes, assess the risks, and prioritise management actions) it will be highly beneficial for managers to understand the relationships between properties and values. (This will be shown in the remainder of this appendix.) Thus, using three sub-steps, Step IV estimates the value of each biological element by:

1) identifying properties and describing their relationships with the values
2) quantifying properties for each biological element
3) combining the outputs from the previous two sub-steps to estimate the relative provision of each value by each biological element.

In the first of these sub-steps practitioners can use literature and/or expert and/or stakeholder review to identify important properties with regard to the values. To reiterate, properties are attributes that describe a biological element. They are not the biological elements themselves nor any related process or value arising from the biological element, but some measure that characterises the element (Table 8 lists and describes the properties and definitions). For example, from the literature cited in the Introduction, there are well-documented positive links between species composition and structure (two properties of biological elements) and values such as aesthetic pleasure and recreation. With the exception of structure and irreplaceability, the properties used in this analysis are described in Smith et al. (2016). Structure can be defined as the three-dimensional distribution of all biological elements that are present (i.e. the spatial distribution of a given composition including age structure, life stages, etc.). Linkages between structure and values have been demonstrated (Nassauer 1995). Within the case study, it proved impracticable to find a measure that consistently linked this property to values. Thus, although an important property, the means of quantifying structure in relation to values may often require further investigation before it can be applied.

Practitioners then develop models based on the available literature and expert and/or stakeholder advice to conceptualise the various relationships between biological element properties and values (Table 9 provides examples). There may be many different kinds of relationships between properties and values (e.g. Table 9). For example, in some cases the relationships between properties and values may be positive and linear. In others, properties may have little or no relationship with some values or might increase positively and then flatten at some point. Where practicable, it would be beneficial for the department to conduct research in the management area to experimentally quantify links between particular properties and values.

Conceptually, sub-step 2) – quantifying the various properties for each biological element – is comparatively straightforward. Nevertheless, the quantification of properties can be difficult. Data may not be available for all biological elements and it may be necessary to rely upon expert opinion. Other compromises may also be required. For example, if composition is an important property, species diversity based upon richness and abundance data (Magurran 2005, Lamb et al. 2009) may be the optimal metric. However, abundance data may not be available and the analysis may have to proceed with richness information only.

Once the property scores for a biological element have been determined, practitioners may combine them with the output from sub-step 1) to predict the value of each biological element: which is sub-step 3). Because the status of each property will vary from one biological element to another (e.g. some elements have greater species diversity than others), it is expected that biological elements will differ in their capacity to support values.

Table 8: Some generally important properties of biota in terms of their human value

Note: (a) these properties are measured at a point in time and within specified spatial boundaries; and (b) other properties may be important in different times and places.

Property	Definition and comment
Natural species composition	The types (taxa) of natural species present and the abundance of each type. As outlined in the Introduction, the direct relationship between composition of biological elements and aesthetics is well documented; however, in the context of natural resource management, this should be an important property for the delivery of most values.
Structure	The three-dimensional distribution of all biological elements present (i.e. the spatial distribution of a given composition including age structure, life stages, etc.). Linkages between structure and values have been demonstrated (Nassauer 1995). Within the case study, it proved impracticable to find a measure that consistently linked this property to values. Thus, although an important property, the department may often need to further investigate the means of quantifying structure in relation to values before it can be applied.
Rarity	"Relative fewness in number; the fact of occurring seldom or in few instances" (Oxford English Dictionary). Specifically in this context, it refers to scarcity of numbers of a species or community with respect to a given geographic boundary. For Toolibin Lake catchment, rarity was taken to include any formal listing as a conservation concern within the context of the South-West Land Division. However, it should be emphasised that these listings incorporate aspects of risk or threat (e.g. International Union for Conservation of Nature 2012), which, strictly speaking, are not part of the concept of rarity as used in the case study. Note that in some specific cases, a particular structure may be rare. This could be scored here or against structure – either would be acceptable, although care must be taken to avoid double-counting. Conservation organisations' significant focus on rare species reflects the strong linkage between this property and those with a strong biodiversity conservation ethic.
Size	The size of a biological element, in particular the area occupied, is considered to be important. For Toolibin Lake catchment, the area (in hectares) of communities was used as an important property. Generally, the larger the area occupied by a biological element, the greater will be its expected contribution to particular values.
Intactness	This is the property of being sound, flawless, entire (adapted from Oxford English Dictionary). 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". Conceptually, intactness is equivalent to, or a subset of, the notion of biological integrity which is defined by Callicott et al. (1999, page 25) as "natural species populations in their historic variety and numbers naturally interacting in naturally structured biotic communities", and includes ecosystem processes. For the case study, there was inadequate data for such a measure. However, when departmental officers were questioned they identified that unusually large amounts of unnatural deaths, or clear evidence of substantial past disturbance such as clearing of vegetation, constituted a property of biological elements that should be recognised. In this work, we have thus returned to the concept of intactness and measured it by assessing extensive deaths or losses of species that appeared unrelated to natural processes.
Irreplaceability	Based on Pressey et al. (1994), this property is defined as the potential contribution of any biological element to a management goal (expressed in terms of human values), or the extent to which the probability of achieving such a management goal is decreased if the biological element is lost. Kukkala and Moilanen (2013) note in their review that systematic conservation planning (which includes concepts such as irreplaceability) builds on older concepts of rarity, size, richness, diversity and naturalness. Thus, it is unsurprising that such properties, either singly or in combination, have been used to measure irreplaceability. These properties are already used in our analysis, thus, it would have constituted double-counting to use them again. Therefore, the property of irreplaceability was not used as a link to values in the case study.

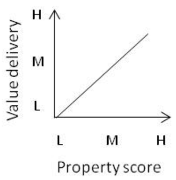
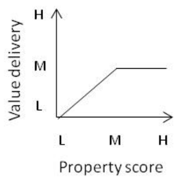
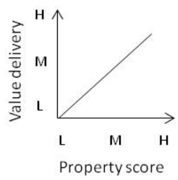
V. *Predict the overall relative value (or utility) of each biological element.*

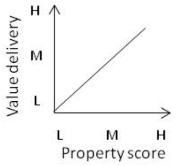
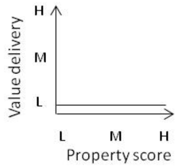
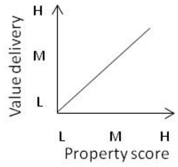
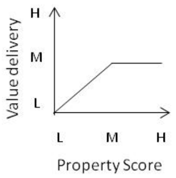
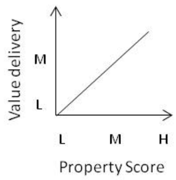
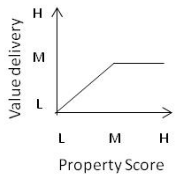
For each biological element, it may be important to combine the expected individual values into a total relative importance score (or utility). Before combining the estimates from Step IV to form a utility estimate, the practitioner could weight them against the corresponding stakeholder ratings generated in Step III (Appendix 4). The output from this process will be a set of biological elements rated by their overall utility in terms of the priority values. Where management resources are limited, the department may select biological elements in order of their rating. A set of higher priority biological elements can be identified.

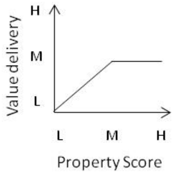
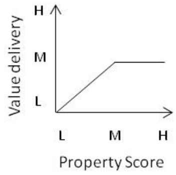
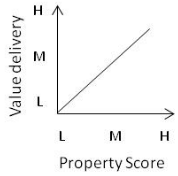
Table 9: The four properties of the biological elements used in the value-delivery analysis

Note: Initially the authors and a technical advisory group of experts (TAG) also explored irreplaceability and structure. They identified irreplaceability as potentially important but, ultimately, viewed this as a composite of the other properties already identified (e.g. size, rarity and composition). Thus, it is redundant with other properties and was rejected.

Also, at the time of this analysis, the group was not yet able to quantify structure via data or expert opinion. It is also noted that where detailed and complete information on species composition (richness and abundance of individual species) and structure (three-dimensional distribution of composition) are available, other properties such as size, intactness and rarity may become redundant. The table reports the proposed relationships between each property and each priority value for the Toolibin Lake catchment. Each graph captures the relationship between the property score (couched in terms of low, moderate or high fuzzy sets; for more detail refer to Pourabdollah et al. (2014)) and the strength of the contribution to a given value (represented as low, moderate or high fuzzy sets). The relationship represented in the graphs is captured in the Fuzzy Logic System (FLS) of Pourabdollah et al. (2014) as a series of rules between the fuzzy sets (e.g. if intactness of mammal element is low, then knowledge/heritage and education value is low). The actual value estimate is subsequently calculated through inference in the FLS.

Property	Knowledge/heritage and education	Productive use	Philosophical/spiritual contentment
Species richness	 **Positive.** Each type (e.g. taxon or community) within a biological element contributes to knowledge/heritage and education value. Therefore, each additional biological taxon/community within an element adds value. Increasing the number of individuals in any one type also increases the opportunity for capturing genetic knowledge, for creating controls for experimentation, etc. For heritage and education, increasing richness will provide increasing educational opportunities.	 **Positive.** Species richness is an important property because the greater the richness, the greater the capacity to manage processes such as nutrient and sediment stripping and erosion control that impinge on productive capacity. Note also the importance of taxonomic redundancy	 **Positive.** If we view one species as having some philosophical/spiritual contentment value, then increasing composition will add to that value. The minimum requirement is that all taxa will be conserved, therefore the greater the biota (expressed as numbers of types and abundance of individuals), the

Property	Knowledge/heritage and education	Productive use	Philosophical/spiritual contentment
		in this context (Main 1981, Walker 1992). Within our management area this is not believed to be a linear relationship, i.e. increasing richness will not significantly contribute to this value once a moderate richness is achieved.	greater the score for a biological element.
Rarity	 **Positive.** We view common taxa and communities as providing little knowledge/heritage and education value beyond that captured in composition, but high rarity will increase knowledge/heritage and education value.	 **None.** This will be irrelevant here, but note that rare species may attract a score under opportunity values where these are a priority.	 **Positive.** Common species attract little philosophical/spiritual contentment value beyond that captured in composition, but people are likely to place a high philosophical/spiritual contentment value on rare biological elements.
Size	 **Positive.** If one unit of area (e.g. 1 ha) provides some degree of knowledge/heritage and education value, increasing area will add to that value. This is partly due to the relationship between area and richness. However, increasing size will, at least initially, provide much greater capacity to conduct research through controlled experiments (knowledge), and space for educational and heritage experiences. However, in the case study we expect to exceed some limit to the relationship between area and knowledge/ heritage and education. For example, in the context of the management area, we do not expect to acquire much more knowledge/heritage and education value from biological elements greater in size than the Toolibin Lake which is	 **Positive.** If one unit of area (e.g. 1 ha) provides some degree of productive use value, increasing area will add to that value. Note that this value will continue to increase – there is unlikely to be a flattening of the 'growth' curve. E.g. increasing the area of perennial vegetation will continue to decrease the likelihood of erosion events.	 **Positive.** If one unit of area (e.g. 1 ha) provides some degree of philosophical/spiritual contentment, increasing area will add to that value. However, in the case study, we expect to exceed some limit to the relationship between area and philosophical/spiritual contentment. For example, in the context of the management area, we do not expect to acquire much more philosophical/spiritual contentment value from biological elements greater in size

Property	Knowledge/heritage and education	Productive use	Philosophical/spiritual contentment
	of a moderate size.		than the Toolibin Lake which is of a moderate size.
Intactness	 **Positive.** The presence of death, or signs of dying, signifies a loss of knowledge, but mostly where the composition is significantly affected, thus the non-linear relationship.	 **Positive.** The more intact a biological element is, the greater its ability to provide adequate resource value to a point. However, as with knowledge/heritage and education, the relationship is not strong until there is obvious, significant loss of intactness, which would imply loss of processes that contribute to protecting productive lands.	 **Positive.** The more intact a biological element is, the greater its ability to provide philosophical/ spiritual contentment. It is assumed here that those seeking this value will respond quite strongly to loss of intactness, even at a low level.

5.3. Results

It is stressed that the results may change with future planning iterations.

Application of the approach

I. Classify the human values to be used in the planning process

Described in Appendix 4.

II. Describe the set of biological elements

The original set of biological elements was:

1) The Toolibin Lake biological diversity
2) A number of important vegetation communities dominated by particular species (e.g. Eucalyptus or Melaleuca)
3) Priority and rare flora
4) Threatened fauna (other than waterbirds)
5) Waterbirds

6) Aquatic wildlife other than that associated with Toolibin Lake
7) Other wildlife.

However, and in line with the iterative nature of planning, in 2013 a technical advisory group of experts reviewed and reformalised the original biological element list used for the values ranking exercise in 2010 (steps I and III). This facilitated steps IV and V. The assumption was made that the values list and ranking from steps I and III still applied to the updated biological element list used in steps IV and V. The TAG identified 14 vegetation elements and seven fauna elements (Appendix 9).

III. Explore and rank the importance of the values arising from the set of biological elements.

From the values elicitation exercise with stakeholder representatives (Appendix 4), the department identified three values (knowledge/heritage and education, productive use, and philosophical/spiritual contentment) as the priority for the management area. These are the focus for the plan. The group explored the underlying basis for the high priority ascribed to productive use. It was revealed that the stakeholders viewed the natural biological elements in the catchment as providing productive use in two ways. Firstly, significant salinity management work was being undertaken on privately owned farmland to better protect the biodiversity ethic values embodied in the natural biological elements. These works were themselves contributing directly to cereal and meat production. Secondly, retaining the biological elements was also a direct contribution to protecting agricultural lands, particularly from secondary salinisation. Given that the first explanation is effectively captured in the philosophical/spiritual contentment value, the second aspect was carried forward as a productive use value. Of note, using the second interpretation of the productive use value means that only vegetation elements are of direct importance for the delivery of that value.

IV. Elicit, quantify and model properties to predict the relative value of each biological element.

i. Identify properties of biological elements and describe their relationships with the key values

After discussion with a TAG, the department identified six properties (Table 8). Due to issues of redundancy and information availability the department used only four of the six properties listed in the analysis – species composition, rarity, size and intactness. Together with the TAG, the department developed models to conceptualise the relationships between these properties and the important values. It is important to acknowledge that there are many other properties that might have been considered. For example, distance from roads, towns and educational institutions will obviously affect important aspects of knowledge/heritage and education value. The discussion below returns to this issue.

ii. Quantify the properties for each biological element

Appendix 8 provides descriptions of the quantification of the element properties. Of particular note, the department used species richness to measure composition instead of a more complex diversity index. This is because richness and abundance data were not available for most biological elements and because it was decided that a more complex diversity index was too conceptually difficult to elicit from experts.

iii. Model properties to predict value delivery by each biological element

The department modelled the conceptualised relationships between the properties and the delivery of the priority human values within a type-1 Fuzzy Logic System (FLS; Wagner 2013, Pourabdollah et al. 2014) which is described in detail in Pourabdollah et al. (2014). The FLS uses a series of inference rules to quantify the values of the biological elements for different property-level combinations (Pourabdollah et al. 2014). Here is an example of a series of inference rules: If 'size' is 'small' and 'intactness' is 'low' and … then 'knowledge/heritage and education' value is 'low'.

V. Predict the overall relative delivery of values (or utility) by each biological element

To estimate utility for each biological element, the department used a linear value model technique (e.g. Gregory et al. 2012; described by Pourabdollah et al. 2014). For each biological element, the department weighted (multiplied) three estimates of value delivery by the associated normalised mean rank score for the given priority value from Step III. For each biological element, the three weighted value estimates were summed.

Summary of the model outcomes

I. Individual value-delivery

The waterbird biological element and the Toolibin Lake biological element rated the highest in terms of knowledge/heritage and education value, followed by the two shrubland biological elements. Refer to *Figure 3*. At the other end of the knowledge/heritage and education continuum, the Silver mallet and Red morrel woodland biological elements scored the lowest. In terms of productive use, the terrestrial reserve vegetation elements rated the highest and the Silver mallet and Red morrel woodland elements the lowest. For philosophical/spiritual contentment, the waterbirds, Dingerlin Nature Reserve shrubland, Toolibin Lake and the Dulbining Nature Reserve woodland rated highly as did a number of the animal elements (e.g. reptiles, mammals and birds). As with the other values, the Silver mallet and Red morrel woodland elements scored poorly in terms of philosophical/spiritual contentment.

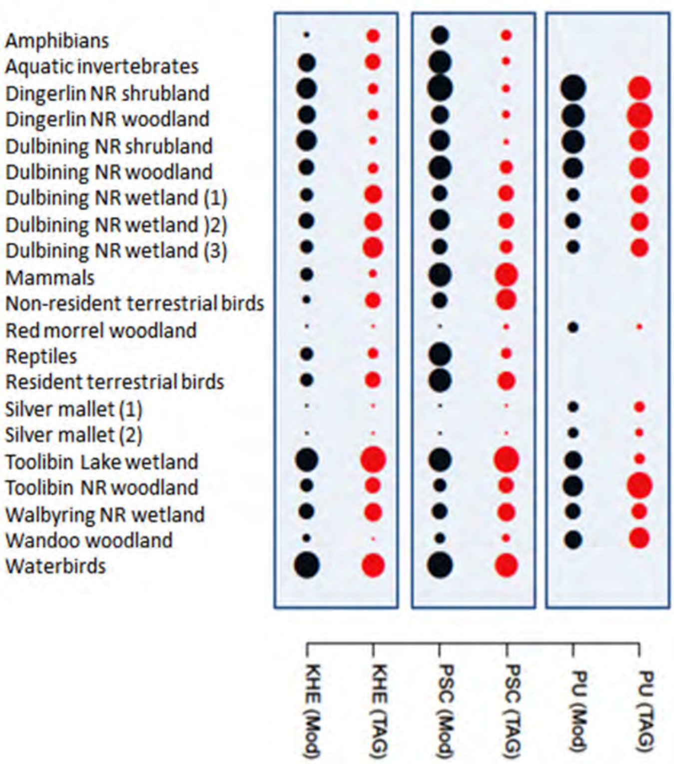


Figure 3: Comparison of the estimated value of each biological element by the property-value model and by directly elicited estimates from a technical advisory group

Note: property-value model is black and the estimates from the technical advisory group are red. Symbol size corresponds positively with expected value.
KHE = knowledge/heritage and education
PSC = philosophical/spiritual contentment
PU = productive use
Mod = model predictions
TAG = aggregated predications from technical advisory group of experts

II. Assessing the model outputs

To provide an additional check of the model outputs, the TAG provided a rating of the provision of each value by each biological element (Appendix 10). By comparing the TAG estimates (stakeholder estimates could similarly be used) with the model estimates, the department gained some useful insights (refer to Figure 4 in main document). In general, the model predictions aligned well with the elicited estimates (refer to Figure 4 in main document), providing good support for the modelling approach. The greatest differences between the two approaches related to the reserve vegetation elements. Most noticeably, the model utility estimates for the Dingerlin Nature Reserve shrubland and the Dulbining Nature Reserve woodland and shrubland elements were higher than those of the experts, whereas the expert opinions on the value of the Dulbining Nature Reserve wetland elements (1) and (3) were higher than the model. Nonetheless, given the small expert group and the sub-optimal property data, the alignment between the two estimates is encouragingly good.

We can summarise the utility estimates as follows. First, the Toolibin Lake element was rated very highly by the model and the highest by the TAG, suggesting that this is a particularly valuable biological element. A group of biological elements (the remaining wetland vegetation elements, the nature reserve woodland and shrubland elements, and the waterbirds) were rated highly by the model and the TAG alike. The most noticeable differences between the two approaches were to be found in the Dulbining and Dingerlin Nature Reserve elements. Both the model and the TAG predicted a group of biological elements to be moderate in their overall utility: terrestrial birds, wandoo woodland, amphibians, mammals, reptiles and aquatic invertebrates. Lastly, the model and the TAG predicted a group of biological elements to be of least utility: Red morrel woodland and the two Silver mallet woodland elements.

5.4. Discussion

The department, working with researchers from the School of Computer Science and Horizon Digital Economy Institute at the University of Nottingham, UK[6], has developed a new modelling approach that uses biological element properties to rate biological elements on their value (Pourabdollah et al. 2014). This method applies mathematical modelling of the relationships between the properties and the values.

Properties can be used to estimate, in relative terms, the provision of values by biological elements. By following the approach described here, managers can identify, explain and better understand the properties that should be managed to maintain or enhance a biological element's contribution to values. If, for example, the Toolibin Lake was chosen for management, it is unlikely its rarity could be altered in a positive sense over the next management period (20 years). However, with continued maintenance of size and species composition and improvement of intactness (e.g. through minimising disturbance and conducting restoration activities), the department should maintain (and even increase) the values being generated. Managers can now select important properties of important biological elements to administer and set targets for management success in terms of meeting stakeholder value expectations.

The model predicted shrubland and woodland biological elements and the Toolibin Lake biological element to be the most important within the management context. However, expert assessments by a TAG differed from the modelling, mostly in relation to several vegetation elements. These differences provide an opportunity to explore and resolve the differences with experts. This is a key strength of the approach as it provides an opportunity to iteratively adapt the modelling through expert (and stakeholder) engagement, increasing the scope for learning and development, communication and information exchange, and ultimately continued improvement in the management of the biological elements. If possible, the department could evaluate the effects of including the structure property, as well as the effects of including additional properties such as charisma and visibility. These improvements

[6] As part of the UK Engineering and Physical Sciences Research Council-funded research project 'Towards Data-Driven Environmental Policy Design', EP/K012479/1, led by Dr C Wagner

would be in addition to better quantifying the properties that were used in the first iteration, which would require additional data collection.

Practitioners must be aware of the consequences of mixing means with ends (and vice versa) in the consideration of priority biological elements to be managed. For example, in a system where a highly valued biological element is a particular vegetation type, it is clear that other biological elements, such as pollinator species, will be important to maintaining the key biological element and ultimately may also need to be managed (depending on a risk analysis). Nevertheless, the valued biological element is the vegetation type; the pollinator species may be one of the means to this end, but ultimately they are not the end itself (nor is the process of pollination). Dealing with risk factors and means is a separate part of the planning process (Wallace 2012) and is addressed in Appendix 10.

In addition to providing managers and planners with a clearer understanding of what they are managing and why, two important additional benefits of the approach relate to subsequent steps in a typical planning framework (e.g. Wallace 2012). First, a sensible planning approach will follow these steps with a risk analysis (Burgman 2005, Metcalf and Wallace 2013). To do so, the department should set management targets with temporal and spatial bounds. The department can now set management targets around the important properties (e.g. no loss of the species composition that characterises the biological element over the management period) and can assess the probability that important risk factors will cause management target failure over the management period (Metcalf and Wallace 2013). By focusing on properties, such a risk analysis will assess the likelihood that values will be maintained, improved or lost, and will identify the key ecosystem processes that must be managed and the management actions that must be taken. The department can also incorporate this information into a benefit analysis (Naidoo et al. 2006, Pearce et al. 2006) by predicting the change in utility expected with a change in a property expected by way of particular management activities. Thus, even though directly eliciting the values delivered by each biological element from experts and/or stakeholders may be a more expedient approach, modelling the links between properties and values (and where possible comparing them to directly elicited estimates) provides many additional advantages that will ultimately lead to a more informed and justifiable decision-making process.

The approach is flexible, can be applied equally well to abiotic elements, and can incorporate additional properties which may be important in other management areas. For example, many values are likely to be strongly affected by factors such as distance to schools and their number of students, distance from roads, ease of internal access, occupational health and safety considerations, and others. For Toolibin Lake, these properties were considered to be sufficiently equivalent across all the biological elements under consideration that they would have no discriminatory power in terms of priority setting. Therefore, such properties were not used in the analysis. It is anticipated that continued research will identify many other properties of biological elements that determine the way people draw value from them.

Following the approach outlined here and within the context of the work of Wallace (2007,

2012) and Metcalf and Wallace (2013), managers and other practitioners will be able to define and catalogue values, biological elements and properties and they will be able to estimate the values of the biological elements without incorrectly introducing processes (and other means) too early into the planning cycle. Of note, the links between properties and human values are inherently subjective and uncertain. However, an important additional virtue of the approach outlined here is that the decision-making process and underlying assumptions are fully documented. Thus, new knowledge and stakeholder preferences may be readily incorporated into additional iterations of the method. Although it is believed that the overall approach is theoretically sound, there is considerable scope for continued development of techniques to identify important properties and biological elements and to justify and quantify their links to important values. With this, exciting opportunities for new research are likely to emerge. Ultimately, the aim is to generate discussion, thought and greater understanding of the links between biological elements, properties and human values. In the opinion of the department, these links are at the heart of the conservation management of biota and the related political debates and decision-making. Consequently, the department must better understand such links and incorporate this understanding into planning, enabling managers to make sagacious decisions concerning our natural environment – the main aspiration of this work.

Appendix 6. Description of the 2013 biological elements

6.1. Introduction

The biological elements in the Toolibin Lake catchment were defined using the approach outlined in Appendix 5. Several vegetation elements were demarked by broad but practical management areas, and fauna was classified by taxonomic groups. The groupings were thought to be appropriate for measuring the delivery of human values to stakeholders.

