Murray–Darling Basin Environmental Knowledge and Research Project

Annual Progress Report: July 2015 – June 2016

Prepared by: The Murray–Darling Freshwater Research Centre

Final Report

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Murray–Darling Basin Environmental Knowledge and Research Project

Annual Progress Report: July 2015 – June 2016

Report prepared for the Department of the Environment and Energy by The Murray–Darling Freshwater Research Centre.

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This report was prepared by The Murray–Darling Freshwater Research Centre (MDFRC). The aim of the MDFRC is to provide the scientific knowledge necessary for the management and sustained utilisation of the Murray–Darling Basin water resources. The MDFRC is a joint venture between La Trobe University and CSIRO. Additional investment is provided through the University of Canberra.

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Summary

Project name	Murray–Darling Basin Environmental Water Knowledge and Research Project
Project outcome (summary)	The Murray–Darling Basin Environmental Water Knowledge and Research (MDB EWKR) Project aims to improve the science available to water managers by better understanding: • the links between ecological responses to flow and medium and long-term changes in condition • the impacts of threats (hydrological, aquatic and terrestrial) which may reduce or prevent the ecological improvement expected through environmental flow regimes.
MDFRC Project Leader	Ben Gawne (02 6024 9647)
MDFRC Project Manager	Jessica Davison (02 6024 9645)
Departmental contact	Nadia Kingham (02 62742606) , Anthony Moore (02 62759795)

Project status information

Executive summary and comment

The 2015–16 financial year began with a briefing on the draft Annual and Multi-year Research Plans to the Jurisdictional Reference Group (JRG) on 22 July. The research plans were developed in April–May 2015 and had already been presented to the Project Steering Committee in June 2015.

In August 2015, the coordinators of the four research themes (Fish, Vegetation, Waterbirds and Food Webs) presented their research plans to the project's Science Advisory Group (SAG). The SAG recommended that further work be undertaken to refine the research questions, to demonstrate how the project could improve predictive capacity and to show how integration would occur between the themes.

The Theme Coordinators worked with their Theme Leadership Groups between September and December 2015 to adapt the research plans in accord with the feedback from the SAG. The updated research plans now included an extended Conceptualisation Phase, which provided the research groups with the opportunity to address the matters raised by the SAG.

The updated research plans were presented to the JRG in February 2016. Between January and June 2016, Theme Coordinators and Theme Leadership Groups worked to address the matters raised by SAG and this conceptualisation work is expected to be completed in September 2016. While the extended Conceptualisation Phase has delayed the research phase of the project, it has helped to better focus the research effort, improve predictive capacity (leading to better decisions by waterway managers) and ensure greater synergy in data collection, analysis and research between and across themes.

Project leadership, management and administration have gone through a significant transition phase in the 2015–16 financial year. From October 2015, MDFRC Pty. Ltd. was incorporated as part of La Trobe University and the project transitioned to management by La Trobe University as the Centre Agent, bringing new contractual, financial, reporting and administrative arrangements into effect.

In October 2015, the MDFRC Director transitioned to being full time as the Project Leader for the MDB EWKR and related LTIM projects, and a new MDFRC Director was appointed and commenced in March 2016. A new full time Project Manager was appointed in April 2016 to replace an interim part-time contract Project Manager and former Project Manager. These changes have resulted in more senior level resources being dedicated to the MDB EWKR project.

During the financial year, six project milestones were delivered in accordance with the Project Head Agreement. These include:

- the Annual Progress Report for 2014–15
- financial information for 2014–15
- the Mid-year Progress Report 2015–16
- the annual work plan and budget for 2016–17 (including a revised Activities Schedule and Risk Management Register)
- the Annual Research Plan 2016–17

- the Multi-year Research Plan 2016–19

The Project Leadership (Project Leader and Project Manager) also ran five regional workshops for waterway managers at the four MDB EWKR research sites. More than 50 waterway managers attended the workshops, which were held in mid-May and early-June 2016. Overall, there was resounding interest in the MDB EWKR project and managers saw value in EWKR's broader approach to improving environmental flows in the Basin.

Exception reporting for the Department to note

Delays in project delivery: The unscheduled extended Conceptualisation Phase has led to delays in planning for the 2016–17 field season (October–November onwards) and commencement of mesocosm studies for the Fish, Food Webs and Vegetation themes. Theme Coordinators have been attempting to minimise delays by working with their Leadership Groups to plan field work in parallel with work on conceptualisation.

Safety: Work Health and Safety (WHS) issues — it is expected that these may have a higher probability of arising as the field work and mesocosm studies commence. Active management and oversight will be needed to ensure that WHS policies and procedures in place with MDFRC and each of the project collaborators are being followed.

Advice/Action required by the Department

For advice/action:

- Nil

Financial summary for the reporting period

These figures are based on a financial statement that was issued by La Trobe University Finance in September 2016. This statement is being reviewed by external auditors.

WBS code	**WBS element**	Budget **2015–16**	**Expenditure 2015–16**
3.1015.01	EWKR	-	$263,819
3.1015.02	Project management, governance	$164,954	$276,907
3.1015.03	Communications	-	$766
3.1015.04	Vegetation Theme	$541,609	$166,572
3.1015.05	Fish Theme	$380,288	$180,759
3.1015.06	Waterbird Theme	$319,005	$163,658
3.1015.07	Food Webs Theme	$467,748	$135,769
3.1015.08	Ecosystem Synthesis Theme	$128,481	$6,834
3.1015.09	Decision support tool	$55,071	$6,752
3.1015.10	Queensland Floodplain Vegetation Water Requirement project	$338,800	$588,800
	Total	***$2,395,956***	**$1,790,636**

1. Introduction

This is the Annual Progress Report for the Murray–Darling Basin (MDB) Environmental Water Knowledge and Research (EWKR) project for the 2015–16 financial year. MDB EWKR is a five year (to 2018–19), $10 million project being undertaken by The Murray–Darling Freshwater Research Centre (MDFRC) in collaboration with scientists from other research centres to improve the science available to support environmental water management, and thereby contribute to achieving Basin Plan objectives.

The MDB EWKR project team collaborates with water managers, environmental asset managers, water planners and relevant community groups to identify research priorities and undertake research targeted at addressing those priorities. The client for the project is the Department of the Environment and Energy (the Department). The purpose of this report is to document project progress, including financial performance (as required by 5.4 of Schedule 2 of the Head Agreement) for the period 1 July 2015 to 30 July 2016.

This report includes:

- details of work undertaken within the reporting period
- status of scheduled activities against the project plan
- explanations of any delays in scheduled tasks
- actions proposed to address any delays
- a statement of the potential impacts of any delays on delivery of project milestones and the overall completion of the project.

This report also incorporates information on project budget/expenditure and includes:

- a statement as to whether the project is proceeding within budget
- an explanation of the budgetary situation
- the actions proposed to address any budget variations
- a statement of the potential impacts of any delays on project budget/expenditure and the overall completion of the project.

2. Progress against scheduled activities

An Activities Schedule was provided to the Department in November 2015 to show when project activities were to take place between November 2015 and December 2016 (refer to Attachment 1). This Schedule was updated in June 2016 in conjunction with the Annual Research Plan (ARP) 2016–17 and the Multi-year Research Plan (MYRP) 2016–19.

The Schedule will be further updated and replaced on completion of the Conceptualisation Phase in September–October 2016 and replaced with a comprehensive MS Project Gantt chart to show project activities for the remainder of the project.

For the purposes of the 2015–16 Annual Progress Report, the November 2015 Schedule is used as the baseline for reporting on commencement and completion of project activities in the 2015–16 financial year. A ‘traffic light’ summary table together with a written explanation on theme progress is provided later in this report; this refers to the November 2015 Schedule as necessary.

In the first four months of the 2015–16 financial year (prior to development of the Schedule), the following took place:

- July 2015 — briefing to the Jurisdictional Reference Group (JRG) on the draft Annual and Multi-year Research Plans.
- August 2015 — draft research plans presented to the Science Advisory Group (SAG), who subsequently recommended that further work be undertaken on the Fish, Vegetation and Food Webs themes to refine the research questions, demonstrate how the project could improve predictive capacity and show how integration would occur between the themes. Minimal further work was required to the draft Waterbirds research plan.
- September to December 2015 — the Fish, Food Webs, Waterbirds and Vegetation Theme Coordinators and their Leadership Groups adapted their research plans in accordance with feedback from the SAG to include an extended Conceptualisation Phase. This process was lengthier than expected due to the time required to establish team roles and responsibilities, agree to research methodologies and deliverables and to develop work schedules. To expedite commencement of research work, themes identified 'no regrets' projects which could be undertaken regardless of the outcomes of the Conceptualisation process. Overall these included literature reviews and data analysis, as well as undertaking a Waterbird pilot field study and metagenomics work for the Food Webs Theme.
- November 2015 to January 2016 — The Waterbirds Theme completed a field pilot study and continued work on the literature review.

The draft research plans outlined the process for the knowledge review and conceptualisation; however, the Christmas break limited activity on implementation of this work. In February 2016, the updated plans were presented to the JRG and feedback included identifying opportunities to collaborate and involve water managers in adopting the research, and considering incorporating further research areas to investigate.

There was then an extended period from February through to April 2016, during which time, subcontracts to engage members of the Leadership Team in the conceptualisation process were prepared, negotiated and sent to collaborating institutions for approval. This process is ongoing as at June 30 2016. The impact of delays in getting contracts finalised and signed varied, with some collaborators willing to commence work while awaiting completion of contracts, and others being unable or reluctant to start without contracts being in place.

The major reasons for the delays in getting contracts in place were:

1) the Christmas and January holiday period when La Trobe University legal and contracts staff were on leave
2) issues around getting MDFRC contracts prepared, approved and signed emerging from the new MDFRC Agreement and transition of Centre Agent from MDFRC Pty. Ltd. To La Trobe University
3) protracted legal negotiations between LTU and multiple (13) collaborating institutions.

From February to June, Theme Coordinators worked with their Leadership Groups in varying capacities on the knowledge review and conceptualisation phase. Theme Coordinators held meetings and workshops with their groups to progress this work and to reflect this in the updated Annual Research Plans and Multi-year Research Plans. In May 2016, revised versions of the document were submitted to the Department for feedback, before being finalised and submitted to the Department in June 2016.

A narrative describing the work undertaken in the reporting period under each activity is given below, as is the status of activities against the work plan timeline.

Throughout the report, a traffic light system is used to indicate progress in terms of adhering to the proposed approaches and delivery dates (Table 1). Tasks considered to be amber or red are further examined in the Risks and Issues section in Table 3.

Table 1. Definition of progress traffic light categories.

Progress	Definition
	Underway. On track for completion by planned date.
	Underway but some difficulties. May be completed slightly after the planned date, or scope or approach modified. Unlikely to impact project delivery.
	Underway but major difficulties. Unlikely to be completed by planned date. Likely to impact project delivery.
	Yet to proceed. Awaiting completion of foundation tasks and milestones.

Table 2. Milestone and payment schedule status.

Milestone	Deliverable	Description	Due date	Payment (GST exclusive)	Status	Comments
Financial year 2015–16						
1	Annual Progress Report for 2014–15	The Recipient must submit an Annual Progress Report for the 2014–15 period in accordance with clause 5.4 of Schedule 2 of the Head Agreement	Within 40 business days after the end of the 2014–15 financial year.	$600,000	Completed	First draft submitted Jan 2016. Final Feb 2016.
2	Financial information for 2014–15	The Recipient must submit financial information in accordance with clause 5.5 of Schedule 2 of the Head Agreement.	Within 60 business days after the end of the 2014–15 financial year.	n/a	Completed	Provided Feb 2016
3	Mid-year Progress Report	The Recipient must submit a detailed Mid-year Progress Report in accordance with clause 5.3 of the Head Agreement.	Within 40 business days after the end of the 2015 calendar year	$600,000	Completed	First draft submitted April 2016. Final May 2016.
4	Annual Report and budget for 2015–16	The Recipient must submit a detailed project work plan for 2016–17. The work plan will be substantially in the form of the template provided by the Department, as updated from time to time.	May–June 2016	$150,000	Completed	Submitted and accepted June 2016
5	Annual Research Plan for 2016-17	The Recipient must submit an Annual Research Plan for 2016–17 that includes a section for each research site. The Annual Research Plan must be developed in accordance with the Phase 2 requirements provided by the Department as updated from time to time.	May–June 2016	$150,000	Completed	Submitted and accepted June 2016

Milestone	Deliverable	Description	Due date	Payment (GST exclusive)	Status	Comments
6	Multi-year Research Plan	The Recipient must annually review the Multi-year Research Plan and update or amend the plan (if required) in consultation with the Department. The Multi-year Research Plan must be amended in accordance with the Phase 2 Requirements provided by the Department as updated from time to time.	May-June 2016	$150,000	Completed	Submitted and accepted June 2016

Performance against project indicators for the period 1 July 2015 – 30 June 2016

Table 3. Table of performance against project indicators for the period 1 July 2015 – 30 June 2016.

Project indicators	Comment	Health status indicator
Overall rating	Phase 1 has now been completed. Towards the end of Phase 1, feedback from a SAG workshop (August 2015) resulted in additional planning via review and conceptualisation for the Fish, Food Webs and Vegetation themes and to a lesser extent, for the Waterbirds Theme. This work will be concluded in September 2016. It has been agreed that an addendum to the Annual Research Plan and Multi-year Research Plan will be provided to the Department in September–early October (2016) to detail changes to the research questions, to show measures to integrate across themes and actions to be taken to improve predictive capacity. It is expected that the research work will remain aligned with overall project objectives. Concurrent work has commended where possible on Phase 2, including designing field work and mesocosm studies and conducting pilot studies. The process of engagement (including with the SAG (August 2015), JRG (February 2016) and the Department) was lengthier and more time consuming for the project team and researchers than envisaged by the Head Agreement. There have also been delays that were both unexpected and beyond the control of the project team/Theme Coordinators associated with getting contracts with collaborators in place due to the transition of MDFRC Pty. Ltd. to La Trobe University. On balance however, these delays should not have a material impact on the success or scheduling of the overall project.	Is the MDB EWKR project delivering outcomes directly associated with the project scope as defined in the Funding Agreement?  Yes
Budget	The 2015–16 budget is under expended by approximately 25% reflecting the delays due to the unscheduled extension to the Conceptualisation Phase. Payments have been made to the Queensland Floodplain Vegetation Water Requirement project as contracted outputs have been delivered, with only one further payment to be made. A revised high level project budget will be prepared for 2016–19 and provided to the Department at the end of September 2016 following the completion of the Conceptualisation Phase.	Is the MDB EWKR project forecast cost of completion tracking to budget?  A revised budget will address delays to date and make adjustments to ensure the project is completed on time and within budget.
Schedule	The overall project is currently running behind the original project schedule. A number of factors have contributed to these delays including: an unscheduled Conceptualisation Phase to respond to the SAG's feedback, the transition from MDFRC to La Trobe University's contracting, finance and reporting systems and changes in Project Leadership arrangements and resourcing.	Is the MDB EWKR project forecast date of completion tracking to the baseline schedule?  Underway but some difficulties. May be completed slightly after the planned date, or scope

Project indicators	Comment	Health status indicator
	The MDFRC Project Leadership Team has developed strategies to minimise the material impact on the timeframe and outcomes of the project including: - structuring and documenting the work flow to maximise efficiencies and synergies between different components of the project. For example, using work generated during the Conceptualisation Phase to feed into SAG and JRG and Adoption (water manager) workshops, inform the project budget and updating of the Annual Research Plan and to provide content for the ASL conference in September - structuring the Conceptualisation Phase process in a way that enables data collection (including field work) to commence in Spring 2016 - developing efficient processes for preparation of research plans and other outputs by providing easy-to-use templates, long lead-in times for Theme Coordinators to start work on research plans and quick feedback from the Project Leadership - dedicating time during fortnightly theme coordinator meetings to identify potential time saving synergies between theme work, identifying opportunities to share research, data and insights and to integrate research and field work - coordinating and streamlining project management tasks including streamlining the preparation (and payment) of sub-contracts for project partners - streamlining project reporting by using monthly project reports prepared by Theme Coordinators and the Project Leadership to brief the Department, the MDFRC Executive and Board and for inclusion in Mid-year and Annual Progress Reports. Phase 2 Milestones 1 to 6 for the 2015–16 financial year have been completed on schedule and accepted. The budget/timeframe impacts of the additional unscheduled Conceptualisation Phase will be assessed as part of evaluation of the Planning Phase (i.e. Phase 1 and Conceptualisation) of the project commencing in September 2016.	or approach modified. Unlikely to impact project delivery.

Project indicators	Comment	Health status indicator
Scope	The project is currently on track to deliver its objectives and the scope of activities as set out in the amended funding agreement.	Is the MDB EWKR project delivering outcomes directly associated with the project scope as defined in the Funding Agreement?  Yes
Risks and issues	A comprehensive review of the Risk Schedule was undertaken as a part of the update of the Phase Two Project Plan in June 2016. The MDB EWKR Risk Schedule is reviewed fortnightly and any new risks identified are added to the Schedule. The Schedule has identified a number of Moderate and two Major risks. The Schedule details actions that are being employed to actively manage these risks. The Major risks identified are as follows: Delays in project delivery: The unscheduled Conceptualisation Phase has led to delays with planning the 2016–17 field season and commencement of mesocosm studies. This is being actively managed with the Theme Coordinators and support is being provided where possible. Safety: Work Health and Safety issues — it is expected that these may have a higher probability of arising as the field work and mesocosm studies commence. Active management and oversight will be needed to ensure that WHS policies and procedures in place with MDFRC and each of the project collaborators are being followed.	Are there any risks that may impact our ability to achieve committed outcomes?  Requires active management. Unlikely to impact project delivery. (Note, the MDB EWKR Project Risk Schedule uses different assessment criteria to assess risk. It does not identify these two risks as likely to lead to major impacts on the project — hence, an orange circle is used here).
Major activities identified for the first half of 2016–17	July–September - Providing a MDB EWKR team response to comments provided by the SAG at the August 2016 SAG workshop - Updating the MDB EWKR Webpage and Collaboration Space - Finalising the Communications and Adoption Strategy - Submitting the Annual Research Plan and Multi-year Research Plan (2016–17) to the Department for approval following the SAG workshop in August 2016 and on completion of the project Conceptualisation Phase - Submitting the revised high level project budget for approval by the Department in September 2016 - Submitting the Annual Financial Information and financial audit in accordance with Milestone 2 in September 2016 August–October - Finalising detailed theme project budgets for internal budgeting purposes August–December	

Project indicators	Comment	Health status indicator
	- Preparing contracts for researchers for the Phase Two field and mesocosm studies, data analysis and reporting September–March - Implementation of the Phase 1 and Conceptualisation Evaluation Ongoing - Updating the MDB EWKR webpage and Collaboration Space (reviewing and updating the Activities Schedule, Risk Schedule and Traffic light reporter) - Conducting regular meetings with the Department, MDFRC Centre director and Theme Coordinators. - Providing monthly updates on project progress to the Department and MDFRC Executive and Board.	

Work plan deliverables

1.1 Theme 1 — Vegetation

Table 4. Tasks and progress for 2015–16.

Component	Activity	Scheduled start	Scheduled end	Responsible agencies	Status against timeline	Comments
V1a. Knowledge review and conceptualisation	V1.1 Knowledge review and conceptualisation.	Dec 2015	End Feb 2016	Leadership Group		Delayed due to subcontract preparation. Expected Oct 2016.
	V1.1.1 Drafting	Dec 2015	Mid-Jan 2016	Leadership Group		Delayed due to subcontract preparation. Expected Oct 2016.
	V1.1.2 Review and approval	Mid-Jan 2016	End Feb 2016	Leadership Group		Delayed due to subcontract preparation. Expected Oct 2016.
V1.2 Analysis of existing data	V1.2.1 Scoping preliminary planning, scoping data sources	Nov 2015	Nov 2015	Leadership Group	Completed	
	V1.2.2 Data collation	Dec 2015	Mid-Apr 2016	Leadership Group		Underway, data-share agreement in place.
	V1.2.3 Data analysis	Mid-Mar 2016	Mid-Jul 2016	Leadership Group, led by Cassie James		Underway, trialling a subset of data while data collation still occurs.
V2. Field site assessments	V2.1Field work planning	Mid-March 2016	Mid-Jul 2016 Aug 2016	Leadership Group		On track

Component	Activity	Scheduled start	Scheduled end	Responsible agencies	Status against timeline	Comments
	V2.1.1 Questions and preliminary experimental design	Mid-March 2016	Mid-Jul 2016	Leadership Group		
	V2.1.2 Site selection	May 2016	Mid-Jun 2016	Leadership Group		
	V2.1.3 Final experimental design	Jun 2016	Mid-Jul 2016	Leadership Group		
V3. Mesocosm studies	V3.1 Mesocosm planning and pilot study	Nov 2015	Mid-May 2016	Leadership Group, led by MDFRC		On track
	V3.1.1 Literature review	Nov 2015	Mid-Dec 2015	Leadership Group, led by MDFRC		
	V3.1.2 Pilot experimental design	Jan 2016	Feb 2016	Leadership Group, led by MDFRC		
	V3.1.3 Pilot Study	Mid-Feb 2016	Mid-Apr 2016	Leadership Group, led by MDFRC		
	V3.1.4 Review and reporting	Mid-Apr 2016	Mid-May 2016	Leadership Group, led by MDFRC		
V4. Theme coordination, leadership and reporting	Theme coordination	Jul 2015	Jun 2016	MDFRC	Completed	June 2016
	2015–16 reporting ARP, MYRP, progress reports, SAG/JRG/regional	Jul 2015	Jun 2016	Leadership Group, led by MDFRC	Completed	June 2016

Section 2 of this report 'Progress against scheduled activities' reports on the overall progress by each theme in meeting project-wide obligations, such as knowledge review and conceptualisation, revising research plans and undertaking field work. Exceptions to this reporting for the Vegetation Theme are detailed below and summarised in Table 4. A summary of theme planning, activities and expected outputs for the reporting period is provided in the following section.

