A hypothesis based fish ecology monitoring program addressing interventions proposed for the Katarapko Anabranch system

SARDI Publication No. F2009/000476-1

SARDI Research Report Series No. 398

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June 2009

Government of South Australia
Department for Environment and Heritage

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Australian Government

MURRAY–DARLING BASIN AUTHORITY

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This publication may be cited as:
Beyer, K., Leigh, S. J. and Zampatti, B. P. (2009) A hypothesis based fish ecology monitoring program addressing interventions proposed for the Katarapko Anabranch system. South Australian Research and Development Institute (Aquatic Sciences), Adelaide, 44pp. SARDI Publication Number F2009/000476-1.

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Printed in Adelaide, October 2009.

SARDI Publication Number F2009/000476-1

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Date: 6 October 2009

Distribution: DEH, SARDI Aquatic Sciences

Circulation: Public Domain

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Acknowledgements

The authors thank Jason Nicol and Chris Bice for comments on a draft of this report. This project received funding from the Department for Environment and Heritage, Berri, South Australia.

Executive Summary

In 2007, the Katfish Reach initiative was developed to provide community involvement and insights into the management of the health of the Katarapko Anabranch system and its associated floodplain. The initiative's vision for the Katfish Demonstration Reach was to create 'a healthier and more productive aquatic and floodplain ecosystem that everyone can enjoy'.

The Katfish Reach Steering Group developed five ecological objectives to improve habitat within the system. In order to achieve these ecological objectives, seven management interventions were proposed in the Katfish Reach Investment Proposal:

1. Improve spring summer inundation of Eckert Island at low river flows;
2. Temporarily partial dry and vary pool level of Eckert Creek anabranch system;
3. Achieve fish passage and increased in-stream flow for Eckert Creek anabranch system;
4. Achieve fish passage and increased in-stream flow for Katarapko Creek;
5. Improve flows, carp control and fish passage at Ngak Indau Wetland;
6. Improve opportunities for wetland inundation frequency and duration at temporary Wetlands 1541, 408, 399 & 900 and the Katarapko Island Saline Water Disposal Basin; and
7. Reduce and control carp populations in the Katfish Reach area.

The aim of this report was to develop a hypotheses based monitoring program related to fish ecology for the seven proposed Katfish Reach management interventions.

To address the interventions proposed for the Katarapko anabranch system, a total of 25 hypotheses were developed. The hypotheses associated with each intervention are presented in detail together with the linked goals, response scales and the indicators to be measured. The monitoring design to address each of the management interventions was developed in accordance with Boys *et al.* (2008). The experimental approach using a BACIP design and associated methodology is described along with the estimated resource requirements.

1. Introduction and background

In 2007, the Katfish Reach initiative was developed to provide a holistic approach and facilitate community involvement in the management of the health of the Katarapko Anabranch system and its associated floodplain (Plate 1). The vision of the Katfish Reach initiative is to create 'a healthier and more productive aquatic and floodplain ecosystem that everyone can enjoy'. Importantly, a range of coordinated actions were developed that addressed the major ecological threats to the plants and animals (notably native fish) that depend upon aquatic and floodplain habitats.

The Katfish Reach Implementation Plan was developed by the Katfish Reach Steering Group to describe in detail the management actions to be undertaken within the Katarapko system. Five ecological objectives were developed (Katfish Reach Steering Group, 2008a):

1. Improving the connectivity between river, creek, wetland, and floodplain environments (for example, through removal of barriers to fish passage and flows);
2. Improving environmental flow management for in-channel, wetland and floodplain environments;
3. Improving the condition of riparian and aquatic habitats;
4. Increasing the population and abundance of native flora and fauna; and
5. Reducing the impacts from pest plant, animal and native species where applicable.

Using the Conservation Action Planning document prepared by The Nature Conservancy (TNC, 2007), eight key ecological assets were identified for the Katarapko system. Threats to the integrity of each asset were determined and ranked. The highest-ranking threat to the Katarapko Anabranch system (which was rated as high for six out of eight assets) was the lack of environmental flows.

In order to achieve the five ecological objectives, a variety of management options were developed for Katfish Reach (Katfish Reach Steering Group, 2008a). Seven of these management options have been proposed as management interventions in the Katfish Reach Investment Proposal (Katfish Reach Steering Group, 2008b):

1. Improve spring summer inundation of Eckert Island at low river flows;
2. Temporarily partial dry and vary pool level of Eckert Creek anabranch system;
3. Achieve fish passage and increased in-stream flow for Eckert Creek anabranch system;
4. Achieve fish passage and increased in-stream flow for Katarapko Creek;
5. Improve flows, carp control and fish passage at Ngak Indau Wetland;
6. Improve opportunities for wetland inundation frequency and duration at temporary Wetlands 1541, 408, 399 & 900 and the Katarapko Island Saline Water Disposal Basin; and
7. Reduce and control carp populations in the Katfish Reach area.