6.2. Vegetation elements

- Toolibin Lake, Walbyring NR wetland and Dulbining NR wetlands (1), (2), (3): *Casuarina obesa* and *Melaleuca strobophylla* threatened ecological community (TEC)

These biological elements contain stands of *C. obesa* and *M. strobophylla* in varying degrees of health.[7] Although ephemeral, these communities were once common across the Western Australian Wheatbelt and, consequently, remaining examples have high conservation value. The TEC is listed as endangered under the *Environment Protection and Biodiversity Conservation Act 1999*, and is listed and endorsed as a critically threatened ecological community by the Western Australian Minister for Environment. *Melaleuca strobophylla* itself has a restricted geographic range in the south-west and further loss of populations of this species could lead to it becoming threatened. These elements also include stands of *Eucalyptus rudis* which is at its easternmost distribution. A range of native annuals and shrubs are also commonly associated with the TEC including *Angianthus tomentosus, Atriplex semibaccata, Austrostipa compressa, Crassula colorata, Maireana brevifolia* and *Waitzia acuminata.*

- Toolibin Nature Reserve woodland

This biological element includes woodland areas dominated by *Eucalyptus loxophleba*, *Allocasuarina huegeliana*, *Acacia acuminata* and *Banksia prionotes* that occur in the areas around some of the wetlands. The department and stakeholders consider these assemblages to be under represented in the Wheatbelt (Toolibin Lake Recovery Team and Toolibin Lake Technical Advisory Group 1994). Collectively, this element is important for a range of invertebrate and terrestrial bird species. For example, *Banksia prionotes* is an important food source for honeyeaters in the Wheatbelt as it provides nectar when no other nectar-producing plants are flowering.

[7] https://rsis.ramsar.org/RISapp/files/549/documents/AU483ECD2014.pdf

- Dingerlin Nature Reserve woodland and shrubland

This biological element features a shrubland that is characterised by a wide diversity of grasses, shrubs and trees, including species such as *Acacia deflexa, Allocasuarina campestris, Banksia sphaerocarpa, Eucalyptus latens, Melaleuca carrii, Santalum* spp., *Verticordia eriocephala* and *Xanthorrhoea drummondii.*

There are various woodland communities in Dingerlin that are characterised by species such as *Eucalyptus flocktoniae, E. kondininensis, E. longicornis, E. orthostemon*, *E. salmonophloia* and *E. wandoo*. Areas close to drainage lines are suffering severely from salinity.

- Dulbining Nature Reserve woodland and shrubland

This biological element includes plant species such as *Eucalyptus loxophleba*, *E. wandoo* and *E. salmonophloia*. In addition to the eucalypt species, it includes a range of annuals, shrubs and trees such as *Allocasuarina huegeliana, Angianthus tomentosus, Atriplex semibaccata, Austrostipa elegantissima, Daviesia debilior, Dianella revoluta, Hakea preissii, Lomandra micrantha, Melaleuca acuminata, M. brophyi, Neurachne alopecuroidea, Pterostylis pyramidalis* and *Rytidosperm caespitosum*.

The Dulbining shrubland probably grades into the Dulbining woodland and, accordingly, there is some uncertainty associated with the actual size. Dulbining Nature Reserve is dominated by species such as *Acacia lasiocarpa, Atriplex semibaccata, Melaleuca acuminata, M. lateriflora* and *M. pauperiflora*, with the occasional emergent eucalypt. Some sections of this biological element are the most degraded in the catchment and lie upstream of Toolibin Lake.

- Wandoo woodland

This biological element is dominated by *Eucalyptus wandoo*. It is the largest privately owned biological element and a listed covenant. Parts of this woodland are becoming severely degraded due to secondary salinity, rising groundwater and waterlogging.

- Red morrel woodland

This biological element is isolated and very reduced in size. The small populations are located on private property, road reserves and in the reserve system. In addition to *Eucalyptus longicornis*, species such as *Acacia acuminata* and *Senna artemisoidies* may be present.

- Silver mallet (1) and (2) woodland

This is a small biological element that is located on private property and is dominated by *Eucalyptus falcata* (formally *argyphea*) with very little understorey. Silver mallet populations are uncommon in the Toolibin catchment and often degraded.

Table 10 lists the species of flora recorded in the vegetation elements. It should be noted that this list is not exhaustive. No vegetation surveys have been carried out at Walbyring Nature Reserve wetland, Dulbining Nature Reserve wetlands (1), (2) and (3) and Wandoo woodland.

Table 10: Species of flora that have, at some point, been listed as occurring in eight vegetation elements

FAMILY Species name	Common name	Priority listed	Toolibin Lake	Toolibin Nature Reserve woodland	Dulbining Nature Reserve shrubland	Dulbining Nature Reserve woodland	Dingerlin Nature Reserve woodland	Dingerlin Nature Reserve shrubland	Red morrel woodland	Silver mallet woodland (1) and (2)
LAURACEAE										
Cassytha flava	dodder laurel						X	X		
JUNCAGINACEAE										
Cycnogeton lineare						X				
Triglochin minutissima			X							
Triglochin mucronata			X	X						
Triglochin sp. A Flora of Australia						X				
Triglochin stowardii						X				
POTAMOGETONACEAE										
Lepilaena cylindrocarpa						X				
RUPPIACEAE										
Ruppia megacarpa						X	X			
Ruppia polycarpa					X	X	X			
COLCHICACEAE										
Wurmbea tenella	eight nancy		X							
ORCHIDACEAE										
Caladenia falcata				X		X				
Caladenia flava	cowslip orchid			X				X		
Pterostylis sanguinea				X						
Pterostylis pyramidalis	snail orchid				X	X				
Thelymitra macrophylla						X				
Thelymitra petrophila						X				
BORYACEAE										
Borya sphaerocephala	pincushions					X	X			
XANTHORRHOEACEAE										
Xanthorrhoea drummondii								X		
ASPARAGACEAE										
Chamaescilla spiralis				X						
Dichopogon capillipes						X				
Dichopogon preissii							X			
Laxmannia grandiflora								X		
Lomandra collina	pale mat rush			X						
Lomandra effusa	scented matrush					X	X			
Lomandra micrantha	small-flower mat-rush				X	X	X			
Lomandra rupestris				X						
Thysanotus patersonii			X	X		X	X			
Thysanotus rectantherus			X	X						
Thysanotus tenuis		P3		X						
ASPHODELACEAE										
Bulbine semibarbata	leek lily		X			X				
HEMEROCALLIDACEAE										
Dianella revoluta	blueberry lily			X	X	X			X	

FAMILY Species name	Common name	Priority listed	Toolibin Lake	Toolibin Nature Reserve woodland	Dulbining Nature Reserve shrubland	Dulbining Nature Reserve woodland	Dingerlin Nature Reserve woodland	Dingerlin Nature Reserve shrubland	Red morrel woodland	Silver mallet woodland (1) and (2)
Stypandra glauca	blind grass		X					X		
CYPERACEAE										
Chorizandra enodis	black bristlerush				X					
Gahnia ancistrophylla	hooked-leaf saw sedge				X	X				
Gahnia trifida	coast saw-sedge				X	X				
Isolepis cernua	nodding club-rush					X				
Lepidosperma rigidulum								X		
Lepidosperma sanguinolentum						X				
Lepidosperma tenue					X					
Lepidosperma tuberculatum							X			
Lepidosperma viscidum	sticky sword sedge							X		
Mesomelaena preissii				X			X	X		
Schoenus aff. brevisetis								X		
Schoenus nanus	tiny bog rush					X				
ANARTHRIACEAE										
Lyginia barbata				X				X		
Lyginia imberbis				X						
CENTROLEPIDACEAE										
Centrolepis polygyna	wiry centrolepis					X				
RESTIONACEAE										
Desmocladus lateriticus					X					
Harperia lateriflora				X				X		
Lepidobolus preissianus						X		X		
Loxocarya cinerea						X	X	X		
POACEAE										
Amphipogon strictus	greybeard grass							X		
Amphipogon turbinatus				X				X		
Austrostipa compressa			X	X	X	X				
Austrostipa elegantissima			X	X		X	X	X		
Austrostipa hemipogon				X		X		X		
Austrostipa nodosa				X				X		
Austrostipa puberula							X			
Austrostipa pycnostachya						X		X		
Austrostipa tenuifolia				X						
Austrostipa trichophylla						X	X			
Lachnagrostis filiformis			X	X						X
Neurachne alopecuroidea	foxtail mulga grass			X	X	X		X		
Poa drummondiana	knotted poa			X						
Rytidosperma caespitosum					X	X	X	X		
Rytidosperma setaceum				X		X		X		
Triodia longipalea				X		X				
PROTEACEAE										
Adenanthos cygnorum	common woollybush						X	X		
Banksia attenuata	slender banksia			X						

FAMILY Species name	Common name	Priority listed	Toolibin Lake	Toolibin Nature Reserve woodland	Dulbining Nature Reserve shrubland	Dulbining Nature Reserve woodland	Dingerlin Nature Reserve woodland	Dingerlin Nature Reserve shrubland	Red morrel woodland	Silver mallet woodland (1) and (2)
Banksia dallanneyi	couch honeypot					X				
Banksia densa var. *densa*								X		
Banksia meganotia		P3						X		
Banksia prionotes	acorn banksia			X		X				
Banksia sphaerocarpa	round-fruit banksia							X		
Banksia tenuis								X		
Conospermum stoechadis subsp. *sclerophyllum*						X				
Grevillea pilulifera	woolly-flowered grevillea							X		
Grevillea aff. uncinulata								X		
Hakea cygna subsp. *cygna*	swan fruit hakea							X		
Hakea incrassata	marble hakea							X		
Hakea lissocarpha	honey bush						X	X		
Hakea preissii	needle tree				X	X				
Hakea prostrata	harsh hakea			X			X	X		
Hakea trifurcata	two-leaf hakea						X	X		
Isopogon teretifolius subsp. *teretifolius*	nodding coneflower							X		
Persoonia quinquenervis								X		
Petrophile seminuda								X		
DILLENIACEAE										
Hibbertia exasperata								X		
CRASSULACEAE										
Crassula closiana						X				
Crassula colorata	dense stonecrop		X			X	X			
Crassula exserta						X				
Crassula peduncularis	purple stonecrop					X				
HALORAGACEAE										
Glischrocaryon aureum	common popflower						X	X		
FABACEAE										
Acacia acuminata	jam		X	X	X	X	X		X	
Acacia deflexa		P3						X		
Acacia erinacea							X	X	X	
Acacia lasiocarpa var. *sedifolia*					X		X			
Acacia leptopetala					X	X				X
Acacia microbotrya	manna wattle					X				
Acacia pulchella	rickly moses				X	X				
Acacia saligna	orange wattle			X						
Acacia spinosissima							X			
Acacia stenoptera	narrow winged wattle							X		
Acacia subflexuosa								X		
Daviesia cardiophylla								X		
Daviesia debilior						X			X	

FAMILY Species name	Common name	Priority listed	Toolibin Lake	Toolibin Nature Reserve woodland	Dulbining Nature Reserve shrubland	Dulbining Nature Reserve woodland	Dingerlin Nature Reserve woodland	Dingerlin Nature Reserve shrubland	Red morrel woodland	Silver mallet woodland (1) and (2)
Daviesia horrida	prickly bitter-pea					X				
Daviesia incrassata								X		
Daviesia rhombifolia								X		
Gompholobium tomentosum	hairy yellow pea					X				
Jacksonia furcellata	grey stinkwood			X		X				
Jacksonia racemosa			X					X		
Mirbelia spinosa								X		
Senna artemisioides									X	
POLYGALACEAE										
Comesperma integerrimum						X			X	
Comesperma scoparium	broom milkwort							X		
Comesperma virgatum	milkwort					X			X	
RHAMNACACEAE										
Cryptandra leucopogon					X			X		
Cryptandra pungens					X	X				
CASUARINACEAE										
Allocasuarina campestris								X		
Allocasuarina huegeliana	rock sheoak			X		X		X	X?	X?
Allocasuarina humilis	dwarf sheoak						X	X		
Allocasuarina microstachya								X		
Casuarina obesa	swamp sheoak		X							
CUCURBITACEAE										
CELASTRACEAE							X	X		
Stackhousia monogyna										
PHYLLANTHACEAE										
Poranthera microphylla	small poranthera			X						
LINACEAE										
Linum marginale	wild flax		X	X	X	X				
GERANIACEAE										
Erodium cygnorum	blue heronsbill		X							
MYRTACEAE										
Baeckea crispiflora							X	X		
Baeckea sp. *fine-leaved*								X		
Beaufortia bracteosa								X		
Beaufortia incana								X		
Callistemon phoeniceus	lesser bottlebrush		X?	X						
Calothamnus quadrifidus	one-sided bottlebrush			X			X	X		
Calytrix leschenaultii								X		
Eremaea pauciflora				X		X				
Eucalyptus thamnoides								X		
Eucalyptus falcata	Silver mallet									X
Eucalyptus flocktoniae	merrit						X			
Eucalyptus incrassata	lerp mallee				X					
Eucalyptus kondininensis	kondinin blackbutt						X			
Eucalyptus latens	narrow-leaved red mallee							X		

FAMILY Species name	Common name	Priority listed	Toolibin Lake	Toolibin Nature Reserve woodland	Dulbining Nature Reserve shrubland	Dulbining Nature Reserve woodland	Dingerlin Nature Reserve woodland	Dingerlin Nature Reserve shrubland	Red morrel woodland	Silver mallet woodland (1) and (2)
Eucalyptus longicornis	Red morrel						X		X	
Eucalyptus loxophleba	york gum			X	X	X	X		X	
Eucalyptus loxophleba x wandoo		P4					X			
Eucalyptus myriadena subsp. myriadena						X				
Eucalyptus neutra							X			
Eucalyptus orthostemon										
Eucalyptus rudis	flooded gum		X	X						
Eucalyptus salmonophloia	salmon gum				X	X	X			
Eucalyptus wandoo subsp. *wandoo*	wandoo				X	X	X			
Leptospermum erubescens	roadside teatree			X	X			X		
Melaleuca acuminata				X	X	X				
Melaleuca adnata						X	X			
Melaleuca atroviridis				X	X					
Melaleuca brophyi			X			X	X	X		
Melaleuca carrii						X		X		
Melaleuca lateriflora subsp. *lateriflora*	gorada			X	X	X				
Melaleuca pauperiflora	boree				X					
Melaleuca pungens								X		
Melaleuca scalena						X	X			
Melaleuca strobophylla			X	X	X	X				
Melaleuca subtrigona						X		X		
Melaleuca tuberculata								X		
Melaleuca viminea	mohan			X						
Pericalymma ellipticum						X				
Verticordia brownii								X		
Verticordia chrysantha								X		
Verticordia eriocephala	common cauliflower							X		
Verticordia grandiflora	claw featherflower							X		
Verticordia multiflora subsp. *multiflora*				X						
Verticordia picta								X		
Verticordia roei subsp. *roei*								X		
Verticordia serrata								X		
SAPINDACEAE										
Dodonaea pinifolia								X		
Dodonaea viscosa	sticky hopbush				X	X				
MALVACEAE										
Alyogyne hakeifolia				X						
Androcalva cuneata				X						
THYMELAEACEAE										
Pimelea argentea	silvery leaved pimelea								X	

FAMILY Species name	Common name	Priority listed	Toolibin Lake	Toolibin Nature Reserve woodland	Dulbining Nature Reserve shrubland	Dulbining Nature Reserve woodland	Dingerlin Nature Reserve woodland	Dingerlin Nature Reserve shrubland	Red morrel woodland	Silver mallet woodland (1) and (2)
SANTALACEAE										
Santalum acuminatum	quandong			X			X	X		
Santalum spicatum	sandalwood			X		X				
Santalum murrayanum	bitter quandong						X	X		
DROSERACEAE										
Drosera macrantha	bridal rainbow			X						
Drosera zonaria	painted sundew			X						
AMARANTHACEAE										
Ptilotus declinatus	curved mulla mulla							X		
Ptilotus manglesii	pom poms					X	X			
Ptilotus polystachyus	Prince of Wales feather		X							
CHENOPODIACEAE										
Atriplex nana			X		X					X
Atriplex semibaccata	berry saltbush		X	X	X	X				
Maireana brevifolia	small leaf bluebush		X		X	X	X		X	
Sarcocornia blackiana			X							
Sarcocornia quinqueflora	beaded samphire		X							
Suaeda australis	seablite					X				
Tecticornia indica			X		X	X				
Tecticornia lepidosperma			X		X	X				
Tecticornia pergranulata			X		X	X				
Threlkeldia diffusa	coast bonefruit		X							
AIZOACEAE										
Carpobrotus modestus	inland pigface		X			X				
PORTULACACEAE										
Calandrinia calyptrata	pink purslane		X	X						
Calandrinia calyptrata	pygmy purslane		X							
ERICACEAE										
Astroloma sp.					X					
Leucopogon dielsianus								X		
Leucopogon sp. Great Southern								X		
RUBIACEAE										
Opercularia vaginata	dog weed		X	X				X		
GENTIANACEAE										
Sebaea ovata	yellow sebaea					X				
LOGANIACEAE										
Phyllangium paradoxum						X				
CONVOLVULACEAE										
Wilsonia humilis	silky wilsonia		X							
Wilsonia rotundifolia	round-leaf wilsonia		X							
LAMIACEAE										
Microcorys exserta								X		
LENTIBULARIACEAE										
Utricularia tenella						X				
CAMPANULACEAE										

FAMILY Species name	Common name	Priority listed	Toolibin Lake	Toolibin Nature Reserve woodland	Dulbining Nature Reserve shrubland	Dulbining Nature Reserve woodland	Dingerlin Nature Reserve woodland	Dingerlin Nature Reserve shrubland	Red morrel woodland	Silver mallet woodland (1) and (2)
Isotoma hypocrateriformis	woodbridge poison					X				
Lobelia tenuior	slender lobelia			X						
Wahlenbergia preissii			X	X						
STYLIDIACEAE										
Stylidium clavatum								X		
Stylidium zeicolor	maize triggerplant							X		
GOODENIACEAE										
Coopernookia strophiolata					X	X				
Dampiera lavandulacea							X			
Dampiera lindleyi								X		
Goodenia glareicola								X		
Goodenia micrantha						X				
Goodenia viscida	viscid goodenia		X							
ASTERACEAE										
Actinobole uliginosum	flannel cudweed						X			
Angianthus tomentosus	camel-grass		X		X	X				
Blennospora drummondii				X		X				
Brachyscome iberidifolia			X		X					
Ceratogyne obionoides	wingwort		X							
Cotula cotuloides	smooth cotula		X							
Erymophyllum tenellum						X				
Gnephosis drummondii				X						
Helichrysum leucopsideum			X							
Lawrencella rosea				X		X				
Millotia tenuifolia	soft millotia			X						
Olearia sp.						X				
Podolepis canescens			X							
Podolepis capillaris	wiry podolepis					X				
Podolepis lessonii			X			X	X			
Podotheca angustifolia	sticky longheads		X	X			X	X		
Podotheca gnaphalioides	golden long-heads		X							
Pogonolepis stricta			X							
Pterochaeta paniculata								X		
Quinetia urvillei			X							
Rhodanthe laevis				X						
Senecio glossanthus	slender groundsel		X	X	X					
Waitzia acuminata	orange immortelle		X	X	X	X	X			
Waitzia suaveolens	fragrant waitzia		X							
PITTOSPORACEAE										
Billardiera coriacea				X			X	X		
ARALIACEAE										
Hydrocotyle diantha			X			X				
Hydrocotyle pilifera			X	X						
Hydrocotyle rugulosa			X			X				
Trachymene pilosa	native parsnip		X	X		X				
APIACEAE										
Apium annuum						X				

FAMILY Species name	Common name	Priority listed	Toolibin Lake	Toolibin Nature Reserve woodland	Dulbining Nature Reserve shrubland	Dulbining Nature Reserve woodland	Dingerlin Nature Reserve woodland	Dingerlin Nature Reserve shrubland	Red morrel woodland	Silver mallet woodland (1) and (2)
Daucus glochidiatus	Australian carrot						X			

P3 *= Priority 3*

P4 *= Priority 4*

For the definition of the priority listings above please see the Conservation Codes for Western Australia at the end of this appendix.

Data collated from the following sources:

- *Brown and Root 2002*
- *Department of Environment and Conservation 2007*
- *Keighery et al. 2004*
- *Recovery plan surveys – Mattiske 1993, Ogden and Froend 1998, Froend et al. 1998, Ogden and Froend 2000, Ogden and Froend 2002, Ecoscape 2005, Ecoscape 2007, Ecoscape 2009*
- *Department of Parks and Wildlife 2016*
- *Peter White (pers. comm.) and Ray McKnight (pers. comm.), Department of Environment and Conservation*

6.3. Waterbirds

Table 11: Waterbirds observed at Toolibin Lake from 1965 to 2011

Note: information sourced from Froend and Storey (1997), Halse et al. (2000) and observations by staff from the then Department of Environment and Conservation (DEC) in summer 2006

*Note: an asterix * denotes waterbird species recorded breeding at Toolibin Lake. Common and scientific names are consistent with Christidis and Boles (2008)*

Scientific name	Common name	Listed species	Guild 1	Guild 2	Guild 3	Guild 4	Salinity
**Biziura lobata*	musk duck				X		0.1-11.4
**Stictonetta naevosa*	freckled duck				X		7.7-9.0
**Cygnus atratus*	black swan				X		0.4-43.5
**Tadorna tadornoides*	Australian shelduck			X			0.4-57.0
**Chenonetta jubata*	Australian wood duck			X			0.1-9.5
**Malacorhynchus membranaceus*	pink-eared duck			X			0.1-17.0
**Anas rhynchotis*	Australasian shoveler			X			1.0-22.2
**Anas gracilis*	grey teal			X			0.1-37.7
Anas castanea	chestnut teal			X			≤2.0-35.0

Scientific name	Common name	Listed species	Guild 1	Guild 2	Guild 3	Guild 4	Salinity
**Anas superciliosa*	Pacific black duck			X			0.2-14.6
**Aythya australis*	hardhead				X		0.4-4.9
**Oxyura australis*	blue-billed duck				X		0.7-6.4
**Tachybaptus novaehollandiae*	Australasian grebe				X		0.7-10.0
**Poliocephalus poliocephalus*	hoary-headed grebe				X		0.7-9.9
**Podiceps cristatus*	great crested grebe				X		0.7-8.3
**Anhinga novaehollandiae*	Australasian darter				X		1.7-7.3
**Microcarbo melanoleucos*	little pied cormorant				X		0.7-17.2
**Phalacrocorax carbo*	great cormorant				X		1.0-4.7
**Phalacrocorax sulcirostris*	little black cormorant				X		0.9-17.2
Phalacrocorax varius	pied cormorant				X		2.0-35.0
Pelecanus conspicillatus	Australian pelican				X		2.0->35.0
Botaurus poiciloptilus	Australasian bittern	Endangered (WA) Endangered (EPBC)		X			
**Ardea pacifica*	white-necked heron			X			≤2.0
**Ardea modesta*	eastern great egret	C, J		X			1.5-10.2
**Egretta novaehollandiae*	white-faced heron			X			0.1-25.8
**Nycticorax caledonicus*	nankeen night-heron			X			0.8-10.2
Plegadis falcinellus	glossy ibis	B, C		X			
Threskiornis molucca	Australian white ibis			X			≤2.0-5.0
Threskiornis spinicollis	straw-necked ibis		X				0.8-2.0
**Platalea flavipes*	yellow-billed spoonbill			X			0.8-7.5
Circus approximans	swamp harrier					X	
**Porphyrio porphyrio*	purple swamphen		X				0.3-4.1
Tribonyx ventralis	black-tailed native hen		X				
**Fulica atra*	Eurasian coot				X		0.2-32.1
Himantopus himantopus	black-winged stilt			X			0.1-21.5
Recurvirostra novaehollandiae	red-necked avocet			X			
Cladorhynchus leucocephalus	banded stilt			X			10.0-25.0

Scientific name	Common name	Listed species	Guild 1	Guild 2	Guild 3	Guild 4	Salinity
Charadrius ruficapillus	red-capped plover			X			35.0
Charadrius veredus	oriental plover	B, J, R		X			
Elseyornis melanops	black-fronted dotterel			X			≤2.0-35.0
Erythrogonys cinctus	red-kneed dotterel			X			
Vanellus tricolor	banded lapwing			X			
Actitis hypoleucos	common sandpiper	B, C, J, R		X			2.0-5.0
Tringa nebularia	common greenshank	B, C, J, R		X			2.0-5.0
Tringa stagnatilis	marsh sandpiper	B, C, J, R		X			≤2.0-5.0
Tringa glareola	wood sandpiper	B, C, J, R		X			
Calidris ruficollis	red-necked stint	B, C, J, R		X			≤2.0-35.0
Calidris acuminata	sharp-tailed sandpiper	B, C, J, R		X			
Chlidonias hybrida	whiskered tern				X		2.0-35.0
Chroicocephalus novaehollandiae	silver gull		X				35.0

WA = Western Australian *Wildlife Conservation Act 1950*
EPBC = Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act); migratory bird species listed under the EPBC Act (as at November 2011)
B = Convention on the Conservation of Migratory Species of Wild Animals (Bonn or CMS)
C = China-Australia Migratory Bird Agreement (CAMBA)
J = Japan-Australia Migratory Bird Agreement (JAMBA)
R = Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA)
Guild 1 = shore: majority of feeding is on dry land
Guild 2 = wading birds and shallow feeders: feeding in water that is less than or equal to 0.5m deep (may also feed within wet mud and guild 1)
Guild 3 = deep feeders: requiring a water depth that is greater than 1m but can also occupy guilds 1 and 2
Guild 4 = aerial feeders: birds of prey
Salinity – preferred waterbird water salinity range (parts per thousand) where known

Note: Toolibin Lake has been recognised as providing important waterbird habitat, particularly for breeding, and meets the Ramsar criterion pertaining to the support of fauna during critical stages in their life cycle. Up to 50 species have been observed at Toolibin Lake, which is one of the highest records of any inland south-west wetland (Halse et al. 2000). Toolibin Lake also supports the highest number of breeding waterbird species (n=25) recorded in any inland south-west wetland (Northern Arthur River Wetlands Committee 1987, Halse et al. 2000).