V1.1 — The knowledge and conceptualisation process has been delayed as outlined in Section 2 of this report.

V1.2 — Analysis of existing data
The revision of the MYRP and ARP as well as delays in subcontracting members of the Leadership Team have delayed this component of work, but because the risks of starting work have been perceived as low, work has continued while these processes have been underway.

V2.1 — Field work planning
This component of work has been affected by the delays in the knowledge review and conceptualisation process. Work commenced in April, and has continued in parallel with the knowledge review, conceptualisation and review of the MYRP and ARP, but at a low level. Criteria for the selection of survey sites were developed and work commenced on the experimental design. As a consequence, these activities were not on schedule to be completed by mid-July 2016.

V3. — Mesocosm studies
This component of work has been affected by the delays in the knowledge review and conceptualisation process. Work commenced in April, and has continued in parallel with the knowledge review, conceptualisation and review of the MYRP and ARP. Active work on the design of the experiment was underway in May and continued through June as various technical challenges were recognised and addressed. As at June 30, 2016, the draft literature review was complete and circulated to the Leadership Group for comment; however, the experimental design for the pilot had not been completed and this meant that subsequent activities were also delayed.

Summary of theme activities for the reporting period

Knowledge review and conceptualisation

At the Vegetation Theme workshop in Melbourne, 19–20 May 2016, the Leadership Group agreed on the direction of the conceptualisation and on the structure of the models and tables that underpin the conceptualisation (Figure 1). The focus will be on providing a framework to define the variety of vegetation responses possible, across different functional traits, levels of ecological organisation and different spatial and temporal scales. The Leadership Group will also focus on different types of functions (e.g. habitat, regulating, process and information) provided by a variety of vegetation responses. The flow component of the conceptualisation recognises the nested nature of the influence of flow and climatic cycles on vegetation responses, from responses to individual events, through to the influence of short-term flow regimes (annual to decadal) and long-term flow regimes (decades to centuries). The overarching management focus of the conceptualisation is to provide information and frameworks to assist the design of watering events for targeted vegetation responses. For further details, refer to the presentation for the SAG workshop, 3 August 2016.

A draft paper outline has been developed and is being led by Sam Capon. The Leadership Group are continuing to progress this and expect to have a draft scientific paper completed by December 2016.

Following feedback from the presentation of our conceptualisation to the SAG (3 August 2016), the Leadership Group will also focus on creating a better link between the conceptualisation and the research components within MDB EWKR.

Figure 1. Development of conceptual models at the Vegetation Theme workshop, Melbourne, 19–20 May 2016.

Data integration and synthesis

The Vegetation Theme conducted a workshop exploring large-scale vegetation data analysis (4–5 November 2015, Canberra). The workshop was about connecting vegetation ecologists, water managers, statisticians and modellers with a broad range of experiences and knowledge, as well as about discussing the potential for analysing large, combined datasets. An overview of the EWKR project was presented and provided context for why the Vegetation Theme is seeking data from collaborators. A series of thought-provoking presentations were given that led into group conversations. These conversations and break-out sessions resulted in robust discussions around priority questions from both science and management perspectives, potential datasets, challenges associated with accessing and managing datasets, as well as potential analysis approaches.
There was agreement that combining and utilising existing datasets is a potentially powerful way of testing hypotheses or looking for patterns on large spatial (and possibly temporal) scales. It is also recognition of the value of datasets and the extensive work undertaken by large numbers of people from a range of organisations and locations. This is the start of the journey! It was a deliberate decision to engage collaborators early and this workshop was just the beginning of the process. The workshop highlighted the importance of having a strong theoretical basis underpinning our analysis and the need to refine data analysis questions.

Approximately 30 people from a range of agencies, universities and organisations were involved in the workshop. Ten presentations were given, and six of these were from participants outside of the Vegetation Theme Leadership Group. Prior to the workshop, information about potential datasets was collated. This involved communication with a large number of external stakeholders. This meta-data (indicating potentially available datasets) was collated from:

- 41 contributors
- 240 individual datasets (53 related to trees, 187 related to understorey)
- a range of geographic regions (mid-lower Murray (Barmah downstream to Chowilla), Lower Lakes, tributaries of the Murray (e.g. Goulburn, Broken, Campaspe), Darling Anabranch, Lower Murrumbidgee, Macquarie Marshes, Northern Basin (e.g. Balonne, Gwydir, Narran, Paroo))
- predominantly from grey literature (only nine datasets in peer-reviewed publications).

Detailed notes and outcomes were circulated from the November workshop including:

- a workshop summary
- guiding principles
- workshop notes
- additional recruitment notes
- the workshop participation list
- the metadata spreadsheet
- PDF copies of the nine presentations given, which related to:
    - the data workshop and EWKR overview (Cherie Campbell)
    - Australian vegetation ecology of wetlands, rivers and floodplains: output (Dr Jane Roberts)
    - analysing large datasets (Dr Cassie James)
    - the metadata summary (Dr Daryl Nielsen)
    - a rehash of Day 1 (Cherie Campbell)
    - the Queensland Floodplain Vegetation project (Dr Bill Senior)
    - applications of stand condition assessments (Dr Shaun Cunningham)
    - a NSW perspective: research opportunities under EWKR (Drs Patrick Driver, Sharon Bowen and Simon Williams)
    - gaining predictive capacity: terrestrial vegetation in river channels (Dr Angus Webb).

A data-share agreement has been prepared and approved by La Trobe legal and is able to be used to enter into agreements with data providers. Conversations have commenced around obtaining data from external providers and a subset of data has been provided to Dr Cassie James to commence preliminary analyses and trial approaches.

Field site assessments

At the Vegetation Theme workshop in Melbourne, 19–20 May 2016, the Leadership Group refined the research questions and methodology for the field site assessments (refer to Annual and Multi-year Research Plans).

The desktop process for the selection of field sites was also confirmed at this workshop and this process has commenced. Relevant data has been sourced, collated and analysed to define monitoring strata for desktop-based site selection, including: state-based or site-based vegetation layers, RIM-FIM layers, and $ML.day^{-1}$ hydrology time series data from relevant locks. Using this information, combinations of the following strata have been defined and mapped as applicable to individual sites:

- vegetation structure: non-woody wetlands, inland shrublands, inland woodlands
- flood return frequency: <1.5 years (near annual), 1.5–3 years, 3–5 years and 5–10 years.

Potential field sites (25 per stratum have been randomly selected within each strata (see Figure 2 as an example). To date this desktop mapping and random selection of sites has been completed for both the Lower Murray and Mid-Murray sites. A smaller selection of sites for monitoring (five per stratum will be finalised against agreed criteria (refer to Annual and Multi-year Research Plans) and in consultation with relevant site managers. A meeting was held with staff from the Mallee Catchment Management Authority (5 August 2016) to refine site selection with site managers for the Lower Murray site. Consultation will also occur with NSW and South Australian representatives as well as relevant staff at the other MDB EWKR field sites. Documentation of site selection, field methods and consistent data sheets is underway.

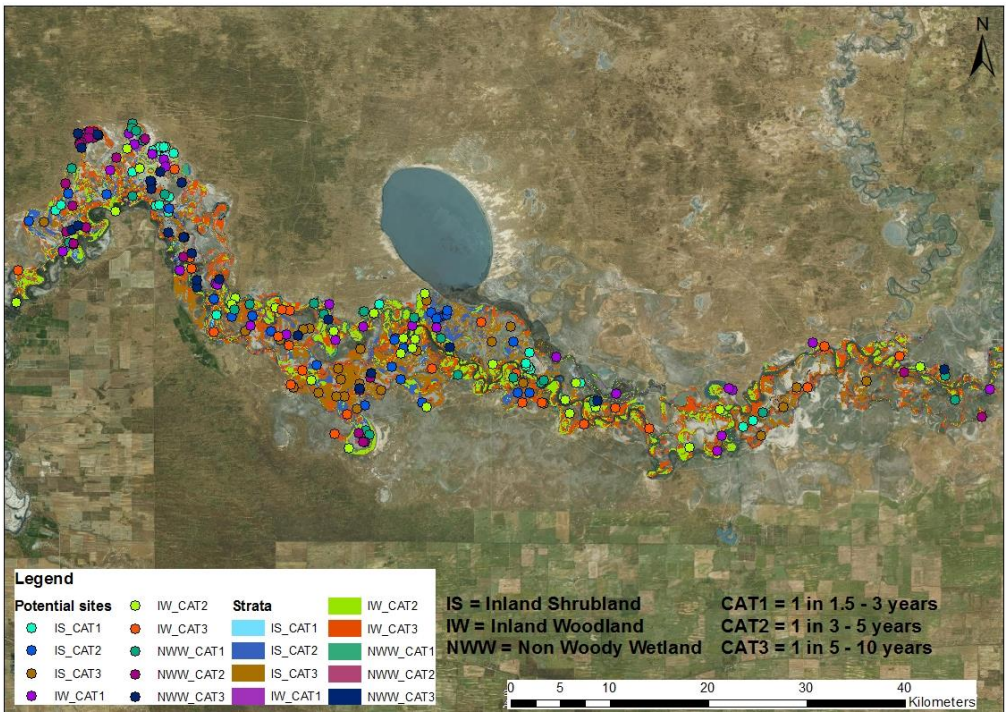

Figure 2. Randomly selected potential field sites stratified by vegetation structure and flood return frequency for the Lower Murray location.

Mesocosm studies

At the Vegetation Theme workshop in Melbourne, 19–20 May 2016, the Leadership Group refined the research questions and methodology for the seedling mesocosm experiment. Conversations around this component have continued via email and teleconference (4 August 2016) and documentation of the finalised methodology is being refined to reflected these conversations. The mesocosm experiments will apply to all four key long-lived woody species, River Red Gum (*Eucalyptus camaldulensis* Dehnh.), Black Box (*Eucalyptus largiflorens* F.Muell.), Coolibah (*Eucalyptus coolabah* Blakely) and Lignum (*Duma florulenta* Meisn.). The experiments will focus on the response of seedlings to sequential flow combinations as well as the influence of seedling condition on response. Technical planning for the experiments is well underway (e.g. equipment/seedlings have been costed, nursery's etc. have been contacted, and the use of equipment has been trialled). It is anticipated that the methodology document will be finalised by the end of August 2016.

Theme coordination, leadership and reporting

This component includes theme research planning, coordination and reporting, including contributions to Annual and Multi-year Research Plans, Mid-year and Annual Progress Reports, within-theme and between-theme communication, SAG, JRG and the Department communication, and external communication. There has been significant investment in this component. A list of activities that have occurred between 1 July 2015 and 30 June 2016 are given below.

- Theme Coordinators Workshop 23 July 2015, Wodonga
- Development of draft research plans and associated budgets (Annual and Multi-year), August 2015
- Science Advisory Group Workshop 27 August 2015, Sydney, presentation of proposed theme research
- Theme Coordinators Meeting 2 September 2015
- Vegetation Theme Data Integration and Synthesis workshop 4–5 November 2015, Canberra

- Revision of draft research plans and associated budgets (Annual and Multi-year), December 2015
- Research teams contracted
- EWKR/the Department Theme Coordinators, JRG and SAG Workshop 10–11 February 2016, Canberra
- Ad hoc discussion of EWKR and potential links to The Living Murray (TLM) project at the TLM Icon Site Managers Forum, 4–5 May, Mildura (cross-project collaboration)
- Queensland Floodplain Vegetation Project Steering Committee Meeting, 16 May 2016, Brisbane
- Lower Murray Regional Workshop, 17 May 2016, Buronga
- Vegetation Theme Workshop 19–20 May 2016, Melbourne
- Ad hoc updates of EWKR to the NSW Murray Lower Darling Environmental Water Advisory Group, 25–26 May, Deniliquin (as well as updates at earlier meetings)
- Commonwealth Environmental Water Office (CEWO) Black Box Working Group teleconference, 31 May 2016 (cross-project collaboration)
- Attendance and input at the NSW Office of Environment and Heritage (OEH) Murray Lower Darling Long Term Watering Plan workshop, 1–2 June 2016, Albury (highly relevant to the adoption of EWKR outcomes)
- CEWO Black Box Working Group Workshop, 24 June 2016, Mildura (cross-project collaboration)
- Theme Coordinator and Integration teleconference meetings weekly or fortnightly
- Revision of Annual and Multi-year Research Plans and associated budgets
- Other meetings, teleconferences, email discussions and stakeholder engagement
- Progress reporting

Figure 3. Vegetation Theme Leadership Group at our annual workshop, May 2016, Cherie Campbell, Daryl Nielsen, Rachael Thomas, Sam Capon, Jason Nicol, Kay Morris, Cassie James.

Integration across themes

A number of activities have occurred to progress and improve integration between the themes, including fortnightly teleconferences with theme coordinators, fieldwork planning in consultation with other themes and workshops. Specific plans for links in terms of field data collection and analysis have now been formed between the Waterbird and Vegetation Theme and will continue in terms of finalising site selection and shared data sheets. The Food Webs Theme is investigating the leachate quality from different vegetation and this will conceptually link to the Vegetation Theme in terms of maintaining distributions of different vegetation types in the landscape. Links between the Vegetation Theme and the Fish Theme will be more theoretical and will be explored through

conceptual models and articulation of the functions various aspects of vegetation play in the landscape.

Stakeholder engagement (table and text describing highlights/achievements)

There has been stakeholder consultation at various stages throughout the MDB EWKR planning process. Some of this consultation has occurred at the whole-of-project scale and other communication has been more specific to themes. Consultation and communication has occurred through both formal channels (e.g. structured workshops, targeted phone calls) as well as ad hoc/opportunistic communication around other projects and/or attendance at non-MDB EWKR related workshops. Where possible, a record of this communication has been kept (Table 5. Stakeholder communication and consultation.).

Table 5. Stakeholder communication and consultation.

Date	Type of communication	Person(s)	Organisation(s)	Notes
23–24 April 2015	Workshop Initial MDB EWKR leadership team workshop, Albury	The Department, Theme Leadership members, MDFRC Project Management	Multiple organisations (see attendance list)	Initial workshop with all Theme Leadership Groups to initiate the research planning component of EWKR
21–22 May 2015	Presentation (Cherie Campbell) 2015 Environmental Watering Forum, Wentworth	Multiple people (see attendance list)	Multiple organisations (see attendance list)	Presentation and panel discussion at the 2015 Environmental Watering Forum. Brief mention of EWKR (and LTIM) as an example of a large-scale basin-wide program in Australia.
16–17 June 2015	Workshop Annual (2014–15) Vegetation Theme research workshop, Sydney	Vegetation Leadership Group	Multiple organisations (see leadership list)	Research planning
27 Aug 2015	Presentation (Cherie Campbell) Science Advisory Group Workshop, Sydney	The Department, SAG, Theme Coordinators, MDFRC Project Management	Multiple organisations (see attendance list)	Presentation of Vegetation Theme research direction to the SAG
16 Sept 2015	Presentation (Cherie Campbell) International Symposium on Aquatic Plants (ISAP) 2015, Edinburgh	Multiple people (see attendance list)	Multiple organisations (see attendance list)	Presentation at the ISAP conference. Brief mention of EWKR (and LTIM) as an example of a large-scale basin-wide program in Australia.
Mid–late Sept 2015 (and earlier preparation)	Presentation, conversations, planning emails (Cherie Campbell)	Multiple people (see Fellowship information)	Multiple organisations (see Fellowship information)	Presentation at the University of Duisburg-Essen and conversations with people there and at the ISAP conference
October 2015	Emails/phone calls Undertaken by multiple people: • All Leadership Group members • Christine Reid	Multiple people (see meta-data table and associated emails)	Multiple organisations (see meta-data table and associated emails)	Vegetation Theme Leadership Group members and Christine Reid contacted various people in relation to obtaining data. There's not a collated record of who was contacted; however, this can be inferred from whose data ended up in the meta-data table for the data workshop (4–5 November). Most people who attended the data workshop were contacted.
4–5 Nov 2015	Workshop EWKR Data component workshop, Canberra	Multiple people (see workshop attendance list)	Multiple organisations (see workshop attendance list)	See email and circulated outputs (summary, notes, metadata information, copy of presentations)
10–11 Feb 2016	Presentation JRG Workshop Canberra	Multiple people (see attendance list)	Multiple organisations (see attendance list)	See notes/feedback captured in EWKR project management

Date	Type of communication	Person(s)	Organisation(s)	Notes
4–5 May 2016	Ad hoc workshop discussion TLM Icon Site Managers Forum (Mildura/Hattah) (Darren Baldwin, Cherie Campbell — following Darren's presentation)	Multiple people (see attendance list)	Multiple organisations (see attendance list)	• Discussion around the potential for EWKR to relate to TLM • Overlap of icon sites is an obvious link but other icon sites are also interested — keen to know specifics of activities and potentially value add by undertaking activities at their sites too • Keen to be kept in the loop generally • Would like to see updates on the website • Most people were unaware of JRG representation of their organisations — it would be beneficial to communicate who the JRG members are to help facilitate communication within organisations
16 May 2016	Workshop attendance (Sam Capon) Queensland Floodplain Vegetation project workshop	Multiple people (see attendance list)	Multiple organisations (see attendance list)	• The Queensland Vegetation project team provided an update of progress to date and planned activities • This update was passed on to the Vegetation Theme Leadership Group at the annual workshop (19–20 May 2016)
17 May 2016	Presentations and workshop Lower Murray Regional Workshop, Buronga	Multiple people (see attendance list)	Multiple organisations (see attendance list)	See notes / feedback captured in EWKR project management
19–20 May 2016	Workshop Annual (2015–16) Vegetation Theme research workshop, Melbourne	Vegetation Leadership Group	Multiple organisations (see leadership list)	Research planning
25–26 May 2016	Ad hoc workshop discussion NSW Murray Lower Darling Environmental Water Advisory Group, Deniliquin	Multiple people (see attendance list)	Multiple organisations (see attendance list)	Ad hoc updates for both EWKR and LTIM, particularly where information relates to sites along the Murray River and Edward-Wakool
31 May 2016	Teleconference CEWO Black Box Working Group	Working group members (see attendance list)	Multiple organisations (see attendance list)	Inter-project communication through representation on the Working Group from the CEWO project *Achieving long-term ecological outcomes for Black Box through active groundwater management*
1–2 June 2016	Workshop NSW OEH Murray Lower Darling Long Term Watering Plan Workshop, Albury	Multiple people (see attendance list)	Multiple organisations (see attendance list)	Attendance and input at this workshop. Of relevance to EWKR in terms of adoption pathways for the uptake of EWKR research outcomes as well as ensuring the relevance of research outputs to long-term planning challenges faced by state and regional water managers
24 June 2016	Workshop	Working group members (see attendance list)	Multiple organisations (see attendance list)	Attendance and input at this workshop. Of relevance to EWKR in terms of inter-project communication and ensuring outputs from each

Date	Type of communication	Person(s)	Organisation(s)	Notes
	CEWO Black Box Working Group meeting, Mildura			project are complementary and will value-add to each other rather than duplicate effort.

1.2 Theme 2 — Fish

Table 6. Tasks and progress for 2015–16.