For the purpose of this report, we have developed scientifically robust hypotheses and methodology to monitor and evaluate the seven proposed management interventions. Hypothesis development and monitoring design were undertaken within the limits of

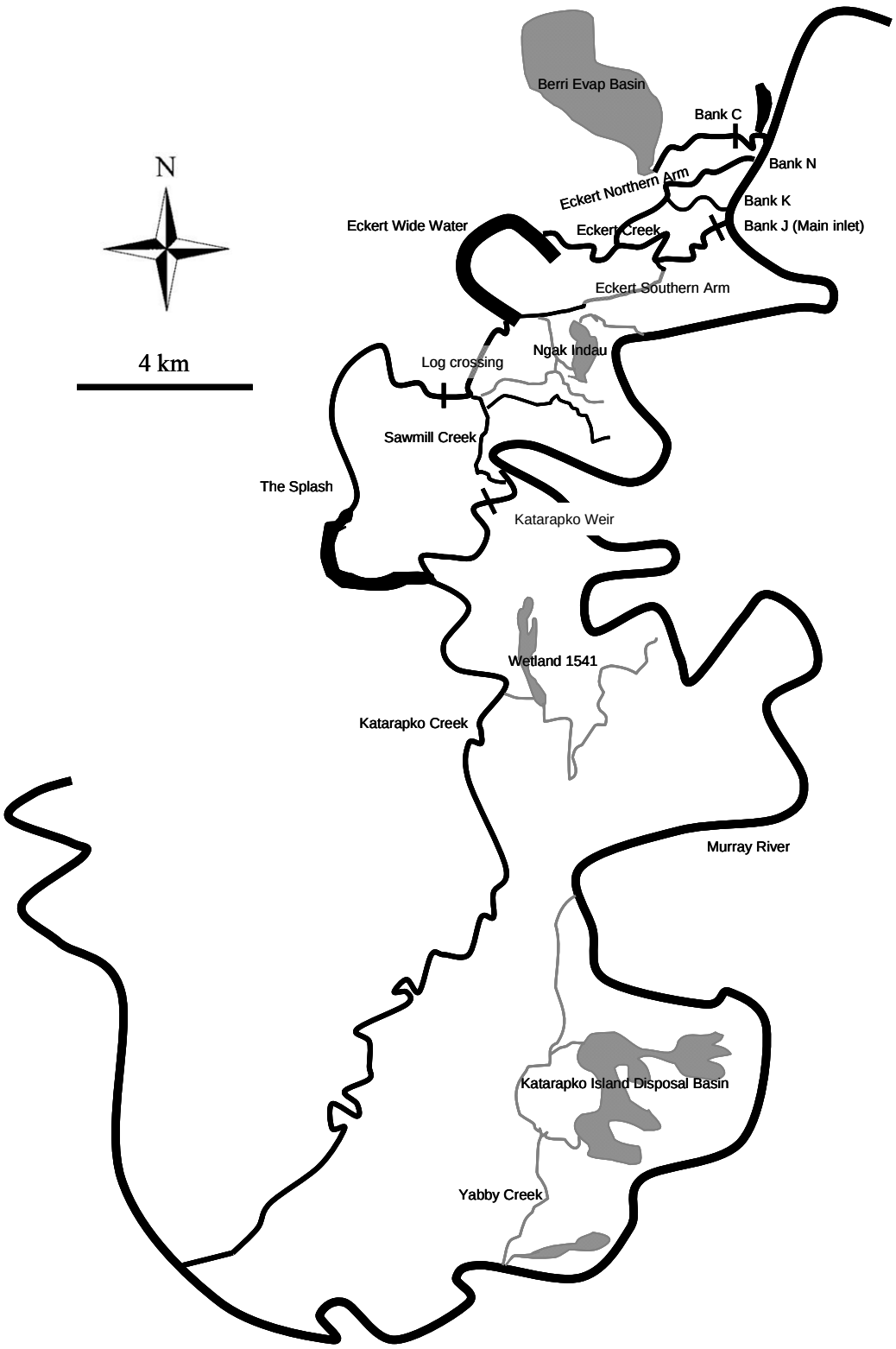

Plate 1: Map of the Katarapko Anabranch system.

information provided on the management interventions (Katfish Reach Steering Group, 2008b) and the current knowledge of fish ecology within the Katarapko anabranch system. In light of this, we provide an interpretation of the proposed management intervention and potential operating regime which we have termed 'action'.

Due to the complex nature of the potential ecological responses to the proposed interventions, each intervention was treated separately, i.e. as a single unit. Additionally, the wording of each management intervention, the implementation timing and associated goals has been taken directly from the Katfish Implementation Plan (Katfish Reach Steering Group, 2008a). The hypotheses, conceptual models, monitoring design and methodology were developed by SARDI – Aquatic Sciences. Event based resource requirements were estimated for each proposed hypothesis.