Recent waterbird surveys at Toolibin Lake have been limited due to an extended dry period and lack of inundation. However, staff undertaking opportunistic observations of waterbirds during a partial fill event in 2006 recorded 33 waterbird species using the Toolibin Lake complexes (Toolibin Lake, Dulbining and Walbyring wetlands) with 12 species breeding. These observations are encouraging and suggest that if conditions are favourable, substantial *numbers of waterbird species will continue to visit and breed at Toolibin Lake and the surrounding wetlands.*

6.4. Terrestrial birds

Table 12: Resident and non-resident terrestrial birds in the management area

Species name	Common name	Resident/ non-resident	Listing
Accipiter fasciatus	brown goshawk	non-resident	
Acrocephalus stentoreus	clamorous reed-warbler	non-resident	
Anthochaera carunculata	red wattlebird	non-resident	
Aquila audax	wedge-tailed eagle	non-resident	
Artamus cinereus	black-faced woodswallow	non-resident	
Artamus cyanopterus	dusky woodswallow	non-resident	
Circus assimilis	spotted harrier	non-resident	
Coracina novaehollandiae	black-faced cukoo-shrike	non-resident	
Coturnix pectoralis	stubble quail	non-resident	
Daphoenositta chrysoptera	varied sittella	non-resident	
Dromaius novaehollandiae	emu	non-resident	
Elanus axillaris	black-shouldered kite	non-resident	
Falco berigora	brown falcon	non-resident	
Falco cenchroides	nankeen kestral	non-resident	
Gergoyne fusca	western gergone	non-resident	
Glossopsitta porphyrocephala	purple-crowned lorikeet	non-resident	
Grallina cyanoleuca	magpie-lark	non-resident	
Haliastur sphenurus	whistling kite	non-resident	
Hieraaetus morphnoides	little eagle	non-resident	
Hirundo neoxena	welcome swallow	non-resident	
Lalage tricolor	white-winged triller	non-resident	
Melithreptus brevirostris	brown-headed honeyeater	non-resident	
Merops ornatus	rainbow bee-eater	non-resident	Migratory EPBC List
Microeca fascinans	jacky winter	non-resident	
Neophema elegans	elegant parrot	non-resident	
Ninox boobook	southern boobook	non-resident	
Pachycephala pectoralis	goldern whistler	non-resident	
Pachycephala rufiventris	rufous whistler	non-resident	
Petroica boodang	scarlet robin	non-resident	
Petroica goodenovii	red-capped robin	non-resident	
Polytelis anthopeplus	regent parrot	non-resident	
Pterochelidon nigrcans	tree martin	non-resident	
Rhipidura albiscapa	grey fantail	non-resident	
Rhipidura leucophrys	willie wagtail	non-resident	
Strepera versicolor	grey currawong	non-resident	
Todiramphus sanctus	sacred kingfisher	non-resident	
Tyto alba	barn owl	non-resident	
Acanthiza apicalis	inland thornbill	resident	
Acanthiza chrysorrhoa	yellow-rumped thornbill	resident	
Acanthiza inorata	western thornbill	resident	
Aegotheles cristanus	Australian owlet-nightjar	resident	
Anthus australis	Australasian (Richard's) pipit	resident	
Barnardius zonarius	Australian ringneck	resident	
Climacteris rufa	rufous rreecreeper	resident	
Colluricincla harmonica	grey strike-thrush	resident	
Corvus coronoides	Australian raven	resident	

Species name	Common name	Resident/ non-resident	Listing
Cracticus torquatus	grey butcherbird	resident	
Dacelo novaeguineae	laughing kookaburra	resident	
Drymodes brunneopygia	southern scrub robin	resident	
Eolophus roseicapillus	galah	resident	
Eopsaltria griseogularis	western yellow robin	resident	
Epthianura albifrons	white-fronted chat	resident	
Falco longipennis	Australian hobby	resident	
Gymnorhina tibicen	Australian magpie	resident	
Leipoa ocellata	malleefowl	resident	EPBC - Vulnerable
Lichenstomus virescens	singing honeyeater	resident	
Lichmera indistincta	brown honeyeater	resident	
Myiagra inquieta	restless flycatcer	resident	
Ocyphaps lophotes	crested pigeon	resident	
Pardolotus striatus	striated pardalote	resident	
Phylidonyris nigra	white-cheeked honeyeater	resident	
Phylidonyris novaehollandiae	New Holland honeyeater	resident	
Platycercus icterotis xanthogenys	western rosella (inland ssp)	resident	
Podargus strigoides	tawny frogmouth	resident	
Pomatostomus supercilious ashbyi	white-browed babbler	resident	
Psephotus varius	mulga parrot	resident	
Sericornis frontalis	white-browed scrubwren	resident	
Smicrornis brevirostris	weebill	resident	
Zosterops lateralis	silvereye	resident	

From Simpson and Day (1996)

***Sedentary** = resident*

***Locally dispersive/nomadic** = resident*

***Migratory** = non-resident*

***Migrant** = non-resident*

***Nomadic** = non-resident*

***Dispersive** = non-resident*

***Combination** = non-resident*

Based on adults not young, which can be dispersive.

6.5. Aquatic invertebrates

Table 13: Aquatic invertebrate species

Note: recorded by Halse et al. 2000, Keighery et al. 2004 and Doupe and Horwitz 1995

*Note: species marked with an asterisk * are indicator species*

Note: genus/species marked with a question mark ? are unconfirmed

Taxonomic group	Species	Toolibin Lake	Dulbining wetland (1)	Walbyring Lake	Arthur River
Amphipoda	*Austrochiltonia subtenuis*	X	X	X	
	Austrochiltonia sp.	X	X	X	X
Anostraca	*Branchinella* sp.		X		
Arachnida	*Eylais* sp.				X
	Limnesia sp.			X	
	Singotypa sp.			X	
	Tetragnatha sp.			X	
	Trombidioidea sp.		X		
Chonchostraca	*Cyzicus* sp.				X
Cladocera	*Ceriodaphnia* sp.		X	X	X
	Daphnia carinata	X	X	X	X
	Daphnia cephalata			X	
	Daphniopsis queenslandensis		X	X	
	Dunhevedia crassa	X		X	
	Echninisca sp.	X	X	X	X
	Leydigia aff. *australis*			X	
	Macrothrix aff. *capensis*	X			
	Macrothrix aff. *indistincta*	X		X	
	Macrothrix schauinslandi		X		
	Moinidae sp.	X		X	X
	Pleuroxus sp.	X			X
	Simocephalus vetulus			X	
	Simocephalus sp.		X		X
Coleoptera	*Allodessus bistrigatus*		X	X	
	Allodessus sp.	X	X	X	X
	Antiporus gilberti		X	X	
	Antiporus sp.	X	X		X
	Australphilus montanus	X	X	X	X
	Berosus approximans		X		
	Berosus discolor	X		X	
	Berosus macumbensis		X	X	
	Berosus munitipennis			X	
	Berosus sp. 1	X	X	X	
	Berosus sp. 2	X		X	
	Berosus sp. 3				X
	Bidessus sp. 1	X			X
	Bidessus sp. 2	X			
	Copelatus sp.			X	
	Curculionidae sp.			X	
	Enochrus elongatus		X	X	
	Enochrus eyrensis		X	X	
	Enochrus maculcieps			X	
	Gymnocthebius sp. 1			X	
	Haliplus fuscatus		X		
	Haliplus sp.				X

Taxonomic group	Species	Toolibin Lake	Dulbining wetland (1)	Walbyring Lake	Arthur River
	Homeodytes scutellaris				X
	Hydaticus sp. 1	X	X	X	X
	?Hydaticus sp. 2	X			X
	Hydrophilidae sp.			X	
	Hydrovatus sp.				X
	Hygrobia australasiae	X	X	X	
	Hyphydrus sp.		X		
	Laccobius sp.				X
	Laccophilus sp. 1	X			
	Laccophilus sp. 2			X	X
	Lancetes lanceolatus	X	X		X
	Liodessus inornatus	X			
	Macroporus sp. 1	X	X		
	Macroporus sp.			X	
	Megaporus howitti		X	X	
	Necterosoma pencillatus	X	X	X	
	Necterosoma sp.	X			
	Noteridae sp.				X
	Paroster sp.	X			X
	?Rhantaticus sp. 1	X			
	?Rhantaticus sp. 2				X
	Rhantus suturalis		X	X	
	Scirtidae sp.		X		
	Sternopriscus multimaculatus			X	
Copepoda	*Apocyclops dengizicus*	X			
	Australocyclops australis			X	
	Boeckella triarticulata	X	X	X	
	Calamoecia ampulla		X	X	
	?Calamoecia sp.	X		X	X
	Mesochra nr *flava*			X	
	Mesocyclops brooksi	X	X	X	
	Metacyclops sp. 442			X	
	Microcyclops sp.			X	
	?Microcyclops sp.	X	X	X	X
	Nitcra? reducta sp. 5		X		
Decapoda	*Cherax albidus* (claw)				X
	Palaemonetes australis		X		X
Diptera Hemiptera	*Anopheles annulipes*		X		
	Anopheles annulipes sp. 1	X			
	Anopheles sp.		X		
	Ceratopogonidae sp. 1	X		X	
	Ceratopogonidae sp. 2	X			
	Ceratopogonidae sp. 3			X	
	Ceratopogonidae sp.			X	
	Chironomus aff. *alternans*		X	X	
	Chironomus aff. *alternans* V24		X		
	Chironomus occidentalis	X			
	Chironomus oppositus	X		X	
	Chironomus tepperi	X	X		X
	Cladopelma curtivalva	X	X	X	
	Cricotopus albitarsus			X	

Taxonomic group	Species	Toolibin Lake	Dulbining wetland (1)	Walbyring Lake	Arthur River
	Cryptochironomus griseidorsum	X		X	
	Culex sp. 1			X	
	Culex sp. 2	X			
	Dicrotendipes conjunctus	X	X	X	
	Dipteran pupae sp. 1	X	X	X	X
	Dipteran pupae sp. 2			X	
	Dipteran pupae sp. 3	X		X	
	Dolichopodidae sp. A		X	X	
	Ephydridae sp. 1	X			
	Ephydridae sp. 2	X			
	Ephydridae sp. 3 SAP		X		
	Ephydridae sp.	X			
	Forcipomyiinae sp.	X		X	
	Kiefferulus interinctus	X	X	X	
	Monohelea sp. 1			X	
	Nilobezzia sp. 1			X	
	Paramerina levidensis		X		
	Polpedilum nubifer	X	X	X	
	Procladius paludicola	X	X	X	X
	Procladius villosimanus		X		
	Stratiomyidae sp. 1	X			
	Stratiomyidae sp. 2	X		X	
	Stratiomyidae sp. 3	X			
	Stratiomyidae sp.		X		
	Tabanidae sp.		X	X	
	Tanytarsus fuscithorax	X		X	
	Tanytarsus fuscithorax/semibarbitarsus		X	X	
	Tipulidae sp.	X			
	Agraptocorixa hirtifrons			X	
	Agraptocorixa parvipunctata	X		X	
	Agraptocorixa sp.		X		
	?Agraptocorixa sp.			X	
	Anisops gratus			X	
	Anisops thienemanni	X	X	X	
	Anisops sp. 1	X		X	X
	Anisops sp. 2			X	
	Corixidae sp. 5			X	
	Micronecta robusta	X		X	
	Micronecta sp. 1			X	
	Micronecta sp. 2			X	
	Microvelia sp.			X	
	Notonectidae sp. 4		X	X	X
	Paranisops sp.	X	X	X	X
	Saldidae sp.		X		
	Sigara mullaka	X		X	
	Sigara sp.	X	X	X	X
Hirudinea	Glossiphoniidae sp.			X	
	Hirudinea sp.	X		X	X
Gastropoda	*?Bayardella* sp.			X	

Taxonomic group	Species	Toolibin Lake	Dulbining wetland (1)	Walbyring Lake	Arthur River
	Isidorella ?bradshawi			X	
	Physastra sp.			X	
Lepidoptera	Pyralidae sp.	X			X
Nematoda	Nematoda sp.			X	X
Odonata	*Austrolestes annulsosus*	X	X	X	
	Austrolestes io		X		
	Coenagriidae sp.	X		X	
	Diplacodes bipunctata	X			
	Hemianax papuensis	X	X	X	
	Hemicordulia tau	X	X	X	
	Orthetrum caledonicum	X			
	Xanthagrion erythroneurum	X	X	X	
Oligochaeta	*Ainudrilus nharna*		X		
	Ainudrilus sp.			X	
	Dero nivea			X	
	Enchytraeidae sp.		X		
	Oligochaeta sp. 1				X
	Oligochaeta sp. 2			X	
	Oligochaeta sp. 3		X		
	Opisthopora sp.		X	X	
	Tubificidae sp.		X		
Ostracoda	*Alboa worooa*	X	X	X	X
	Bennelongia australis			X	
	Bennelongia sp.	X			X
	Candocypris novaezelandiae	X		X	
	Cypretta baylyi			X	
	Cyprinotus edwardi	X	X	X	
	Cyprinotus ?edwardi	X	X	X	X
	Diacypris spinosa	X			X
	Mytilocypris ambiguosa	X	X	X	
	Mytilocypris ?ambiguosa	X	X	X	X
	Mytilocypris mytiloides	X		X	
	Mytilocypris tasmanica chapmani	X	X		
	Mytilocypris sp. 2	X	X		X
	Sarscypridopsis aculeata	X		X	X
Platyhelminthes	Platyhelminthe sp.			X	X
Trichoptera	*Ecnomus* sp.			X	
	Notalina spira	X		X	
	Oecetis sp.			X	
	Triplectides australis	X		X	

6.6. Natural mammals, reptiles and amphibians

Below are tables of natural mammals (Table 14), reptiles (Table 15) and amphibians (Table 16) known or likely to occur within the Toolibin Lake catchment.

Information is taken from Tyler et al. (2000), Van Dyck and Strahan (2008), Wilson and Swan (2003), Ray McKnight and Brett Beecham DEC (pers. comm.) and DEC (2007).

Table 14: Natural mammal species known or likely to occur in the catchment

Scientific name	Common name
Known to occur (have been sighted)	
Tachyglossus aculeatus	short-beaked echidna
Phascogale calura *	red-tailed phascogale
Trichosurus vulpecula	common brushtail possum
Macropus fuliginosus	western grey kangaroo
Likely to occur	
Dasyurus geoffroii **	western quoll
Sminthopsis gilberti	Gilbert's dunnart
Sminthopsis crassicaudata	fat-tailed dunnart
Macropus eugenii	tammar wallaby
Macropus irma	western brush wallaby
Mormopterus planiceps	western free-tailed bat
Tadarida australis	white-striped free-tailed bat
Nyctophilus geoffroyi	lesser long-eared bat
Nyctophilus timoriensis	greater long-eared bat
Chalinolobus gouldii	Gould's wattled bat
Chalinolobus morio	chocolate wattled bat
Vespadelus regulus	southern forest bat
Cercartetus concinnus	western pygmy possum
Tarsipes rostratus	honey possum

** Threatened endangered*

*** Threatened vulnerable*

Table 15: Natural reptile species known or likely to occur in the catchment

Scientific name	Common name
Known to occur (have been sighted)	
Amphibolurus minimus	western bearded dragon
Morelia spilota	carpet python
Nephrurus milii	barking gecko
Pseudonaja affinis	dugite
Tiliqua occipitalis	western blue-tongue
Tiliqua rugosa	bobtail
Varanus gouldii	Gould’s goanna
Likely to occur	
Aprasia repens	sand-plain worm-lizard
Christinus marmoratus	marbled gecko
Cryptoblepharus plagiocephalus	
Ctenotus impar	south-western odd-striped ctenotus
Delma fraseri	
Diplodactylus granariensis	western stone gecko
Egernia multiscutata	bull skink
Echiopsis curta	bardick
Lerista distinguenda	
Lialis burtonis	Burton’s snake-lizard
Menetia greyii	
Morethia obscura	
Parasuta gouldii	Gould’s hooded snake
Pygopus lepidopodus	common scaly-foot
Varanus rosenbergi	heath monitor

Table 16: Natural amphibian species known or likely to occur in the catchment

Scientific name	Common name
Known to occur (have been sighted or heard)	
Heleioporus albopunctatus	western spotted frog
Limnodynastes dorsalis	banjo frog
Litoria moorei	motorbike frog
Likely to occur	
Crinia georgiana	quacking frog
Myobatrachus gouldii	turtle frog
Neobatrachus albipes	white-footed frilling frog
Neobatrachus pelabatoides	humming frog
Pseudophryne guentheri	Günther’s toadlet

6.7. Conservation codes for WA flora and fauna

Specially protected under Schedules 1 to 4 of the *Wildlife Conservation Act 1950*

- 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 and Wildlife Conservation (Rare Flora) Notice for Threatened Flora (which may also be referred to as Declared Rare Flora).

Species* which have been adequately searched for and are deemed, in the wild, to be either rare, in danger of extinction, or otherwise in need of special protection, and have been gazetted as such.

- X: Presumed extinct species

Specially protected under the *Wildlife Conservation Act 1950,* listed under Schedule 2 of the Wildlife Conservation (Specially Protected Fauna) Notice for Presumed Extinct Fauna and Wildlife Conservation (Rare Flora) Notice for Presumed Extinct Flora (which may also be referred to as Declared Rare Flora).

Species* which have been adequately searched for and there is no reasonable doubt that the last individual has died, and have been gazetted as such.

- 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.

Birds that are subject to an agreement between governments of Australia and Japan, China and The Republic of Korea relating to the protection of migratory birds and birds in danger of extinction.

- 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.

Threatened fauna and flora are further recognised by the department according to their level of threat using IUCN Red List criteria. For example, Carnaby's cockatoo (*Calyptorynchus latirostris*) is specially protected under the *Wildlife Conservation Act 1950* as a threatened species with a ranking of endangered.

Rankings

- CR: Critically Endangered

Considered to be facing an extremely high risk of extinction in the wild.

- EN: Endangered

Considered to be facing a very high risk of extinction in the wild.

- VU: Vulnerable

Considered to be facing a high risk of extinction in the wild.

Priority Flora and Priority Fauna Lists rankings

Species that have not yet been adequately surveyed to be listed under Schedule 1 or 2 are added to the Priority Flora and Priority Fauna Lists under Priorities 1, 2 or 3. These three categories are ranked in order of priority for survey and evaluation of conservation status so that consideration can be given to their declaration as threatened flora or fauna.

Species that are adequately known, are rare but not threatened, or that meet criteria for Near Threatened, or that have been recently removed from the threatened list for reasons other than taxonomic ones, are placed in Priority 4. These species require regular monitoring. Conservation-dependent species are placed in Priority 5.

- Priority One: Poorly known species

Species that are known from one or a few collections or sight records (generally less than five), all on lands not managed for conservation (e.g. agricultural or pastoral lands, urban areas, Shire, rail reserves and Main Roads WA roads, gravel and soil reserves and active mineral leases), and that are under threat of habitat destruction or degradation. Species may be included if they are comparatively well known from one or more localities but do not meet adequacy of survey requirements and appear to be under immediate threat from known threatening processes.

- Priority Two: Poorly known species

Species that are known from one or a few collections or sight records, some of which are on lands not under imminent threat of habitat destruction or degradation, for example, national parks, conservation parks, nature reserves, State forest, unallocated Crown land, water reserves, etc. Species may be included if they are comparatively well known from one or more localities but do not meet adequacy of survey requirements and appear to be under threat from known threatening processes.

- Priority Three: Poorly known species

Species that are known from collections or sight records from several localities not under imminent threat. They may also be known from collections or sight records from few but widespread localities with either large population size or significant remaining areas of apparently suitable habitat, much of it not under imminent threat. Species may be included if they are comparatively well known from several localities but do not meet adequacy of survey requirements and known threatening processes exist that could affect them.

- Priority Four: Rare, Near Threatened and other species in need of monitoring

(a) Rare

Species that are considered to have been adequately surveyed, or for which sufficient knowledge is available, and that are considered not currently threatened or in need of special protection, but could be if present circumstances change. These species are usually represented on conservation lands.

(b) Near Threatened

Species that are considered to have been adequately surveyed and that do not qualify for Conservation Dependent, but that are close to qualifying for Vulnerable.

(c) Other species in need of monitoring

Species that have been removed from the list of threatened species during the past five years for reasons other than taxonomy.

- Priority Five: Conservation-dependent species

Species that are not threatened but are subject to a specific conservation program, the cessation of which would result in the species becoming threatened within five years.

Appendix 7. Identification of the biological elements for Toolibin Lake catchment

Following the framework devised by Fauth et al. (1996), one suitable approach to define biological elements is to differentiate combinations of organisms by geography, resources and phylogeny. To arrive at the biological element list, a technical advisory group of experts (TAG) first applied a phylogenetic approach (e.g. Cavalier-Smith 1998) and identified three kingdoms thought to be important for the management area – plant (refer to recovery plan main document), animals and fungi. Fungi were left at the kingdom level due to a lack of knowledge and were ultimately deemed indefinable and removed from the process, pending new information.

After considerable discussion, it was decided that the vegetation elements should be demarked by broad but practical management areas (specifically wetlands and nature reserves). Within the nature reserves, two broad vegetation element types were identified, those dominated by shrub species (mature height approximately <2m; referred to as 'shrubland elements') and those dominated by tree species (mature height approximately >2m; referred to as 'woodland elements'). These two classes fit into the 'resource' set of Fauth et al. (1996). The separation between these two broad categories is fragile (shrublands contain woodland species and vice versa) but from a management perspective the approach was believed to be a satisfactory starting point. In other contexts, shrublands and woodlands have proven to be differentiable in terms of human value (e.g. Chicago Region Biodiversity Council 1999). It is recognised that these two categories contain numerous potential sub-categories that could be explored later in the management cycle if necessary, and that detailed species descriptions (at least as much as is possible with current information) will help managers to understand the compositional complexity associated with each biological element. Thus, following the lexicon of Fauth et al. (1996), the vegetation elements are 'ensembles' as they are based upon a mix of taxonomy (be it a high level), geography and resources.

It was determined that the animal elements could be classified at lower taxonomic levels. Animals were first split into vertebrates and invertebrates. Invertebrates were further classified as terrestrial and aquatic; a very broad resources classification. However, due to a lack of information, the terrestrial invertebrates were also removed from the process until such time as more information is available. Consequently, both fungi and terrestrial invertebrates were identified as areas for future research. It was also noted that a clear description of the species included in the aquatic invertebrate element (within constraints of current information) will be important.

Vertebrates were further divided into classes: Amphibia, Reptilia, Aves and Mammalia. The Aves class was then divided by broad resource characteristics into waterbirds, resident terrestrial birds and non-resident terrestrial birds. Following Fauth et al. (1996) the birds and aquatic invertebrates can be thought of as 'ensembles' (as, in addition to phylogenetic and resource considerations, they are also defined in geographic terms by the spatial extent of the management area). The mammals, reptiles and amphibians can be thought of as 'assemblages' as they reflect phylogenetic and geographic criteria only. The groupings were thought to be appropriate in the context of the stakeholder values.

Finally, in defining a biological element:

1) It was considered that all individuals of a given taxonomic unit equal. This ignored age, condition and other differences between individuals, including genetic differences (which incorporate sexual differences). For the level of analysis we typically use, this was considered a reasonable assumption, although it would not be acceptable under other scenarios. For example, other analyses may focus on females of a particular species or may require a level of knowledge – such as individual genotypes – that is not often available.
2) All biological elements, even of the same type, can be spatially distinct and could have differences in area and taxonomic composition. Therefore, the department treated biological elements within a broader management area as individual elements, even if they were of the same type (e.g. the several geographically distinct wetland vegetation communities that occur within the Toolibin Lake catchment).
3) Operational decisions will involve differentially applying funds to biological elements. Therefore, it is ultimately necessary to rank all biological element types within the one analysis. Hence, in defining the biological elements, the department took care to minimise redundancy.

Appendix 8. Quantifying the properties

8.1. Richness

Spatially replicated quadrat-based natural vegetation data was available for six vegetation elements that were collected in 2002 (Dingerlin Nature Reserve woodland and shrubland; Brown and Roots Services Asia Pacific Pty Ltd 2002) and 2009 (Toolibin Reserve woodland, Toolibin Lake vegetation and Dulbining Nature Reserve woodland and shrubland; Ecoscape 2009). Data in the quadrats had been collected in previous years, but it was decided to only use the most recent data to minimise issues relating to the potential loss of species. The quadrats are in areas that have succumbed to secondary salinisation and had subsequently undergone considerable management (Froend et al. 1997). Consequently, we could not be certain that species detected in previous surveys, but not during the more recent survey, were not lost to the system. A spatially replicated hierarchical Bayesian occupancy-detection model with data-augmentation (as described by Kéry and Royle 2008) was used to estimate species richness for these six elements. Refer to Kéry and Royle (2008) for a detailed description of the modelling approach.

Access to raw survey data for the remaining biological elements was not available. As a consequence, experts or the literature were used to derive richness estimates for the remaining biological elements (Table 17).

8.2. Rarity

Rarity (Table 17) was considered at the South West Land Division level and classified it as high, moderate or low:

- High – entire biological element is listed as rare
- Moderate – component species of the biological element are listed as rare
- Low – no evidence that the biological element as a whole or any of its component species are rare.