Component	Activity	Scheduled start	Scheduled end	Responsible agency	Status against timeline	Comments
F1. Knowledge review and conceptualisation	F1.1 Fish recruitment and conceptualisation	Jan 2016	Dec 2016	MDFRC, Charles Sturt University and Arthur Rylah Institute		On track
	F1.1.1 Theoretical synthesis and conceptualisation	Jan 2016	Dec 2016	Charles Sturt University		On track
	F1.1.2 Knowledge and management of flows and fish recruitment in the MDB	Jan 2016	End Sep 2016	Arthur Rylah Institute		Date was modified to end Dec due to delays in getting contract signed
	F1.1.3 Review and synthesis of the factors limiting spawning and recruitment	Jan 2016	End Oct 2016	MDFRC		The date and nature of this deliverable for this activity was modified (as discussed and agreed to 25/8). The delivery date is now end Dec 2016 and the deliverable is a summary/ position paper.
	F1.1.4 MDB fish recruitment conceptualisation integration	End Apr 2016	End Oct 2016	MDFRC		The date and nature of this deliverable

Component	Activity	Scheduled start	Scheduled end	Responsible agency	Status against timeline	Comments
						for this activity was modified (as discussed and agreed to 25/8). The delivery date is now end Dec 2016 and the deliverable is a summary/ position paper.
	F1.2 Summary of prior and current projects	Jan 2016	End May 2016	MDFRC		Delayed — see relevant section below
F3 Theme coordination, leadership and reporting	F4.1 Theme coordination	Jul 2015	Jun 2016	MDFRC	Completed	Jun 2016
	F4.3 Project reporting	Jul 2015	Jun 2016	MDFRC	Completed	Jun 2016

Progress against scheduled theme activities

Section 2 of this report 'Progress against scheduled activities' reports on the overall progress by the Fish Theme in meeting project-wide obligations, such as knowledge review and conceptualisation, revising research plans and undertaking field work. Exceptions to this reporting for the Fish Theme are detailed below and summarised in Table 5. A summary of theme planning, activities and expected outputs for the reporting period is provided in the following section.

Overall

After the SAG workshop and associated feedback, the Leadership Team worked between August and October to develop an approach for the conceptualisation process. The process was finalised at a teleconference on 20 October 2015 and an update provided to the Department in early November 2015. A draft Annual Research Plan was then completed in early December 2015. This outlined the process for the three knowledge reviews, conceptualisation and subsequent integration. In order to progress work on the theoretical review, MDFRC agreed to employ two CSU staff on a casual basis. These staff were then able to start the review process. For the other reviews, the Christmas break limited activity on both the Knowledge Review and the preparation of subcontracts until the end of January when leadership team members and LTU legal staff returned to work.

There was then a period extending from late January through into April during which time, contracts to engage members of the Leadership Team in the conceptualisation process were prepared and sent to collaborating institutions for approval. This process is described in more detail in the Vegetation Theme.

The MYRP and ARP were both revised in April and May 2016, and submitted to the Department in early June.

F1.1 — Theoretical synthesis and conceptualisation
This component of work was commenced after the approach to conceptualisation had been agreed and approved by the Department in early November 2015. Progress was facilitated by the MDFRC agreeing to employ two CSU post-doctoral research fellows to undertake the literature review. By early May, enough progress had been made that Paul Humphries (lead researcher for this activity) was able to start discussions with Darren Baldwin (Food Webs Theme Coordinator) about integration between the Fish and Food Webs themes.

F1.2 — Knowledge and management of flows and fish recruitment in the MDB
This component of work was affected by the delays in the contracting process and then once contracts were approved, further delays were encountered due to other project commitments for key staff including John Koehn. The major activities undertaken were planning and then hosting a conference for water managers in Melbourne on 5 May. The workshop provided an opportunity to discuss current approaches to the delivery of environmental flows for fish and critical knowledge gaps. The workshop complemented a review of the scientific and management literature on management of flows to achieve outcomes for fish in the MDB.

V1.3. — Review of factors limiting spawning
The review of factors limiting spawning and their interaction with flow was delayed due to demands placed on the Theme Coordinator's time associated with project coordination, preparation for the JRG workshop and development of the contracts. Once these commitments were completed, the review was commenced and the scientific and management literature were assessed to identify and prioritise key threats to fish recruitment.

V1.4 — Integration
The Integration component is reliant on the outputs from the other three reviews, and so commencement was delayed. The Integration activity was focussed on a workshop of the Theme Leadership Team, which is scheduled to be held on 26 to 28 July 2016.

Summary of activities for the reporting period

The following sections explain how each component of the theme is being developed and outlines the expected research outcomes.

Knowledge review and conceptualisation

This activity seeks to improve our conceptual understanding of the relationship between fish and flow and will:

1. improve our conceptual understanding of the relationship between flow and fish populations in such a way that greater and more appropriate levels of detail and complexity can be understood and communicated
2. underpin the design of the other activities undertaken by the Fish Theme

3. represent a significant project output of direct and immediate value to both water managers and researchers
4. become an input to the development of the MDB EWKR project's adoption tools.

The conceptualisation process has been divided into four components: theoretical (global), management (MDB), non-flow related stressors and threats, and an integration of all of these to provide a management-focussed, MDB-specific conceptualisation of fish recruitment based on the best available science and most up-to-date management information (Figure 4).

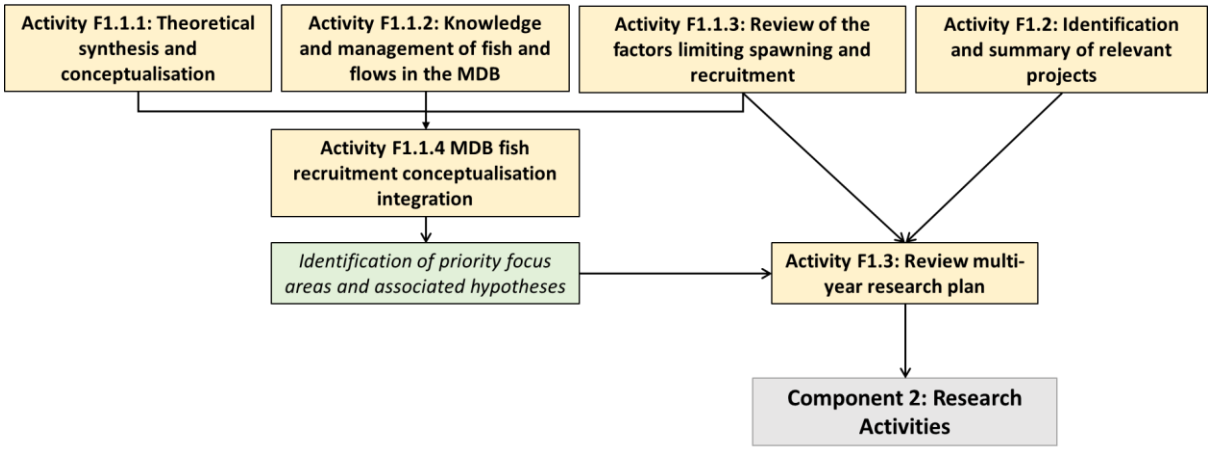

Figure 4. Diagram depicting the linkages between the foundational activities that are being undertaken by the Fish Theme.

Theoretical synthesis and conceptualisation

This activity was sub-contracted to be undertaken by Paul Humphries (Charles Sturt University (CSU) in collaboration with Nicole McCasker (CSU), Richard Kopf (CSU), Alison King (Charles Darwin University (CDU)), Rick Stoffels (MDFRC) and Brenton Zampatti (South Australian Research and Development Institute (SARDI)). The work was commenced in February 2016 and is due to be completed by December 2016. Deliverables from this activity include:

- dissemination of key findings and answers to the integration questions (as identified in the integration framework) prior to the Fish Theme Workshop in July 2016 (July 31 — completed)
- a scientific publication.

Project objective: to integrate life-history theory, behaviour and physiology, river ecosystem concepts and fish recruitment hypotheses to establish current understanding, determine knowledge gaps and develop testable hypotheses relating to flow/fish recruitment relationships. Specifically, this activity aims to:

1. investigate if and how physiological, behavioural and life-history traits are correlated
2. how these three components interact with the key features of river ecosystems — and flow in particular — to contribute to fish recruitment
3. explore the relevance of river ecosystem concepts for explaining patterns and processes in fish recruitment and population dynamics
4. relate current ideas and hypotheses about fish recruitment from all aquatic environments to rivers and riverine fishes
5. identify knowledge gaps, generate hypotheses and guidelines for future research to better inform future management.

In addition, this activity took on the additional task of reviewing the literature in order to provide information to enable an appropriate definition of recruitment for the EWKR Fish Theme.

Good progress has been made with this activity and progress-to-date is summarised below:

Recruitment definition

Based on an extensive review of the freshwater, marine and estuarine literature regarding relative mortality rates among different developmental stages and the frequency in which key life-stages were attributed to driving recruitment variability in fish populations, the following definition of recruitment was recommended (and has subsequently been accepted): 'the process of survival to the end of the first year of life'. Both the abundance of survivors to the first year and the processes that govern survival to the first year are considered as part of this definition.

Current hypotheses about fish recruitment to riverine fish

An extensive literature review was conducted examining the relative importance of different sources of mortality and how these vary with development stage. Most studies examined one source of mortality only with a limited number of studies examining two factors simultaneously and even fewer examining three factors. This limitation in the approach of most recruitment studies means that the relative importance of different sources of mortality is virtually impossible to assess. In addition, very few studies were undertaken in riverine systems.

There are a large number of recruitment hypotheses that have been developed and in most of these the temporal coincidence of food or predators is the dominant paradigm. One recruitment hypothesis, the Fundamental Triad, which was developed for marine pelagic broadcast spawning species considers spatial *and* temporal coincidence of food and larvae. This type of model may be well-suited to being adapted to freshwater systems and species; however, it must also consider predation, temperature as well as movement (movement relates to how an individual accesses food and avoids predation). A freshwater adapted model would also need to explicitly incorporate flow variability and geomorphic complexities.

River ecosystem models

Literature pertaining to river ecosystem models and river ecosystem functioning more broadly was reviewed to assess the relationship between riverine ecosystem functioning and fish recruitment. Most river ecosystem models have been developed to explain:

- sources of energy (C)
- sources of nutrients (N and P)
- nature of storage, transport & transformation or material and energy,

as they pertain to different types of rivers and/or climates. With the exception of the flood pulse concept and the river wave concept, flow is not explicitly considered in these models. Most models also do not relate directly to fish and fish recruitment and most fish recruitment studies do not consider river ecosystem models or even mechanisms that underpin fish responses.

Life history, physiology, and behavioural traits and fish recruitment

The review of the literature pertaining to species traits revealed that the traits most commonly and traditionally thought of as influencing recruitment are life-history traits. However, other traits such as physiology and maternal condition are increasingly being considered. For example, the Pace-of-Life Syndrome is a model, which incorporates life-history traits with behavioural and physiological

traits. Winemiller and Rose's life-history model adds an additional intermediate group. Recruitment variability is also expected to differ according to life-history strategy in part as a result of metabolic constraints (size, temperature and energy/food). Movement patterns, which do not always correlate strongly with life-history strategy, must also be considered.

How fish traits, river ecosystems and flow contribute to fish recruitment

Significant progress has been made towards developing a river ecosystem recruitment model that integrates all of the above to make qualitative predictions regarding the likely recruitment success of different types of species under varying levels of flow and geomorphic complexity. This model will continue to be developed and refined.

Knowledge and management of flows and fish recruitment in the MDB

This activity was sub-contracted to be undertaken by John Koehn (ARI) in collaboration with Stephen Balcombe (Griffith University) and Brenton Zampatti (SARDI). The work was commenced in mid-April (commencement delayed by approximately 10 weeks due to delays in a draft contract being supplied) and is due to be completed by December 2016. Deliverables for this activity include:

- dissemination of key findings and answers to the integration questions (as identified in the integration framework) prior to the Fish Theme Workshop in July 2016 (July 31 — completed)
- an ARI client report to La Trobe/MDFRC
- a management-focussed publication. This will then be converted to a refereed scientific journal article.
- outputs, which may also be communicated directly to the funders and fish and flow managers via presentations and fact sheets.

Project objective: to provide an up-to-date synthesis of information (knowledge and management) for fish and flows in the MDB.

Approach:

1. Current knowledge: Literature review to determine the current knowledge concerning flow-related ecology and directions for managing fish populations in the MDB. Published journal papers and grey literature (reports).
2. Current fish-flow management: Questionnaire and workshop with key fish-flows managers to determine needs and priorities. The workshop held at ARI on the 5 May that included fish ecologists and fish-flows managers representing regions across the MDB.
3. The workshop then used a consensus approach to identify priority knowledge gaps. In order to get a range of views regarding knowledge gaps for potential EWKR projects, the workshop utilised the results from a previously distributed questionnaire, workshop presentations (ecological literature, management directions and regional managers), and held considerable discussions, to develop a priority list of knowledge gaps from an ecological (science only) perspective and those prioritised by managers. These knowledge gaps were collated, and sent to all participants for their further consideration, amendment and agreement.

Results

Current knowledge

We undertook a review of the published and grey literature to elucidate contemporary knowledge and emerging trends in flow-related fish ecology relevant to the MDB. Starting with 750 papers, this

list was reduced down to 57 relevant fish-flow ecology papers from information provided by titles and abstracts. All relevant papers were published from 2000 onwards. Most papers were limited in both spatial (e.g. single site or river) and temporal scale (<1 year duration) and the main fish-habitat topics were related to water quality. The majority of the research occurred in lowland habitats.

The review found some key knowledge gaps:

- scale — understanding about scale temporal and spatial
- rates — growth, survival
- understanding of factors that grow populations
- outcomes of watering for a target species (on associated species)
- links between flow and habitat hydrodynamics leading to fish outcomes
- location relevance — how transferrable are results?
- limited information about the Northern Basin
- threatened species — often targeting last gasp efforts rather than longer- term understanding of population needs.

The trends indicate that our fish flow ecology science has moved from single site, single life-stage outcomes to more integrated studies that consider multiple interactions between flow components and life-stages to enable the understanding of whole population responses to flow.

Key species

Considering initial consultation with State and Commonwealth water managers (2014), outcomes from the fish-flow manager's questionnaire and workshop and locations within catchments where flow can be managed, key large-bodied species are: Murray cod (*Maccullochella peelii peelii* Mitchell), Golden perch (*Macquaria ambigua* Richardson), Trout cod (*Maccullochella macquariensis* Cuvier), Silver perch (*Bidyanus bidyanus* Mitchell), Macquarie perch (*Macquaria australasica* Cuvier), and Freshwater catfish (*Tandanus tandanus* Mitchell). The flow requirements for the priority small-bodied species in the lowland habitats are less-well known and tend to be largely restricted to off-channel habitats. The priority small bodied-species are: Southern pygmy perch (*Nannoperca australis* Günther), Southern purple-spotted gudgeon (*Mogurnda adspersa* Castelnau), Olive perchlet (*Ambassis agassizii* Steindachner), Murray hardyhead (*Craterocephalus fluviatilis* McCulloch), and Yarra pygmy perch (*Nannoperca obscura* Klunzinger).

Current knowledge and thinking regarding the ecology on MDB fishes and their populations in relation to flows in the MDB

Current flow ecology knowledge is limited to a restricted number of species and life-stages, with the major knowledge being for spawning and recruitment for Murray cod and Golden perch and then to a lesser extent for Silver perch and Macquarie perch. There is limited knowledge for Freshwater catfish, and much of this knowledge is from coastal streams. Our understanding around flow requirements for promoting recruitment of the small-bodied priority species is even more limited than the larger-bodied species (Table 1).

As with the general knowledge of life-stages for the MDB priority fish species, most of our understanding of key recruitment drivers relates to the larger-bodied species, particularly Murray cod, Trout cod and Golden perch (Table 2). There is limited knowledge for understanding the influence of flow as a driver and its influence on other drivers for the successful recruitment of small-bodied species and Freshwater catfish. There are clear knowledge gaps for all species in relation to biotic recruitment drivers, such as competition and predation and disease.

In general, our knowledge of the influence of flow and other drivers is lacking. Even where we do have some confidence in our knowledge of these factors, how strongly they link to actual population

increase is less well known. For example, we are gaining more knowledge on fish movements, but the actual outcomes for the populations is often unknown.

Contemporary fish-flow management in the MDB

In 2014, EWKR sought to capture the research priorities of State (SA, VIC, NSW and QLD) and Commonwealth (MDBA and the Department) water and natural resource managers through questionnaires and a series of workshops. The common fish research themes/questions resulting from this process were:

- What scale do populations operate at? Population dynamics and recruitment, demographic processes, connectivity etc. Scales include: site, regional and, landscape.
- Drivers for population dynamics and recruitment.
- Food webs, primary productivity, food resources.
- Flow-related thresholds, less than optimum duration, partial events, etc.
- Refuge habitats, intermittent rivers, Northern Basin.

In addition to this preliminary engagement, this current phase of the project involved consultation with managers that have specific responsibilities for fish and flows. We invited representative management agencies across the MDB to attend a workshop and participate in an associated questionnaire. The fish-flow manager workshop had 19 attendees, with questionnaire responses from 13 (in bold).

Objective: To engage with fish-flow managers to determine their needs and perceived research priorities in an MDB context.

Table 7. Categorised list of participants at the Fish and Flow Workshop held in May 2016.

Fish ecologists	Fish-flow managers	Water managers	Project managers
Attended			
John Koehn*	**Anthony Townsend (NSW)**	**Damian McCrae (CEWO)**	Amina Price
Brenton Zampatti*	**Katherine Cheshire (NSW)**	Louise Chapman (Mallee)	Nadia Kingham
Harry Balcombe*		Emma Wilson (OEH)	Anthony Moore
Lee Baumgartner		**Alana Wilkes (CEWO)**	Jessica Davison
Wayne Koster		**James Dyer (OEH)**	
		Jan Whittle (SA)	
		Fiona Spruzen (Vic. W & C)	
		Rebecca Turner (SA)	
Apologies			
Ivor Stuart	**Heleena Bamford (MDBA)**	**Tim Hosking (NSW)**	
Zeb Tonkin	Adam Sluggett (MDBA)	Beth Ashworth (VEWH)	
Jase Thiem	Sam Davis (NSW)	Ryan Breen (SA)	
	Marty Asmus (NSW)	Peter Brownhalls (Qld) del	
		Andrew Warden (CEWO)	
		Debbie Love (Nth) staff	
		Tracey Steggles	
		Anna Lucas (Vic. W & C)	
		Courtney Johnson (VEWH)	
		Paul Reich (Vic. W & C)	
		Paula D'Santos (OEH)	

*Project team

Manager's objectives:

1. To ultimately have more native fish in their rivers. They want successful life-cycle completion from spawning and recruitment right through to a larger adult population size.
2. Measurable benefits from flow management (e.g. increased distributions, abundance) — this may include interim measures (e.g. quantifiable improvements in all life-stages).

Hydrographs are a useful tool for flow managers and are now widely used; there is much interest in refining these. Providing causal relationships of fish response to flow components is a key request from fish-flow managers. Managers are looking for more guidance/interaction with fish ecologists and the provision of definitive, easily applicable information.

Summary of the agreed priority knowledge gaps identified in the fish-flows manager's workshop

Following the presentations outlined above, the workshop concluded by undertaking a consensus process to derive an agreed list of knowledge gaps. This list was then refined and sent to all workshop participants for their further comment and agreement. The priority knowledge gaps are listed below:

Ecological knowledge gaps

Highest priorities

1. **Population dynamics (incorporating all life-stages)**
2. **Spatial and temporal scales and population processes**
3. **Rates: survival; growth**
4. **Recruitment (drivers, food, etc.)**

Secondary priorities

5. **Fish condition (and effects on survival and recruitment)**
6. **Fecundity**

Management knowledge gaps

Highest priorities

1. **Population dynamics** (i.e. all life-stages)
2. **Recruitment** (into adult population)
3. **Movement, dispersal and connectivity**
4. **Mechanisms/causal links and thresholds (scale of variability; what are the drivers)**

Secondary priorities

5. **Trade-off processes**
6. **Species-specific responses to flows**
7. **Life-stage-specific responses to flows**
8. **Scale: Landscape/system — site**
9. **Refugia flow thresholds, maintain or not, top up or not**
10. **Recovery time (drought/blackwater) — recolonisation, barriers**

Manager's priority species

Manager's species priorities are often public driven, generally focusing on large-bodied native fishes. Nevertheless, there is also consideration of the whole of fish community, umbrella or keystone species and particularly the need to address the needs of threatened species. Estuarine and diadromous species are also priorities in South Australia.

Large-bodied (priority order): Murray cod, Golden perch, Trout cod, Silver perch, Macquarie perch, Freshwater catfish.

Small bodied (priority order): Southern pygmy perch, Southern purple-spotted gudgeon, Olive perchlet, Murray hardyhead, Yarra pygmy perch.
Carp.

Review and synthesis of the factors limiting spawning and recruitment and how these are influenced by flow and other stressors

This activity is being undertaken by Amina Price (MDFRC) in collaboration with Lee Baumgartner (CSU), Paul Humphries (CSU) and John Koen (ARI). Work on the activity commenced in February 2016 and will be completed by December 2016. The aim of this activity is to synthesise existing knowledge to describe the key limitations on potential fish responses (focussing on spawning and recruitment), how these vary spatially and temporally and the influence of flow and other stressors. The specific questions that will be addressed are:

- What are the factors limiting fish spawning and recruitment?
- What is the relationship between these factors, flow and other stressors?
- Do these factors vary in space and time?
- Are there any factors which are data poor?
- Are complementary actions needed where factors can't be influenced with flow?