The conceptual models presented are based on a set of beliefs on how the Katarapko anabranch as an ecosystem is likely to respond to an intervention. The models present these beliefs diagrammatically, and they illustrate the current knowledge and assumptions about how the system may operate, identify gaps in knowledge and assisted with the generation of the hypotheses regarding indicator behaviour. The conceptual models that have been developed for the purpose of this report are preliminary, and may require adaptation based on potential changes in the physical and hydrological conditions of the Katarapko ecosystem and the nature of the interventions.

1.1 Aim

Develop and cost a hypotheses based monitoring program for seven proposed Katfish Reach management interventions.

The monitoring design and resource requirements to address each of the seven proposed Katfish Reach management interventions were developed and estimated in accordance with Boys *et al.* (2008).

The monitoring design included:
- Hypotheses description (monitoring target);
- Detailed description of monitoring method(s);
- Site selection; and
- Monitoring timing in regard to respective intervention.

The resource requirements included:
- Event based resource requirements;
- Time (days and staff days) required for survey and data entry; and
- Time (days and staff days) required for data analysis and report writing.

1.2 Structure of the report

The task of developing hypotheses to address the proposed management interventions entailed complex evaluations and discussions of the ecological processes potentially occurring, or likely to occur, within the Katarapko anabranch system. For the purpose of this report we have provided this information in a simplified and condensed manner in the form of overview tables and conceptual models.

2. Overview

This section provides an overview of the seven interventions and the associated goals, hypotheses, scales of response/measurement, and indicators to be measured (Table 1). To understand the processes within the Katarapko anabranch system in response to the proposed management intervention and the reasoning behind the developed hypotheses, Table 1 is best read in conjunction with the conceptual models presented in Section 3.

Table 1: Overview of the seven interventions and the associated goals, hypotheses, scales of response, and indicators to be measured.

Interventions	Goals	Hypotheses	Scale of response/measurement		Indicators to be measured
			Temporal	Spatial	
Intervention 1: Improve spring-summer inundation of Eckert Island at low river flow. [Intervention to be implemented by 2011; Construction of blocking banks by 2010]	**Assets to benefit:** Eckert Creek, The Splash and Sawmill Creek; Temporary freshwater wetlands; Floodplain woodlands; Floodplain shrub land and Open plain. **Threats targeted:** Lack of environmental flows; Lack of fish passage; Locks 3 & 4 (maintenance of stable pool levels).	H1: Temporary artificial inundation will alter the structure of the fish community within the Eckert Island system.	3-5 years	Sub-Reach Scale (e.g. Eckert Creek, Splash, Katarapko Creek)	• Abundance • Species richness • Biomass • Native vs Non-native species

Interventions	Goals	Hypotheses	Scale of response/measurement		Indicators to be measured
			Temporal	Spatial	
Intervention 1: -see above-	-see above-	H2: Temporary artificial inundation will alter habitat availability and subsequently alter the habitat use by fish within the Eckert Island system.	3-5 years	-see above-	• Habitat diversity & abundance • Fish-Habitat associations
Intervention 1: -see above-	-see above-	H3: Temporary artificial inundation will alter recruitment success in some fish species within the Eckert Island system.	3-5 years	-see above-	• Length/age frequencies; • YOY fish abundance
Intervention 2: Temporarily partially dry and vary pool level of Eckert Creek anabranch system [Intervention in place by 2011]	**Assets to benefit:** Eckert Creek anabranch system **Threats targeted:** Locks 3 & 4 (maintenance of stable pool levels); Lack of flows; Lack of fish passage; Alien fish.	H4: Temporarily drying various reaches of the Eckert Island system will alter fish community structure.	3-5 years	Sub-Reach Scale (e.g. Eckert Creek, Splash)	• Fish abundance • Species richness • Biomass • Native vs Non-native species [see also H1]
Intervention 2: -see above-	-see above-	H5: Temporarily drying various reaches of the Eckert Island system will alter habitat availability and subsequently alter the habitat use by fish.	3-5 years	-see above-	• Habitat diversity & abundance • Fish-Habitat associations [see also H2]

Interventions	Goals	Hypotheses	Scale of response/measurement		Indicators to be measured
			Temporal	Spatial	
Intervention 2: -see above-	-see above-	H6: Temporarily drying various reaches of the Eckert Island system will alter recruitment success in some fish species.	3-5 years	-see above-	• Length/age frequencies • YOY fish abundance [see also H3]
Intervention 3: Achieve fish passage and increased in-stream flow for Eckert Creek anabranch system [Fish passage around Eckert Creek Log Crossing to be in place by 2011; Removal of present flow and fish passage barriers by 2010/2011; Increase in-stream velocity at pool level of Eckert Creek (0.3 m/s) from July to January each year]	**Assets to benefit:** Eckert Creek anabranch system **Threats targeted:** Lack of flows; Flow control structures; Lack of fish passage; Alien fish.	H7: Increasing connectivity will alter the structure of the fish community within the Eckert Creek anabranch system.	3-5 years	Sub-Reach Scale (e.g. Eckert Creek)	• Abundance • Species richness • Biomass • Native vs Non-native species • Fish movement (immigration, emigration)
Intervention 3: -see above-	-see above-	H8: Increasing connectivity (increase lotic habitats) will alter habitat availability and subsequently alter the habitat use by fish within the Eckert Creek anabranch system.	3-5 years	-see above-	• Habitat diversity & abundance • Fish-Habitat associations