8.3. Size

For each vegetation element, the department estimated size (Table 17) by calculating the estimated area of occupancy (in ha). The aquatic invertebrate, amphibian and waterbird elements were assigned a size equivalent to the sum of the wetland areas. The area of occupancy of the remaining fauna elements was unknown but believed to occur across most of the available habitat (as captured by the vegetation elements) and a size (600 ha) that was well within the 'large' set in the Fuzzy Logic System (FLS) was used for the modelling (Appendix 5). In future work the department is considering the use of type-2 fuzzy sets and systems (e.g. see Mendel 2001) to more directly capture the degree of uncertainty associated with the properties.

8.4. Intactness

Intactness of the vegetation elements was estimated as the proportion (0 to 1) of an element exhibiting demonstrable evidence of wholesale vegetation clearing (e.g. no vegetation, or large scale tree planting) and dead trees (Table 17). The logic was that there are four key causes of disturbance leading to a loss of intactness in the vegetation elements in the management area: wholesale clearing, secondary salinisation, senescence and previous ring-barking of trees. The latter three disturbances are still evidenced by the presence of dead trees.

To calculate intactness for the vegetation elements, the percentage of the element not cleared was divided by the number of dead trees (dead trees/ha of not cleared element). Where there were no dead trees, intactness was set to the percentage area not cleared. The estimates were natural log transformed (0.001 was added to zero estimates) and normalised to vary between zero (no intactness) and one (completely intact).

The intactness of the fauna elements could not be easily estimated. However, as far as we are aware, with the exception of the amphibian element, all fauna elements have lost species and so lack intactness, to some degree. The department tentatively enumerated the fauna element's intactness as moderate (0.5) until such time when a better quantification of intactness can be derived. Amphibian intactness was set to high (1.0).

Table 17: Property data for each biological element

Element	Size (area in ha)	Species richness	Rarity	Intactness
Amphibians	413	13	0	1
Aquatic invertebrates	413	185	0	0.5
Dingerlin Nature Reserve shrubland	47	146	0.5	0.9
Dingerlin Nature Reserve woodland	30	110	0.5	0.89
Dulbining Nature Reserve shrubland	238	124	0	0.48
Dulbining Nature Reserve wetland (1)	17	10	1	0.48
Dulbining Nature Reserve wetland (2)	6	37	1	0.78
Dulbining Nature Reserve wetland (3)	14	25	1	0.45
Dulbining Nature Reserve woodland	371	65	0.5	0.65
Mammals	600	8	0.5	0.5
Non-resident terrestrial birds	600	37	0	0.5
Red morrel woodland	10	10	0	0.36
Reptiles	600	30	0.5	0.5
Resident terrestrial birds	600	31	0.5	0.5
Silver mallet (1) woodland	3	10	0	0.35
Silver mallet (2) woodland	7	10	0	0.27
Toolibin Lake	302	37	1	0.59
Toolibin Nature Reserve open woodland	222	100	0	0.65
Walbyring Nature Reserve wetland	74	37	1	0.55
Wandoo woodland	141	30	0	0.82
Waterbirds	413	50	1	0.5

Appendix 9. Expert assessment of value of the biological elements

9.1. Introduction

The department ran a workshop to quantify ratings by a technical advisory group of experts (TAG) of the values of each biological element. A small group (n=5) of experts attended the workshop, all of whom were familiar with the biological elements and the three key values.

9.2. Workshop description

The workshop began with a group discussion about the definitions of the human values and the biological elements. The department then facilitated a discussion about the rating process. This included a presentation of an unrelated example (Figure 4) and a practice session with a more realistic example. It should be noted that the group purposely opted for a 'rating of importance' approach as described below, rather than a 'ranking' approach. Through rating, the perceived difference in importance of individual biological elements can be captured. In contrast, ranking provides information solely about the priority/rank of each biological element in terms of their value, thus omitting detail; for example, if one biological element is far more important than another.

Thus, for each biological element-value combination an ellipse was drawn on a scale (e.g. Figure 4) to express the importance of the biological element to the value (location on the scale) and the experts' uncertainty (the width of the ellipse). The question asked for each biological element-value combination was:

> *Over the management period of 20 years, how important is the [biological element] to the [value]?*

The group discussed the question and the process, and any confusion raised was clarified. It was also noted that the spatial context of the exercise was limited to the boundary of each biological element, and that the value was to be assessed as being independent from any potential interactions with other biological elements and/or values. With respect to the importance of each biological element, the group thought of each key value in terms of the total amount that would be available from all of the biological elements. Each expert received three score sheets, one for each value, and the biological elements in each score sheet were presented in a randomised order.

9.3. Results

The facilitators extracted the minimum and maximum for each ellipse and entered the resulting interval into a spreadsheet. The intervals which encode the expert opinion were subsequently aggregated across all experts, based on the interval agreement approach (Figure 5; for full description and of the approach see Wagner et al. 2014 and Smith et al. 2016).

Figure 6 to Figure 8 present aggregated ratings across all experts of the importance of each biological element to each human value. Table 18 presents defuzzified results.

Table 18: Summary based on centroid values for experts' ratings of value delivery by biological element

N/A = not applicable

Biological element	Knowledge/ heritage and education	Productive use	Philosophical/ spiritual contentment
Amphibians	4.846	N/A	5.435
Dingerlin Nature Reserve shrubland	4.230	5.066	4.816
Dingerlin Nature Reserve woodland	4.401	5.387	5.074
Dulbining Nature Reserve shrubland	3.808	4.705	4.649
Dulbining Nature Reserve woodland	4.333	4.715	5.917
Dulbining Nature Reserve wetland (1)	6.069	4.333	6.346
Dulbining Nature Reserve wetland (2)	6.104	4.333	6.659
Dulbining Nature Reserve wetland (3)	6.598	4.359	5.883
Mammals	3.829	N/A	7.702
Non-resident terrestrial birds	5.206	N/A	7.674
Red morrel woodland	2.138	2.746	4.477
Reptiles	4.247	N/A	5.486
Resident terrestrial birds	5.539	N/A	6.89
Silver mallet (1) woodland	1.881	3.466	3.556
Silver mallet (2) woodland	2.015	3.248	3.556
Toolibin Lake	7.517	3.566	8.415
Toolibin Nature Reserve woodland	5.313	5.468	6.488
Walbyring Nature Reserve wetland	5.856	4.247	6.956
Wandoo woodland (Sims)	2.611	4.746	5.089
Waterbirds	6.838	N/A	8.073
Aquatic invertebrate community	5.289	N/A	4.808

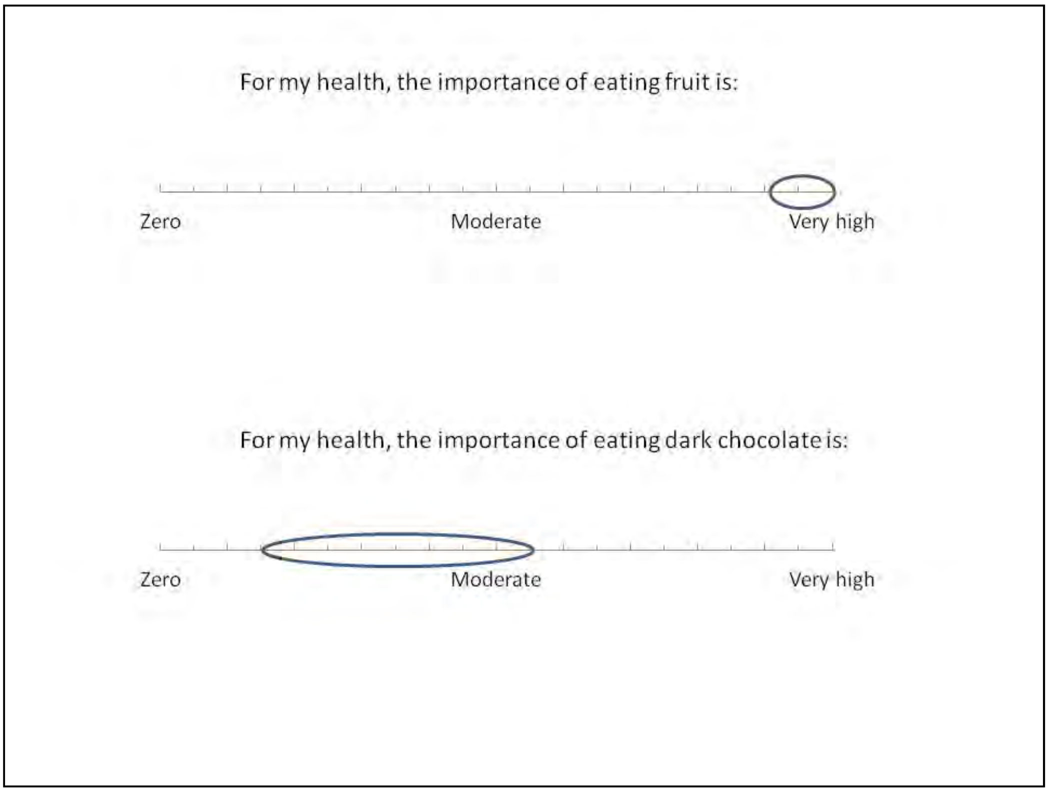


Figure 4: Example used to train the experts to rank the importance of each biological element with respect to the key values

Note: includes an example of the scaling system used throughout the process. The technique of asking experts to draw an ellipse on the scales to represent their answer allowed them to capture uncertainty about their response (e.g. in the top part of the figure, the respondent is highly certain while in the bottom part [wider ellipse] the respondent expresses more uncertainty). In this paper we do not explore the source of this uncertainty (e.g. lack of knowledge or variation in experience).

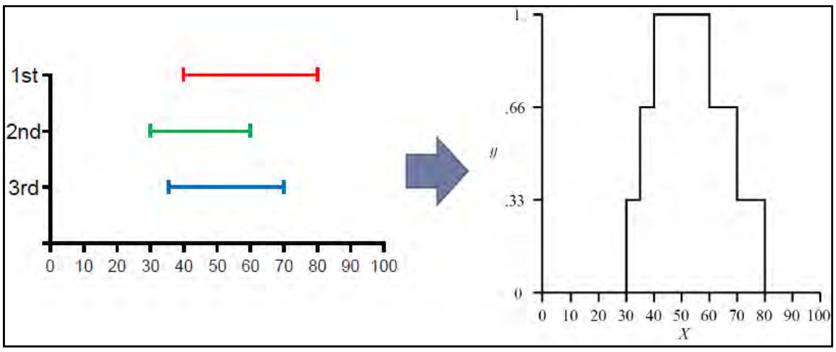


Figure 5: Example of the interval agreement approach for three source intervals (e.g. from three experts)

*Note: the interval agreement model (a fuzzy set) on the right weights the overlap of the three intervals, i.e. where only a single interval exists, the degree of membership in the set is 1/n*1=1/3*1=0.33, where at least two intervals overlap, the degree of membership is 1/n*2=0.66 and where all intervals overlap the degree of membership is 1/n*3=1.*

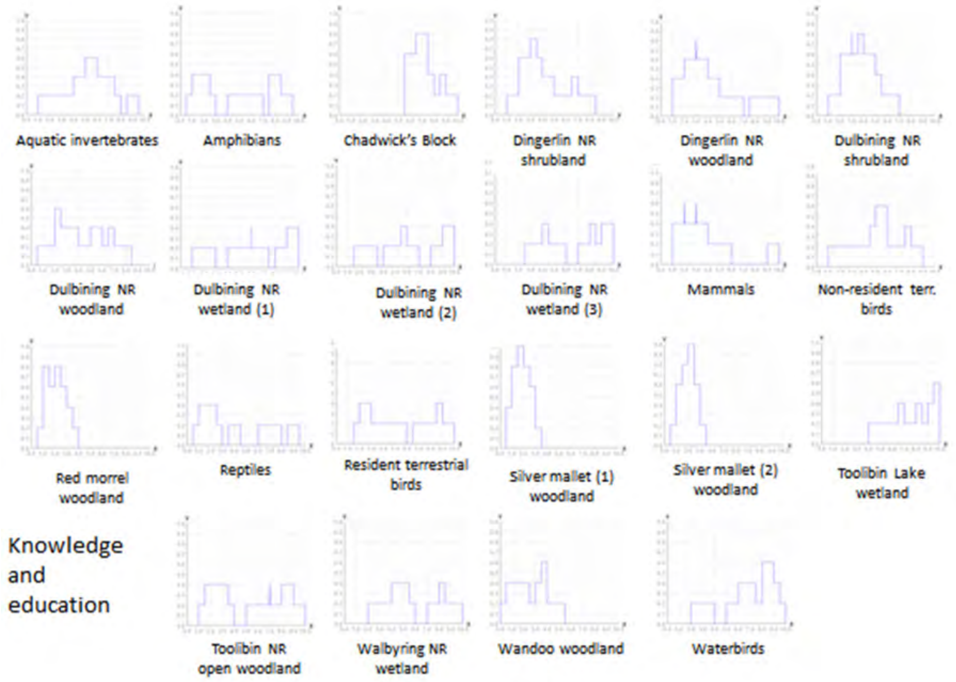


Figure 6: Aggregated estimates of the knowledge/heritage and education value of each biological element

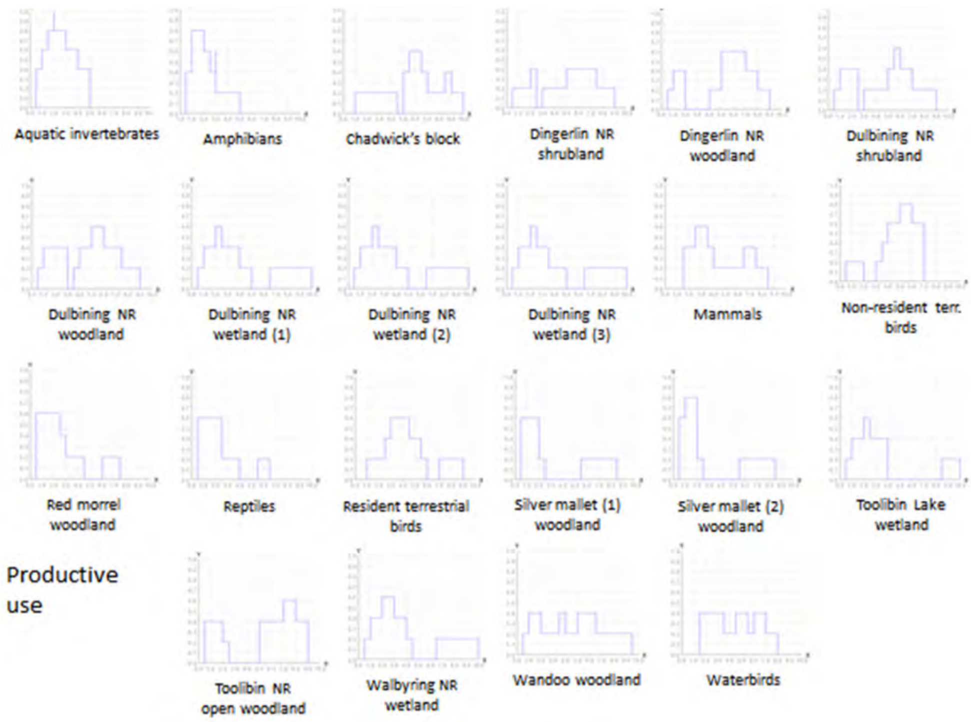


Figure 7: Aggregated estimates of the productive use value of each biological element

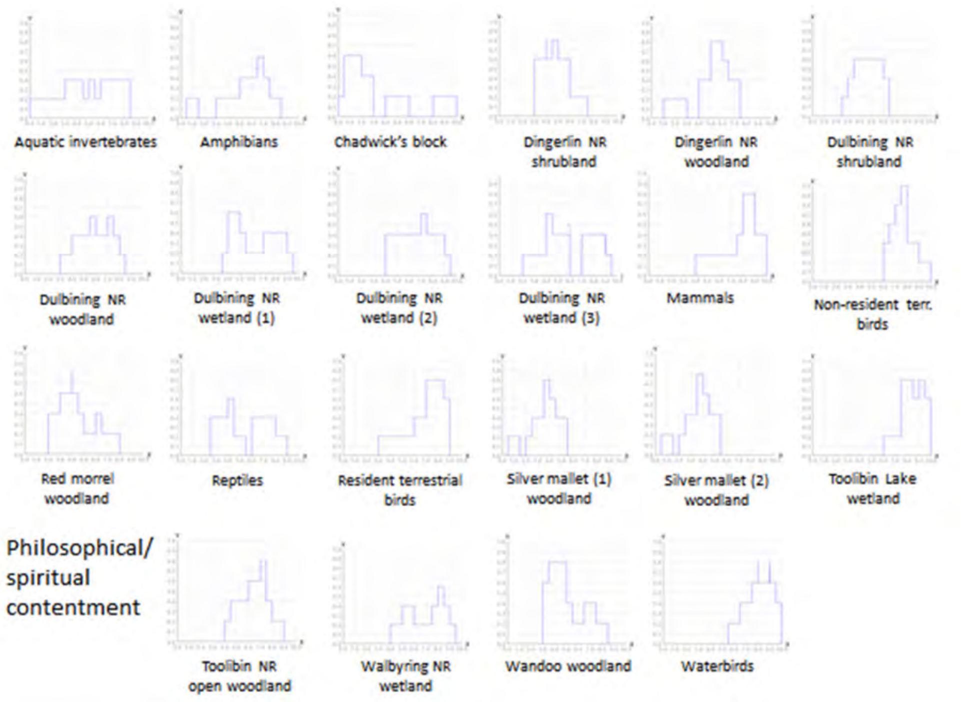


Figure 8: Aggregated estimates of the philosophical/spiritual contentment value of each biological element

Appendix 10. Risk factor analysis

10.1. Description of the risk factor analysis

Metcalf and Wallace (2013) conducted a detailed risk factor analysis for the native biota of Toolibin Lake itself. A technical advisory group of experts (TAG) conducted a simpler risk factor analysis for a set of priority biological elements. The TAG consisted of the then District Manager, Program Leader Nature Conservation, Nature Conservation Officer, Conservation Office (Toolibin Lake), Recovery Catchment Technical Officer and Wheatbelt Regional Ecologist.

The simpler risk factor analysis was a multi-step process, conditional on the timeframe of the management plan (2015-35) and within the spatial boundaries of the biological elements.

First, the group conducted an analysis of the proximal risks (Table 19). The TAG developed a set of management targets for the priority biological elements (refer to recovery plan main document). The group discussed and trialed the process, after which they conducted the analysis as individuals. The analysis involved estimating the likelihood that each proximal risk would cause goal failure for each priority biological element over the management period with current management.

The Conservation Officer (Toolibin Lake) then compiled the individual assessments into a final analysis. The group re-convened (minus several individuals) to talk through the assessment, resolve any issues and agree on final probabilities.

Key risk factors that emerged from the process – those with a probability of goal failure greater than five per cent – were the focus of the remaining risk analysis.

10.2. Brief summary of key risk factors

Altered hydrology

The group identified several important risk factors relating to altered hydrology for a number of the biological elements, namely the Toolibin Lake, Dulbining Nature Reserve wetland (2), Dulbining Nature Reserve shrubland, Dulbining Nature Reserve woodland and the Toolibin Nature Reserve woodland (Table 20). These risk factors included secondary salinity and a lack of water (Table 20).

Disease, especially relating to *Phytophthora* spp. outbreak

The group identified the potential of a *Phytophthora* spp. outbreak (or dieback) as a significant risk factor for the woodland and shrubland biological elements (Table 20).

Fire management

The group identified the potential for senescence relating to fire management as a significant risk factor for several vegetation elements (Table 20). This specifically relates to the lack of fire or inadequate fire frequency. The proximal risk was identified as a lack of reproduction. Additional distal risk factors could include, but are not limited to, lack of smoke, degradation of the seed bank and poor recruitment, inadequate colonisation, reduction in vegetation diversity with successional change, reduction in genetic variability, pest species invasion, and changed substrate and habitat quality (e.g. declining replacement of important soil nutrients or changed light conditions). Additionally, fires occurring too frequently could lead to similar risks.

Lack of light

The group identified lack of light as a significant proximal risk factor for the Dulbining Nature Reserve shrubland and woodland biological elements (Table 20). Distal causes of a lack of light resulting in goal failure include inadequate fire regimes and competition with introduced plant species.

Table 19: Proximal risks that may cause goal failure in the Toolibin Lake catchment

Threatening process	Proximal risk 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
	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

Table 20: Results and qualifying comments from the 'simpler' analysis

Note: refer to the recovery plan main document to see the 'simpler' analysis

Note: the table includes notes generated during the discussion about each biological element-risk factor combination, followed by an estimate of the likelihood that a risk factor will cause goal failure

Proximal risk factor	Community	Comments	Likelihood risk factor will cause target failure
Pesticides/ herbicides	Dulbining NR wetland (2)	The only type of event that people could think of that might cause goal failure was a crop duster crash into the lake, or a crop duster discharging its load over the lake. A flood event could also move persistent chemicals into the water column or sediment from surrounding agricultural land, sheep dip sites etc. Spray drift could also affect a much wider area if conditions were suitable (i.e. inversion, low-lying part of the landscape, up to several square km).	2%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	People considered the event of a tanker load of 24-D rolling on the highway. Spray drift from agricultural lands could affect a much wider area if conditions were suitable (i.e. inversion; up to several square km). Possibly same situation at Merredin eucalypt (Growden Rd) – one-off affect. Dulbining is buffered by reserves. Risk can increase as landscape changes to cropping rather than sheep. The snail orchid occurs within the Dulbining shrubland and woodland element and is an important species with a small area of distribution. Not directly adjacent to agricultural lands (risk is a bit greater for this species [5%].)	1%
	Waterbirds (Toolibin Lake & Dulbining NR wetlands (assumed 25 species)	Crop duster dispersal has consequences, and the likelihood is high. If it killed all present individuals in one event it would not wipe out all species; they would come back. For example, if everyone sprayed for weeds in the catchment and then a rainfall event occurred, crop duster would flow into the lakes and concentrate on the lake floor. There would be a cumulative effect on waterbirds, but they would come back.	<1%
Acidity/alkalinity	Dulbining NR wetland (2)	As a proximal factor, the group was unable to think of any circumstances when this could occur - <1%.	<1%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	Acid sulphate soils on Robert's private property, not a problem for Dulbining shrubland woodlands, but could be a problem for TEC lakes. However, this is not a proximal factor – see heavy metals e.g. cadmium from superphosphate; or aluminium toxicity from naturally occurring Al.	<1%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	Crop duster dispersal has consequences, likelihood is high. If it killed all present individuals in one event it would not wipe out all species; they would come back. For example, if everyone sprayed for weeds in the catchment and then a rainfall event occurred, crop duster would flow into the lakes and concentrate on the lake floor. There would be a	<1%

Proximal risk factor	Community	Comments	Likelihood risk factor will cause target failure
		cumulative effect on waterbirds, but they would come back.	
Heavy metals	Dulbining wetland (2)	Possibilities are cadmium in fertiliser, acid spill on sufficient scale to release heavy metals (e.g. aluminium), deep drainage from farmland. No evidence currently of any of these. Aluminium is not a heavy metal; concentrations of available aluminium rise rapidly as pH drops from 6.0 to 4.5, and the risk of toxicity with it. Any process that lowers soil pH has the potential to cause problems.	<1%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	Possibilities are cadmium in fertiliser, acid spill on sufficient scale to release heavy metals (e.g. aluminium), deep drainage from farmland. No evidence currently of any of these. Aluminium is not a heavy metal; concentrations of available aluminium rise rapidly as pH drops from 6.0 to 4.5, and the risk of toxicity with it. Any process that lowers soil pH has the potential to cause problems.	<1%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	Build-up of heavy metals possible but not probable.	<1%
Nitrogen toxicity	Dulbining NR wetland (2)	Sources are fertilisers (e.g. crop dusters) or exotic nitrogen fixers. No evidence currently of any of these at levels that could cause an issue.	<1%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	Sources are fertilisers (e.g. crop dusters) or exotic nitrogen fixers. No evidence currently of any of these at levels that could cause an issue.	<1%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	Crop duster dispersal has consequences, likelihood is high. If it killed all present individuals in one event it would not wipe out all species; they would come back. For example, if everyone sprayed for weeds in the catchment and then a rainfall event occurred, crop duster would flow into the lakes and concentrate on the lake floor. There would be a cumulative effect on waterbirds, but they would come back.	<1%
Phosphorus toxicity	Dulbining NR wetland (2)	Could affect microflora in the soil that affects nutrition, and can also lead to direct toxicity – can be proximal factor. Dealt with under nutrients below.	<1%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	Could affect microflora in the soil that affects nutrition, and can also lead to direct toxicity – can be proximal factor. Dealt with under nutrients below.	<1%
	Waterbirds (Toolibin Lake,	Crop duster dispersal has consequences, likelihood is high. If it killed all present individuals in one event it	<1%