Deliverables from this activity include:

1. Dissemination of key findings and answers to the integration questions (as identified in the integration framework) prior to the Fish Theme Workshop in July 2016 (completed).
2. A management-focussed report which will then be converted to a refereed scientific journal article. The report will be delivered by December 2016.
3. It is anticipated that we will also communicate the outcomes from this activity directly to funders and managers via presentations and a fact sheet.

Good progress has been made with this activity and the progress-to-date is summarised below:

1. Identification of direct and indirect recruitment drivers (factors which limit recruitment) (see Table 8 below).
2. Development of conceptual threat models depicting the relationships between threats, flow and recruitment drivers. These include a description of the key spatio-temporal scales that influence these relationships, and where appropriate, this variability is incorporated into the models. These models also provide an indication of the relative influence of flow versus non-flow related factors on each recruitment driver under different spatio-temporal scenarios. The key threats, impacts, ecological effects and associated recruitment drivers are shown below (Table 8). Examples of the threat models developed for water temperature are also shown (Figure 5 and Figure 6).

Table 8. Direct and indirect (mediating) recruitment drivers.

Direct recruitment drivers	Mediating (indirect) recruitment drivers
Quality and quantity of foods ingested	Nutrient and carbon inputs
Temperature	Connectivity
Predation	Hydraulic habitat
Disease and parasites	Macrophyte cover
Desiccation	Snag cover
Water quality	Water quality
Pollutants	Community composition (competition and predation)

Other sources of mortality (infrastructure)	Species traits
Movement and retention	Spawning success (adult populations; spawning cues; spawning habitat)

Table 9. The key non-flow related threats and processes that might impact on the recruitment drivers.

Key threat	Key impacts (stressors)	Ecological effects	Affected recruitment drivers
Altered land use	Erosion, channelisation, altered patterns of runoff and overland flow, sedimentation, geomorphological change; riparian alteration and degradation; altered substrates; altered nutrient regimes, pollutants; raised groundwater levels; de-snagging	Smothering, infilling or scouring of aquatic habitat (substrates and hydraulic habitat); loss of shading; loss of instream structural habitat; changes to food webs; changes to water quality; changes to community composition; changes to adult population, size and condition; changes to organic matter inputs (amount, timing type)	Temperature; predation rates; food quality and quantity; turbidity and sedimentation; salinity; eutrophication; dissolved oxygen; acidification
Barriers	Loss of lateral (floodplain) connectivity, loss of longitudinal connectivity; cold water pollution; raised groundwater levels; stranding in impoundments and weir pools; pumping into inappropriate habitat	Altered nutrient regimes; changes to organic matter inputs (amount, timing, type); altered sediment regimes; channelisation and scouring; geomorphological change; alteration to hydraulic habitat; changes to community composition; changes to adult population size, structure and condition; reduced up- and downstream dispersal of juveniles; reduced downstream dispersal of eggs and larvae; reduced growth or mortality resulting from stranding in sub-optimal habitats; physical damage and mortality resulting from passing though pumps, weirs and dams.	Temperature food quantity and quality; dissolved oxygen; turbidity and sedimentation; salinity; eutrophication; acidification; infrastructure-related mortality
Climate change	Increased water temperatures; changes to precipitation patterns; changes to evaporation rates	Changes to species distribution patterns; changes to aquatic vegetation; changes to riparian and floodplain condition; altered nutrient regimes; changes to organic matter inputs (amount, timing, type); altered sediment regimes;	Temperature; predation rates; food quantity and quality; dissolved oxygen; turbidity and sedimentation; salinity; eutrophication; acidification
Alien species	Disturbance of substratum	Changes to species distribution patterns and community composition; changes to aquatic vegetation; competition rates	Predation rates; food quality and quantity; turbidity and sedimentation
Harvesting		Changes to community composition; changes to adult population size, structure and condition	Predation rates; food quality and quantity

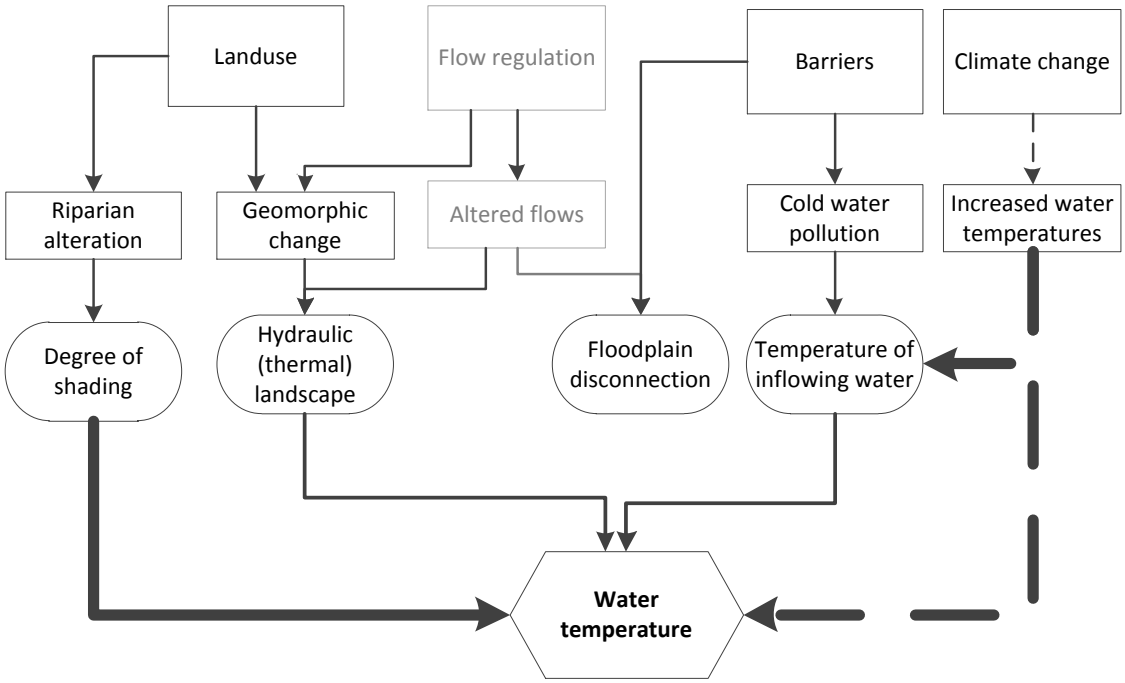

Figure 5. Temperature threat model for unregulated headwaters and tributaries.

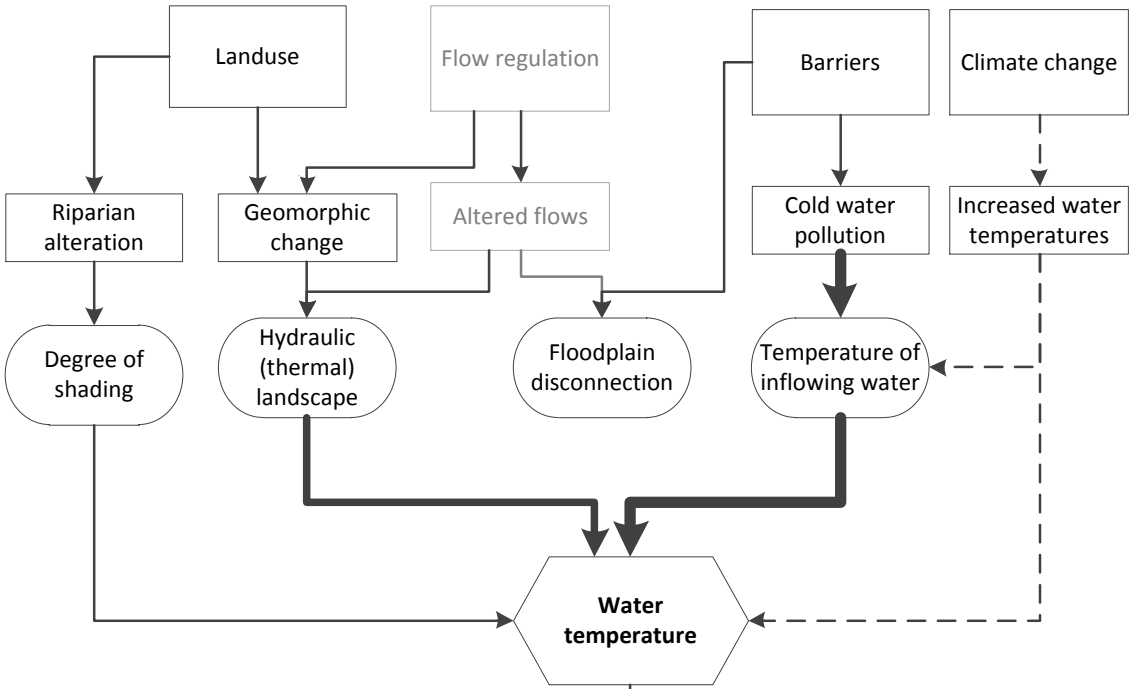

Figure 6. Temperature threat model for main channel habitats.

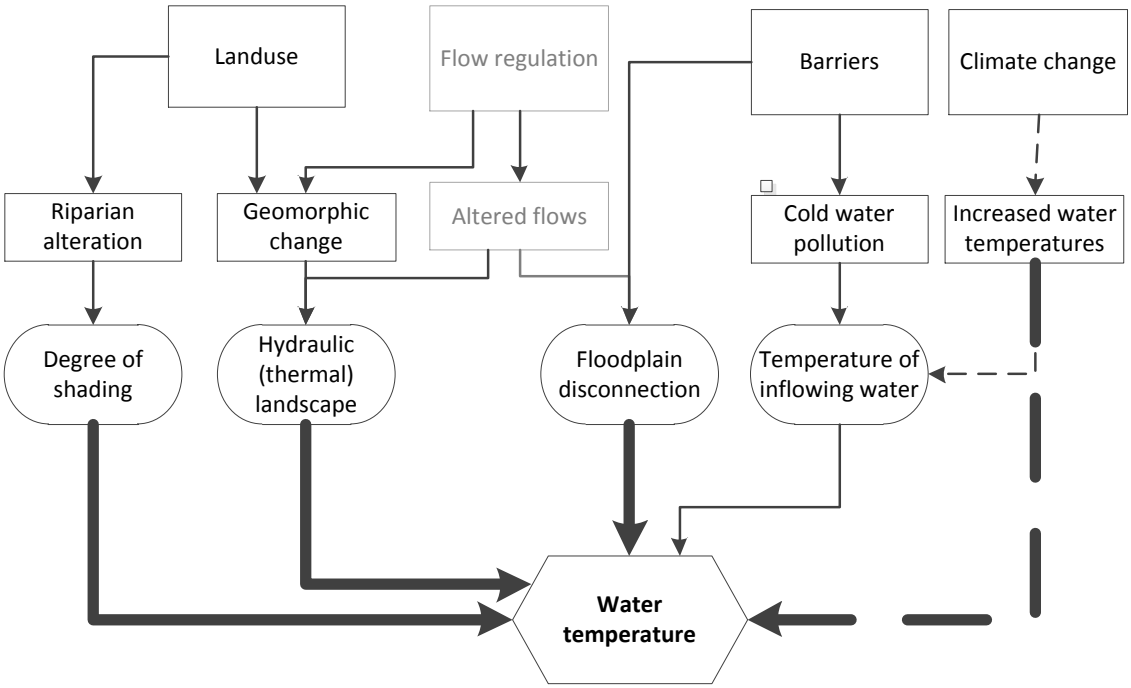

Figure 7. Temperature threat model for main channel habitats.

1. Description of the complementary actions that could be used to enhance fish response when managing flows for fish outcomes.
2. Identification of knowledge gaps relating to the relationship between non-flow-related constraints (threats) and recruitment.

This will work will be written up following the Fish Theme Workshop in July 2016.

MDB fish recruitment conceptualisation integration

This activity is being led by Amina Price (MDFRC) with input from the entire Fish Theme Leadership Group. Planning for the conceptual integration commenced in December 2015 and this activity will be completed by December 2016. The aim of this activity is to integrate the outcomes from the previous three foundational activities to develop a management-focussed MDB-specific conceptualisation of fish recruitment based on the best available science and most up-to-date management information. For different MDB fish species, this activity will:

- prioritise causal relationships between flow and recruitment for MDB fish species in terms of:
  - their influence on outcomes
  - our current level of understanding
  - their capacity to be influenced by existing management levers
- identify and prioritise knowledge gaps.
- Develop testable hypotheses that are applicable to flow management scenarios and MDB fishes

Deliverables from this activity include:

- conceptual integration framework (completed)
- revised Multi-year Research Plan and 2016–17 Annual Plan (due September 2016)
- a Murray–Darling Basin fish-flow recruitment conceptualisation paper: the audience for this paper is primarily expected to be the management community within the MDB and the scientific community (December 2016).

It is anticipated that the outputs from this activity will also be communicated to managers via a fact sheet and presentations.

Work to date has focussed on the development of a conceptual integration framework (Figure 8 and Figure 9), which provides a clear framework to guide the direction of the three input activities to ensure that a fully integrated MDB-specific conceptualisation of fish recruitment can be developed.

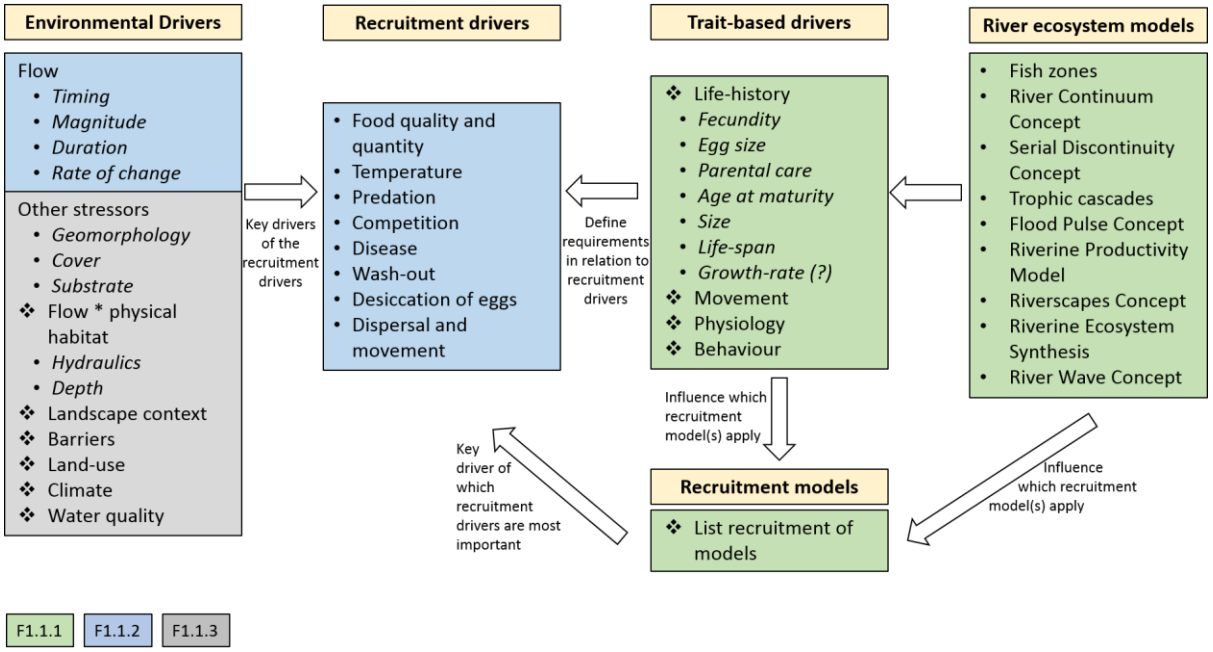

Figure 8. Fish Theme Conceptual Integration: topics to be covered by each of the three input activities. Blue= Activity F1.1.1 (management of fish and flows); Green=Activity F1.1.2 (theoretical synthesis); Grey=Activity F1.1.3 (spawning and recruitment limitations synthesis).

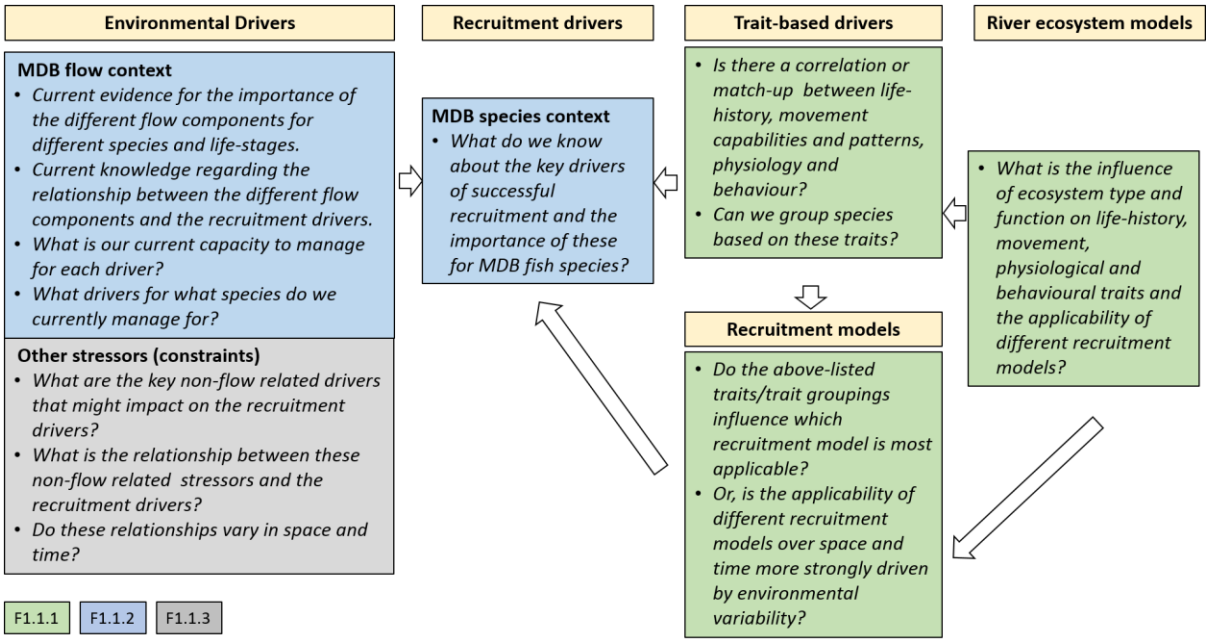

Figure 9. Fish Theme Conceptual Integration: questions to be addressed by each of the three input activities. Blue= Activity F1.1.1 (management of fish and flows); Green=Activity F1.1.2 (theoretical synthesis); Grey=Activity F1.1.3 (spawning and recruitment limitations synthesis).

This integration framework was developed by the MDFRC, workshopped with the leaders of the three input activities (Amina Price, John Koehn and Paul Humphries) and then sent out for review to the Fish Theme Leadership Group.

Since the development of the integration framework, regular meetings and communication have occurred to ensure that all activities remain focused on addressing the relevant topics and questions.

The conceptual integration workshop will be held on the 26–28 July 2016 in Albury. This workshop will bring together the outputs from the three input activities to (i) document, discuss and integrate our current knowledge, (ii) identify and prioritise the key knowledge gaps, and (iii) decide on the research activities that will form the remainder of the work undertaken by the Fish Theme. Following this, the outputs of the workshop will be further developed and written up into an MDB fish recruitment conceptualisation.

Activity F1.2 Identification and summary of relevant projects

The SAG noted that the work undertaken within EWKR needs to build on work undertaken by other large projects (e.g. the Flagship Cluster) and to be explicit in relation to linkages with other programs (in particular LTIM). In response to this, the leadership group agreed that an additional activity, involving cataloguing and summarising relevant projects (national and international) that the work within the Fish Theme should either build on or link with, should be undertaken at the same time as conceptualisation is being developed.

This activity is being undertaken by the MDFRC with inputs from the Fish Theme Leadership Group.

The key deliverable for this activity is a document listing all relevant past and current projects and summarising the information such as the project aims and objectives, study sites, methods and, in the case of completed projects, the key findings. This was due to be delivered for the July Fish Theme Workshop.

This relatively small activity has been delayed, primarily because of a lack of input from the Fish Theme Leadership Group. Whilst we have been able to compile some information regarding other large projects (e.g. LTIM, Fish and Flows in the Northern Basin, Quantifiable environmental outcomes; CSIRO Cluster Project), there may be information pertaining to projects that we were not aware of, or didn't have access to information about, which has not been considered. Because this work remained incomplete (we were still waiting for responses from a number of members of the Fish Theme Leadership Group), the information that we have compiled to-date is not written up and summarised into a document. We don't believe that this will limit our capacity to build on work that other projects have undertaken because the key projects have either been summarised in our internal documents or are known by members of the leadership group attending the workshop.