Interventions	Goals	Hypotheses	Scale of response/measurement		Indicators to be measured
			Temporal	Spatial	
Intervention 3: -see above-	-see above-	H9: Increasing connectivity will alter recruitment success in some fish species within the Eckert Creek anabranch system.	3-5 years	-see above-	• Length/age frequencies • YOY fish abundance
Intervention 3: -see above-		H10: Increasing connectivity will reduce fish accumulations immediately below structures/barriers within the Eckert Creek anabranch system.	3-5 years	-see above-	• Abundance • Species richness • Biomass • Fish movement (immigration, emigration) [see also H7]
Intervention 4: Achieve fish passage and increased in-stream flow for Katarapko Creek [Katarapko Creek Weir modified by 2010; Removal of present flow and fish passage barriers by 2010/2011; Increase in in-stream velocity at pool level of Katarapko Creek (0.2m/s) from July to January each year]	**Assets to benefit:** Katarapko Creek **Threats targeted:** Lack of flows; Flow control structures; Lack of fish passage; Alien fish.	H11: Increasing connectivity will alter the structure of the fish community within Katarapko Creek.	3-5 years	Sub-Reach Scale (e.g. Katarapko Creek)	• Abundance • Species richness • Biomass • Native vs Non-native species • Fish movement (immigration, emigration)

Interventions	Goals	Hypotheses	Scale of response/measurement		Indicators to be measured
			Temporal	Spatial	
Intervention 4: -see above-	-see above-	H12: Increasing connectivity (increase lotic habitats) will alter habitat availability and subsequently alter the habitat use by fish within Katarapko Creek.	3-5 years	-see above-	• Habitat diversity & abundance • Fish-Habitat associations
Intervention 4: -see above-	-see above-	H13: Increasing connectivity will alter recruitment success in some fish species within Katarapko Creek.	3-5 years	-see above-	• Length/age frequencies • YOY fish abundance
Intervention 4: -see above-	-see above-	H14: Increasing connectivity will reduce fish accumulations immediately below structures/barriers within Katarapko Creek.			• Abundance • Species richness • Biomass • Fish movement (immigration, emigration) [see also H7 & H10]

Interventions	Goals	Hypotheses	Scale of response/measurement		Indicators to be measured
			Temporal	Spatial	
Intervention 5: Improve flows, carp control and fish passage at Ngak Indau Wetland [Upgrade existing hydrological structures at Ngak Indau wetland completed by 2009]	**Assets to benefit:** Temporary freshwater wetlands (Ngak Indau) **Threats targeted:** Lack of flows; Flow control structures; Lack of fish passage; Alien fish	H15: Replacing in- and outlet structures (increasing connectivity) will alter the structure of the fish community within the Ngak Indau Wetland.	3-5 years	Sub-Section Scale (e.g. Ngak Indau Wetland)	• Abundance • Species richness • Biomass • Native vs Non-native species • Small- vs Large-bodied fish species • Fish movement (immigration, emigration)
Intervention 5: -see above-	-see above-	H16: Fitting carp screens to all in- and outlet structures will alter the structure of the fish community (decrease influx of large-bodied fish species) within the Ngak Indau Wetland.	3-5 years	-see above-	• Abundance • Species richness • Biomass • Native vs Non-native species • Small- vs Large-bodied fish species • Fish movement (immigration, emigration)

Interventions	Goals	Hypotheses	Scale of response/measurement		Indicators to be measured
			Temporal	Spatial	
Intervention 5: -see above-	-see above-	H17: Increasing connectivity by replacing in- and outlet structures (increasing lotic habitats) will alter habitat availability and subsequently alter the habitat use by fish within the Ngak Indau Wetland.	3-5 years	-see above-	• Habitat diversity & abundance • Fish-Habitat associations
Intervention 5: -see above-	-see above-	H18: Increasing connectivity by replacing in- and outlet structures will alter recruitment success in some fish species within the Ngak Indau Wetland.	3-5 years	-see above-	• Length/age frequencies • YOY fish abundance
Intervention 6: Improve opportunities for wetland inundation frequency and duration at temporary Wetlands 1541, 408, 399 & 900 and the Katarapko Island Saline Water Disposal Basin [Achieve wetland inundation frequency and duration by 2010/2011]	**Assets to benefit:** Temporary wetlands; Floodplain woodlands; Murray hardyhead habitat; Floodplain shrub land and open plain **Threats targeted:** Lack of flows; Flow control structures; Increased soil salinity from disposal basins; Lack of fish passage; Alien fish	H19: Replacing in- and outlet structures (increasing connectivity) will alter the structure of the fish community within the temporary wetlands and the Katarapko Island Saline Water Disposal Basin.	3-5 years	Sub-section Scale (e.g. temporary wetlands within the Katarapko Demonstration Reach)	• Abundance • Species richness • Biomass • Native vs Non-native species • Small- vs Large-bodied fish species • Fish movement (immigration, emigration)