Proximal risk factor	Community	Comments	Likelihood risk factor will cause target failure
	Dulbining NR wetlands (assumed 25 species)	would not wipe out all species; they would come back. For example, is everyone sprayed for weeds in the catchment and then a rainfall event occurred, crop duster would flow into the lakes and concentrate on the lake floor. There would be a cumulative effect on waterbirds, but they would come back.	
Groundwater salinity	Dulbining wetland (2)	No bores on the lake floor. There are bores around the lake but they are not monitored. Thought to not be as deep as Dulbining Lake (needs confirmation) – room to spare before groundwater impacts on the surface. No visible signs of groundwater impact, but can't be far off. Unknown but potentially high. Waterway is helping to a degree.	>20%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	Groundwater is probably still slowly rising but unknown time period. No pumps here. Areas with high density of salmon gums; salmon gums are in the flats. Unknown if they are any different to Dulbining shrubland/woodland. Not known where water is drawn from. Knowledge gap. This may be a much bigger problem for the snail orchid (e.g. > 70%) which is in a more confined area.	40%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	No, unless they are subterranean birds.	<1%
Surface water salinity	Dulbining NR wetland (2)	It doesn't have the regular surface water coming in. It only fills in flood events. Not considered an issue. Observation: has handled 2–3 years of flooding.	5%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	Dulbining waterway is in nature reserve. Not an issue for the elements in general; however, in the northern sections of Dulbining shrubland and woodland elements, salmon gums are in the flats and may be at risk. May be an even larger problem for the snail orchid as the area where this species occurs gets wet. We don't know – does it need it to be waterlogged for this species? At the moment, freshwater floods it, but it certainly could become saline. Could be as high as 20% for snail orchid. We lack knowledge.	0%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	Management action precludes us from putting water in the lake; however, no water: no birds. A number of birds require fresh water for breeding. It would reduce the number of indicators for ducklings to survive. Birds could breed on dams and fly down to the lake. Goal does not refer to breeding. We suspect the indicator birds would still be there. Goal needs to be reassessed. Current management restricts water from entering the lake over a certain threshold. This will go under water as a resource. Could get a rainfall event which fills the lake without management	<1%

Proximal risk factor	Community	Comments	Likelihood risk factor will cause target failure
		intervention.	
Physical damage	Dulbining NR wetland (2)	Another waterway would cause goal failure, but not on the agenda.	<5%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	Potential sources are tornadoes, earthworks (none proposed). Damage by human vandals. < 1% - with greatest risk is through vandals (e.g. cars, bikes etc.). For snail orchid, kangaroo and sheep trampling is a possibility. The population of snail orchids is hidden away under *Melaleuca* trees, but trampling is a possibility. Possibility of echidnas digging them up. Trampling is highly unlikely to cause extinction, but what about pigs – they are known to target orchid tubers and turn over the soil (could be 5% for snail orchid).	<1%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	Storms, hail, cyclone, shooting, impaling not enough for goal failure.	<1%
Fire	Dulbining NR wetland (2)	Lot of dead material on the lake floor. Barer understorey than Toolibin Lake, more timber on ground and standing, fire could be of greater intensity. No firebreaks in or around the lake. Unknown.	<5%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	Potentially fire and lack of fire could cause goal failure. Still unlikely e.g. Pingelly or Tarin Rock. Lake systems could protect some of the vegetation. Probably not a lot of fire-sensitive species left. Weed burden can contribute to fuels. A single fire is unlikely to cause an extinction, and 2 fires in succession within 5–10 years is highly unlikely, <1% if using figures from Parsons and Gosper 2011. Lack of fire highly likely; are there any serotinous seeders e.g. Banksias, Hakeas that would become locally extinct once adults senescence 40–50 years after previous fire? For salmon gum, fire would change the composition; the area does not look weedy. We would expect regeneration after a fire, although not much fuels to carry fire for regeneration. If it is hot enough to kill salmon gum then it won't sprout from epicormics, if fire is too hot it would have consumed canopy-borne seed. Other species could take advantage and change composition. Lack of fire within the time period is not likely to be an issue (could be up to 5% for salmon gum area). We lack knowledge for snail orchid, but other orchids are fine when fire goes through in non-flowering periods but will die if flowering. Lack of knowledge.	<1%
	Waterbirds (Toolibin Lake, Dulbining NR	No, birds will fly away. Loss of breeding hollows for ducks?	<1%

Proximal risk factor	Community	Comments	Likelihood risk factor will cause target failure
	wetlands (assumed 25 species)		
Temperature	Dulbining NR wetland (2)	Fire component considered above (e.g. part of temperature), but worth treating separately. Extreme temperatures can cause vegetation death – proteins break down and 'denature' at temperatures above ~41°C; plant tissue death occurs above ~46°C) – predicted to be more common and possibly extreme events, worse in combination with drought. No obvious deaths occurred in last 2 events, seems unlikely they will cause goal failure. Frost damage also a possibility, but unlikely to kill enough vegetation to cause goal failure.	<2%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	Same as Dulbining wetland (2) vegetation community. Temperature may excite the insect population and cause defoliating effect rather than tree death. Could happen if it occurred in subsequent years but would need multiple threats to cause goal failure.	<2%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	e.g. Hopetoun extreme temperature event killed many birds, including Carnaby's black cockatoos, but will not cause goal failure unless multiple events. Note: could there be an effect by water temperature on aquatic organisms that provide food for birds?	<1%
Other toxins	Dulbining NR wetland (2)	Botulinum and Cyanobacteria – one episode in memory, will not affect plants.	<1%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	Allelopathic effect of wild radish, thistles, mint weed.	<3%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	Botulism, Cyanobacteria or blue-green algae could happen but unlikely to cause goal failure. Consecutive events will impact. Prolonged habitation of birds would increase the risk of toxins being a problem, e.g. bird faeces. If visitation and breeding success are the goals then it is unlikely that this would cause goal failure over a 20-year period.	<5%
Light (bad)	Dulbining NR wetland (2)	A lot less light gets in there but we believe that is how the ecosystem functions.	<1%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	As for Dulbining wetland (2) vegetation community. For snail orchid, too much light if the *Melaleuca* thin or die. Knowledge gap.	<1%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	Not an issue. Birds will fly away.	0%

Proximal risk factor	Community	Comments	Likelihood risk factor will cause target failure
Noise	Dulbining NR wetland (2)	No pumps, not an issue	<1%
	Dulbining NR shrubland & woodland, Toolibin NR woodland		0%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	No. Pumping has been occurring since 1996, none known.	0%
Food (nutrients). Carbohydrates are for animals	Dulbining NR wetland (2)	Excess phosphorus (P) is also known to be toxic to some native plants, as they are unable to regulate uptake when excess P is available. Excess P leads to other nutrient deficiencies. Some circumstances may limit the capacity of plants to uptake nutrients (e.g. salinity/pH); P-deficiency can lead to metal toxicity in plants in some circumstances.	<2%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	As for Dulbining wetland (2) vegetation community. Weeds compete for nutrients. For snail orchid, knowledge gap on the understanding of orchids and symbiotic relationship with *Melaleuca* or other species.	<2%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	Lack of food in a one-off event would not cause goal failure; however, cumulative events would. Lack of food resources could change the composition or reduce the number of birds. If seasonal conditions are conducive does that mean food is there for the birds? Shell ducks can come in and eat all food and leave nothing for black ducks to eat.	<5%
Oxygen	Dulbining NR wetland (2)	It is unlikely to fill up as often as Toolibin Lake. Holds water a lot longer, but needs an extreme rainfall event to fill up. Need multiple flood events.	<1%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	Sufficient coating of dust/ash settling on leaves could inhibit gas exchange, including O^2 uptake.	<1%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	Possibly not an issue, but deoxygenating of water due to algal bloom would presumably have a severe impact on aquatic fauna?	<1%
Light (not enough)	Dulbining NR wetland (2)	More overstorey than Toolibin Lake, so not much light getting through, which may impact seedling germination. Algae possibly smothered and killed seedlings, assuming light deprivation killed plants = 1 occurrence in last 20 or more years at Toolibin Lake.	<1%

Proximal risk factor	Community	Comments	Likelihood risk factor will cause target failure
		Unlikely to cause goal failure. Weeds shading native plants.	
	Dulbining NR shrubland & woodland, Toolibin NR woodland	Sufficient coating of dust/ash settling on leaves could prevent O^2 uptake. Weeds competing for light. Weed burden e.g. wire weed matting and smothering or shading, build-up of stubble. Could be a big issue for salmon gum areas of woodland, weed competition may lead to a lack of light for the snail orchid – up to 20%.	<1%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	Probably not an issue, but water turbidity following a flood would affect algal growth and therefore the aquatic food chain.	<1%
Lack of water	Dulbining NR wetland (2)	Same as Metcalf and Wallace	29%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	Depending how long and/or the severity of drought, this is a possibility. We know we have rainfall deficiency since 1975. We don't know what affect lack of water has on terrestrial flora and what water stores available. There would be a risk to the composition e.g. *Banksia prionotes*. Species numbers have dropped already. If we had average rainfall decline at 10% plus drought periods, it is very possible. Weeds competing for water. For the snail orchid, weed competition, drought, salinity, knowledge gap on orchids and interaction with water. Active growing periods for *Melaleuca* is summer and orchids in winter.	50%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	With current management actions no water in and pumping water out can cause goal failure. If seasonal conditions are right the quality of water may not be right. We need to be clear what the threat is here. A lack of water for the birds means no food, and therefore no visiting or breeding. So the proximal threat is lack of food, not lack of water. If a lack of food has only a 5% chance of causing goal failure, then how can a lack of water have a high chance of causing goal failure?	<1%
Carbon dioxide	Dulbining NR wetland (2)	Not a problem. However, elevated CO_2 levels will lead to changes in growth rates of different species – C3 to C4 plants, natives and weeds; therefore, competition could alter species' interactions and composition, and increase weed competition. I guess this is not proximal but does interact with other threats.	<1%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	Not a problem. However, elevated CO_2 levels will lead to changes in growth rates of different species – C3 to C4 plants, natives and weeds; therefore, competition could alter species' interactions and composition, and increase weed competition. I guess	<1%

Proximal risk factor	Community	Comments	Likelihood risk factor will cause target failure
		this is not proximal but does interact with other threats.	
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	Knowledge gap.	<1%
Life media and substrates	Dulbining NR wetland (2)	Not applicable.	
	Dulbining NR shrubland & woodland, Toolibin NR woodland	We don't know.	<1%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	Not applicable.	
Disease, parasites	Dulbining NR wetland (2)	*Phytophthora* low possibility at this stage, as species that characterise TEC are not believed to be vulnerable to *Phytophthora. E. rudis* may be susceptible. Likely to be introduced but low chance of goal failure.	2%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	More species than in Toolibin Lake that are susceptible to *Phytophthora*. Poor quarantine rules may cause unknown, introduced diseases which could cause goal failure. Knowledge gap for the snail orchid.	20%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	We have added competition into this section. Avian bird flu is outside our goal. Overcrowding can increase disease. Competition between birds.	<1%
Predation/grazing	Dulbining NR wetland (2)	Kangaroos and rabbits are considered to be a reasonable threat, but unlikely to cause goal failure. It is possible that kangaroos could be a problem if they get into high enough densities. Currently controlling kangaroos. May be some insect herbivory, also locust plagues can causes defoliation, but regrowth typically occurs. Did not target *C. obesa*, but may target other TEC species. Unlikely to allow pesticide application to Toolibin TEC, would need risk assessment before application. Don't believe locusts will breed on floor of lake. Sheep and other stock should not be an issue. Ants may be an issue with respect to seed predation and other issues.	<1%
	Dulbining NR shrubland &	Lerps, locusts, borers, wandoo crown decline – although these would not cause goal failure they	5%

Proximal risk factor	Community	Comments	Likelihood risk factor will cause target failure
	woodland, Toolibin NR woodland	could impact on the vegetation. Kangaroos and rabbits at Dulbining – potential risk, numbers would need to increase significantly to cause goal failure. For the snail orchid, kangaroos, rabbits, bobtails are all possible grazers. **Orchids in general are susceptible to grazing, relates to shrublands.** DPaW baits for rabbits in the vicinity. Knowledge gap.	
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	Foxes, cats, raptors would impact, management action is for baiting.	<1%
Lack of mates	Dulbining NR wetland (2)	Probably not an issue. Continuing regeneration of more obvious species. Regeneration of both species have flowered and set seed.	<1%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	Loss of insects = no pollination. Some orchids require specific pollinators. Weeds may not be palatable for pollinators. For snail orchid, if they don't flower they could possibly produce more bulbs; may not flower for many years. Knowledge gap.	1%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	Generally very few birds breed at Toolibin and come back to Toolibin Lake as fledglings, unless there is an early season. They would all be breeding now (August) – observations Greg Durell.	<1%
Lack of genetic diversity	Dulbining NR wetland (2)	If the population dropped below 200 reproductively mature individuals it could be an issue. Probably enough *obesa* and *strobophylla*, but not sure about other species.	<1%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	Not enough information, no baseline data. David Coates work at Dongolocking on *Calothamnus* and other species. David's work on less than 200. See David Coates. Knowledge gap for snail orchid. A lot of orchids have small populations with one specific pollinator which will go long distances for pollination.	<1%
	Waterbirds (Toolibin Lake, Dulbining NR wetlands (assumed 25 species)	Not sedentary.	<1%
Lack of reproduction	Dulbining NR wetland (2)	Unlikely to cause goal failure	<1%
	Dulbining NR shrubland & woodland, Toolibin NR woodland	Lack of fire is likely to cause goal failure over the management period due to senescence. However, requires research to really understand the risk. **Note: Shrublands only**	20%
	Waterbirds (Toolibin Lake,	If breeding is part of the goal, then a lack of reproduction (assuming conditions are appropriate) is	<1%

Proximal risk factor	Community	Comments	Likelihood risk factor will cause target failure
	Dulbining NR wetlands (assumed 25 species)	unlikely to occur.	
Other notes	Dulbining NR shrubland & woodland, Toolibin NR woodland	Weed, fire and problem species in combination will have an adverse effect on the goal. Salinity + water logging. A lot of knowledge gaps for the snail orchid.	

Appendix 11. Weed species

This appendix details weed species (Table 21) known to occur in the general area and the subset species that have been recorded in the biological elements.

1 = Toolibin Nature Reserve open woodland

2 = Dulbining Nature Reserve shrubland

3 = Dulbining Nature Reserve woodland

4 = Dingerlin Nature Reserve shrubland

5 = Dingerlin Nature Reserve woodland

6 = Wandoo woodland

7 = Red morrel woodland

8 = Silver mallet woodland (1 and 2)

*= known to occur in general area (anecdotal evidence)

Table 21: Weed species

Scientific name	Common name	Recorded in Toolibin Lake catchment biological elements
Aira caryophyllea	silvery hairgrass	1,3, 5
Aira cupaniana	silvery hairgrass	
Amaranthus albus	tumbleweed	
Arctotheca calendula	cape weed	1, 3
Asparagus asparagoides	bridal creeper	
Avellinia michelii		3
Avena barbata	bearded oat	1, 3
Brassica tournefortii	Mediterranean turnip	1
Briza maxima	blowfly grass	1, 3
Briza minor	shivery grass	3
Bromus diandrus	great brome	
Bromus hordeaceus	soft brome	1, 3
Bromus madritensis	Madrid brome	1
Bromus rubens	red brome	3, 5
Centaurium erythraea	common centaury	2, 4
Cerastium comatum		1
Cerastium glomeratum	mouse ear chickweed	1
Chamaecytisus palmensis	tagasaste	
Chrysanthemoides monilifera		
Conyza bonariensis	flaxleaf fleabane	
Cotula bipinnata	ferny cotula	1, 3
Cotula coronopifolia	waterbuttons	1, 3
Crassula natans		1, 3
Cucumis myriocarpus	prickly paddy melon	*
Cyperus tenellus	tiny flatsedge	
Dittrichia graveolens	stinkwort	
Ehrharta longiflora	annual veldt grass	1, 3
Eragrostis curvula	African lovegrass	*
Erodium botrys	long storksbill	
Erodium moschatum	musky crowfoot	

Scientific name	Common name	Recorded in Toolibin Lake catchment biological elements
Freesia alba x leichtlinii		
Fumaria capreolata	whiteflower fumitory	
Gladiolus tristis	largeflower gladiolus	
Heliotropium europaeum	common heliotrope	
Hordeum hystrix	Mediterranean region barley grass	3
Hordeum leporinum	barley grass	1, 2, 3
Hypochaeris glabra	smooth catsear	1, 3
Isolepis marginata	coarse club-rush	1
Juncus acutus	spiny rush	
Juncus bufonius	toad rush	1
Lepidium africanum	rubble peppercress	
Lythrum hyssopifolia	lesser loosestrife	
Mesembryanthemum nodiflorum		1, 2, 3
Monoculus monstrosus		
Oxalis pes-caprae	soursob	
Parentucellia latifolia	common bartsia	1,
Petrorhagia dubia		1, 4
Plantago coronopus	buckshorn plantain	3
Raphanus raphanistrum	wild radish	*
Romulea rosea	guildford grass	3
Sagina apetala	annual pearlwort	1,
Sonchus asper	rough sowthistle	
Sonchus oleraceus	common sowthistle	1, 3
Spergula arvensis	corn spurry	
Spergularia diandra	lesser sand spurry	1, 3
Spergularia marina		1, 3
Spergularia rubra	sand spurry	2
Stachys arvensis	staggerweed	
Stellaria media	chickweed	1,
Trifolium arvense	hare's foot clover	
Trifolium campestre	hop clover	
Trifolium glomeratum	cluster clover	
Trifolium stellatum	star clover	
Trifolium subterraneum	subterranean clover	
Trifolium tomentosum	woolly clover	1, 3
Ursinia anthemoides		1, 3, 5
Vellereophyton dealbatum	white cudweed	

Appendix 12. Fire-sensitive plant species

This appendix (Table 22) is a list of plant species (serotinous obligate seeders or re-sprouters) that show increasing rates of senescence and mortality with time since fire, and may be at risk of localised extinction. Because of this they are thought to be useful indicators of the maximum tolerable fire interval for shrubland/kwongan vegetation in the southern Wheatbelt. (Based upon Brooks and Carley 2013a, Gosper et al. 2013 and B. Beecham pers. comm.)

Those species recorded in the catchment's biological elements are marked with an asterisk *.

Table 22: Indicator plant species

Known indicator species
*Allocasuarina campestris**
*Allocasuarina huegeliana**
Banksia nivea
*Banksia prionotes**
Banksia violacea
*Beaufortia bracteosa**
Eremaea pauciflora
*Hakea cygna**
Hakea gilbertii
Hakea lehmanniana
Hakea pandanicarpa
*Hakea trifurcata**
Isopogon sp. Fitzgerald River
Isopogon sp. Newdegate
*Isopogon teretifolius**
Isopogon villosus
*Melaleuca acuminata**
Melaleuca acuminata subsp. *acuminata**
*Melaleuca pungens**
*Melaleuca viminea**
Petrophile brevifolia
Petrophile circinata
Petrophile ericifolia
Petrophile phylicoides

Appendix 13. Benefit analysis

13.1. Introduction

Natural resource managers are often faced with the daunting task of managing complex environments (Ostrom 1999, Kellert et al. 2000) for a range of values with limited resources (Naidoo et al. 2006). Thus, in many management areas, there will be a greater expectation of value realisation than resources permit (Wilson et al. 2009). This means that managers must make decisions about how and where to allocate resources; an area that has received attention (e.g. Hobbs and Kristjanson 2003, Wilson et al. 2009).

To build on the work of Wallace (2012), a series of steps to quantify the value realisation from different biological elements has been developed, as has software to facilitate the planning process (Pourabdollah et al. 2014). By following the approach, natural resource managers will, firstly, have a sensible classification of the values that are rated on their importance by stakeholder representatives. Secondly, they will understand the important biological element properties in terms of realising values. And, thirdly, they will have identified the most important biological elements. By following the approach outlined by Metcalf and Wallace (2013), managers should come to understand which processes most threaten the biological elements in terms of their value, allowing them to develop a set of possible management actions (Wallace 2012). Where funding is limiting and management actions need to be prioritised, a benefit analysis will provide additional information for prioritisation. Here we present a preliminary analysis that can be applied when the benefit is expressed in terms of the priority values that are expected for a series of biological elements relative to a series of potential management actions. This appendix addresses a step in the planning framework outlined by Wallace (2012).

13.2. Methods

As already alluded to, the approach outlined here relies upon the completion of several preliminary, but mostly standard, natural resource management steps (Wallace 2012). Practitioners must have classified the values, identified the biological elements, and established the relationships between key properties of the biological elements and the biological elements' capacity to generate values (refer to recovery plan main document and appendices 4 through 10). Finally, it is wise to conduct an assessment of the processes that threaten the biological elements, using properties to set management targets (Appendix 10). it is stressed that, with ongoing planning and continued consultation with experts and stakeholders, the various outputs and results will improve.

For the Toolibin Lake catchment, three values were identified to be most important: knowledge/heritage and education, productive use, and philosophical/spiritual contentment (Appendix 4). Eight priority biological elements were identified for assessment, and these were determined to be under threat from altered hydrology and fire regimes, and from the introduction of problem species (Metcalf and Wallace 2013 and Appendix 10). The biological elements determine the spatial extent of management. The stakeholder group thought that the values derived from each biological element were mostly mediated by four currently quantifiable properties: species richness, intactness, size and rarity.

The group estimated the importance of each biological element within a type 1 fuzzy logic system (FLS) developed by Pourabdollah et al. (2014). The system models values as a function of a set of property states. Importantly, the FLS can be used to combine information from individual property-value relationships into a 'property-value utility' response curve for each biological element (e.g. Figure 9). The value utility score represents an estimate of the overall values that may be derived from a biological element and can be modelled as a function of individual properties. Thus, each property-value utility response curve can be used to predict the utility (or benefit) expected for a particular property score for a particular biological element. Pourabdollah et al. (2014) provides a detailed description of the FLS and its use.

This analysis used the predicted relationships between one important property (species richness) and value utility. This relationship expresses the overall value utility expected with changes in species richness (as measured at the beginning of the management period; e.g. Figure 10). Even though size, rarity and intactness were used in the values analysis (Appendix 5), these properties were not incorporated into the subsequent risk analyses. This meant that there were no management targets or actions that related to these properties. It was expected, nonetheless, that any change in these three properties would be preceded by change in species richness and thus the department decided, in consultation with an advisory group of experts (the experts are described below), that richness was the key property in terms of management activities. Additionally, intactness is an estimate of how much species composition had been lost before the start of the management period. Over the ensuing management period, a loss of species richness would be equivalent to a significant loss of intactness and so the two properties are correlated.

Even though only one property was examined in the case study, in theory, there is no limit to the number of properties that could be used in the analysis. The approach is designed such that it can be extended to incorporate multiple properties. At the management option-biological element level, the benefits associated with different properties can be summed as long as the properties incorporated into the analysis are classified such that redundancy is minimised. As redundancy among the properties increases, the predicted benefits will become less additive, reducing the validity of the estimated benefits. All analyses were conducted in Juzzy (Wagner 2013) and Microsoft Excel©.

Table 23 lists the eight management options that the group of experts identified for comparison. Five experts were engaged, each with different education, training and experience, but all of whom were sufficiently familiar with the biological elements, the various management options and the likely effects of applying the different management options in terms of changing species richness over the management period. One expert was a regional ecologist, another a nature conservation program leader and the other three were nature conservation officers. At the time of the elicitation, all five experts were employed by the former WA Department of Parks and Wildlife.

Each management option actually incorporates a series of actions to address the important threatening processes. For example, the management of problem species includes the control of introduced plants to reduce the risk of competition to the natural species (e.g. Lawes and Grice 2010) and disease which can cause significant mortality in natural species (Shearer et al. 2007). Managing grazing on seedlings by problem species is important to minimise impacts on the reproductive success and survival of natural species (e.g. Tiver and Andrew 1997) and so on. Importantly, once this 'broader' level assessment has been conducted, the same approach could be applied at the intra-option level. Through iteration, the 'broader' level assessment may need to be adapted as new information garnered from an intra-option level assessment becomes available, and so on.

Table 23: Management options relating to addressing the key threatening processes

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

To capture the opinions of the experts, two group workshops were conducted (on 20 August and 18 December 2013) – the first with all of the experts and the second with three of the experts (two were unavailable). All experts were made aware of any changes to the predictions that emerged from the second session and gave them the opportunity to confidentially raise any concerns – none did. Of note, all of the experts had been involved in formal elicitation procedures (including calibration attempts) relating to the Toolibin Lake catchment (e.g. some of the experts were involved in elicitation procedure described by Metcalf and Wallace 2013). Thus the experts were considered to be well trained. As a result of their training, knowledge and experience, the group was deemed unlikely to, firstly, be dominated by any particular individual or, secondly, provide estimates that suffered from excessive over or under confidence.

Nonetheless, individuals were always provided the opportunity to discuss the group estimates individually and anonymously outside the sessions. Although not the focus of this appendix, we do note that more formal elicitation procedures (e.g. Burgman 2005, Speirs-Bridge et al. 2010, Metcalf and Wallace 2013) may be used in other management situations.