Activity F1.3 Review Multi-year Research Plan

Following the Fish Theme workshop being held 26–28 July in Albury, the existing MYRP will be reviewed and updated based on the outcomes of activities F1.1.4 and F1.1.5, with the review to provide further definition of Components F2 and F3. This activity will be led by Amina Price, with input from the Theme Leadership Group.

F3 Theme coordination, leadership and reporting

The Fish Theme Coordinator and Leadership Group have met regularly via teleconferences and face-to-face meetings (see list below), and have made substantial progress in research planning. conceptualisation and reporting.

Integration

The Fish Theme Coordinator has invested significant time in improving integration with other Themes. This has included meetings between members of the Fish Theme Leadership Group with the Food Webs Theme Coordinator to discuss links and strategies, integration discussions during the Theme Leadership Group meetings and regular project management, and Theme Coordinator meetings discussing integration. Specific plans for links and integrated projects are being formed between the Fish and Food Webs themes. Links between the Fish Theme and the Waterbirds and Vegetation themes will be more conceptual and will be explored through the Food Webs Theme.

Stakeholder consultation and engagement

There has been stakeholder consultation at various stages throughout the MDB EWKR planning process. Some of this consultation has occurred at the whole-of-project scale and other communication has been more specific to themes. Consultation and communication has occurred through both formal channels (e.g. structured workshops, targeted phone calls), as well as ad hoc/opportunistic communication around other projects and/or attendance at non-MDB EWKR-related workshops. A record of this communication is provided in Table 10.

Table 10. Stakeholder communication and consultation.

Date	Activity	Person(s)	Organisation(s)	Notes
23 Jul 2015	Theme Coordinators Workshop, 23 July 2015, Wodonga	EWKR Theme Coordinators and Project Leadership Team	MDFRC, CSIRO	Research planning and integration
29 Jul 2015	Fish Theme teleconference	Fish Theme Leadership Group and Darren Baldwin	Multiple organisations	Research planning
Aug 2016	Development of draft research plans and associated budgets (annual and multi-year)	Fish Theme Leadership Group	Multiple organisations	Research planning
27 Aug 2015	Presentation (Amina Price) Science Advisory Group Workshop, Sydney	The Department, SAG, Theme coordinators, MDFRC Project Management	Multiple organisations (see attendance list)	Presentation of Fish Theme research direction to the SAG
9 Sep 2015	Fish and Food Webs themes integration meeting	Fish and Food Webs theme Coordinators, Rick Stoffels, project leadership team	MDFRC, CSIRO	Research planning
13 Oct 2015	Conceptualisation planning meeting	Amina Price, Paul Humphries, Rick Stoffels	MDFRC, CSIRO, CSU	Research planning
21 Oct 2015	Fish Theme teleconference	Fish Theme Leadership Group	Multiple organisations	Research planning
21 Oct 2015	Theme Coordinators Workshop	EWKR Theme Coordinators and Project Leadership Team	MDFRC, CSIRO	Research planning and integration
3 Nov 2015	Fish Theme conceptualisation planning meeting	Amina Price, Paul Humphries, Rick Stoffels, Alison King	MDFRC, CSIRO, CSU, CDU	Research planning
Nov 2015	Fish Theme update document for The Department re: conceptualisation	Amina Price	MDFRC	

Date	Activity	Person(s)	Organisation(s)	Notes
Dec 2015	Revision of draft research plans and associated budgets (Annual and Multi-year)	Amina Price	MDFRC	
15–16 Dec 2015	Fish Theme conceptualisation planning meeting	Amina Price, Paul Humphries, John Koehn, Lee Baumgartner	MDFRC, CSU, ARI	Research planning
Jan–Mar 2016	Preparation of research contracts	Amina Price	Multiple organisations	
10–11 Feb 2016	Presentation JRG Workshop Canberra	Multiple people (see attendance list)	Multiple organisations (see attendance list)	See notes/feedback captured in EWKR project management
Feb 2016	Mid-year Progress Report	Amina Price	MDFRC	
5 May 2016	Fish Theme Managers Workshop	Multiple people (see attendance list)	Multiple organisations (see attendance list)	
16 May 2016	Fish Theme conceptualisation meeting	Amina Price, Paul Humphries	MDFRC, CSU	Progress update meeting
May 2016	Revision of draft research plans and associated budgets (Annual and Multi-year)	Amina Price	MDFRC	
2 Jun 2016	Fish Theme teleconference	Fish Theme Leadership Group	Multiple organisations	Progress update
16 Jun 2016	Theme Coordinators Integration teleconference	EWKR Theme Coordinators and Project Leadership Team	MDFRC, CSIRO	
21 Jun 2016	Fish and Food Webs Integration meeting	Amina Price, Darren Baldwin, Paul Humphries	MDFRC, CSIRO, CSU	
Mar–Jun 2016	Collaborators contracted			

1.3 Theme 3 — Waterbirds

Table 11. Tasks and progress for 2015–16.

Component	Activity	Scheduled start	Scheduled end	Responsible agency	Status against timeline	Comments
B1 Knowledge review	B1.1 Knowledge review and conceptualisation	Oct 2015	End Jan 2016	CSIRO	Complete	Jun 2016
	B1.1 Drafting	Oct 2015	Mid-Dec 2015	CSIRO	Complete	
	B1.1 Reviews and approval	Mid-Dec 2015	End Jan 2016	CSIRO	Complete	
B2 Field research	B2.1 Field research pilot study	Oct 2015	May 2016	CSIRO and UNSW	Complete	May 2016
	B2.1.1 Preparation	Oct 2015	End Nov 2015	CSIRO and UNSW	Complete	Nov 2016
	B2.1.2 field data collection — pilot	Dec 2015	End Feb 2016	CSIRO and UNSW	Complete	May 2016
	B3.1.3 Data collation, analysis	Apr 2016	May 2016	CSIRO and UNSW	Complete	Jun 2016
	B3.1.3 Reporting	Apr 2016	May 2016	CSIRO and UNSW	Complete	
B3 Coordination and reporting	B3.1 Theme coordination	Ongoing		CSIRO	Complete	Jun 2016
	B3.2 Theme leadership	Ongoing		CSIRO, UNSW, UC	Complete	Jun 2016
	B3.3 Annual progress report 2015–16	Jun 2016	Jun 2016	CSIRO and UNSW	Complete	Jun 2016

Progress against scheduled theme activities

Section 2 of this report 'Progress against scheduled activities' reports on the overall progress by each theme in meeting project-wide obligations, such as knowledge review and conceptualisation, revising research plans and undertaking field work. Exceptions to this reporting for the Waterbirds Theme are detailed below and summarised in Table 6. A summary of theme planning, activities and outputs for the reporting period is provided in the following section.

Overall

The SAG feedback from the meeting in August 2015 required improvements to the conceptualisation and logic and rationale; however, undertaking these activities still allowed time for implementation of a pilot field season, the outcomes of which would contribute to planning for subsequent field sampling. As a consequence, the Annual Research Plan was updated by the end of August and preparations for field work were commenced. Letters were exchanged between MDFRC and CSIRO in late October to enable field work to commence in early November when the first sampling trip was undertaken to Barmah.

Once field work was completed, data analysis was undertaken through February and March and progress and results discussed at a Leadership meeting on 8 March. Since this time, the team have been preparing a short summary report of the outcomes. There has also been considerable effort put into the preparation of contracts for the next phase of work, which has still not been approved as at June 30. Planning for field work in spring and summer of 2016 was undertaken between April and May, with regular Leadership meetings held to discuss the types of trackers to be purchased and allocation of trackers to sites. Decisions have been made, but as at June 30, the order has not been placed due to delays in the contracting process. This planning was used to inform the development of the 2016–17 Annual Research Plan and for updating of the Multi-year Research Plan, a process that was undertaken during April and May. A draft Annual Plan was completed on 18 May 2016.

B1 — Knowledge review

A draft review of the influence of flow had been completed in early 2015. After the SAG feedback, further work was undertaken to refine the review and develop the conceptual models. This work was commenced in late 2015 and the report updated in early 2016. A major component of this was a review of information on the diet of waterbirds, which was undertaken in support of discussions with the Food Webs Theme to support integration between the themes. An updated literature review was completed in April 2014.

B2.1 — Pilot field survey

Planning for the pilot field sampling was commenced in September 2015, with a letter of agreement exchanged between MDFRC and CSIRO in early November 2015. Field work at Barmah commenced in November and subsequent trips were undertaken until February 2016. The field sampling sought to gather data on colony size, the areas used for nesting and their characteristics and also through the use of motion sensitive cameras estimates of nest success and observation of parental behaviour. Three field trips were undertaken (breeding initiation, fledging, end of breeding), with all activities undertaken in close cooperation with the regional water managers from NSW OEH and the Goulburn-Broken CMA.

B2.2 — Data collation and analysis

The data analysis was initiated in February 2016, with CSIRO employing staff to process the images from the cameras. The data was analysed to determine nest success, predator activity and nest attendance by adults. There is scope for further analysis on feeding behaviour; however, resources were not available to support this more detailed work. The data analysis was completed in May 2016.

B2.3 — Pilot reporting
The data analysed as part of Activity B2.2 was used for two purposes; first to inform the development of the 2016–17 Annual Research Plan and this was achieved with the draft plan being submitted in May 2016. The data is also being written up in a report for managers. The report is in preparation but, at June 30, has not been completed due to priority being given to the development of the Annual Plan, additional time being allocated to both getting the contracts approved and working with the Food Webs Theme to progress integration between the themes.

Summary of activities for the reporting period

The following sections explain how each component of the theme work has been planned and implemented.

Completion of the literature review

In scoping research activities for the MDB EWKR Waterbirds Theme, a literature review was undertaken to consolidate existing knowledge on waterbird responses to flooding, stressors and threats (McGinness 2015: *Waterbird responses to flooding, stressors and threats*). The objective of this review was to provide a solid foundation for MDB EWKR research, by reviewing past studies, providing conceptualisations of the drivers of waterbird recruitment, and identifying key knowledge gaps and research questions. During the 2015–16 financial year, this review (McGinness 2015) was revised to summarise key messages and knowledge gaps in a new front section and to provide more detail around conceptual models.

The review summarises known waterbird responses to flows and flooding in Australia, with an emphasis on the Murray–Darling Basin, and synthesises knowledge gaps highlighted in the literature. It also reviews the international literature regarding how various other stressors and threats affect waterbirds (habitat loss, fragmentation and change, predation, climate change, pollution, disease, human disturbance, competition), and how these interact with the effects of flows.
While increasing waterbird populations and maintaining waterbird diversity are important targets for environmental flows in Australia, knowledge gaps exist that affect our ability to manage and predict waterbird populations and diversity at appropriate scales. The review revealed that the largest of these gaps in knowledge relate to:

Demographics
- Survival and mortality rates, especially of fledglings and juveniles (and therefore recruitment)
- Population age structures and sex ratios
- Population and sub-population boundaries

Movements
- Immediately following and between breeding events — timing, distances travelled, differences between juveniles and adults, site fidelity, key foraging habitat locations and characteristics, effects of habitat availability, quality and productivity on bird condition and survival

- During breeding events — distances travelled, habitat characteristics, effects of habitat availability, quality and productivity on breeding site choice, site fidelity, event size and success
- Mechanisms, cues or drivers behind bird movements and choices and how these interact

Effects of interactions between flow-related drivers of waterbird responses and other stressors, pressures or threats, especially:

- Habitat loss, fragmentation and change
- Predation — rates, species, and timing
- Climate change and adverse or extreme weather

These knowledge gaps exist even for common and conspicuous taxa, such as colonially-nesting waterbirds, that are often thought to be relatively well-understood. They are particularly severe for cryptic and uncommon taxa. Filling these knowledge gaps will assist managers to:

- Identify, maintain, and/or restore key waterbird habitats — especially critical foraging habitats
- Better understand the spatial and temporal scales at which key habitat characteristics are required
- Better target water, vegetation and threat management actions to ensure 'event readiness' at nesting sites between flooding events and maximise waterbird recruitment
- Better predict the effects of water management and threats

Completion of the research plans and associated budgets

The Annual and Multi-year Research Plans and associated budgets for the Waterbirds Theme have been subject to several revisions, with changes made following feedback from the Department, SAG, JRG, and EWKR management and leadership. They are now fine-tuned and ready for contracting and implementation for the next three years. Planning, budget and contract information has been consistently supplied ahead of time.

Completion of the pilot study

Introduction

The pilot study was designed to:

1. collect new bird breeding success data, taking advantage of the breeding event occurring in Barmah-Millewa Forest during the 2015–16 summer
2. develop, test and improve survey methods and equipment for future quantification of breeding success and the impacts of associated threats and pressures.

Methods and study area

Pilot study fieldwork was conducted in Reed Beds Swamp, Millewa Forest, New South Wales, Australia. Other nearby breeding sites including Boals Deadwoods in Barmah Forest, Victoria were too inaccessible to attempt within the logistical limits of the pilot study, or not suitable for intensive data collection and analysis because of disturbance by the public or strategic raven predation (following boats).

The nests of three species were monitored: Australian White Ibis (the most common species), Straw-necked Ibis, and Royal Spoonbill.

The main tasks were:

- On-ground colony mapping and counts, including nest and adult counts, egg and chick counts at tagged nests, and recording nesting habitat characteristics

- Setting up, testing and installing motion-sensing and timelapse cameras, followed by image data extraction and analysis

On-ground colony mapping and associated counts were conducted in three sessions: November 2015, December 2015, and January 2016.

There were also three primary camera deployments, each with different settings tested:

1. November to December 2015 (30 cameras)
2. December 2015 to January 2016 (29 cameras)
3. January to February 2016 (15 cameras).

Every nest clump and camera location was GPS marked, and maps were constructed of their locations for each visit.

White Ibis nesting; photograph taken by Heather McGinness, CSIRO and the MDB EWKR project.

Preliminary results

On-ground colony mapping and counts over time

UNSW (K Brandis, M Bellio) conducted three field trips (9 November, 2 December, 16 December) to monitor marked nests in Reed Beds, Barmah–Millewa.

Summary notes

- Total clumps marked: 29
- Total nests marked: 222
- Reed Bed East: 9 clumps (1 RSP, 8 WHI/SNI); 79 nests
- Reed Bed West: 20 clumps (11 RSP, 9 WHI); 143 nests
- 6 records of destroyed nests (of marked nests)
- 11 nests deserted (of marked nests)

Table 12. Summary of egg and chick stage (chick, runner, squirter) numbers for Royal Spoonbill (RSP) and Australian White Ibis (WHI) at Reed Beds colony during each survey.

Colony	Species	Eggs 9/11/15	Chicks 9/11/15	Eggs 2/12/15	Chicks 2/12/15	Eggs 16/12/15	Chicks 16/12/15	Runners 16/12/15	Squirters 16/12/15
East	RSP	0	0	0	3	0	0	0	0
East	WHI[#]	43	0	64	70	17	23	24	37
West	RSP	0	0	51	0	33	39	2	0
West	WHI	31	0	210	7	78	109	20	6

Clutch sizes
Overall WHI = 2.3 (RBEast=2.45; RBWest=2.2)
Overall RSP = 2.8 (RBEast only)
Overall SNI =1.8 (RBEast only)

Table 13. Summary of clutch sizes (RSP-Royal Spoonbill, WHI-Australian White Ibis, SNI-Straw-necked Ibis).

Clump	Mean clutch size	Species	n	Colony
67	2.4	WHI	5	Reed Beds West
50	1	WHI	3	Reed Beds West
49	2	WHI	2	Reed Beds West
31	2.5	WHI	9	Reed Beds West
47	2.8	WHI	18	Reed Beds West
45	2.4	WHI	28	Reed Beds West
69	2.5	WHI	2	Reed Beds West
68	2	WHI	19	Reed Beds West
34	3.7	RSP	18	Reed Beds East
22	2	RSP	4	Reed Beds East
33	3	RSP	2	Reed Beds East
38	2.7	RSP	4	Reed Beds East
44	4	RSP	3	Reed Beds East
43	2.6	RSP	2	Reed Beds East
53	2.5	RSP	1	Reed Beds East
53	2	RSP	3	Reed Beds East
51	1.8	SNI	1	Reed Beds East
3	2	WHI	7	Reed Beds East
8	2.8	WHI	23	Reed Beds East
46	2.5	WHI	22	Reed Beds East
21	2.5	WHI	6	Reed Beds East
32	2.7	WHI	2	Reed Beds East
79	2.2	WHI	1	Reed Beds East

Success rates across all species
56% of eggs marked at T1 (9/11/15) were still present in nests or had hatched at T2 (2/12/15).
73% of eggs/chicks at T2 (2/12/15) were still present in nests or had hatched at T3 (16/12/15).
It is difficult to calculate an overall success rate for the entire time as many nests were added on the second field trip.

Straw-necked Ibis nesting; photograph taken by Heather McGinness, CSIRO and the MDB EWKR project.

Australian White Ibis nesting, Photograph taken by Heather McGinness, CSIRO and the MDB EWKR project.

Success by species
Royal Spoonbill T2–T3 only (starting nesting later than WHI) 83% success
Straw-necked Ibis T2–T3 only (not marked on first survey) 0% success (1 clump, 44 nests)
Australian White Ibis T1–T2 = 56%; T2-T3 = 82% success

Royal Spoonbill adults and chicks, Photograph taken by Heather McGinness, CSIRO and the MDB EWKR project.

Monitoring camera image analysis

Data extraction from camera images is complete for all deployments. The various settings tested have informed new protocols for the next field season aimed at addressing specific questions. Across the November and December deployments, a total of 144 nests were monitored by cameras for varying periods, with 20 nests monitored during both deployments. The duration of camera monitoring at each nest was often short (Table 14), and the dataset was complex because of variation in settings being tested, memory and battery limitations, camera swivel attachment problems and other logistical issues. In addition, where nests did not progress or were subject to predation, cameras were relocated. Consequently most cameras did not provide a continuous record of activities at each nest throughout the breeding period (Table 15), and the dataset was limited for the purpose of quantifying nest fates. However, the dataset did yield preliminary results of interest

describing numbers of eggs and chicks (Table 15) and aspects of predation, nest attendance, disturbance and bird behaviour.

Table 14. Number of nests with cameras: November and December deployments.

	Deployment 1 (November)	Deployment 2 (December)
Australian White Ibis	61	55
Royal Spoonbill	16	7
Straw-necked Ibis	1	23

Table 15. Summary statistics of the number of consecutive days of images and photos obtained per nest (across both November and December deployments).

	No. of days of images	No. of days of useful images on nest(s)	No. of photos
Mean	18	11	17082
Stdev	12	10	14769
Max	44	44	43624
Min	1	1	391

Table 16. Egg and chick counts at camera-monitored nests: November and December deployments.

Counts	AWI	RSB	SNI	Grand total
Number of nests	98	23	24	145
Total eggs laid	193	20	48	261
Total no. eggs failed to hatch	73	1	3	77
Total no. eggs in last useful images	80	8	21	109
Total no. chicks that died	7	1	2	10
Total no. chicks that fledged (older runners or flappers)	22	7	6	35
Total no. chicks in last useful images (all ages)	59	10	22	91

Predation was recorded at 24 nests (17% of the total number of nests with cameras). Of these, six were visited by predators more than once. All predation events were by native bird species, and 94% involved egg theft or consumption (Table 17). Only two chick predation events were recorded, while 34 eggs were recorded as taken or eaten. Three eggs were recorded as taken by Australian White Ibis from adjacent nests. All predation events recorded were on Australian White Ibis nests, except one — a Straw-necked Ibis chick being taken by a Swamp Harrier away from the nest. Most predation events occurred in one small area of the ibis colony, while other areas were not impacted. Entire clumps of nests were typically impacted within short periods. There were no predation events recorded at Royal Spoonbill nests.

The following sequence shows a young white-belled sea-eagle filling his crop with Australian White Ibis eggs that were being incubated just 30 minutes previously. Photograph taken by Heather McGinness, CSIRO and the MDB EWKR project.

Table 17. The number of eggs and chicks taken or killed for each species: November and December deployments.

Species	No. eggs taken/killed	No. chicks taken/killed
Australian Raven	4	
Australian White Ibis	3	
White-bellied Sea Eagle (juvenile)	11	
Purple Swamphen	3	1
Raptor sp.	1	
Swamp Harrier	5	1
Unknown	7	

All predation events recorded occurred during daylight hours. Predation events recorded for Australian ravens occurred in the middle of the day between approximately 11.30 am and 3 pm, while predation by juvenile White-bellied Sea Eagles mostly occurred late in the day between approximately 6 pm and 7.30 pm. Swamp Harriers and Purple Swamphens were recorded morning and afternoon.