Interventions	Goals	Hypotheses	Scale of response/measurement		Indicators to be measured
			Temporal	Spatial	
Intervention 6: -see above-	-see above-	H20: Fitting carp screens to the inlet structures will alter the structure of the fish community (decrease influx of large-bodied fish species) within the temporary wetlands and the Katarapko Island Saline Water Disposal Basin.	3-5 years	-see above-	• Abundance • Species richness • Biomass • Native vs Non native species • Small- vs Large-bodied fish species • Fish movement (immigration, emigration)
Intervention 6: -see above-	-see above-	H21: Replacing in- and outlet structures (increasing connectivity & lotic habitats) will alter habitat availability and subsequently alter the habitat use by fish within the temporary wetlands and the Katarapko Island Saline Water Disposal Basin.	3-5 years	-see above-	• Habitat diversity & abundance • Water quality (e.g. salinity) • Fish-Habitat associations
Intervention 6: -see above-	-see above-	H22: Replacing in- and outlet structures (increasing connectivity) will alter recruitment success in some fish species within the temporary wetlands and the Katarapko Island Saline Water Disposal Basin.	3-5 years	-see above-	• Length/age frequencies • YOY fish abundance

Interventions	Goals	Hypotheses	Scale of response/measurement		Indicators to be measured
			Temporal	Spatial	
Intervention 7: Reduce and control carp populations in the Katfish Reach area [Implementation timing not specified]	**Assets to benefit:** Eckert Island system, Temporary Wetlands. **Threats targeted:** Alien fish.	H23: Reducing the numbers of mature large-bodied carp (reduced competition during early life for native species) will alter recruitment success in some fish species within Ngak Indau, 1541, 408, 399 & 900 wetlands under managed wetting events, and the Eckert Creek anabranch system.	3-5 years	Sub-reach/Sub-section Scale (e.g. wetlands within the Katfish Demonstration Reach, Eckert Creek)	• Length/age frequencies • YOY fish abundance
Intervention 7: -see above-	-see above-	H24: Fitting carp screens to inlet regulators structures will alter the structure of the fish community (decrease influx of large-bodied fish species) within the Ngak Indau, 1541, 408, 399 & 900 wetlands under managed wetting events.	3-5 years	-see above-	• Abundance • Species richness • Biomass • Native vs Non-native species • Small- vs Large-bodied fish species • Fish movement (immigration, emigration)

Interventions	Goals	Hypotheses	Scale of response/measurement		Indicators to be measured
			Temporal	Spatial	
Intervention 7: -see above-	-see above-	H25: Fitting a 'Williams carp cage' to the inlet structure (Bank J) of Eckerts Creek will alter the structure of the fish community (decrease influx of large-bodied fish species) into the Eckert Creek anabranch system.	3-5 years	-see above-	• Abundance • Species richness • Biomass • Native vs Non-native species • Small- vs Large-bodied fish species • Fish movement (immigration, emigration)

3. Experimental approach

For each of the seven interventions, three to four hypotheses were developed. Overall, the 25 hypotheses address the following main issues relating to fish ecology in the Katarapko Anabranch system (associated hypotheses codes are indicated in brackets; see also Section 2 for details; the methodology used to address each of the hypotheses is described in Section 4):

1. Fish community structure (H1, H4, H7, H11, H15, H19, H24, H25),
2. Habitat availability (H2, H5, H8, H12, H17, H21),
3. Fish habitat use (H2, H5, H8, H12, H17, H21),
4. Recruitment success (H3, H6, H9, H13, H18, H22, H23),
5. Fish movement (H7, H10, H11, H14, H15, H19, H20, H24, H25),
6. Fish accumulations below in-stream barriers (H10, H14), and
7. Non-native species, notably carp (H16, H20, H23, H24, H25).

For all 25 hypotheses the 'Paired Before-After-Control-Impact' Design (BACIP) was deemed the most appropriate monitoring design to assess indicator behaviour in response to the seven management interventions within the Katarapko anabranch system (Boys *et al*., 2008). This design requires at least one treatment and one control location. For the BACIP design to be successfully applied within the Katarapko Anabranch system, sampling should take place multiple times before and after the implementation of each intervention. If this is not the case and sampling does not start before an intervention is implemented then the experimental design becomes invalid. As a result, while monitoring can still proceed using the proposed methodology, the 'fallback' design is the 'Control-Intervention' design (Boys *et al*., 2008). This design is less desirable as it is less powerful than the BACIP design because Before-Intervention information, which is of great importance to demonstrate ecological responses in fish, would not be available. To satisfy the conditions of the 'Control-Intervention' design at least one treatment and multiple control locations are required, with sampling taking place multiple times after the intervention.