For the first workshop, the five experts worked together to provide a best answer to the following question for each management option-biological element combination:

> *Given adequate resources and the application of our existing suite of practicable management approaches, what per cent of the current species richness would you expect to lose over the management period of 20 years?*

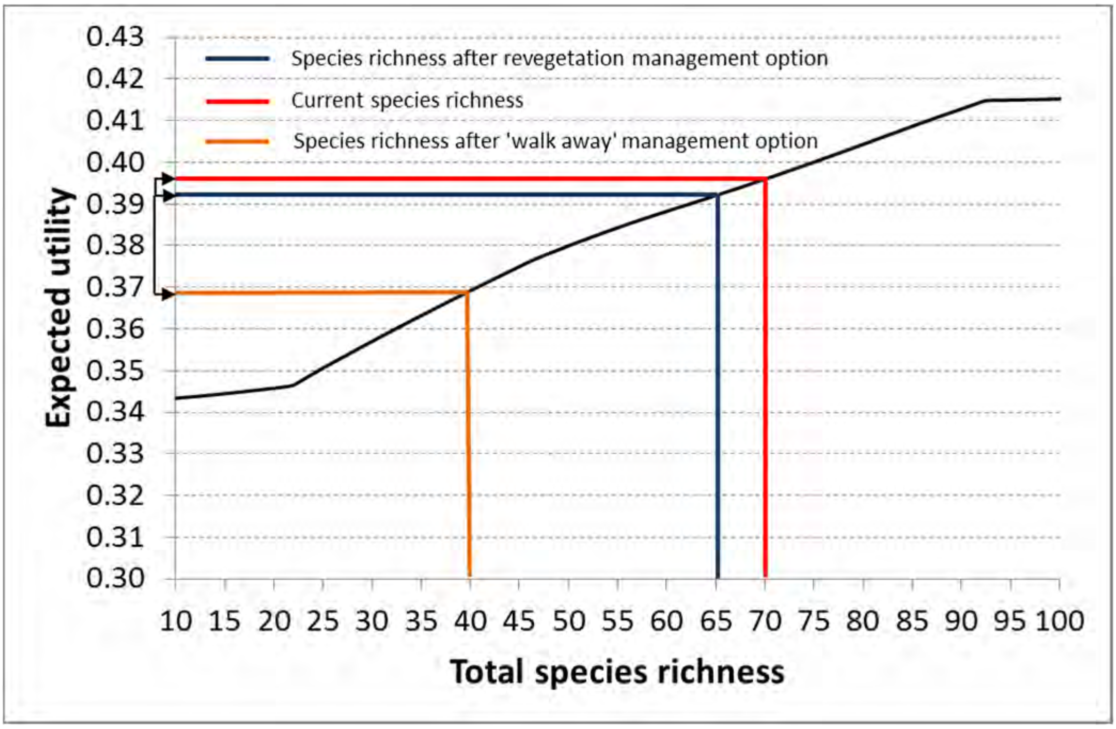


Figure 9: Example of the predicted change in overall value utility for a vegetation element as a function of species richness

Note: the graph shows two hypothetical management options (revegetate and 'walk away') to demonstrate the calculation of management benefit. The difference in utility between the revegetation option and the current richness (based upon current management) is positive and approximately 0.0035 relative units. The difference in utility between the 'walk away' option and the current richness (based upon current management) is negative and approximately -0.0235 relative units. Thus we can quantitatively estimate the relative benefit, in human value terms, of the two management options.

During the first session the group addressed any difficulties or uncertainties and discussed and agreed upon the elicitation question. The group defined terminology and each expert was made aware of the current estimates of species richness for each biological element.

To give the experts time to consider the results and do any further research, a second and final session was conducted about four months later. The aim of this session was to reassess the estimates and to make any final changes, should they be required. For the elicitation, management options in terms applying the known suite of practicable and feasible actions without resource limitation, were couched. To manage weeds, for example, the experts were familiar with the various approaches that would normally be employed (e.g. spraying, physical removal, etc.) to remove problem weed species over the management period. By following this approach, the experts took into account the effectiveness of the various actions that underpin each management option in their estimate of per cent change in species richness. This was deemed to be appropriate for this particular management scenario. However, estimates of the risk of failure and effectiveness of the options could be incorporated into the approach in a more formal way if required (e.g. Pannell et al. 2013).

13.3. Results

For each biological element, the relationship between expected utility and species richness is provided in Figure 10 and the benefit expected for each management option is presented in Table 24. Table 25 reports the overall benefit for each management option. The group predicted the management of altered hydrology in the catchment to be the most important option in terms of preserving biological element value (Table 25). The group expected the four options that included altered hydrology to provide a positive outcome in terms of utility (an overall increase in utility and richness) over the management period. They were, in order of rating:

- manage all threatening processes
- manage altered hydrology and problem species
- manage altered hydrology and fire
- manage altered hydrology alone.

A loss in species, and consequently utility, was expected from all other management options. Other than the 'walk away' option, management option 2 (problem species), provided the least benefit (Table 25).

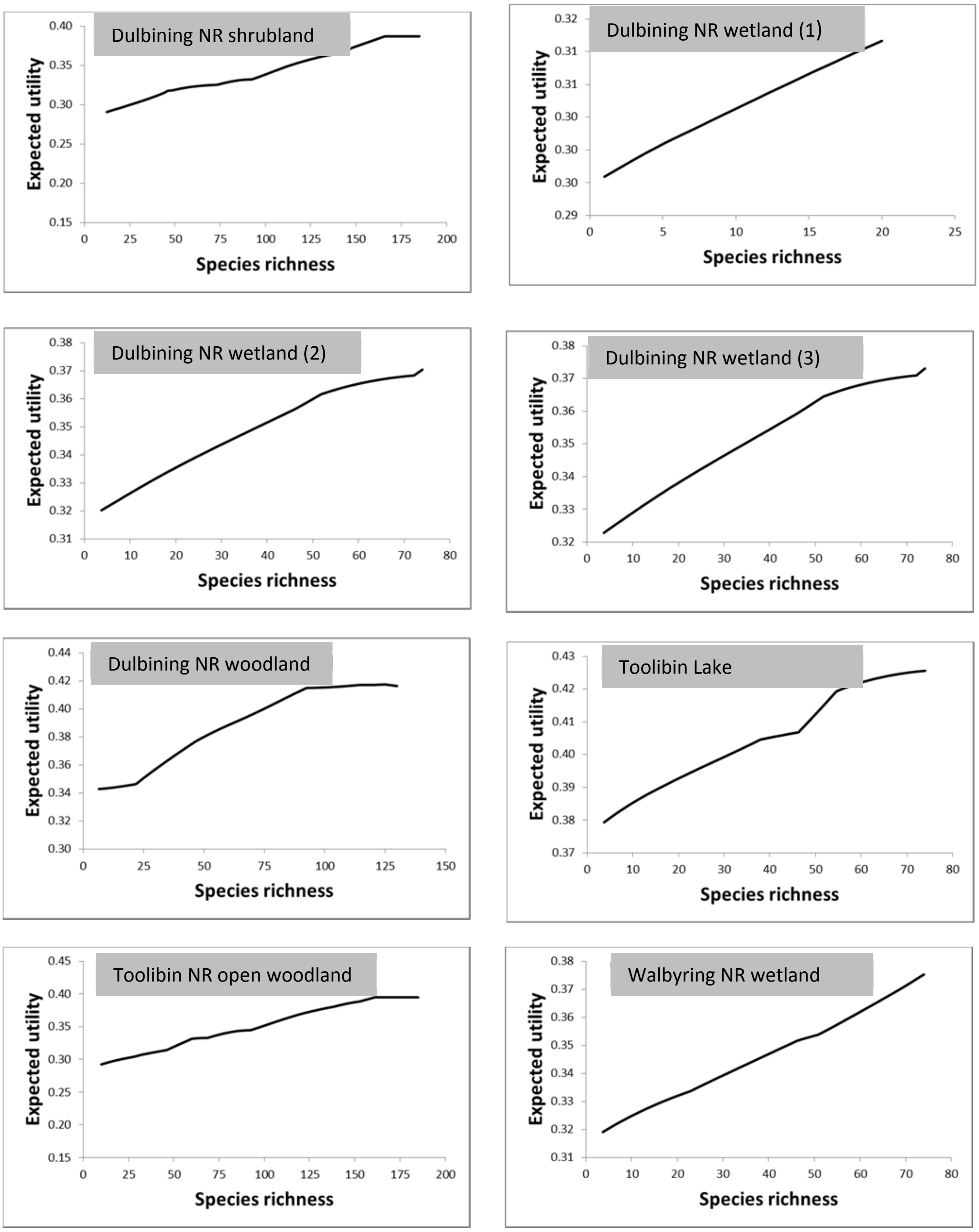


Figure 10: Expected relationship between species richness and utility for each priority biological element

Note: other properties were held constant at their current score

Table 24: Biological element level benefit expected for each management option

Management option	Toolibin Lake	Dulbining NR wetland (1)	Dulbining NR wetland (2)	Dulbining NR wetland (3)	Walbyring NR wetland	Toolibin NR woodland	Dulbining NR woodland	Dulbining NR shrubland
1	-0.001255	-0.004315	0.000000	0.000000	-0.001426	-0.004619	-0.000990	-0.000766
2	-0.001255	-0.004315	0.000000	0.002426	-0.001426	-0.003718	-0.000990	-0.000766
3	-0.001255	-0.004315	0.000000	0.000000	-0.001426	-0.000932	-0.000990	0.000000
4	0.000000	0.001721	0.000000	0.003921	0.003090	-0.003718	0.000000	-0.000766
5	-0.001255	-0.004315	0.000000	0.002426	-0.001426	0.001903	-0.000990	0.001510
6	0.000000	0.002563	0.000000	0.006006	0.003090	-0.002812	0.000000	-0.000766
7	0.000000	0.001721	0.000000	0.003921	0.003090	-0.003718	0.000000	0.001510
8	0.000000	0.002563	0.000000	0.006006	0.003090	0.002845	0.000000	0.002208

Table 25: Overall expected benefit for each management option

Note: Management options are described in Table 23

Management option	Ranked overall benefit
8	0.0167
6	0.0081
7	0.0065
4	0.0042
5	-0.0021
3	-0.0089
2	-0.0100
1	-0.0134

13.4. Discussion

A benefit analysis can help inform decisions when we are managing natural biological elements for the delivery of human values. Stakeholders' expectations of values from a set of biological elements should drive prioritisation and decision-making (Gregory et al. 2012).

It is particularly important to understand how change in a property of a biological element leads to change in the value it generates. This is because it is the biological element properties that are the target of on-ground management activities. This provides a direct link between management activity and the capacity for people to derive value. The steps leading to this point in the planning process indicate that changes in species richness will directly influence the values people derive from the biological elements.

A series of management options that influence the species richness property in terms of their expected generation of human values were assessed. This enabled ranking of those management options for their expected overall benefit. By dividing benefit estimates by the costs of the management actions (i.e. a benefit-cost analysis), managers can make more informed decisions about the best way to use available funds.

The approach used here is believed to be unique. This is because it not only builds on a theoretically sound values classification (Wallace 2012), but also integrates the conceptualised and quantified relationships between the values and the properties of the biological elements that mediate element utility. Importantly, the properties themselves should be prioritised by an assessment of risk (e.g. Metcalf and Wallace 2013). Consequently, by following the approaches discussed here, managers will be in a strong position to make decisions because they will have a clear succinct understanding of:

1) the relative importance of values that their stakeholders (or their representatives) derive from the management of an area's biological elements
2) the relationship between biological element properties and the values that may be generated
3) the processes that threaten the properties
4) the consequence of management activities in terms of change in the delivery of values from the biological elements.

Ultimately, the approach outlined here relies upon eliciting values, identifying biological element properties and quantifying the relationships between the two. It also includes estimating the probabilities of risk to biological elements. By their nature, all of these sources of information will be dynamic, uncertain and subject to bias. In a typical management situation, not all stakeholders (or their representatives) will be surveyable. Further, gleaning information from stakeholders, experts and the literature incorporates various forms of uncertainty and bias (Burgman 2005), the measurement of variables is uncertain, and relationships change over time. Importantly, some of these sources of uncertainty can be reduced and accounted for through the various modelling (e.g. Royle et al. 2004, MacKenzie et al. 2006, Gorresen et al. 2009) and elicitation (Burgman 2005, Martin et al. 2011, Wagner et al. 2014) approaches that practitioners can employ. Bearing this in mind, research is currently progressing to develop better approaches to quantify the relationships between biological element properties and values, and to incorporate uncertainty in the approach by using Type-2 Fuzzy Logic (Wagner and Hagras 2010).

Consequently, at every level of scrutiny there will be uncertainty and the capacity for a multitude of different management scenarios, making decision-making a particularly challenging task (Gregory et al. 2012). Hence, the department places great importance on the need for planning to be iterative and adaptive by nature. It is also important to start from the broad and work towards the more specific. Such complexity in the management of natural resources can make it difficult to maintain perspective, providing much of the impetus for the development of the approaches described in this appendix. Importantly, by iterating, testing and reviewing the planning outputs with experts and stakeholder representatives throughout the management period, the department can identify change and incorporate it appropriately. That is, the department can approach management in a more experimental manner (cf. Duncan and Wintle 2008). Following the approach outlined here, managers can be more explicit in terms of what actions are proposed and how much human value they expect to deliver. Finally, where there are inadequate resources to manage all of the threatening processes, some loss in value can be expected. Importantly, though, the department can now clearly articulate any expected loss or gain in value.

Appendix 14. Surface water flow actions and monitoring

14.1. Surface water flow actions and monitoring to investigate when conceptual model complete

A. Develop a program to investigate and undertake minor works to the more southern outlet (on the treeline to the dam) of Dulbining (1) wetland to better manage the inundation after flow events.
B. Investigate the need to modify the overland flow path of water east of the Toolibin North Road and Brown Road intersection and upgrade the culverts at the intersection.
C. Assess the need for improvement to culverts across the Wickepin Harrismith Road at the inlet to Toolibin Lake by undertaking further surveying and engineering analysis.
D. Assess the feasibility to manage surface water flows into and out of Toolibin and Walbyring lakes at the south-western end of Toolibin Lake.
E. Assess feasibility of upgrading the east and west drains between Wogolin Road South and Brown Road to improve flows and reduce inundation.
F. Assess the causative factors for the salt outbreak in the Dingerlin Nature Reserve in management area 06 (Muirden and Coleman 2014) and assess options to manage.
G. Investigate, install and maintain surface water monitoring sites to best capture relevant and good quality data.

14.2. Monitoring

It is recommended that the department monitor a set of priority surface water sites for the entire management period.

Table 26: Recommended high priority surface water monitoring sites

Note: recommended by Muirden and Coleman (2014), who also provide more detail in terms of required equipment and associated maintenance

Monitoring site number	Site name	Description
609010	Toolibin Lake Inflow	Existing Department of Water and Environmental Regulation (DWER) site: measures flows across Harrismith Road and towards Toolibin Lake.
609038	West Drain	Former DWER site now operated by the department: measures flows from the NW catchments.
609037	East Drain	Former DWER site now operated by the department: measures flows from the north catchments.
13DUL003	Upper Dulbining Channel	Proposed new site on the eastern Dulbining Channel (located up stream of the East Drain confluence) to monitor flows from the Salt Lake [MA08], East [MA03] and South East [MA05] areas.

It is recommended that a set of lower priority surface water sites are monitored in the short term.

Table 27: Recommended moderate priority surface water monitoring sites

Note: (from Muirden and Coleman [2014])
Potential 'investigation' sites to better understand the hydrology of the Toolibin flats are monitored. This would include 'episodic' monitoring by reading post-event water levels to determine flow rates and 'snapshot' monitoring to measure water levels and water quality at many sites during winter flows.

Monitoring site number	Description and notes
12BRO	MA12 has had a significant amount of management action, but little monitoring of its impacts. Currently, there is no monitoring at this site.
13DUL007	To provide data to design any extension to Dulbining Channel or the Harrismith Road Crossing. Also, to understand the impacts of any change in flooding due to/from Dulbining Channel. This site replaces WQ from 13DUL006.
03BRO001	Flow from the salt pan area north of Brown Road has been recorded in the past, but the large flows and salt loads from this area are likely to be false due to poor measurement practices. This could become a high priority for management, so flows and loads need to be confirmed before work is undertaken.
03BRO002	Flow from the main MA03 area has never been recorded, but indications are that it is very different from the western side of the catchment. This needs to be confirmed and the water quality of its flow quantified.
03TON002	This site is needed to provide correlation with a new site downstream at 13DUL003.

Table 28: Recommended 'snapshot' sites for surface water monitoring

Note: refer to Muirden and Coleman (2014) for site naming convention and associated locational maps

Snapshot site number	New or existing
10HAL	Existing gauge board
10WDR	Existing gauge board
10NWT	New site (located 700m Sth of 10WDR)
609038	Existing gauging station
11DOR	Existing gauge board
11EDR001	Existing gauge board
11EDR003	New site (located 160 m d/s for Wogolin Sth Road)
609037	Existing gauging station
12NET	New site (potential site located 2 km d/s Toolibin Nth Road)
12BRO	Reinstated site (same located; modified control)
03TIN	Existing gauge board
03BRO001	Reinstated site (located further d/s)
03BRO002	Relocate site (located 5m u/s); existing gauge board
03TON001	Reinstated site (same location)
05TIN	Existing gauge board
05HAR	Existing gauge board
05TON002	New site (located at Toolibin North Road)
13DUL003	New site (located u/s of East Drain confluence)
13DUL006	Existing gauge board
13DUL007	Existing gauge board
13DUL1	Existing gauge board (Dulbining 1 Lake)
13DUL2	Existing gauge board (Dulbining 2 Lake)

Snapshot site number	New or existing
13DUL3	Existing gauge board (Dulbining 3 Lake)
609010	Existing gauge board
14TIN (1&2)	Existing gauge board
609009 (sump)	Existing gauge board (Toolibin Lake)
01HLC	Existing gauge board
01DEC	Existing gauge board
15WON	New site (located south of Toolibin original outlet)
WALB	Existing gauge board (Walbyring Lake)

Appendix 15. Management guidelines for the hydrological infrastructure

1) Background information

- Surface water inflow in winter is most likely to exceed 2000 µS/cm@25°C (≈1000mg/L).
- The first summer surface water inflow event is likely to be fresh (≤ 2000 µS/cm@25°C).
- Significant catchment-scale rainfall events which generate surface water flows are likely to enter Toolibin Lake, regardless of the gate status.
- For waterbirds and aquatic invertebrates, monitoring should commence approximately 1 month after fill event.
- Apart from *Biziura lobata* (musk duck) and *Cygnus atratus* (black swan), all waterbirds can complete their breeding cycle (juveniles fledging) within about 90 days which is approximately the time it takes to drain the lake when full.
- Vegetation monitoring to continue as detailed in recovery plan.
- Major cause of juvenile bird mortality will be associated with predation by introduced predators. If breeding event occurs instigate immediate introduced predator control.
- Note, the Department of Water and Environmental Regulation (DWER) surface water monitoring site 609010 has telemetry providing catchment officers with information on flows and water quality. Importantly, the EC measured at site 609010 may differ to the EC measured at the gates. Therefore, until such time that telemetry is installed at the actual gate, decisions to open or close the gates will rely upon data measured by hand at the gates.
- Additional post rain event procedures (e.g. 'snapshot' monitoring) should be followed.

2) Diversion gate

Provisional guidelines pending the outcomes of continuing hydrological research.

Guideline 1: Gates stay open as default position.

Guideline 2: Gates should never be closed if groundwater before the rain event is within 2.5 metres below ground level (mbgl).

Guideline 3: If groundwater below the lake is within 2.5 mbgl before fill event and water salinity is ≤ 2000 µS/cm@25°C, as measured at the gates, close gate.

3) Sump pump

Rule 1: If groundwater below the lake is < 4.0 mbgl before the fill event turn on sump pump.

Rule 2: If groundwater below the lake is ≥ 4.0 mbgl before the fill event, water should not be in the lake for more than seven months. A full lake takes three to four months to empty by pumping.

Rule 3: If surface water in the lake exceeds 10,000 µS/cm@25°C at any time, turn on sump pump to drain the Lake.

Rule 4: Obtain verbal sign-off by Regional Manager before turning on sump pump and closing-opening the diversion gates and confirm in file note when returned to office.

4) Approvals

In relation to approval, the flow of decision-making should be:

1. Regional Manager, Wheatbelt Region sends advice to Assistant Director, Science and Conservation Division, with a recommendation. This is copied to Program Leader, Wetland Conservation Program for information.
2. Assistant Director, Science and Conservation Division endorses the recommendation, or otherwise, and copies advice back to Regional Manager, Wheatbelt and other recipients to the original email.
3. Regional Manager considers advising Director, Regional and Fire Management Services if deemed controversial.

Approved: Regional Manager, Wheatbelt

Appendix 16. Standard operating procedures for groundwater monitoring

Responsible officer: Recovery Catchment Technical Officer (RCTO)

Introduction

Bore monitoring is underaken at the catchment bores biannually and lake bores quarterly.

Estimated time

Lake – ½ day

Catchment – 2 days

Equipment required

- Toughbook with DCT Data collection tool loaded
- monitoring sheets, clipboard, maps and directions in folder
- GPS (RCTO's GPS has all waypoints for TL bore monitoring)
- 2 x measuring tapes and ploppers (located in the Toolibin vehicle – these have been corrected)
- wellington boots
- wet weather gear
- catchment bore run

You will need to contact landholders to advise them you will be entering their property. Names and contact numbers are listed in the green folder.

Work required

You will have received and transferred the latest DCT master spreadsheet to the laptop. Use Toughbook to enter data. Use your DBCA sign-on and password.

Navigate to bores using maps provided in the Toolibin folder.

All bores have been labeled with metal tags on wire. Ensure correct bore label before measuring.

Note date, tape correction and collector details on the monitoring sheet.

There is a separate spreadsheet for the monthly and catchment bores in the green folder.

Measure and record the groundwater level in metres and record on monitoring sheet in *Raw Top PVC (m) (below ground level-BGL)*. Note any other comments which affect the bore run e.g. missing bores, damaged etc. Refer to Manual groundwater measurement diagram in the green folder.

Refer to *Data Management Procedure OP-DAT-005: Data Collection Tool (DCT) – File management and data entry* procedures to enter data into the Data Collection Tool.

Save spreadsheet as *DCT_Toolibin_yearmonthday.* On return to the office transfer spreadsheet to T:\407-Operations (District)\Shared Data\Toolibin\HYDRO - GROUNDWATER\MONITORING\NRB Data Entry Tool\TL_Bore_data\LAKE\2016 and transfer and email to Lindsay Bourke in WCP.

Once Lindsay has processed the data he will email the master spreadsheet ready for the next month's data collection.

Original spreadsheets are filed in the green monitoring folder.

Approved

Conservation Officer (Toolibin Lake)

2015

Wetlands Conservation Program Guideline
Guideline: OP-DAT-005 Document version: Draft for review

Data Management Procedure OP-DAT-005: Data Collection Tool (DCT) – File management and data entry

Document version: Draft for review
Author: Lindsay Bourke
Custodian: Lindsay Bourke
Currency: May 2015 (updated July 2015)
Revision due: May 2016

1) Scope

The scope of this document is to provide a clear standard operating procedure for the use of the Data Collection Tool (DCT), specifically the management of the database and data entry. Data entry can be performed in the field or in the office; however, is preferably completed in the field by the same personnel who are collecting the data.

2) Overview

The Data Collection Tool (DCT) was developed by WCP staff, DBCA in order to improve data collection standards in the field. It enables data to be viewed in real-time, allowing data entry and quality control to be performed at point of collection. The tool also aims to maintain a consistent and comprehensive data structure and database for water level measurements.

The use of the DCT results in the compilation of a list of new water level records. These measurements require review before they are archived to the permanent "master" database, which in turn is used by field staff for future quality control of newly acquired data. Details on the process for archiving this newly acquired data are addressed in procedure OP-DAT-006, while the focus of this document is the process for the management of database versions and data entry.

3) Prerequisite

Other than a working knowledge of Windows software and computer hardware, there are no prerequisites to operate the DCT. However, personnel responsible for the collection of field data must understand the methodology for the measurement of groundwater levels, which are detailed in procedure FP-GW-001.

4) Operational procedures

4.1 Reviewing and approving data

Newly acquired data is stored within the "new_SWLs" worksheet. All new measurements that are pending approval for archiving to the master database are stored in this location. This sheet can be accessed by clicking the "View Measurements" button on the home page, then selecting the "new_SWLs" worksheet. Measurements are stored with the field “measurement code”, which is a concatenation of the bore name and the numerical date of the measurement, resulting in a unique measurement code for each entry.

A limit of acceptable change has been allocated to the DCT to identify potential data measurement or entry errors. By default this is set as a change of more than 5 m of the current measurement from the first record. Measurements which are potentially erroneous are flagged with Quality Code “140” (data not yet checked).

Instructions

1. Arrive on site.
2. Identify site name.
3. Open Data Collection Tool. Enable macros (see Microsoft homepage for details).
4. The first time that you open the Data Collection Tool for the monitoring run select “Create a new file”: Naming convention is *DCT_NDRC_YYMMDD* (e.g. DCT_Toolibin_150119.xlsm).
2. Select “Open this file” if adding more measurements for today, or if you are reviewing data from this sheet. If you select the “Create a new file” more than once it will ask if you want to overwrite the previous file that has been created.
3. Update the checklist sheet with list of sites for this monitoring run.
   i. Click on the “Checklist” sheet.
   ii. Click the blue “Lock/Unlock Checklist”. A dialogue box will appear to confirm edits to the list.
   iii. Copy and paste the list of bore names into column “A” using the same names in the site table.
   iv. Click the blue “Lock/Unlock Checklist” to lock “Checklist” sheet again.
   v. This checklist can be used to confirm that all bores are monitored. When new data is entered into the “new_SWLs” sheet the cell in the Measured today? column will change from no to yes.
4. On the “Form” sheet select the correct site from the dropdown list next to field “Bore ID”, alternatively type in site name.
5. View red dot on map to confirm the location.
6. Measure the depth of the water level to the top of the reference point (typically the top of PVC casing, or top of steel headworks) (follow procedure FP-GW-001)
7. In the “Measurement Date” blue cell enter todays date (dd/mm/yyyy) (alternatively use shortcut “ctrl+;”)
8. Enter the depth to groundwater value in the “SWL” field (note, depths are entered as positive values below top of reference). If the bore is dry, then enter 999 in the “SWL” field. If a scheduled monitoring event was to occur and was not completed, then enter the value 996. Enter comments to indicate why the site was missed.