Egg predation: Swamp Harrier and Australian Raven. Photograph taken by Heather McGinness, CSIRO and the MDB EWKR project.

Royal Spoonbills spent less time away from the nest than Australian White Ibis and Straw-necked Ibis. Nest attendance varied widely from nest to nest for Australian White Ibis, while Royal Spoonbills and Straw-necked Ibis were more consistent. The amount of time for which a parent was absent from the nest also appeared to vary with temperature, with less time absent at very high and very low temperatures.

Australian White Ibis eggs, chicks, and juvenile; photograph taken by Heather McGinness, CSIRO and the MDB

Australian White Ibis nesting behaviour: parental swapping, and a ‘bachelor party’; photograph taken by Heather McGinness, CSIRO and the MDB EWKR project.

Disturbances by predators or by humans while birds were preparing nests or at egg stage resulted in significantly greater lengths of time for which parents were absent from the nest than disturbances while chicks were present. When parental absence was caused by disturbance (predators or humans), more time was spent away from the nest at mild temperatures of 12–19 °C than at higher temperatures.

Further analyses in more detail are planned, including separate analysis of the January deployment dataset and investigations of potential interactions between stressors and other parameters.

Camera installations; photograph taken by Heather McGinness, CSIRO and the MDB EWKR project.

Table 18. Testing and comparison of remote motion-sensing and timelapse camera setups and programmed settings to inform future deployments. The various settings tested have informed new protocols for the next field season aimed at addressing specific knowledge gaps, as listed below.

Camera category	Variables	Type	Motion sensitivity	Pics per trig. Motion	Period armed for motion sensing	Time-lapse interval	Pics per trig. Time lapse	Period armed for timelapse	Pic rate (secs)	Quiet period	Nests in cam view
Recruitment: counts and growth	Species	Timelapse	None	N/A	N/A	5 minutes	1	24 hrs	N/A	N/A	Multiple
	Eggs	Timelapse	None	N/A	N/A	5 minutes	1	24 hrs	N/A	N/A	Multiple
	Hatchlings	Timelapse	None	N/A	N/A	5 minutes	1	24 hrs	N/A	N/A	Multiple
	Squirters	Timelapse	None	N/A	N/A	5 minutes	1	24 hrs	N/A	N/A	Multiple
	Runners	Timelapse	None	N/A	N/A	5 minutes	1	24 hrs	N/A	N/A	Multiple
	Flappers	Timelapse	None	N/A	N/A	5 minutes	1	24 hrs	N/A	N/A	Multiple
	Flyers	Timelapse	None	N/A	N/A	5 minutes	1	24 hrs	N/A	N/A	Multiple
	Adults	Timelapse	None	N/A	N/A	5 minutes	1	24 hrs	N/A	N/A	Multiple
	New egg laid? y/n	Timelapse	None	N/A	N/A	5 minutes	1	24 hrs	N/A	N/A	Multiple
	Chick(s) leaving nest? y/n	Timelapse	None	N/A	N/A	5 minutes	1	24 hrs	N/A	N/A	Multiple
	No. eggs rejected	Timelapse	None	N/A	N/A	5 minutes	1	24 hrs	N/A	N/A	Multiple
	No. eggs failed to hatch	Timelapse	None	N/A	N/A	5 minutes	1	24 hrs	N/A	N/A	Multiple
	No. chicks dead (not predation)	Timelapse	None	N/A	N/A	5 minutes	1	24 hrs	N/A	N/A	Multiple
	Total eggs laid before+during deployment	Timelapse	None	N/A	N/A	5 minutes	1	24 hrs	N/A	N/A	Multiple
Behaviour	Parent returning y/n	Motion	High	2	24 hrs	Hourly	1	Diurnal 7 am–7 pm	Rapidfire	?	1 OR 2 with good visibility
	Minutes eggs/chicks alone	Motion	High	2	24 hrs	Hourly	1	Diurnal 7 am–7 pm	Rapidfire	?	1 OR 2 with good visibility
	Parent departing y/n	Motion	High	2	24 hrs	Hourly	1	Diurnal 7 am–7 pm	Rapidfire	?	1 OR 2 with good visibility
	Minutes eggs/chicks attended	Motion	High	2	24 hrs	Hourly	1	Diurnal 7 am–7 pm	Rapidfire	?	1 OR 2 with good visibility
	Adult feeding chick? y/n	Motion	High	2	24 hrs	Hourly	1	Diurnal 7 am–7 pm	Rapidfire	?	1 OR 2 with good visibility
	Ibis nestcrash starts	Motion	High	2	24 hrs	Hourly	1	Diurnal 7 am–7 pm	Rapidfire	?	1 OR 2 with good visibility
	Ibis nestcrash ends	Motion	High	2	24 hrs	Hourly	1	Diurnal 7 am–7 pm	Rapidfire	?	1 OR 2 with good visibility
	Behavioural observations	Motion	High	2	24 hrs	Hourly	1	Diurnal 7 am–7 pm	Rapidfire	?	1 OR 2 with good visibility
Predation	Predation y/n	Motion	High	3	24 hrs	8 am, 6 pm	1	24 hrs	Rapidfire	0	Multiple
	Predator sp.	Motion	High	3	24 hrs	8 am, 6 pm	1	24 hrs	Rapidfire	0	Multiple
	Predation date	Motion	High	3	24 hrs	8 am, 6 pm	1	24 hrs	Rapidfire	0	Multiple
	Predation time	Motion	High	3	24 hrs	8 am, 6 pm	1	24 hrs	Rapidfire	0	Multiple
	No. eggs taken/killed	Motion	High	3	24 hrs	8 am, 6 pm	1	24 hrs	Rapidfire	0	Multiple
	No. chicks taken/killed	Motion	High	3	24 hrs	8 am, 6 pm	1	24 hrs	Rapidfire	0	Multiple
Disturbance	Human disturbance time	Motion	High	3	24 hrs	8 am, 6 pm	1	24 hrs	Rapidfire	0	Multiple

Theme coordination, leadership and reporting

The Waterbirds Theme Coordinator and Leadership Group have met regularly via teleconferences and face-to-face meetings (see list below) and have made substantial progress in research planning, conceptualisation, implementation and reporting.

The Waterbirds Theme Coordinator has invested significant time in improving integration with other themes. This has included a dedicated workshop in Canberra with the Food Webs Theme, preparation and circulation of conceptual models and related documents, meetings with the Vegetation and Food Webs Theme Coordinators to discuss links and strategies, Theme Leadership Group meetings to discuss these, and regular project management and Theme Coordinator meetings discussing integration. Specific plans for links in terms of field data collection and analysis have now been formed between the Waterbird and Food Webs themes and the Waterbird and Vegetation themes. Links between the Waterbirds Theme and the Fish Theme will be more conceptual and will be explored through the Food Webs Theme.

Activities

- Waterbirds Theme teleconference 10 July 2015
- Waterbirds Theme Workshop 15 July 2015, Canberra
- Theme Coordinators Workshop 23 July 2015, Wodonga
- Stakeholders Workshop 28 July 2015, Dubbo
- Waterbirds Theme Workshop 30 July 2015, Canberra
- Meeting 21 August 2015
- Science Advisory Group Workshop 27 August 2015, Sydney
- Theme Coordinators Meeting 2 September 2015
- Waterbirds Theme Workshop 4 September 2015
- Waterbirds Theme teleconference 17 September 2015 with Michael Wilson, MDBA re. waterbird tracking
- Development of draft research plans and associated budgets (Annual and Multi-year)
- Teleconference 21 September 2015
- Teleconference 23 September 2015
- Waterbirds Theme teleconference 24 September 2015
- Waterbirds Theme Workshop 25 September 2015, Canberra
- Waterbirds Theme teleconference 19 October 2015 with Keith Ward, GBCMA
- Theme Coordinators Workshop, 21 October 2015, Wodonga
- Waterbirds Theme teleconference 22 October 2015
- Animal Ethics Committee applications submitted
- Scientific Licence applications (NSW, VIC) submitted
- Revision of draft research plans and associated budgets (Annual and Multi-year)
- Research teams contracted
- Pilot fieldwork 8–12 November 2015
- Pilot fieldwork 1–4 December 2015
- Waterbirds Theme teleconference 16 December 2015
- Pilot fieldwork 16–17 December 2015
- Pilot fieldwork 12–15 January 2016
- Pilot fieldwork 15–18 February 2016
- EWKR/the Department Theme Coordinators, JRG and SAG Workshop 10–11 February 2016, Canberra
- Processing and analysis of pilot fieldwork data — commenced

- Waterbirds Theme teleconference 4 March 2016
- Waterbirds Theme meeting 8 April 2016, Canberra
- Waterbirds Theme Food Webs Workshop 14 June 2016, Canberra
- University of Canberra Postdoctoral Fellow Interviews 12 May 2016, Canberra
- Waterbirds Theme Teleconference 16 May 2016
- Jurisdictional Workshop, 19 May 2016, Dubbo
- Theme Integration Meeting — Waterbirds Theme, 25 May 2016
- Jurisdictional Workshop 9 June 2016, Canberra
- Waterbirds Theme teleconference 20 June 2016
- Theme Coordinator meetings and Integration meetings weekly or fortnightly
- Revision of Annual and Multi-year Research Plans and associated budgets
- Other meetings, teleconferences, email discussions and stakeholder engagement
- Progress reporting

Plans for 2016–17

- Further data analysis and interpretation of pilot study results
- Engagement with stakeholders, SAG, JRG, other EWKR Themes and other communications
- Purchase of satellite tracking equipment and new monitoring cameras
- Detailed movement and habitat use studies of at least 40 individuals of a focal species over the duration of the EWKR project using tracking devices (satellite/GPS), ABBBS leg banding and possibly radio-tracking. Trackers will be deployed in two phases: tracking of adults captured at the beginning of the breeding event and tracking of juveniles captured at fledging. Tracking of bird movements will focus on a single species — probably Straw-necked Ibis. The final species tracked and monitored will depend on which species nest and where.
- Colony mapping and adult count estimation, nest counts, monitoring of eggs and chicks, and collection of scat, regurgitate and shed feather samples at a subset of tagged nests (where these data are not already collected by other programs)
- Monitoring of predation (species, impacts, timing, location) and of eggs and chicks including quantification of feeding rates, chick condition and survival using analysis of images from remote motion-sensing and time-lapse cameras focused on nests.
- Surveys of nesting habitat characteristics (e.g. species, nest position, nest materials, water depth, vegetation type etc.)
- Surveys of foraging habitats surrounding nesting sites (species counts, foraging strike rates, water depth, vegetation type, distance from colony) at different points during the nesting cycle
- Detailed data collection within colonies will focus on multiple colonial nesting species that represent a range of diets, nesting habitat requirements and foraging habitat requirements: e.g. *Ibis* (Australian White and Straw-necked); *Spoonbills* (Royal and Yellow-billed); and *Egrets* (Great, Intermediate, and Little)
- Engagement with stakeholders and other communications
- Other activities as detailed in the Research Plan

1.4 Theme 4 — Food Webs

Table 19. Tasks and progress for 2015–16.

Component	Activity	Scheduled start	Scheduled end	Responsible agency	Status against timeline	Comments
W1.Foundational studies	W1.1 Knowledge review and conceptualisation	Nov 2015	Sep 2016	UC, MDFRC		
	W1.1.1 Initial literature review	Nov 2015	Nov 2015	MDFRC	Complete	
	W1.1.2 Establishment	Dec 2015	Dec 2015	MDFRC	Complete	Delayed due to subcontract preparation. Completed April 2016.
	W1.2 Method development and review of experimental approaches and method development	Dec 2015	Jun 2016	MDFRC, UC		Delayed due to subcontract preparation. Expected completion Nov 2016.
	W1.2.1 Review experimental approaches	Dec 2015	Feb 2016	MDFRC	Complete	Delayed due to subcontract preparation. Completed March 2016.
	W1.2.2 Review analytical methods	Dec 2015	Feb 2016	MDFRC	Complete	Delayed due to delays with subcontracting. Completed April 2016.

Component	Activity	Scheduled start	Scheduled end	Responsible agency	Status against timeline	Comments
	W1.2.3 Test methods	Mar 2016	May 2016	MDFRC	Complete	Delayed due to delays with subcontracting. Completed June 2016.
	W1.2.4 Reporting	Jun 2016	Jun 2016	MDFRC UC, Deakin and CSIRO		Delayed due to delays with subcontracting. Expected Oct 2016.
	W1.3 Modelling review and strategy development	Jan 2016	Jul 2016	Deakin University, CSIRO		Delayed due to delays with subcontracting. Expected Sept 2016.
	W1.3.1 Establishment	Jan 2016	Jan 2016	Deakin CSIRO	Complete	Delayed due to delays with subcontracting. Completed March 2016.
	W1.3.2 Review modelling approaches	Feb 2016	Mar 2016	Deakin CSIRO	Complete	Delayed due to delays with subcontracting. Completed June 2016.
	W1.3.3 Preliminary strategy	Apr 2016	Apr 2016	Deakin CSIRO		Delayed as dependent on integration between methods, knowledge review and

Component	Activity	Scheduled start	Scheduled end	Responsible agency	Status against timeline	Comments
						modelling for other themes. Expected Oct 2016.
W4. Theme coordination, leadership and reporting	F4.1 Theme coordination	Ongoing	Ongoing	MDFRC	Complete	
	F4.3 Theme leadership	Ongoing	Ongoing	MDFRC	Complete	
	F. End of project reporting	Jun 2018	Jun 2019	MDFRC		On track

Progress against scheduled theme activities

Section 2 of this report 'Progress against scheduled activities' reports on the overall progress by each theme in meeting project-wide obligations, such as knowledge review and conceptualisation, revising research plans and undertaking field work. Exceptions to this reporting for the Food Webs Theme are detailed below and summarised in Table 19. A summary of theme planning, activities and expected outputs for the reporting period is provided in the following section.

Overall

Upon receipt of the SAG feedback in August 2015, the Food Webs Leadership Team spent the period from September to December 2015 developing a conceptualisation process that was described in the updated Annual Research Plan. The Leadership Team held a workshop on 16 December 2015 to finalise the planned approach. There was then a hiatus over the Christmas break. In January, the focus shifted to getting contracts in place to support the completion of the 3 activities. This was particularly important for the Knowledge Review and the Modelling Review that were led by University of Canberra and CSIRO, respectively. The delays in contracting delayed commencement of these activities; however, this was mitigated to some extent by the recruitment of Rob Rolls by the University of Canberra to start work in March 2016 in the absence of a signed contract.

Upon receipt of the draft Annual and Multi-year Research Plans in May, the Department raised a number of issues around progress achieved within the Food Webs Theme. This feedback prompted the Leadership Team to refocus their efforts and engage with the Fish and Waterbirds themes to identify opportunities for Integration. These activities culminated in a Theme Leadership workshop on 8 June 2016 that led to the production of a scoping document for the Knowledge Review and Conceptualisation and a preamble for the Food Webs Theme that were provided to the Department. The workshop was also followed by a Waterbird–Food Webs workshop in Canberra on 14 June and

several meetings between the Food Webs Theme Coordinator, the Fish Theme Coordinator and a member of the Fish Theme Leadership Group to progress integration between themes.

Through for the remainder of May and June, the Theme Leadership Team worked on finalising the MYRP and ARP, and these were submitted to the Department in June. The updates were not major as only limited progress had been made due to delays in contracting and the need to engage with the Fish and Waterbird themes.

W1. Knowledge review and conceptualisation

The Knowledge review and conceptualisation undertook a systematic review of the literature that built on the Knowledge Status and Needs report. The review evaluates the relative importance and certainty of key food web interactions in order to support prioritisation of the many possible activities. As described above, progress on this activity was delayed until March 2015 when Rob Rolls was appointed by the University of Canberra to undertake the work. Since then, there has been significant progress and a draft publication is being prepared.

W1.2. Method development

This activity sought to identify the best analytical techniques available to investigate priority food web interactions identified in the Food Webs conceptualisation (W1.1), and to undertake some limited testing of the techniques using samples made available through other projects. Work through late 2015 had added further information to the knowledge status and needs report and identified a number of promising methods. Some additional work was undertaken on the review in February 2016 and the review completed by the end of February.

In the December 2015 workshop, the Leadership Team agreed to undertake some further evaluation, which was undertaken by MDFRC staff in conjunction with the Theme Leadership Group. Commencing in March 2016, MDFRC staff tested two potential methods:

1) Metagenomic analysis of gut contents that appeared to offer a fast and accurate way of determining what prey had been consumed. There were, however, technical issues that would need to be overcome in terms of eliminating the host animal's DNA from the analysis.
2) Evaluation of the effects of different sources of organic matter on microbial communities. This work sought to understand the extent to which changes in vegetation that lead to changes in the type of available organic matter would influence the microbial community. It was thought that changes in the microbial community may have cascading influences up the food web, which has been found in response to willow removal.

Work in these two areas progressed until June 2016 when the Leadership Team decided to wait until the conceptualisation process had been completed to ensure that the methods being tested were the methods needed to answer the priority questions.

W1.3 Model development

The review of food web modelling approaches sought to identify the most appropriate approach to modelling given the need to integrate between the MDB EWKR research themes, particularly in relation to the waterbird and native fish outcomes. The review is being led by Barbara Robson and Rebecca Lester with input from the Theme Leadership Group.

As noted above, progress on this activity was delayed, first by delays in the contracting process, then by Barbara Robson's changed role within CSIRO, and finally due to some uncertainty amongst the Leadership Team concerning the role of modelling within the Theme, the extent to which the Theme should use existing models and the role of individual members of the Leadership Team.

All of these factors have meant that this review has not been completed at June 30. It is anticipated that it will be completed once the Leadership Group has agreed on the priority questions, which will have a bearing on the modelling approach.

Summary of activities for the reporting period

The following sections explain how each component of the theme is being planned and developed, and outlines the expected research outcomes.

Flow has three major functions in riverine systems; disturbance acting to influence community composition and dynamics, the provision of cues for major life-history events, and as an influence on energetics through transferring materials longitudinally along the river, laterally between the river and its margins, and vertically between the sediment and the water column.

In the Murray–Darling Basin, the role of flow in disturbance dynamics and as a trigger of life-history events (such as breeding or dispersal) is reasonably well known. Over several decades we have gained an understanding that low flow can reduce the biomass and change the composition of ecological communities. Flooding in the years following the Millennium Drought has allowed a greater understanding of the role of high flow disturbance. Similarly, work on a range of species including native fish, floodplain vegetation, woodland birds, small mammals and amphibians has shown that flow events are important triggers for life-history events such as flowering, seed set and breeding.

What is much less clear is the role of flow in generating the resources that are needed for these key life-history events to result in recruitment of plants and animals into breeding populations. There have now been numerous instances where bird breeding, for example, has been triggered by a flow event, but where the birds have either aggregated and then not nested, or nested and failed to raise chicks to independence. Similarly, even where fish breeding is initiated by a flow event, we have limited evidence that the resulting fish larvae have access to the resources needed to allow them to grow to sexual maturity.

The Food Webs Theme has identified the relationship between environmental flows and the provision of resources across life-stages of plants and animals to be a critical knowledge gap in the Murray–Darling Basin. This has led us to take a bioenergetic approach to investigating the effect of environmental flows. Bioenergetics describes ecological systems as a series of 'stocks' of energy (the nutritional value of plants or animals) and 'fluxes' between those stocks. Given the gaps in current empirical understanding of food web dynamics in the Murray–Darling Basin, we have proposed to approach the theme in two stages. In the first stage, we will undertake a process to consolidate our knowledge (foundational activities) to help underpin the second stage of the project, which will focus on computer model development, calibration and validation, utilising both field studies and laboratory analyses.

Foundational activities

In 2015–16, we undertook a series of foundational activities to ensure a solid basis for the data acquisition and modelling work, which will begin in 2016–17.

W1.1 Food web conceptualisation

The purpose of this activity is to identify and document key ecosystem components and processes that together will be used to develop a detailed conceptual model linking flow with food webs in lowland rivers. The component is well advanced, and a draft report is due in early August.

A postdoctoral appointment was made in April 2016 at the University of Canberra to build on the earlier review activities undertaken in 2015. Since commencing, they have drafted a scope, structure and work plan to achieve subcomponent 1.1 of the EWKR Food Webs Theme project ('model conceptualisation'). The review first examined what key conceptual models of riverine functioning says about trophic dynamics under five flow regimes — reflooding following drying, base flow, in-channel freshes, bank-full flooding and over bank floodplain inundation (Table 20). Then an extensive examination of the literature (reviewing approximately 200 published papers) was undertaken to determine whether or not there is any empirical evidence to support these models. There are significant limitations in the published literature. In general there has been a focus on energy production at the expense of energy transfer. Most empirical research is ultimately using data to test support of which energy sources are 'fueling' food webs, but there are limited data or understanding on the transfer of energy within food webs). There also has been an emphasis of structural attributes of food webs with less emphasis on the functional transfer of energy among food web components. We have a better understanding of (i) 'who is eating who' and (ii), structural organisation of communities, both under the name of 'food web', rather than 'to what extent does energy from prey source A makes it consumer B?'). The literature reflects a stronger interest in the effect(s) of individual species than on community and ecosystem interactions. Finally, there has been little direct emphasis on the effect(s) of hydrological and hydrological regimes on the production and transfer of material within and among ecosystems. A summary of what has been gleaned on the production and transfer of energy under different flow regimes is summarised in Table 21.