For the purpose of inter-annual comparison and to identify changes in indicator behaviour over time in response to each management intervention, the selected sites should be sampled once per year in March/April. Data should be collected at least 1 year before the implementation of each intervention and for a minimum of three years but ideally for five years after. Given the current information on the approximate timing of the interventions, the proposed monitoring schedule should result in information being collected before the implementation of the intervention.

We have provided detail on the general region which should be used for the selection of either control or impact sites. Reaches which are likely to be affected by the management intervention will be the 'impact' sites, while unaltered reaches will be the 'control' sites. Within the document, numbers and locations of the proposed sampling sites are presented. These locations, however, can only be finalised once further detail on the implementation of the interventions is available, e.g. due to construction delays there may be a change in the implementation timing. Furthermore, each intervention and the selected sampling sites to test associated hypotheses is treated as independent from

actions undertaken as part of all other proposed management interventions, and this applies throughout the report.

3.1 Intervention 1

Intervention 1: Improve spring-summer inundation of Eckert Island at low river flow.

ACTION: Artificial inundation of Eckert Island 3 to 4 months (spring/summer) for at least 1 in 3 years. A regulator will be installed to the downstream end of Eckert Island and blocking banks will be constructed (existing ones refurbished).

A detailed overview of the mechanisms for potential responses and/or indicator behaviour is presented in the conceptual model for this intervention (Figure 1).

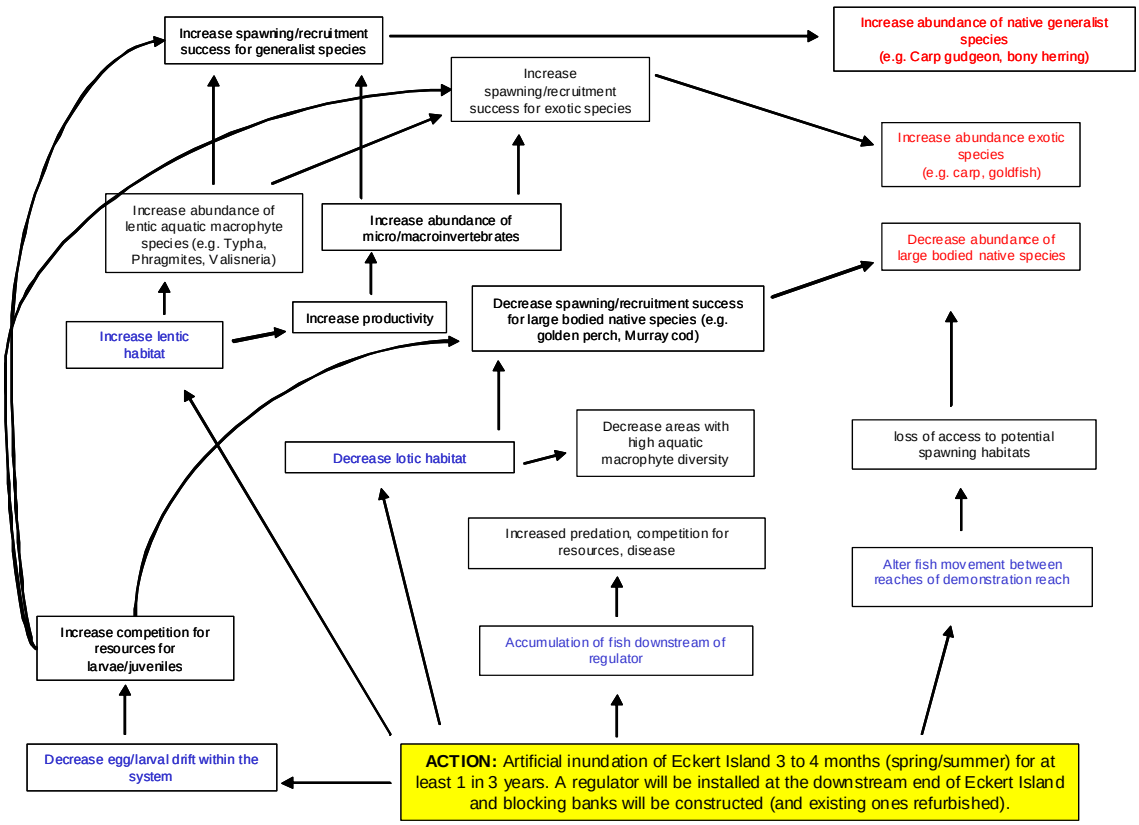

Figure 1: Conceptual model detailing the mechanisms for potential responses and/or indicator behaviour related to Intervention 1.

H1: Temporary artificial inundation will alter the structure of the fish community within the Eckert Island system.