9. Select “Update Charts”. View the hydrograph to see if the new measurement (shown as a red dot) sits in an acceptable range. This is the first point of quality control for the data.
10. Click “Record Measurement”.
11. Data is transferred to the worksheet “new_SWLs”.

Note: If you later find out that an incorrect water level value has been entered complete the following:

1. Open the “new_SWLs” worksheet.
2. Select the entry in the “Measurement Code” field in column A and select “review data”. You will be prompted with an “OVERWRITE WARNING” on the form sheet.
3. Enter correct value, “Update Charts” to review data, then “Record Measurement” to update the “new_SWLs” worksheet.
4. In instances where the incorrect date has been entered then you will have to make a new entry and provide details of the error in the “Comment” field. The error can be later rectified by the database administrator.

4.2 Transfer of data to the database administrator

Instructions

1. Return to the office.
2. Copy all DCT files to the local server to an archive directory for long-term storage.
3. Make all DCT files read only (right click on file, select properties, check “read-only”).
4. Copy all files to the Narrogin transfer folder (\\narr-site-001\Transfer).
5. Email the database administrator to confirm that files have been transferred.
6. The database administrator will then review the data, transfer quality checked data to the archive and create a new working version of the DCT and will transfer this version to the regional office.
7. Regional staff to transfer new version of the DCT to the field laptop.
8. All previous versions should be deleted from the laptop to ensure that the latest version is used.

Appendix 17. Standard operating procedures for – ephemeral (fill) event

Responsible officer: Conservation Officer (Toolibin Lake)

Introduction

A fill event is anything where a perceptible volume of water has entered the lake (usually implying surface flows (email Darren Farmer and Jasmine Rutherford, 2016)).

The Senior Hydrologist at Wetlands Conservation Program has modified a worksheet (Attachment A) T:\407-Operations (District)\Shared Data\Toolibin\HYDRO - SURFACE WATER\RAINFALL DATA\Ephemeral (fill) events to capture fill event data e.g. Date, time, conductivity, temperature, flows and water level at gauge board.) The spreadsheet is straightforward. However, for any further assistance the WCP hydrologists can be contacted.

Events for the last decade (2000s) have been compiled into a single worksheet in Excel and a back-up in Access.

References

- T:\407-Operations (District)\Shared Data\Toolibin\HYDRO - SURFACE WATER\RAINFALL DATA\Ephemeral (fill) events
- Know What You Are Monitoring – Hydrological Monitoring Training by Lance Mudgway (copy in Toolibin Library and in References)
- Draft Guidelines – Management of Diversion Gates
- TL Procedures – Connecting and Activating the Sump Pump

Equipment required

- waders
- camera and telephoto lens
- hand-held conductivity/salinity meter
- GPS
- water sampling containers
- distilled water
- data collection book
- measuring staff

- gloves
- data field sheet.

Work required

Surface water monitoring involves capturing water level (WL), water quality (WQ) and photos for each site including dates and times. See reference on hydrological monitoring training.

Decision about which to monitor should be made in consultation with WCP hydrologists and depends on the size of the event. All data is entered into the attached field sheet, and on return to the office data is entered into T:\407-Operations (District)\Shared Data\Toolibin\HYDRO - SURFACE WATER\RAINFALL DATA\Ephemeral (fill) events. The spreadsheet also has a conductivity conversion worksheet for salinity readings.

The following are the basic sites which need to be monitored (see map at Attachment B).

Toolibin Nature Reserve

A. Diversion Gate upstream of weir
B. Booloo (west) creek downstream of culvert
C. Diversion channel/boundary track crossing in south-west corner
D. TL25 GB (gauge board)
E. Sump GB
F. DWER gauging station GB – levels only

Catchment

G. Wickepin-Harrismith Road downstream of culvert
H. Toolibin Road North culvert (road side drain from Brown Rd)
I. Toolibin Road and Brown Rd intersection NE corner upstream
K. East drain downstream Brown Rd
L. West drain downstream Brown Rd

Dulbining

M. Dulbining waterway at Oval Road
N. Dulbining Lake GB
O. Dulbining 2 GB
P. Dulbining 3 GB

1) All data including email communications from WCP must be saved in the folder, and photos in the IMAGES folder. Any communications dealing with opening the diversion gates and pumping the sump need to go on the CIS file.
2) Depending on the size of the event other issues to consider are:
   - Survey of aquatic invertebrates. Contact Wetlands Conservation Program Leader, Adrian Pinder at WCP.

- Survey of waterbirds. Contact David Cale, Technical Officer.
- Depending on the size/volume of the event arrange for aerial imagery to be captured. Depending on funds this may be a flight with a local aero club and staff with camera capturing images or contracting an aerial imagery specialist e.g. Wings Photographics.

3) Another alternative is high resolution satellite imagery such as Rapideye. In the past Rapideye imagery has tasked over Lake Bryde. To capture a rainfall event the responsible officer must notify the department’s Remote Sensing Section. They need to know as soon as possible to get the satellite tasked to capture a cloud-free image before the lake dries out. Although not as clear and sharp as an aerial photo, Rapideye imagery has a pixel size of 6.5 metres. They can arrange to capture the image and ortho-rectify if required.

Approved

Conservation Officer (Toolibin Lake)
2015

Attachment A

SITE ID	EASTING_ MGA50	NORTHING_MG A50	SITE_DESCRIPTIO N	Sampl ed by (initial s)	Site visited_ Yes/No	DATE	TIME	EC_microS/ cm	Temp_^{0} C	TDS_mg /L	Flow observations (including no or recent flow information)	Water_ level_ mLD	Photo_ Record_ Yes/No	General Comments
A	556750.26	6358462.39	Diversion Gate											
B	556047.04	6357995.87	Booloo (west) creek											
C	555998.47	6356563.89	Diversion											
D	557389.50	6357286.63	TL25 GB (gauge											
E	556405.69	6357005.54	Sump GB											
F	557295.81	6357661.42	DWER gauging station											
G	557507.27	6359035.40	Wickepin-Harrismith											
H	561556.69	6360255.73	Toolibin Road North											
I	561822.54	6360899.81	Toolibin Road and											
J														
K	559934.98	6360842.10	East drain											
L	558993.25	6360870.29	West drain											
M	558987.92	6359376.00	Dulbining waterway											
N	557629.60	6359178.13	Dulbining Lake GB											
O	557992.68	6358990.74	Dulbining 2 GB											
P			Dulbining 3 GB											

Electrical conductivity metre calibrated by (Initials)

Attachment B

Appendix 18. Monitoring of vegetation elements

Photographs can be used to collect a visual representation of vegetation change over time. This data can be used to monitor the biological elements, in terms of the richness, abundance and reproduction of key indicator natural species in relation to the key threatening processes.

To maximise the value of photo-point monitoring, the photographs must be taken from the exact same location each time with an identical camera set up (focal length, ISO, aperture, etc.). Thus the approach requires permanent photo locations with a small amount of infrastructure to mount the camera in an identical manner each time the locations are monitored. The monitoring program is designed to collect information on:

1) change in abundance of different plant species
2) population structure to monitor reproduction (flowering, generation of new reproductively active individuals)
3) the introduction of any weed species
4) sickness or death in the existing vegetation.

The skills required, therefore, are the ability to:

1) set up and collect photographs
2) effectively store and manage photographs and the information generated from them
3) analyse photographic images which includes identifying important species.

The objectives of the monitoring program are outlined in detail in the *Toolibin Lake Catchment Recovery Plan: 2015–35*.

18.1. Methods

The department has prepared randomly located monitoring sites (Table 29). Both property and process data need to be collected concurrently (refer to Section 2.6 ‘Monitor’ sub-section ‘Adapative monitoring and evaluation’, *Toolibin Lake Catchment Recovery Plan: 2015–35*).

Establishment of a photo-point monitoring site

Equipment to set up site:

1) Three metal star pickets per site

    Note: safety issues must be considered. For example, it may be important to paint pickets in a bright colour, locate them so they are easy to see, and not put them where cars or people are likely to hit them.

2) Hammer/‘dolly’/picket rammer
3) Spirit level
4) Three aluminium tags per site, plus:
    a. Pen/pencil to write on the tags
    b. Wire
    c. Pliers
5) Three plastic star picket caps per site
6) Compass
7) GPS receiver
8) Measuring tape
9) Map of each site

Equipment to take photographs:

1) Digital camera permanently connected to a plastic star picket cap, plus:
    a. Extra batteries
    b. Sufficient memory cards
    c. Camera set-up description
        i. Focal length
        ii. Aperture (camera should be set to constant aperture and variable shutter speed). Should be the same for every photograph regardless of the site or date.
        iii. ISO
        iv. Auto focus setting
2) Data sheets, pencils, erasers and clipboard (or could be done on an electronic device)
3) For each sampling occasion it is important to carry a photo from the previous sampling occasion and a copy of the previous data sheet.
4) Whiteboard attached to a plastic star picket cap (to hang on one of the sighter posts) and whiteboard pens (to write the site name and date).

Table 29: Photo-point monitoring sites

Site number	XCOORD	YCOORD	Other site	Biological element
E-WH-TLB-PM-1	554981.742	6355648.995	NA	Walbyring NR wetland
E-WH-TLB-PM-2	555390.694	6355882.661	NA	Walbyring NR wetland
E-WH-TLB-PM-3	555408.207	6355467.895	NA	Walbyring NR wetland
E-WH-TLB-PM-4	554971.421	6355338.741	NA	Walbyring NR wetland
E-WH-TLB-PM-5	554806.947	6355810.633	NA	Walbyring NR wetland
E-WH-TLB-PM-6	555537.031	6356027.077	NA	Walbyring NR wetland
E-WH-TLB-PM-7	557198.877	6356205.347	NA	Toolibin NR woodland
E-WH-TLB-PM-8	557845.456	6357615.199	NA	Toolibin NR woodland
E-WH-TLB-PM-9	557450.157	6358669.305	NA	Toolibin NR woodland
E-WH-TLB-PM-10	556826.058	6358735.699	NA	Toolibin NR woodland
E-WH-TLB-PM-11	557988.385	6357820.009	NA	Toolibin NR woodland
E-WH-TLB-PM-12	556455.735	6358509.636	NA	Toolibin NR woodland
E-WH-TLB-PM-13	557623.975	6356567.13	NA	Toolibin NR woodland

Site number	XCOORD	YCOORD	Other site	Biological element
E-WH-TLB-PM-14	557606.841	6359539.747	NA	Dulbining NR wetland (1)
E-WH-TLB-PM-15	557513.508	6359293.465	NA	Dulbining NR wetland (1)
E-WH-TLB-PM-16	557771.477	6359154.327	NA	Dulbining NR wetland (1)
E-WH-TLB-PM-17	557943.3628	6359067.103	NA	Dulbining NR wetland (2)
E-WH-TLB-PM-18	557959.861	6358911.61	NA	Dulbining NR wetland (2)
E-WH-TLB-PM-19	558059.325	6358943.714	NA	Dulbining NR wetland (2)
E-WH-TLB-PM-20	558513.963	6358621.055	NA	Dulbining NR wetland (3)
E-WH-TLB-PM-21	558503.464	6358765.315	NA	Dulbining NR wetland (3)
E-WH-TLB-PM-22	558673.155	6358647.864	NA	Dulbining NR wetland (3)
E-WH-TLB-PM-23	561563.48	6358953.897	NA	Silver mallet (2) woodland
E-WH-TLB-PM-24	561487.035	6359116.206	NA	Silver mallet (2) woodland
E-WH-TLB-PM-25	561448.651	6358783.714	NA	Silver mallet (2) woodland
E-WH-TLB-PM-26	561176.273	6359567.276	NA	Red morrel woodland
E-WH-TLB-PM-27	560835.865	6359383.341	NA	Red morrel woodland
E-WH-TLB-PM-28	560324.904	6359396.195	NA	Red morrel woodland
E-WH-TLB-PM-29	561375.163	6357926.459	NA	Silver mallet (2) woodland
E-WH-TLB-PM-30	561078.372	6357955.92	NA	Silver mallet (2) woodland
E-WH-TLB-PM-31	561518.415	6357972.746	NA	Silver mallet (2) woodland
E-WH-TLB-PM-32	559131.373	6359288.133	NA	Dulbining NR shrubland
E-WH-TLB-PM-33	561614.678	6360689.796	NA	Dulbining NR shrubland
E-WH-TLB-PM-34	561151.368	6359948.879	NA	Dulbining NR shrubland
E-WH-TLB-PM-35	560683.253	6359798.375	NA	Dulbining NR shrubland
E-WH-TLB-PM-36	561180.693	6360683.856	NA	Dulbining NR shrubland
E-WH-TLB-PM-37	560892.674	6360268.383	NA	Dulbining NR shrubland
E-WH-TLB-PM-38	560941.121	6360440.633	NA	Dulbining NR shrubland
E-WH-TLB-PM-39	559652.488	6359490.428	NA	Dulbining NR shrubland
E-WH-TLB-PM-40	560841.675	6360000.828	NA	Dulbining NR shrubland
E-WH-TLB-PM-41	558090	6358594	41	Toolibin NR woodland
E-WH-TLB-PM-42	556968.018	6359380.851	NA	Dulbining NR shrubland
E-WH-TLB-PM-43	558173.816	6360006.751	NA	Dulbining NR shrubland
E-WH-TLB-PM-44	557620.241	6358789.968	44	Toolibin NR woodland
E-WH-TLB-PM-45	556846.069	6360689.958	NA	Dingerlin NR woodland
E-WH-TLB-PM-46	557062.2505	6358806.677	46	Toolibin NR woodland
E-WH-TLB-PM-47	557269.518	6360493.261	NA	Dingerlin NR woodland
E-WH-TLB-PM-48	557546.212	6360885.145	NA	Dingerlin NR woodland
E-WH-TLB-PM-49	557298.288	6360768.601	NA	Dingerlin NR woodland
E-WH-TLB-PM-50	557368.6	6360842.321	NA	Dingerlin NR shrubland
E-WH-TLB-PM-51	556396.252	6360938.012	NA	Dingerlin NR shrubland
E-WH-TLB-PM-52	556503.755	6360507.384	NA	Dingerlin NR shrubland
E-WH-TLB-PM-53	557403.616	6360701.287	NA	Dingerlin NR shrubland
E-WH-TLB-PM-54	556741.781	6361019.118	NA	Dingerlin NR shrubland
E-WH-TLB-PM-55	557120.741	6360494.677	NA	Dingerlin NR shrubland
E-WH-TLB-PM-56	558384.188	6364835.215	NA	Wandoo woodland
E-WH-TLB-PM-57	557896.924	6364258.73	NA	Wandoo woodland
E-WH-TLB-PM-58	558300.767	6365032.479	NA	Wandoo woodland
E-WH-TLB-PM-59	557706.96	6364470.974	NA	Wandoo woodland
E-WH-TLB-PM-60	558032.051	6364607.973	NA	Wandoo woodland
E-WH-TLB-PM-61	557831.47	6363688.907	NA	Wandoo woodland
E-WH-TLB-PM-62	557396.76	6363927.312	NA	Wandoo woodland
E-WH-TLB-PM-63	558368.79	6359526.578	NA	Dulbing NR woodland
E-WH-TLB-PM-64	558622.457	6358882.237	NA	Dulbining NR woodland
E-WH-TLB-PM-65	560363.808	6360840.653	NA	Dulbining NR woodland

Site number	XCOORD	YCOORD	Other site	Biological element
E-WH-TLB-PM-66	559646.05	6360845.398	NA	Dulbining NR woodland
E-WH-TLB-PM-67	558261.6383	6359139.021	NA	Dulbining NR woodland
E-WH-TLB-PM-68	558206.3547	6358852.838	NA	Dulbining NR woodland
E-WH-TLB-PM-69	560771.167	6360813.712	NA	Dulbining NR woodland
E-WH-TLB-PM-70	558907.147	6359835.511	NA	Dulbining NR woodland
E-WH-TLB-PM-71	559227.455	6359977.599	NA	Dulbining NR woodland
E-WH-TLB-PM-72	560710.007	6360075.968	NA	Dulbining NR woodland
E-WH-TLB-PM-73	557819.255	6358819.405	NA	Dulbining NR woodland
E-WH-TLB-PM-74	560460.453	6360548.873	NA	Dulbining NR woodland
E-WH-TLB-PM-75	559764.721	6360550.725	NA	Dulbining NR woodland
E-WH-TLB-PM-76	557423.238	6359121.278	NA	Dulbining NR woodland
E-WH-TLB-PM-77	559000.043	6358844.197	NA	Dulbining NR woodland
E-WH-TLB-PM-78	557969.722	6359615.49	NA	Dulbining NR woodland
E-WH-TLB-PM-79	559325.235	6360227.162	NA	Dulbining NR woodland
E-WH-TLB-PM-80	558782.241	6359409.606	NA	Dulbining NR woodland
E-WH-TLB-PM-81	560295.63	6360196.747	NA	Dulbining NR woodland
E-WH-TLB-PM-82	557923.997	6359223.817	NA	Dulbining NR woodland
E-WH-TLB-PM-83	560326.11	6359623.354	NA	Dulbining NR shrubland
E-WH-TLB-PM-84	557323.676	6359676.625	NA	Dulbining NR shrubland
E-WH-TLB-PM-85	556607.02	6360787.229	NA	Dingerlin NR woodland
E-WH-TLB-PM-86	556310.968	6357281.274	T13s	Toolibin Lake
E-WH-TLB-PM-87	557316.277	6357305.413	T55s	Toolibin Lake
E-WH-TLB-PM-88	556721.752	6357496.214	T43m	Toolibin Lake
E-WH-TLB-PM-89	556378.031	6356745.414	T55m	Toolibin Lake
E-WH-TLB-PM-90	556508.244	6356789.014	T24m	Toolibin Lake
E-WH-TLB-PM-91	557264.465	6357239.195	T52s	Toolibin Lake
E-WH-TLB-PM-92	557286.849	6356746.824	T11m	Toolibin Lake
E-WH-TLB-PM-93	556170.148	6356690.06	T22s	Toolibin Lake
E-WH-TLB-PM-94	557077.316	6358183.742	T20m	Toolibin Lake
E-WH-TLB-PM-95	557192.047	6358295.05	T58m	Toolibin Lake
E-WH-TLB-PM-96	556712.473	6357996.268	T27m	Toolibin Lake
E-WH-TLB-PM-97	556553.205	6356640.197	T06s	Toolibin Lake
E-WH-TLB-PM-98	556214.782	6357302.888	T46s	Toolibin Lake
E-WH-TLB-PM-99	556764.383	6356942.753	T59m	Toolibin Lake
E-WH-TLB-PM-100	556429.596	6356443.566	T01m	Toolibin Lake
E-WH-TLB-PM-101	556582.306	6357800.785	T08m	Toolibin Lake
E-WH-TLB-PM-102	556973.283	6356363.94	T52m	Toolibin Lake
E-WH-TLB-PM-103	557021.272	6356416.878	T31s	Toolibin Lake
E-WH-TLB-PM-104	557341.477	6357940.523	T16m	Toolibin Lake
E-WH-TLB-PM-105	556475.0815	6356365.793	T37m	Toolibin Lake

Process to set up a site

To establish a site go to each GPS location (Table 29) in each biological element at an appropriate time of day (Figure 11). At each GPS location set up the star pickets such that they create a triangle with sides 20m long and the base 15m long. There are four considerations with respect the exact location of the star pickets:

1) One of the star pickets will become the mount for the camera. The picket should be put into the ground with one of the fins pointing to the centre of the opposite baseline of the triangle. Paint the base so that movement can be detected. Make

sure the pickets can be seen in the camera's viewfinder when they are being installed.

2) The V made by the fins on the other side of the star picket should be pointing at the sun at the time period allocated for that site. Each site should be photographed at the same time of the day (± 30 minutes) on each sampling occasion.
3) Determine an area for the photo-monitoring point and identify the location for the camera star picket and then measure out and position the two sighter star pickets.
4) Carefully install star pickets to be as perpendicular to the ground as possible. Attach metal tags to the star pickets and label them with the site number and function. Mark all pickets as appropriate (e.g. paint or reflector tape).

It is also important to minimise obstructions in the photographs and to locate the site on flat ground where possible. The distance between the ground and the camera should be approximately 1m. The camera post should be perpendicular to the ground which should be checked on each sampling occasion.

Photo-point monitoring steps

1) Make sure the camera is still securely attached to the star picket cap (camera must be in landscape orientation).
2) Check condition of the camera star picket (should be in the same position and similarly perpendicular to the ground).
3) Install camera.
4) Check all settings on the camera and tick each one off on the data sheet.
5) Place whiteboard on the sighter star pickets and write site number, time and date on the whiteboard.
6) Compare site with previous site photograph and look for any major changes. If there are changes record them on the data sheet.
7) Take photograph using the timer function on the camera (Figure 12).

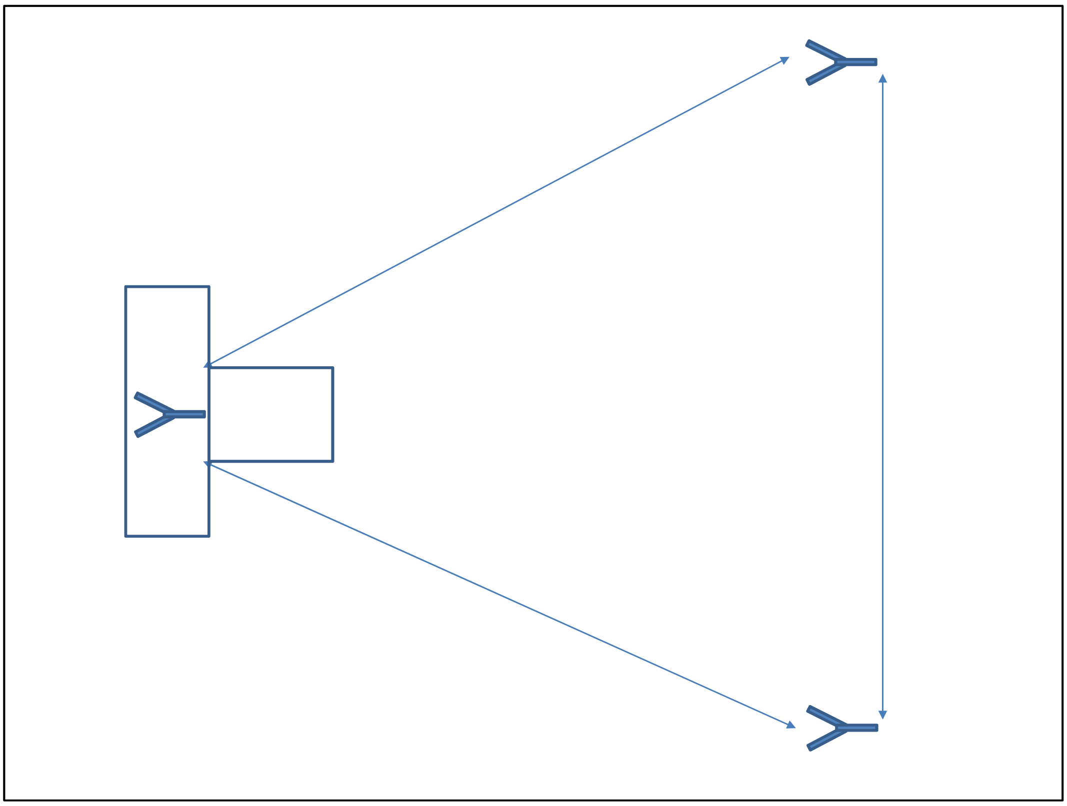


Figure 11: Aerial view of the camera and star picket set up

Note: sun should be to the rear of the camera

Figure 12: Example of a monitoring photograph

Note: A camera and sighter star pickets have been digitally added and several plant species for monitoring have been identified and digitially marked.

Analysis steps

1) Download photographs to the correct folder and label appropriately.
2) For the first photograph for the monitoring site, create a copy (appropriately labelled) and identify and digitally mark plants to be monitored on the copy photograph. In each photograph, individuals from species with deep (>4 mbg), moderate (2 to 4 mbg) and shallow (<2 mbg) root systems should be identified if possible. For example, for the lake and wetland vegetation elements, *M. strobophylla* (deep rooted) and *C. obesa* (intermediate rooted) are broadly distributed and likely to be identifiable in photographs. They would therefore be appropriate species for monitoring. Key indicator natural species with shallower root systems that are amenable to photo-point monitoring, possibly from genera such as *Waitzia* or *Verticordia*, should also be included.
3) Enter the data into the monitoring software. Once species have been identified and their abundances at each site quantified, the limits of acceptable change (LoAC) for the vegetation elements should be monitored and assessed using the software provided.

With randomly located monitoring sites initially surveyed (i.e. reference abundance estimates taken from the initial photographs), monitoring can proceed.

Site selection and frequency of monitoring

Not all sites necessarily need to be included on every monitoring occasion. The number chosen each time should be based on available resources. On any sampling occasion, subsets of the monitoring sites can be randomly chosen from the initial full set. However, a loss of monitoring sites equates to a loss of statistical power.

While monitoring needs to be conducted at the same time of year, it need not be conducted at regular intervals. The sampling interval can be determined based on when resources are available.

Should more funding be secured, a more detailed sampling regimen would follow the same approach using the triangular quadrats, but with comprehensive species composition data collected in quadrats at each photo-point site. As with the photo-point monitoring data, the more detailed approach can be adjusted to suit available resources (e.g. number of monitoring sites sampled during a monitoring event).