Following on from the review we propose a 'Nutritional Landscape' approach to understanding food web dynamics in lowland rivers and how they are impacted by flow. Nutritional Landscape is a term borrowed from the human nutritional literature and explores food dynamics in a spatially (and potentially temporally explicit way).

Table 20. Summary of conceptual models describing energy production, transfer and use within river environments, and inferences of the role of different hydrological components of rivers and their floodplains.

Model	Overarching emphasis	Hydrological component				
		Channel re-wetting following drying	Low flow (Baseflow)	In-channel pulses	Bank-full floods	Overbank floodplain inundation
River continuum concept (RCC) (Vannote et al., 1980)	A predictable longitudinal sequence of organic matter input and food web structure along the continuum of physical and chemical gradients in rivers	Drying stops the production of benthic algae and allows for the accumulation of terrestrial detritus	Longitudinal variation in the sources of energy and food web composition is most apparent	Increased delivery of terrestrial detritus from upstream reaches	Longitudinal variation in energy sources and food web structure is reduced as discharge transports terrestrial detritus downstream	Increased biomass of terrestrial inputs to the food web due to inundation
Flood pulse concept (FPC) (Junk et al., 1989)	Nutrient and energy exchange between the main channel and floodplain environments of lowland rivers is facilitated by inundation and connection during flooding	Terrestrial material accumulated during drying periods is rapidly incorporated into the food web during the moving littoral of the aquatic/terrestrial transition zone (ATTZ)	Insufficient magnitude of flow to connect the floodplain to the channel environment	Insufficient magnitude of flow to connect the floodplain to the channel environment. Potentially some input of terrestrial material from benches	Insufficient magnitude of flow to connect the floodplain to the channel environment. Potentially some input of terrestrial material from benches	Pulse of energy input from floodplain into main channel environments; limited production in channel during this period due to high turbidity
Serial discontinuity concept (Ward and Stanford, 1983, 1995)	Longitudinal resource gradients (predicted by the RCC) are disrupted by the effect of instream structures altering the downstream transport of material and creation of stable environments with little water movement	Identical to the RCC	Longitudinal transport of terrestrial energy sources accumulated during drying is hindered by barriers; increased pelagic production in weir pools; possibly	Increased retention of organic material (terrestrial) in weir pools; loss of some production due to settling and burial in weir pools; decreased availability of	Increased retention of organic material (terrestrial) in weir pools; decreased availability of terrestrial energy in flowing channels downstream of weirs	Elevated input and transport of terrestrial energy, although less than under unregulated conditions

Model	Overarching emphasis	Hydrological component				
		Channel re-wetting following drying	Low flow (Baseflow)	In-channel pulses	Bank-full floods	Overbank floodplain inundation
			dominant benthic production in flowing stream sections	terrestrial energy in flowing channels downstream of weirs		
Riverine productivity model (RPM) (Thorp and Delong, 1994)	Local primary production and riparian inputs are important energy sources as they are more readily incorporated into the food web than organic matter delivered from headwaters or floodplains	Rapid increase in autochthonous production and terrestrial-derived energy incorporated into consumers	Instream primary productivity is the primary contributor to secondary production	Despite increasing inputs of terrestrial energy sourced from upstream, local energy inputs remain as the primary energy source	Despite increasing inputs of terrestrial energy sourced from upstream, local energy inputs remain as the primary energy source	Increased inputs of terrestrial energy from the floodplain are mostly available to local food webs and become less important with increasing distance
River wave concept (Humphries et al., 2014	River flow is a series of waves of varying characteristics, and the source and transport of organic matter differs throughout the rise and fall of each wave	Terrestrial inputs provide energy for the food web during initial inundation	Both in-channel primary production and terrestrial detritus fuel food webs	Longitudinal transport of autochthonous material dominates energy input	Increasing inputs of terrestrial energy from channel edges and the riparian zone	Both allochthonous and terrestrial production and inputs fuel food webs
Riverine ecosystem synthesis/functional process zones (Thorp et al., 2006)	Existing models (e.g. RCC, RPM, FPC) can be integrated with a patch dynamics framework. Hydro-geomorphic differences among patches form distinctive functional process zones.	Unable to determine although assumed that terrestrial energy dominates energy input to food webs	Autochthonous primary production provides energy inputs to food webs	Living or detrital phytoplankton is the dominant form of energy mobilised and transported	Living or detrital phytoplankton is the dominant form of energy mobilised and transported	Autochthonous primary production is the main energy source for floodplain food webs, although dependent on temperature

Model	Overarching emphasis	Hydrological component				
		Channel re-wetting following drying	Low flow (Baseflow)	In-channel pulses	Bank-full floods	Overbank floodplain inundation
Hydraulic food chain models (Power et al., 1995)	Standing stocks of energy within food webs are determined by rates of consumption by higher consumers, efficiency of biomass transfer, mortality of consumers, and inputs of energy in to the ecosystem. Temporal variation in hydrology affects each of these aspects of the food web, yet effects of hydrology are determined by the interaction between discharge and channel–floodplain geomorphology, which manifest as differences in stream hydraulics.	Accumulated terrestrial matter is available to the food web in conjunction with an increase in instream primary production	Large-bodied consumers actively avoid shallow habitats due to the risk of predation by terrestrial consumers (e.g. waterbirds)	Energy lost from the food web via downstream transport is replaced via inputs from upstream; consumption of energy by consumers ceases at a point where ingestion is reduced and organisms are displaced from the substrate ('slip speed'); constant elevated discharge leads to starvation of non-hydrodynamic consumers	Scouring flows remove benthic autotrophs such as benthic algae, and contribute to a large pulse of downstream longitudinal transport of organisms	Large amounts of terrestrial energy are made available to the food web, and consumers redistribute onto the floodplain to make use of this material; during post-inundation recession, mobile consumers return to main channel

Table 21. Summary of published evidence of the role of hydrological components on the production and transfer of energy within freshwater food webs.

Hydrological component	Energy production	Energy transfer
Channel drying	Accumulation of terrestrial organic matter for incorporation in the food web on inundation Reduced mechanical breakdown and decomposition of terrestrial organic matter by bacteria and detritivores Desiccation of aquatic primary producers (benthic algae) enhances the contribution of terrestrial energy sources	Extinction of keystone species that maintain essential nutrients within the food web Reduced secondary production of primary consumers Loss of apex predators causing reduced food chain length and top-down trophic cascade effects on primary producers
Baseflow/low flow	Recolonisation and recovery of aquatic algae during rewetting increases autochthonous primary production Variable effects of base flow on primary productivity (benthic algal productivity is increased under base flow conditions or reduced due to deteriorating water quality)	Aquatic energy production supports consumers in floodplain rivers. However, high mortality of consumers during no-flow or low-flow conditions has been hypothesised to be due to low energy availability. Seasonal variation in energy incorporated into consumer biomass suggests that both autochthonous and terrestrial sources are necessary for the persistence of consumers Longitudinal and lateral transfer of material and organisms by flowing water is disrupted or limited by no-flow or low-flow, reducing feeding success and energy transfer to consumers in both aquatic and riparian habitats Geomorphological and physical features created during low conditions alter the availability of prey for consumers
In-channel pulses	Total production of energy increases during in-channel pulses via the inundation of channel banks and benches retaining terrestrial detritus Increased water velocity positively affects autochthonous primary production, up to a point of channel scouring where drag-disturbances lead to loss of benthic producers	Increased mechanical breakdown of terrestrial matter due to abrasion and hydraulic forces (turbulence) Increased longitudinal movement of energy (e.g. drifting invertebrates) positively linked with water velocity and discharge enhances the body growth, condition and population biomass of consumers Prey capture by drift feeding consumers is impacted as discharge exceeds the swimming performance and energetic costs of sourcing food Frequent inundation and drying of channel edge habitats impacts persistence of invertebrates that spawn on river edges, which in turn affects transfer of energy from primary producers to consumers Variable effects of in-channel hydrological variability on food chain length suggest that hydrology is one of a suite of factors determining food web size

Hydrological component	Energy production	Energy transfer
Bank-full floods	Net terrestrial energy inputs to aquatic food web increases due to the inundation of dry edge habitats or overland transport during flooding Drag forces scour autochthonous producers from the stream channel Increased turbidity, often associated with flooding, restricts solar inputs to the stream bed Primary production is reduced or ceased by smothering of benthic biofilm by transported sediments	Removal of primary consumers by flooding lowers prey availability for riparian consumers, reducing body growth Reduced autochthonous energy availability contributes to poor body condition of consumers Reduced population density of multiple trophic levels in the aquatic food web during flooding hypothesised to be due to lower total energy available Top-down consumer effects on standing stock availability of primary producers via trophic cascades
Floodplain inundation	Greater inundated surface area enhances the autochthonous primary production on the floodplain Production from terrestrial detritus is enhanced during inundation Availability of terrestrial carbon in to the food web is increased by drying and wetting compared to sustained inundation	Apex consumer biomass is enhanced during foraging in newly inundated habitats on the floodplain Greater secondary production of primary consumers (e.g. zooplankton, detritivores), particularly on the floodplain Frequent drying and wetting of the floodplain increases availability and nutritional value of energy sources for consumers

W1.2. Method review and testing

There are numerous methodological approaches to exploring food web dynamics. The objective of this activity is to determine the most appropriate, feasible and cost effective methods to be used in EWKR, and as has emerged through our consultation with water managers, in broader Monitoring and Evaluation programs.

Both the SAG and the JRG felt that the project would benefit most from adopting a bioenergetics approach to the questions regarding flows and food webs, rather than from mapping lowland river food webs. Furthermore, both the Waterbird and Fish themes feel that the greatest link between the two themes and the Food Webs Theme is through studying juvenile nutrition (see above). Therefore, this activity has focused on methods to determine key prey items of juvenile native fish and colonial nesting water birds, understanding the nutritional value of those prey items, and identifying the basal resources that underpin those resources.

Identifying prey items*:* Traditional methods of determining prey items through physical examination of regurgitate (in the case of birds), gut content and scats is time consuming, inaccurate and, in the case of juvenile fish, very difficult. Linking a DNA sequence to a species has become fairly routine with molecular 'barcode markers' becoming standardised for animals, plants and fungi. Determining diet from DNA sequences in gut and faecal samples has been a more recent innovation in terms of next-generation sequencing (NGS) and is particularly valuable when the morphological stage of remains are not conducive to reliable identification. However, the abundance of DNA mixtures, the digested nature of prey DNA (smaller sized fragments) and the presence of consumer DNA contaminating samples exposes several significant challenges rendering typical barcoding unsuitable. These new approaches often result in compromises to taxonomic resolution, which is counter to the ambition of the studies. There is also no universal approach; rather, a suite of technologies that offer pros and cons that need to be understood in terms of the technical constraints and the predator-prey system under investigation. A review of available methods has been undertaken to assess the most effective in terms of cost, effort and output. The review identified blocking predator DNA and using COI barcoding as the best approach.

The method validation experiment was conducted as an *in silico* analysis and involved retrieving all Australian fish COI nucleotide sequences from Genbank and alignment with Mega7. The published use of COI mini-barcode fish primers is specific to the Northern Hemisphere and mostly saline species, so *in silico* checks are advised. Alignments were visualised and a range of potential primers were tested for binding site conservation for the mini-barcodes. With the primer sites identified across the database, the sequences were then trimmed to the amplicons size. This allows *in silico* restriction enzyme cleaving with Cleaver software, which identifies restriction enzyme cutting sites against selected sequences. The approach was tested using Mountain galaxias (*Galaxias olidus* Günther) and Golden perch as the predator. The enzyme BglII made the least cuts to all other fish species, i.e. the enzyme will exclude the predator and two other fish species (Freshwater catfish and Australian smelt (*Retropinna semoni* Weber)), which means that those two species would not be detectable in the analysis of gut contents. Early results suggest that the approach is feasible, but only if the gut content is suitably preserved.

Nutritional value of prey*:* Understanding the calorific (energy value) of prey items represents only a small component of bioenergetics. Even if a prey item is energy dense, it may have little value in sustaining an organism because it lacks essential amino acids, fatty acids and trace minerals necessary for maintaining growth — an important consideration for recruitment. The MDFRC has recently purchased a new ultra-high performance liquid chromatograph with a quadrupole mass-spectrometer for the determination of amino-acids in prey items. This instrument has been installed and is currently being commissioned. We have also recently installed a graphite furnace on our

atomic adsorption spectrophotometer to allow us to determine trace metals in prey items. We are in the process of identifying suitable external contractors for fatty acid analysis.

Basal resources*:* The dominance of blue-green algae in the southern Basin has emerged as a potential threat to lowland river food webs. In 2016, a dense bloom of blue-green algae impacted on 1700 km of the Murray, Edward and Wakool rivers. Blue-green algal blooms that affect large swathes of river channel are rare world-wide. Historically, such blooms have been reported in the Murray River in the early-1930s following the commissioning of Lake Hume (a process called trophic upsurge, which has to do with the release of nutrients from inundated plants and soil), and in the mid-1940s coinciding with the War Drought. However, the Murray River has been subjected to mega-blooms in 2003, 2007, 2009, 2010 and 2016. Given the potential link between these blooms and climate change, there is a likelihood that such large and persistent blooms will become even more common into the future, and in fact may become the dominant basal resource in the river. Our earlier review identified that blue-green algae are a nutritionally poor basal resource for fish in particular.

In our earlier examination of the literature, compound-specific stable isotope analysis, especially of essential fatty acids and amino acids, was highlighted as a potentially powerful technique for the identification of basal resources in food webs. However, after approaching both a local (CSIRO Oceans and Atmosphere) and an international (Stable Isotope Facility at the University of California Davis) service provider, it is evident that there is only a limited capacity to get samples analysed (typically 10–50 samples per year).

After consultation with key stakeholders, the theme will develop a framework for explicitly incorporating aspects of trophic dynamics into Monitoring and Evaluation plans for understanding the impact of environmental flows on ecosystem functioning.

W1.3. Model scoping

There are a wide variety of food web models and modelling approaches in the literature (e.g. Ecopath, Bayesian belief networks, dynamical systems modelling, network structure modelling), each with strengths and weaknesses, and each with different data requirements and predictive capabilities. To ensure that MDB EWKR develops a robust and defensible food web model that is well suited to the type of data that we can collect and appropriate for the type of management scenario to which it will be applied, the objective of this activity is to review the current state of the art in food web modelling.

In 2015–16, the team from CSIRO and Deakin University has commenced a comprehensive review of food web modelling approaches in the scientific literature, focusing on recent papers. The review is currently predominantly focused on mass-balances approaches that may be most relevant to predict flow-driven changes in food webs. More than 200 papers have been identified as being relevant and 50 have been assessed in detail for their data requirements, ability to make use of data collected in EWKR across the various themes, relevance to the conceptual models, suitability for environmental flow response scenarios and the evidence for their predictive capacity. Summary statistics from that review are being developed including patterns of use through time, ecosystem types that each modelling approach has been applied to and the number of validated models for each approach. Two key findings to date are the relative lack of studies applying food web models to riverine systems, particularly where unidirectional flow has been incorporated into the model explicitly, and the tendency for food quality to be excluded from many model types. Both are avenues that we will explore in the review to assess their applicability to the EWKR food web model.

Work has commenced on drafting the modelling review and the team are on track to submit the manuscript to a leading peer-reviewed journal by the end of the Conceptualisation Phase, and to

provide a recommendation as to the most appropriate modelling approach to yield management-oriented results that explicitly assess food web response to environmental flows.

W4. Theme coordination, leadership and reporting

This component includes theme research planning, coordination and reporting, including contributions to Annual and Multi-year Research Plans, Mid-year and Annual Progress Reports, within-theme and between-theme communication, SAG, JRG and the Department communication, and external communication. There has been significant investment in this component. A list of activities that have occurred between 1 July 2015 and 30 June 2016 are given below.

- Theme Coordinators Workshop 23 July 2015, Wodonga
- Theme Leadership meeting, Sydney 8 August 2015
- Development of draft research plans and associated budgets (Annual and Multi-year), August 2015
- Science Advisory Group Workshop 27 August 2015, Sydney, presentation of proposed theme research
- Theme Coordinators meeting 2 September 2015
- Theme Leadership Update report 26 October 2015
- Theme Leadership Update report 24 November, 2015
- Theme Leadership meeting (teleconference) 8 December 2015
- Revision of draft research plans and associated budgets (Annual and Multi-year), December 2015
- Modelling Component teleconference 5 February 2016.
- EWKR/the Department Theme Coordinators, JRG and SAG Workshop 10–11 February 2016, Canberra
- Leadership Meeting 15 April 2016
- Ad hoc discussion of EWKR and potential links to TLM at the TLM Icon Site Managers Forum, 4–5 May, Mildura (cross-project collaboration)
- Theme Leadership meeting, Melbourne, 8 June 2016
- Food Webs–Waterbird workshop 14 June 2016
- Scoping document produced on 15 June 2016
- Food Webs –Waterbird integration meeting week of 20 June
- Theme Coordinator and Integration teleconference meetings weekly or fortnightly
- Revision of Annual and Multi-year Research Plans and associated budgets
- Other meetings, teleconferences, email discussions and stakeholder engagement
- Progress reporting

W5. Integration across themes

Members of the Food Webs Leadership Group have also been liaising with the Fish and Waterbirds themes to ensure that conceptual models developed in both of these themes (due within the next few months) are incorporated into the final review document. Energy flow and nutritional value is a common element across the Waterbirds, Fish and Food Webs themes. Both the Waterbirds and Fish themes are interested in the food resources that are required to support recruitment, in particular the food resources needed to support juvenile birds and fish.

Members of the Food Webs Leadership Group met with the Waterbirds Theme twice in June 2016 to discuss integration. For the Waterbirds Theme, critical aspects of food web dynamics are to facilitate chicks to fledge and juveniles surviving to adults, of which the first issue, chicks fledging has been

identified as the most important. Understanding what food web dynamics are required to assist chicks to fledge requires an understanding of how much energy it actually takes to raise a chick, understanding the nutritional value of the chick feed and understanding how flows can be used to influence positive outcomes for bird breeding through their impact on food webs.

W6. Stakeholder engagement (table and text describing highlights/achievements

There has been stakeholder consultation at various stages throughout the MDB EWKR planning process. Some of this consultation has occurred at the whole-of-project scale and other communication has been more specific to themes. Consultation and communication has occurred through both formal channels (e.g. structured workshops, targeted phone calls) as well as ad hoc/opportunistic communication around other projects and/or attendance at non-MDB EWKR related workshops. Where possible, a record of this communication has been kept (Table 22).

Table 22. Stakeholder communication and consultation.

Date	Type of communication	Person(s)	Organisation(s)	Notes
5 Aug	Workshop Annual Food Webs Theme research workshop, Sydney	Food Webs Leadership Group	Multiple organisations (see leadership list)	Research planning
27 Aug 2015	Presentation (Darren Baldwin) Science Advisory Group Workshop, Sydney	The Department, SAG, Theme Coordinators, MDFRC Project Management	Multiple organisations (see attendance list)	Presentation of Vegetation Theme research direction to the SAG
10–11 Feb 2016	Presentation JRG Workshop Canberra	Multiple people (see attendance list)	Multiple organisations (see attendance list)	See notes/feedback captured in EWKR project management
6 Apr 2016	Presentation to Southern-Connected Basin Environmental Watering Committee	Multiple People	Multiple Organisations	Presentation of conceptual understanding of carbon dynamics and flows in lowland rivers, including understanding the role of environmental flows in transferring energy subsidies from floodplains to rivers
4 May 2016	TLM Icon Site Managers Forum (Mildura)	Multiple people	Multiple organisations	Presentation of conceptual understanding of carbon dynamics and flows in lowland rivers, including understanding the role of environmental flows in transferring energy subsidies from floodplains to rivers
24 May 2016	Regional Engagement Workshop, Shepparton	Multiple People	Multiple organisations	Presentation of the objectives and activities of the EWKR Food Webs Theme to jurisdictional representatives associated with Barmah–Millewa and Gunbower forests.
1–2 Jun 2016	Workshop NSW OEH Murray Lower Darling Long Term Watering Plan Workshop, Albury	Multiple people (see attendance list)	Multiple organisations (see attendance list)	Presentation of conceptual understanding of carbon dynamics and flows in lowland rivers, including understanding the role of environmental flows in transferring energy subsidies from floodplains to rivers. Also presented on approaches to incorporate environmental processes, including trophic dynamics, into environmental flow monitoring and evaluation programs
5 Jun	Workshop Annual Food Webs Theme research workshop, Melbourne	Food Webs Leadership Group	Multiple organisations (see leadership list)	Research planning

1.5 Adoption

The MDB EWKR project has engaged with managers from the beginning of the project in order to ensure that the project would address their needs and to seek input to the development of this Adoption Strategy through both an evaluation of Decision Support Tools and subsequent consultation about their decision-making processes and knowledge-seeking strategies. These activities have also helped develop relationships with key stakeholders that will be important to successful adoption.