The aim of this study is to assess the differences (changes over time) in fish abundance, species composition and diversity in relation to Intervention 1.

To address this hypothesis, the Eckert Island complex was divided into four sections based on current meso-habitat types. Reaches potentially affected by the management intervention will be the 'impact' sites, while unaltered reaches will be the 'control' sites:

Impact:

1. Eckert Creek (Bank J to Wide Water) - fast flowing habitat;
2. Eckert Wide Water - backwater habitat;
3. Lower Splash - backwater habitat;
4. Lower Eckert (end of Wide Water to lower Splash) - slow flowing habitat.

Control:

5. Katarapko Creek.

Three sites are to be sampled in each of these five sections.

H2: Temporary artificial inundation will alter habitat availability and subsequently alter the habitat use by fish within the Eckert Island system.

The aims of this study include the assessment of:

- changes in habitat diversity and abundance within the Eckert Island system in response to artificial inundation; and
- changes in fish-habitat associations within the system.

The sites chosen for this hypothesis will be the same as for H1.

H3: Temporary artificial inundation will alter recruitment success in some fish species within the Eckert Island system.

This study aims to assess the level of recruitment success within the Demonstration Reach for individual fish species and the potential changes in response to the intervention.

The sites chosen for this hypothesis will be the same as for H1.

3.2 Intervention 2

Intervention 2: Temporarily partially dry and vary pool level of Eckert Creek anabranch system.

ACTION: Temporarily dry some sections (North Arm, South Arm, The Splash) of the Eckert Island complex for 4 to 5 months (spring/summer) in 3 out of 5 years using a series of regulators.

A detailed overview of the mechanisms for potential responses and/or indicator behaviour is presented in the conceptual model for this intervention (Figure 2).

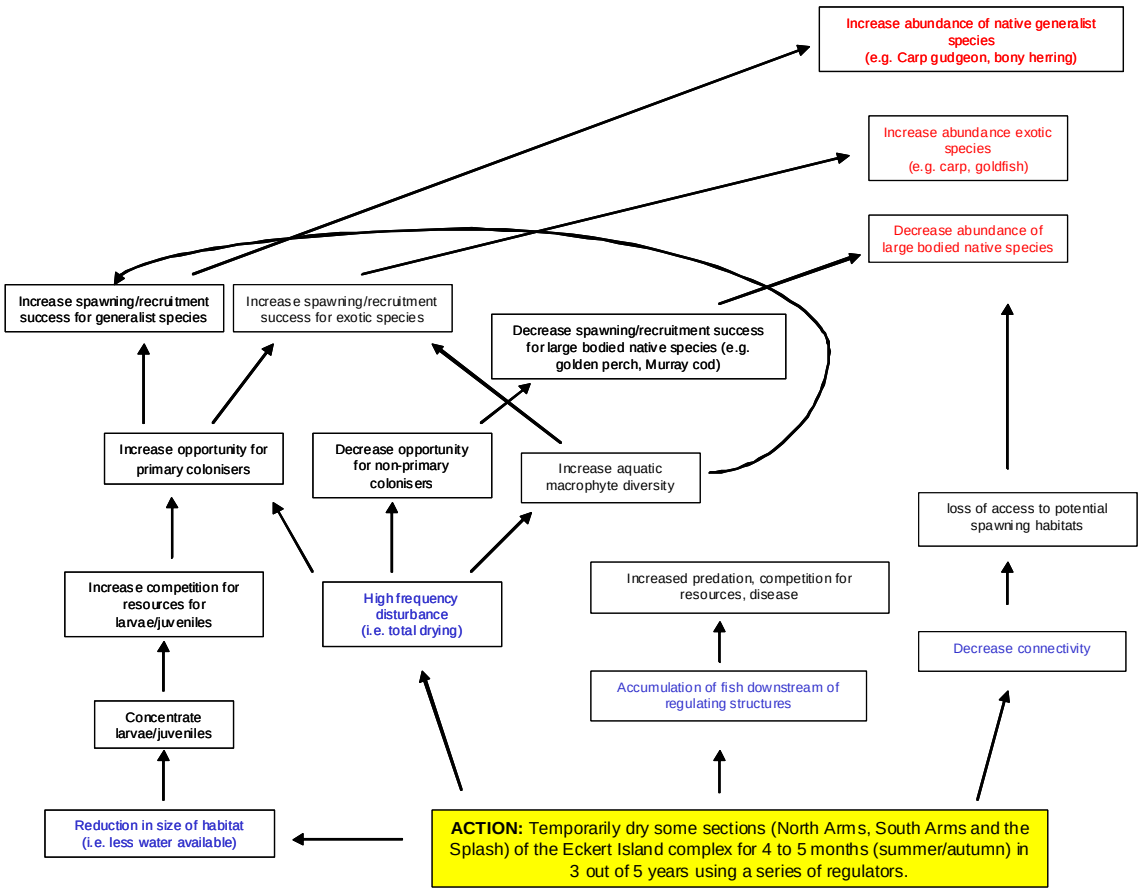

Figure 2: Conceptual model detailing the mechanisms for potential responses and/or indicator behaviour related to Intervention 2.