Data software and recording process

Excel™ software (file name: Photo-Point-Monitoring-Software-11-04-2016 revised) has been developed[8] to house and analyse the photo-point data and to facilitate setting, viewing and assessing LoAC. Upon opening the file you will see the main page (Figure 13). From this page, enter the number of species you have detected across the photographs, the number of quadrats (or monitoring sites) and measurement date.

[8] Created by Jackson Carr.

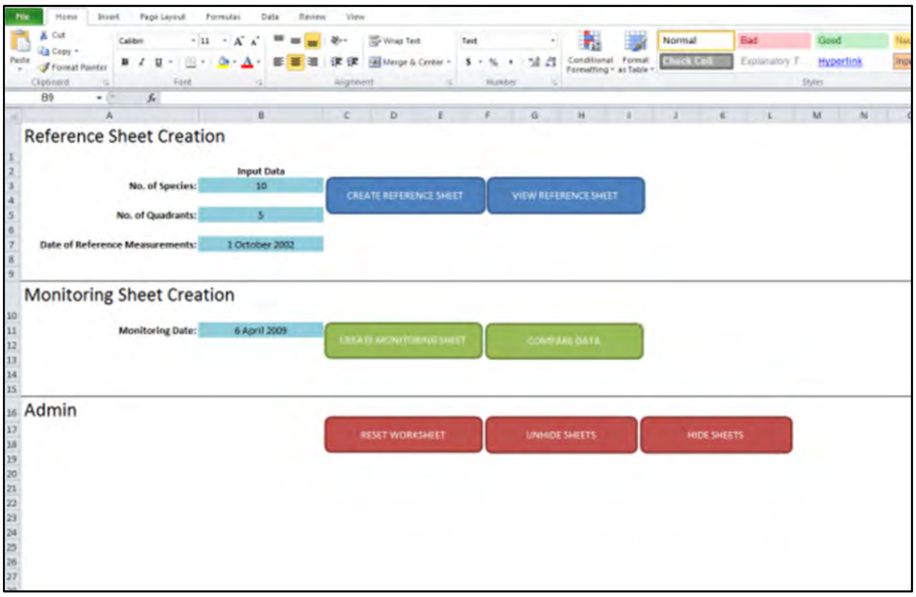
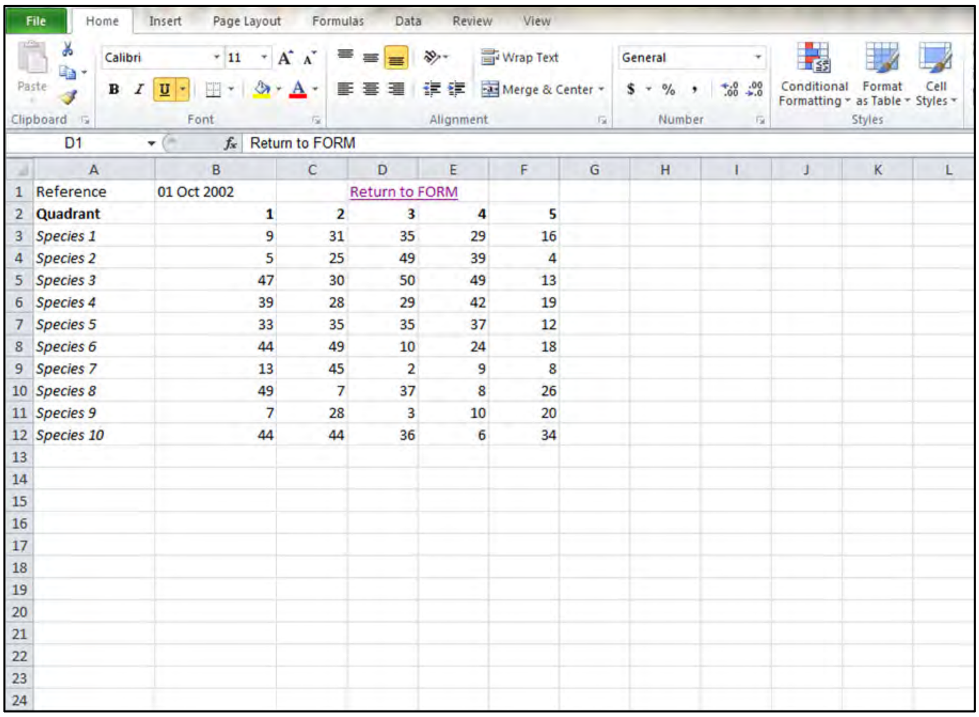


Figure 13: Photo-point monitoring software front page

The software is set up to compare changes in abundance of each species at each photo-point monitoring site relative to an initial or ‘reference’ data set. A separate file should be created for each biological element (i.e. set up a file for each biological element and then rename the file with the biological element name in the file name). To create the reference data set for each biological element, first enter the number of species, the number of quadrants and the date of reference measurements. Then click the ‘CREATE REFERENCE SHEET’ button.

You will be asked if you want to ‘Create a new reference sheet with this data?’, to which you should reply ‘OK’. You are then asked to ‘Please enter data and update the species names for the reference sheet’. Press ‘OK’. This will take you to a sheet with a column for the species and columns for each quadrant (Figure 14).

The sheet also displays a reference date and a ‘Return to FORM’ hyperlink. The species names and reference data are hand entered into the appropriate cells. When this is done, click the ‘Return to FORM’ hyperlink to go back to the main page.



	A	B	C	D	E	F
1	Reference	01 Oct 2002		Return to FORM		
2	**Quadrant**	**1**	**2**	**3**	**4**	**5**
3	*Species 1*	9	31	35	29	16
4	*Species 2*	5	25	49	39	4
5	*Species 3*	47	30	50	49	13
6	*Species 4*	39	28	29	42	19
7	*Species 5*	33	35	35	37	12
8	*Species 6*	44	49	10	24	18
9	*Species 7*	13	45	2	9	8
10	*Species 8*	49	7	37	8	26
11	*Species 9*	7	28	3	10	20
12	*Species 10*	44	44	36	6	34

Figure 14: Reference sheet form

Once you have collected some monitoring data you can enter the information by typing in the 'Monitoring Date' in the appropriate cell and pressing the 'CREATE MONITORING SHEET' button (Figure 13). You will be asked 'Do you want to create a monitoring sheet for the date listed in cell B11?'. Click 'Yes'. You will then be asked to 'Please enter data for this monitoring period'. Click 'OK'. You can now enter the abundance data for each species-quadrant combination by hand. Then press 'Return to FORM'.

You are now ready to compare the new monitoring data with the reference set. Press the 'COMPARE DATA' button. In the 'Difference Limit' cell enter a value (0 to 1) to express a minimum/maximum limit of change (0.25 would be equivalent to a 25% change). Click on cell "B:4" and choose the monitoring data. If necessary scroll up – sometimes the first reference sheet is hidden from view. Press the 'UPDATE' button and the software will automatically generate a set of responses for each species-quadrant combination. The responses are: 'No Change' (species abundances have not changed by more than the Difference Limit), 'Increase' (abundance has increased beyond the Distance Limit), 'Decline' (abundance has decreased beyond the Distance Limit) and 'Lost' (abundance has dropped to zero; e.g. Figure 15).

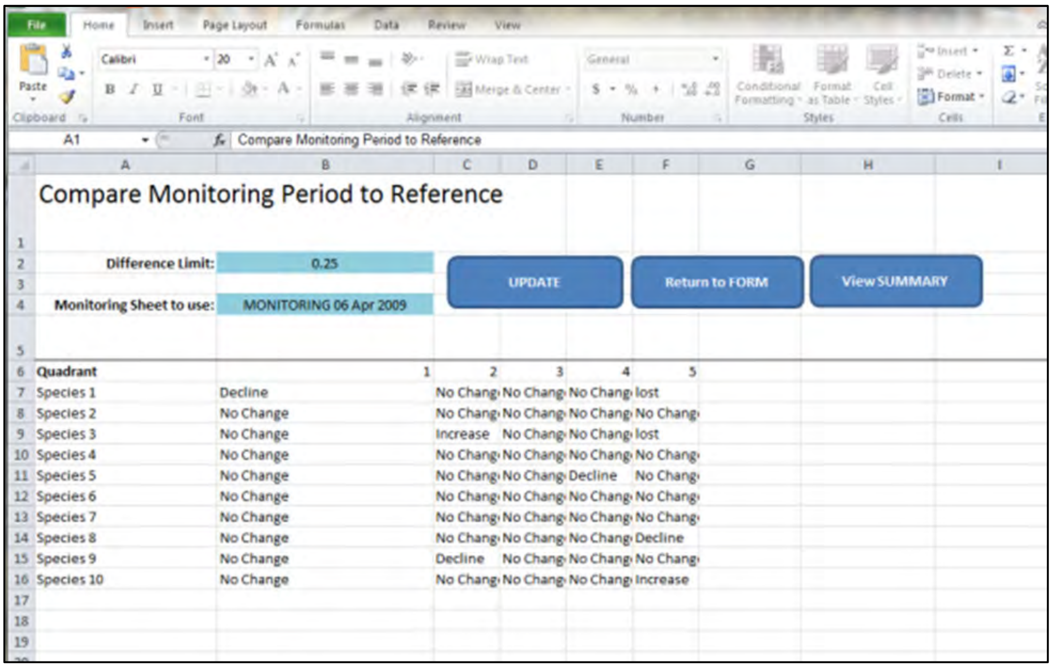
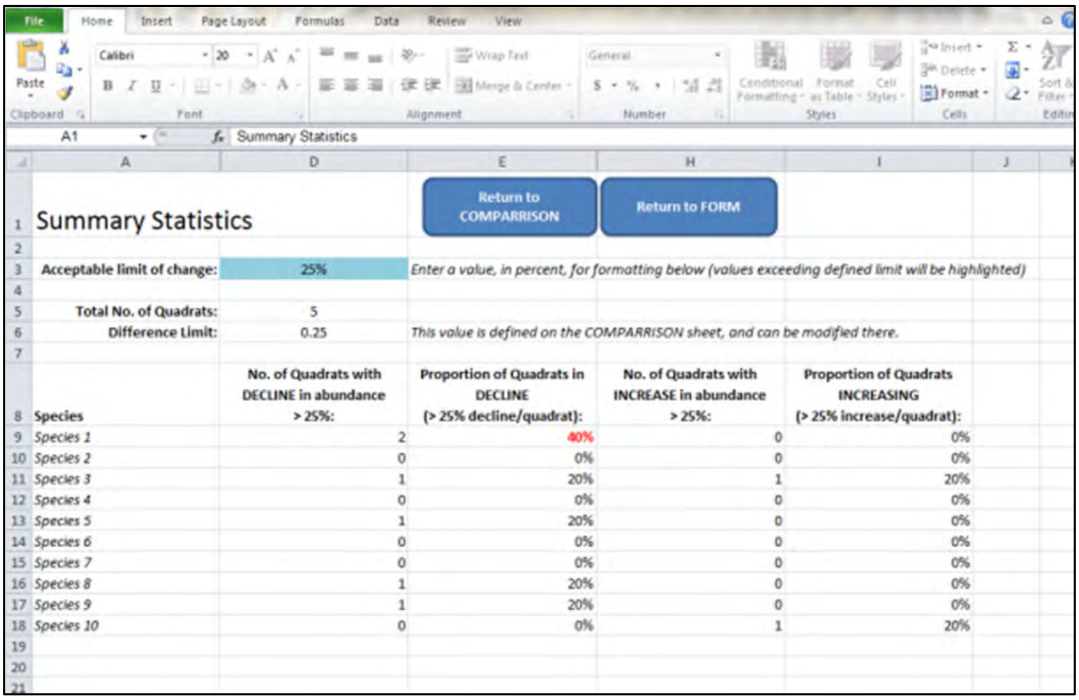


Figure 15: Compare sheet

If you click the 'VIEW SUMMARY' button (Figure 15), you will be presented with a 'Summary Statistic' (Figure 16: Summary statistic page). If you enter an acceptable limit of change (now in % - 0 to 100), species that have declined beyond the 'Difference Limit' and the 'Acceptable limit of change' will be highlighted in red when they exceeded the lower limit and green when they have exceeded the upper limit. If you set the 'Difference Limit' to 0.25, for example, and the 'Acceptable limit of change' to 25, the results would be expressing the number of species that have changed by more than 25% in more than 25% of quadrats.

The software also has a 'RESET FUNCTION' and 'HIDE SHEETS' and 'UNHIDE SHEETS' functions. In general it is best not to unhide and/or modify the calculation sheets.



Summary Statistics

Return to COMPARRISON | Return to FORM

Acceptable limit of change: 25%

Enter a value, in percent, for formatting below (values exceeding defined limit will be highlighted)

Total No. of Quadrats: 5

Difference Limit: 0.25

This value is defined on the COMPARRISON sheet, and can be modified there.

Species	No. of Quadrats with DECLINE in abundance > 25%:	Proportion of Quadrats in DECLINE (> 25% decline/quadrat):	No. of Quadrats with INCREASE in abundance > 25%:	Proportion of Quadrats INCREASING (> 25% increase/quadrat):
Species 1	2	40%	0	0%
Species 2	0	0%	0	0%
Species 3	1	20%	1	20%
Species 4	0	0%	0	0%
Species 5	1	20%	0	0%
Species 6	0	0%	0	0%
Species 7	0	0%	0	0%
Species 8	1	20%	0	0%
Species 9	1	20%	0	0%
Species 10	0	0%	1	20%

Figure 16: Summary statistic page

Data management

Digital images and videos must be archived in an appropriate database with the location information. Any data collected from an image or video must be appropriately referenced to the image, quality controlled and stored. Strict protocols for the collection, interpretation and management of the images and their data need to be developed and followed, to ensure appropriate documentation and archiving.

Digital photographs from photo-points must have appropriate metadata:

- photograph number
- date of capture
- time of capture
- site name
- site location
- camera model
- lens
- focal length
- aperture
- shutter speed
- colour settings
- time of day
- compass direction
- height of camera above ground.

Appendix 19. Monitoring protocol for *Melaleuca strobophylla*

19.1. Background

Melaleuca strobophylla is a key species in the Toolibin Lake vegetation threatened ecological community (TEC). As a deep-rooted species, *M. strobophylla* is highly sensitive to changes in water quality in the lake. The department has produced maps to support the hydrological research that is (and has been) conducted in the lake and to provide general maps of areas of *M. strobophylla* survival, death and regeneration for a range of other purposes.

Three categories of *M. strobophylla* were mapped (refer to Figure 17):

1) dead trees
2) live trees
3) regenerating shrubs.

The final polygon shapefiles ('All_Dead', 'All_Trees' and 'All_Regeneration') should be interpreted as broadly representing crude estimates of increasing plant density (or abundance) with increasing polygon size where the smallest polygons represent individual plants.

19.2. Methodology used to generate distribution maps for Toolibin Lake

Plants were categorised as:

1) **Live trees** (with live leaves and differentiable from regenerating plants by the lack of leaf matter along the lower trunk) which had a trunk and a canopy.
2) **Dead trees** which were identified by a lack of any live leaf material on the plant. Dead individuals were only recorded if they were standing and when the characteristic 'paper bark' was present. Consequently, the mapping of dead trees may be an underestimate – especially of comparatively old deaths if the bark has been removed.
3) **Regenerating shrubs** which were characterised by live leaf matter occurring over the plant with no clear truck or canopy.

Examples are shown in Figure 18 and all individuals could clearly be assigned into one of the three categories. Note: no attempt was made to differentiate the 'health' or stress history of the live plants.

The approach involved walking along 'digital' transects that traversed the wetland floor in an east-west direction and were separated by 20m. Figure 19 provides an explanation of the approach. If a surveyor encountered an individual live, dead or regenerating plant as they walked along the transect, the plant was given a waypoint mark which was recorded onto a data sheet. Stands of plants that required too much time to mark all individuals were treated in one of two ways:

1) Where the stand encompassed several transect lines in a north-south direction (e.g. Figure 19), a start (the beginning of the stand) and a stop (the end of the stand) mark was made and recorded.
2) Where the stand was small (e.g. did not traverse more than one or two transects in a north-south direction), the perimeter of the stand was marked. These areas indicate dead, living and/or regenerating individuals that could not be marked individually.

Thus the data consists of:

1) marked individual plants
2) start-stop marks of stands that ran across several transects
3) mapped stand perimeters.

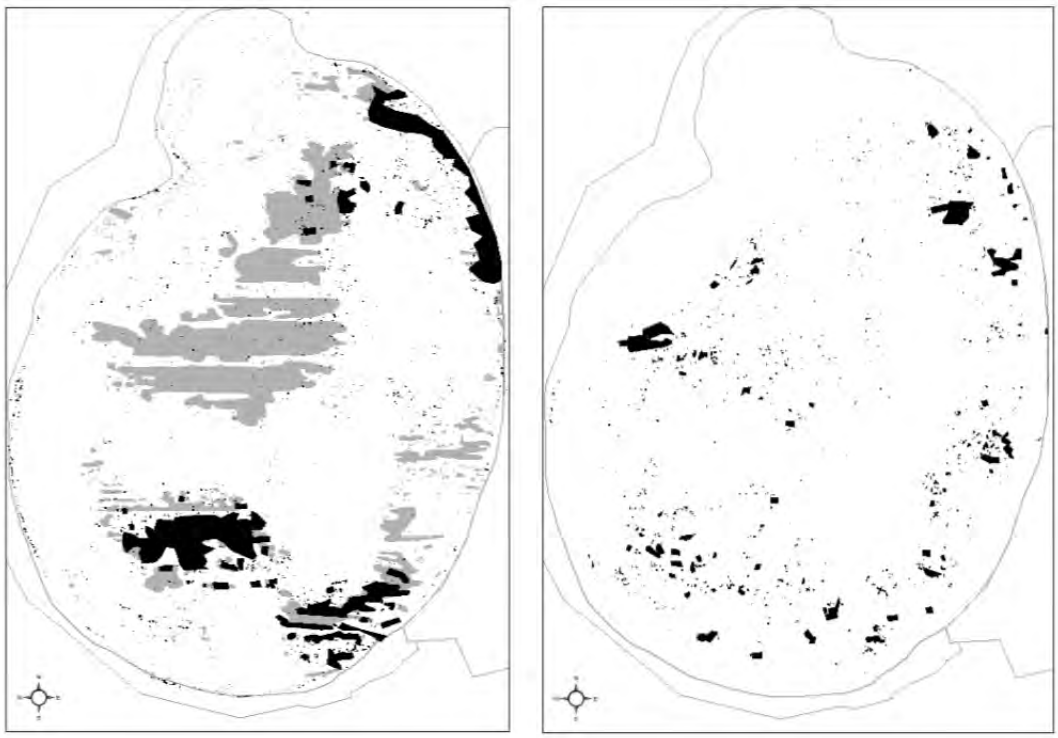


Figure 17: Areas of Toolibin Lake where live (black) and dead (grey) Melaleuca strobophylla *were mapped in 2013 (left map) and areas of Toolibin Lake where regenerating* M. strobophylla *was mapped in 2013 (right).*

Note: Collectively the areas where live and dead trees were mapped (green and yellow areas in left map) represent the former distribution of M. strobophylla. *The lake is approximately 1.8km wide.*

Consequently, the final shapefiles represent broad size-density relationships where the bigger the polygon the greater the density of live, dead or regenerating plants.

In 2013, the transects were mapped by 11 different people (in different combinations) on 5, 10, 18, 19, 24 and 26 September and 1 October 2013. On any given survey day, the individuals walked along a set of adjacent transects at a similar pace, allowing people to communicate with each other as they surveyed. The number of individuals varied from survey day to survey day. Each individual recorded their track, which may be used at a later date to develop a more quantitative map.

The surveyors used four different Garmin GPS models. Accuracy decreased with cloud cover and canopy cover and at times was no greater than about ± 30m. Additionally, the surveyors varied in their experience (and indeed surveyors that worked on multiple days improved in their surveying skills over time).

To create the maps, the start-stop waypoints were turned into lines and polygons were hand digitised around the line ends. Similarly, lines were drawn around the perimeter waypoints which were then turned into polygons. Individual plant waypoints were turned into polygons and all three polygon types were combined into single layers for each plant category.

Note: the maps are hand digitised and have not yet been quality controlled. Users of the maps should be aware of the limitations in terms of accuracy, detectability (of plants) and precision, and understand that the size-density relationships expressed by the polygons are very general.

Figure 18: Different classes of M. strobophylla

Note: Regenerating shrub (top left), dead tree (top right) and dead tree (left side of bottom image), shrub (centre of bottom image) and live tree (indicated by arrow in bottom picture)

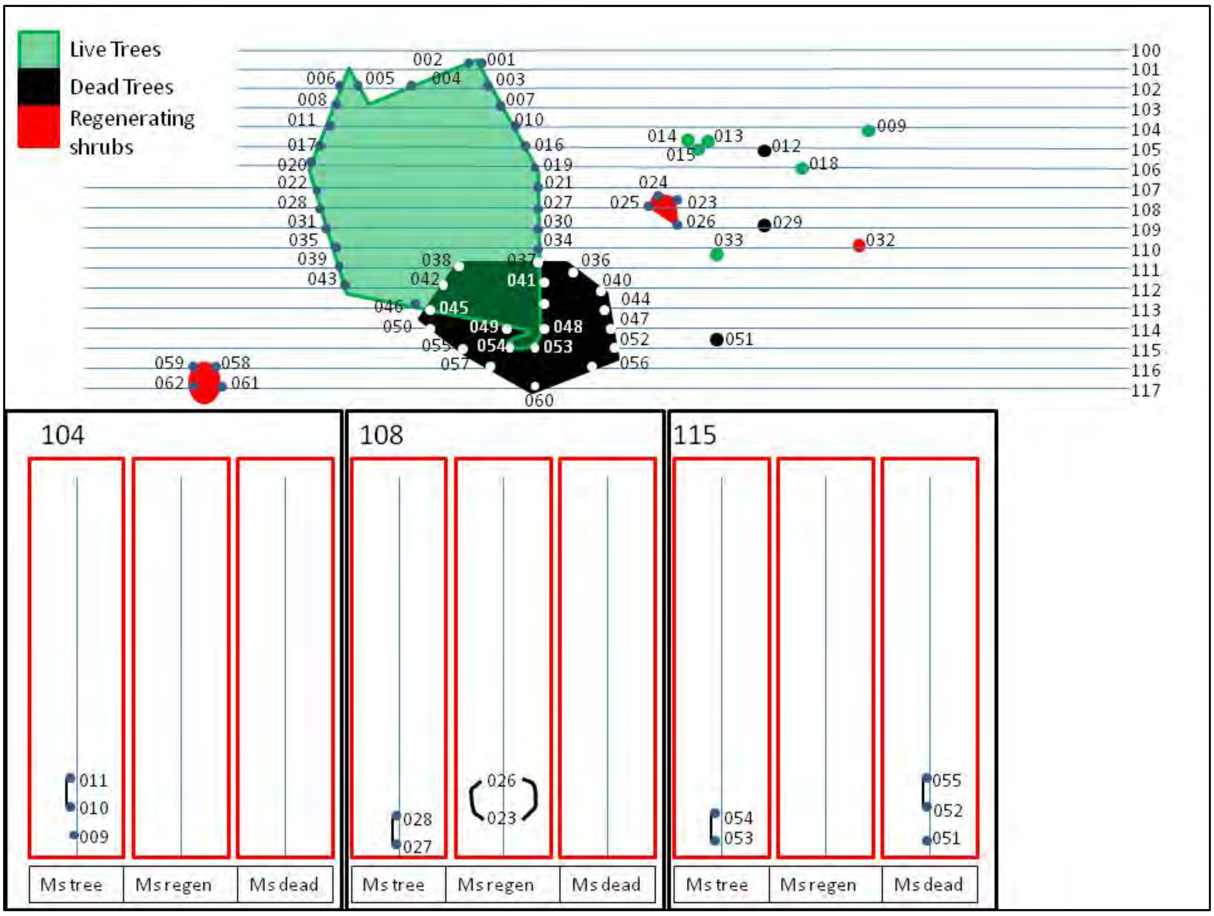


Figure 19: Explanation of the methodological approach to map M. strobophylla

Note: Three example data sheets are shown at the bottom of the figure. Waypoints are made and recorded as shown, and distribution of plants is then mapped by creating polygons around the start-stop waypoints and the perimeter waypoints.

Appendix 20. Plant genera with species known to be affected by *Phytophthora* species

Taken from Dieback Working Group and Threatened Species Network (2008)

Table 30: Plant genera with species known to be affected by Phytophthora *species*

Note: an asterisk denotes that most species in genus are susceptible to* Phytophthora

Proteaceae	Myrtaceae	Epacridaceae	Other
Adenanthos	Agonis	Andersonia*	Allocasuarina
Banksia*	Beaufortia	Astroloma*	Anarthia
Conospermum	Calothamnus	Leucopogon*	Boronia
Dryandra	Calytrix	Lysinema*	Conostylis
Franklandia	Eremaea	Monotoca*	Dampiera
Grevillea	Eucalyptus	Sphenotoma*	Dasypogon
Hakea	Hypocalymma	Styphelia*	Daviesia
Isopogon*	Kunzea		Eutaxia
Lambertia*	Melaleuca		Gastrolobium
Persoonia*	Regelia		Hibbertia*
Petrophile*	Scholtzia		Hovea
Stirlingia*	Thryptomene*		Jacksonia
Synaphea	Verticordia*		Lasiopetalum*
Xylomelum			Latrobea
			Macrozamia
			Oxylobium
			Phlebocarya
			Xanthorrhoea
			Xanthosia

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