In the 2015–16 year, activities were undertaken to support development of an Adoption Plan for the EWKR project. In line with the fundamentals of adoption, these activities were undertaken in consultation with the managers who will be the focus of the adoption activities. The following sections identify the major activities undertaken.

1.5.1 Reviewing approach to adoption

In light of feedback delivered through both the review of Decision Processes and Decision Support Tools and the JRG, the MDFRC reviewed its approach to adoption and, in line with the advice from the JRG, committed to the development of an adoption plan that would include a process of ongoing engagement with managers. The project team recognised the challenges associated with both achieving and evaluating adoption given that flow management decisions are based on a wide range of inputs and that these are often accessed and applied through an extensive consultation process. It also became clear that adoption is not a simple linear process of accessing information and applying it to a decision. Adoption usually occurs in a number of phases that starts with an awareness of new knowledge, moves into a period of exploring and trialling, before then applying and finally evaluating the new knowledge (Figure 10).

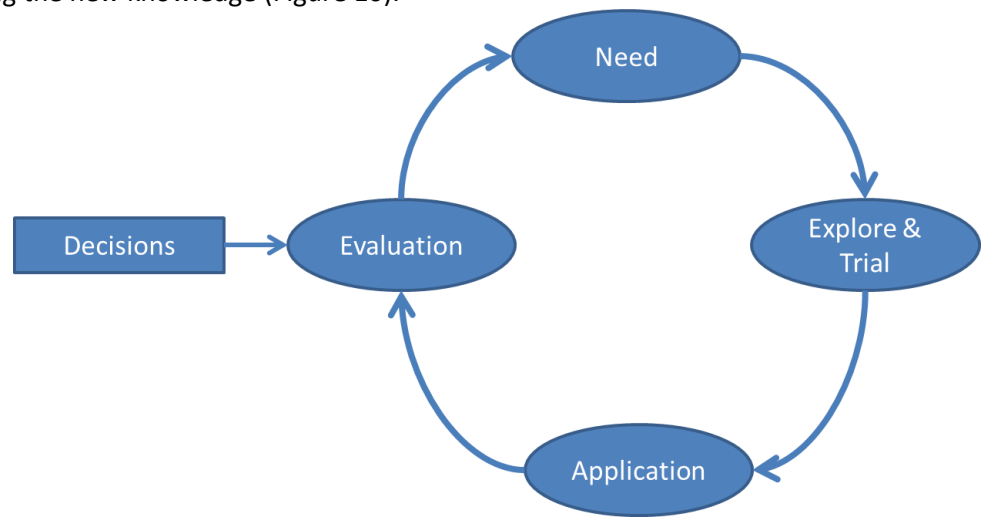

Figure 10. Adoption is driven by need. In the current context the need is for knowledge to underpin decisions. When a decision needs to be made there is an evaluation of the knowledge available to inform the decision and once needs have been identified, the manager will seek and trial new knowledge before applying it and finally evaluating whether the knowledge has influenced the need.

In recognition of the complexity, the project team developed a model, which recognised that adoption is driven by need, but that information needs to be managed in a way that ensures that it is:

1. accessible
2. relevant

3. applicable
4. feasible
5. credible.

These characteristics can be considered to act as filters through which information needs to pass before it can be adopted (Figure 11. Illustration of the MDB EWKR adoption model identifying that adoption is driven by managers' knowledge needs, which emerge from the decisions they need to make. In order to be adopted, knowledge needs to pass through five filters: Accessibility, Relevance, Applicability, Feasibility and Credibility.).

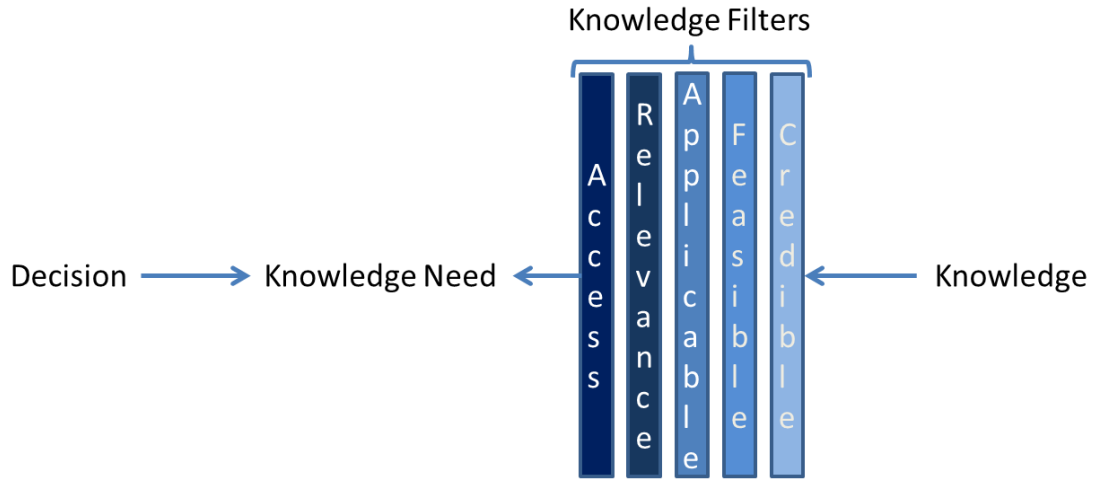

Figure 11. Illustration of the MDB EWKR adoption model identifying that adoption is driven by managers' knowledge needs, which emerge from the decisions they need to make. In order to be adopted, knowledge needs to pass through five filters: Accessibility, Relevance, Applicability, Feasibility and Credibility.

1.5.2 Jurisdictional Reference Group workshop

The JRG have several roles within the Project's Adoption Strategy, including:

- ensuring that the knowledge generated by the project aligns with managers' needs
- helping promote awareness of Project outputs among their network
- incorporating MDB EWKR derived knowledge into the consultation processes that they participate in.

A JRG workshop was held in February 2016 to both seek their input to the Multi-year Research Plan and to seek their input on development of the Project's Adoption Strategy. From the perspective of the Adoption Strategy, the JRG reinforced the need for strong commitment to communication and an ongoing process of adoption throughout the life of the project.

1.5.3 Regional workshops

In May and June of 2016, six regional workshops were held with managers that sought input on approaches to adoption. A list of attendees and their institutions is provided in Table 23. The workshops built on the review of DST that had revealed that decision processes are made in consultation with a large number of stakeholders and experts. Given this process, one of the major pathways by which knowledge is applied to management decisions is through the consultation process and that the MDB EWKR project could improve adoption if it capitalised on these existing networks rather than seeking to impose a new or additional sources of knowledge on managers. The workshops discussed decision-making processes and identified the networks of expertise used by the managers who attended.

Table 23. List of regional workshops, their attendees and institutions.

Workshop location	Date	Attendees	Institution
Buronga, NSW (Lower Murray)	17 May	• Iain Ellis • Anthony Moore • Louise Chapman • Scott Jaensch • Andrew Greenfield • Richard Mintern • Cherie Campbell	• NSW Fisheries • DoEE • Mallee CMA • NSW OEH • Mallee CMA • CEWO • MDB EWKR (MDFRC)
Dubbo, NSW (Macquarie)	19 May	• Tim Hosking • Paul Keyte • Steph Suter • Debbie Love • Patrick Driver • Sam Davis • Julie-Anne Harty • David Preston • Heather McGinness	• NSW OEH • NSW OEH • NSW OEH • NSW OEH • NSW Fisheries, JRG Rep • NSW Fisheries • NSW OEH • NSW OEH • MDB EWKR (CSIRO)
Shepparton Vic (Mid-Murray)	24 May	• Keith Chalmers • Paul Childs • Alison Borrel • Kathryn Stanislawski • Keith Ward • Lisa Duncan • Darren Baldwin	• Vic CEW • NSW OEH • NSW OEH • NC CMA • GB CMA • GB CMA • MDB EWKR (CSIRO/MDFRC)
Adelaide (Lower Murray)	1 June	• Michelle Campbell • Irene Wegner • Jan Whittle • Tumi Bjornsson • Jason Higham • Kane Aldridge • Tracey Steggles • Karl Hillyard • Dan Hanisch • Alison Stokes	• CEWO • DEWNR • DEWNR, JRG Rep • DEWNR • DEWNR • DEWNR, JRG Rep • DEWNR • DEWNR • DEWNR • DEWNR
Toowoomba Qld (Lower Balonne)	2 June	• Steve Goudie • Jim Weller • Andrea Prior • Peter Brownhalls • Rosemary Millward • Rosemary Coburn • Suzie Johnson • Glenn McGregor • John Ritchie • Paul Webb	• DNRM • DNRM • DNRM • DNRM • CEWO • DNRM • DNRM, JRG Rep • DSITI, JRG Rep • DNRM • QMDC
Canberra	9 June	• Sam Roseby • Paul Marsh • Karen Stuart-Williams • Nerida Sloane • Linda Reid • Hilary Johnson • Bruce Campbell • Nadia Kingham	• CEWO • CEWO • CEWO • CEWO • CEWO • CEWO • CEWO • DoEE

Workshop location	Date	Attendees	Institution
		• Anthony Moore • Bonnie Learmonth • Tristan Skinner • Kelly Marsland • Carmel Pollino • Heather McGinness	• DoEE • DoEE • MDBA • MDBA • CSIRO • MDB EWKR (CSIRO)

In terms of adoption, some of the key messages to emerge from the workshops were:

- decisions processes include a high degree of consultation
- managers are knowledge hungry but time poor
- managers rely on their networks that include managers, experts and local stakeholders
- science is only one input that managers integrate with other sources of information including management experience, community and indigenous knowledge
- the conceptual models that will be produced by MDB EWKR are of interest to managers
- there was a preference for decision-making frameworks over DST
- being solution focussed is often more effective than being problem focussed
- infographics are a good way to communicate with managers, public, media. This includes maps and GIS products
- consultation with experts tends to be about outcomes whereas conversations with managers tends to be about risks. These diametrically opposed views are often hard to reconcile/integrate.
- it is difficult to focus on ecosystems — get pulled to plan for higher profile species. A framework to consider ecosystem would be helpful.

Figure 12. Attendees at the mid-Murray regional workshop discussing the project over lunch. From left to right are Paul Childs (NSW OEH), Keith Ward (GB CMA), Jessica Davison (MDFRC), Keith Chalmers (VEW), Anna Parker (NC CMA), Alison Borrell (NSW Parks), Kathryn Stanislawski (NC CMA), Darren Baldwin (MDFRC) and Jess Wilson (MDFRC).

Figure 13. Attendees at the Macquarie regional workshop listening to a presentation from Heather McGinness. From left to right are Jessica Davison (MDFRC), Nadia Kingham (DoEE), Patrick Driver (NSW Fisheries), Sam Davis (NSW Fisheries), Steph Suter (NSW OEH), Debbie Love (NSW OEH), Tim Hosking (NSW OEH) and Paul Keyte (NSW OEH).

1.5.4 Development of Adoption Strategy

Building on the feedback from the JRG workshop and subsequent regional workshops, the MDFRC drafted an Adoption Strategy that broadly describes the processes and activities by which the MDB EWKR Project Team seek to facilitate the uptake of the project's information, concepts, tools or practices, in order to support achievement of the Department's anticipated outcomes. The specific activities to be undertaken by the project in 2016–17 will be identified once the research themes update their plans. The plan is designed to complement the Communications Strategy that is currently being revised in consultation with the Department. The Plan identifies five broad types of activities that will be undertaken by the MDB EWKR project:

1. Collaboration, which represents an effective and powerful means of developing relationships that provide a foundation for adoption.
2. Engagement in Management Processes. The MDB EWKR Adoption Strategy will be to utilise these existing networks to facilitate adoption both through the identification of existing networks and the development of new relationships.
3. Capacity Building. Application of knowledge to management decisions may be improved through development of the skills necessary to access, adapt and apply knowledge to specific situations.
4. Synthesis. Synthesis activities seek to package knowledge in a way that supports its application to specific management needs.
5. Knowledge Management will ensure that the project's legacy will be managed so that it remains available and accessible to researchers and managers well beyond the end of the project.

A second output from the regional workshops was information on managers' networks of experts that will inform implementation of the Adoption Plan. The MDFRC is in the process of refining this network analysis; however, a draft map is included at Figure 14. Draft manager network derived from information supplied at the MDB EWKR regional workshops.. Each of the dots in the network diagram represent an individual who is either a water manager, or an expert who is consulted by water managers. Arrows show the direction that information from the expert has 'travelled'. Dots with the most lines connected to them that are 'providing' information are of interest to the project team as these individuals are comparatively well connected to water managers and could help channel and/or expedite adoption of MDB EWKR knowledge.

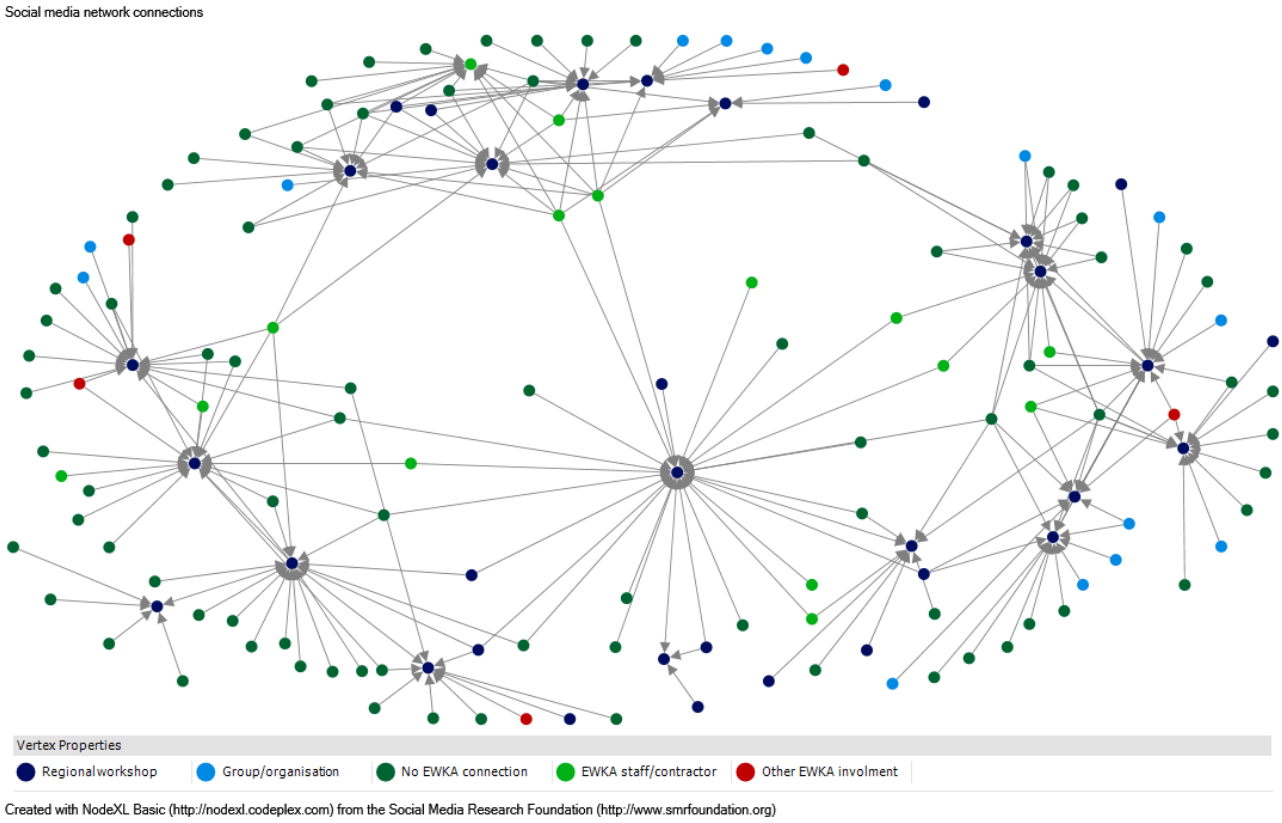

Figure 14. Draft manager network derived from information supplied at the MDB EWKR regional workshops.

1.6 Lessons Learned Survey

Table 24. MDB EWKR team response to DoEE questions.

Question	MDFRC response
1. From the MDFRC perspective, what where the main challenges of MDB EWKR this year?	Changes in a number of key roles and responsibilities including: • the transition of the former MDFRC Director to a full time role in leading the EWKR and related LTIM projects • appointment of a new MDFRC Director and • the resignation of and subsequent recruitment of a full time EWKR Project manager. These changes have resulted in more senior level resources being dedicated to the EWKR project. It also led to some delays as new roles and responsibilities were established and as the newly appointed Director and Project Manager became conversant in their new roles. The transition from MDFRC Pty. Ltd. to La Trobe University resulted in delays to various aspects of the project including: • financial reporting (translating/transferring from a MYOB system to the La Trobe SAP system) • new financial approval processes and project reporting • different legal requirements and templates for EWKR sub-contractors. With most of these new arrangements now in place, further delays in these areas are not anticipated.
2. What elements worked particularly well?	Regular meetings including those with the Department, those between the Project Leader, Project Manager and Theme Coordinators as well as amongst the Theme Leadership Groups continued to improve communication and build overall coordination and integration across the project. The Department providing quick feedback on draft milestones documents using templates which gave sufficient time for the EWKR team to respond and meet deadlines. The Department staff were readily available to answer questions and provide assistance; as well as providing support and advice during workshops. Improvements in project management processes including development of tools such as the Risk schedule, Activities schedule, Subcontracts tracker, Quarterly flow chart and Traffic light reporter, which assist the Project Leader and

Question	MDFRC response
	Project Manager to manage risks and design and manage the overall work program. During the reporting period, a Budget and Expenditure table (with regular expenditure updates being provided by LTU Finance) was being developed to assist the Project Leadership Group manage and report on project budget and expenditure. The May–June regional workshops with waterway managers, which provided opportunities to strengthen relationships and seek feedback on approaches to Adoption and to identify opportunities for collaboration with research and field work. The August 2015 SAG workshop led to refinement of the research questions, placed greater emphasis on predictive capacity and ensured better integration across themes. The February 2016 JRG workshop provided opportunities for the research teams to share their foundational research work and present their proposed work programs. Various theme workshops helped to expedite conceptualisation work (including Fish, Vegetation and Food Webs workshops). Workshops, presentations to and discussions with waterway managers on work on individual themes helped build relationships, while ensuring outputs would be relevant to waterway managers. The Waterbirds Theme Coordinator continued work with the Leadership Goup to finalise the literature review and undertake pilot field work to ensure the Waterbirds Theme is well prepared for the 2016–17 field season.
3. What elements needed improvement?	Financial reporting at a more frequent (monthly) and more detailed (theme) level is being set-up to assist the Project Leader, Project Manager and Theme Coordinators to better manage the overall project and theme budgets over the next three years. The recommendation by the Department to combine the Communications Strategy and Adoption Theme into a Communications and Adoption Plan will help to highlight synergies and identify opportunities where efforts can be integrated and coordinated. It will also reduce the amount of effort needed to report against a separate (Adoption) Theme. Consideration of an Ecosystem Synthesis approach as a part of the Communications and Adoptions Plan, again rather than as part of a separate theme, will also reduce

Question	MDFRC response
	the effort needed for developing and reporting against a separate theme. Integration across themes was not a key priority in the first 12 to 18 months of the EWKR project as teams were still developing and refining their own theme research questions and activities. Efforts to integrate across the themes have been building and are now a standing item on the agenda of the fortnightly Theme Coordinator meetings. Theme Coordinators now review each other's research plans and attend each other's theme leadership group workshops to discuss opportunities for integration in data analysis and field work. Opportunities are also being sought to contribute to answering each other's research questions.
4. What would you do differently next time/ in the future?	Seek opportunities to maximise the benefit from project milestones and other project products to reduce duplication of effort. For example, preparation of an Achievements Paper may have been easier and quicker to develop once the Annual Progress Report was completed.
5. What could the Department do to better assist you in delivering the project?	Consolidation of feedback on each project milestone into one template would be helpful. Prompt feedback to milestone deliverables and other products would contribute to avoiding delays in meeting Project milestones.