H4: Temporarily drying various reaches of the Eckert Island system will alter the fish community structure.

The aim of this study is to determine changes in the fish community structure within the Eckert Island system in response drying parts of the system.

Site selection is similar to hypotheses H1 to H3, where the Eckert Island complex has been divided into four sections based on current meso-habitat types. Reaches potentially affected by the management intervention will be 'impact' sites, while unaltered reaches will be 'control' sites:

Impact:

1. The Splash (upper section) – fast flowing habitat
2. The Splash (lower section) – backwater habitat
3. Northern Arms (Eckert Creek) – slow flowing habitat
4. Southern Arms (Eckert Creek) – slow flowing habitat

Control:

5. Eckert Creek (Bank J to Wide Water) - fast flowing habitat;
6. Eckert Wide Water - backwater habitat;

7. Lower Eckert Creek (end of Wide Water to log crossing) - slow flowing habitat.

Three sites are to be sampled in each of these seven sections.

H5: Temporarily drying various reaches of the Eckert Island system will alter habitat availability and subsequently alter the habitat use by fish.

The aims of this study are to determine:

- changes in habitat diversity and abundance in response to drying some sections of the Eckert Island complex; and
- changes in Fish-Habitat associations within the system.

The sites chosen for this hypothesis will be the same as for H4.

H6: Temporarily drying various reaches of the Eckert Island system will alter recruitment success in some fish species.

This study aims to assess the level of recruitment success within the Demonstration Reach and the potential changes in response to the drying of some sections of the Eckert system.

The sites chosen for this hypothesis will be the same as for H4.

3.3 Intervention 3

Intervention 3: Achieve fish passage and increased in-stream flow for Eckert Creek anabranch system.

ACTION: Modification and/or replacement of existing structures and the installation of new structures within the Eckert Island complex. This intervention includes the application of fish passage options on selected structures and increasing flow velocity through the system using selected regulators. A 'Williams carp cage' will be fitted at the inlet structure of Eckerts Creek (Bank J).

A detailed overview of the mechanisms for potential responses and/or indicator behaviour is presented in the conceptual model for this intervention (Figure 3).

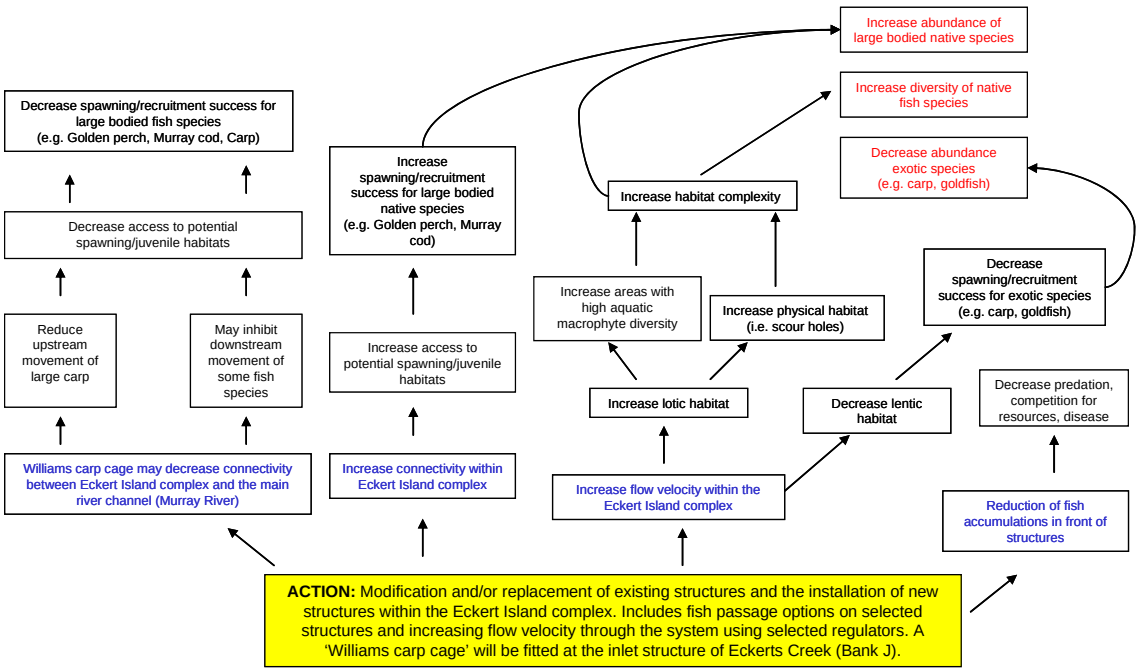

Figure 3: Conceptual model detailing the mechanisms for potential responses and/or indicator behaviour related to Intervention 3.

H7: Increasing connectivity will alter the structure of the fish community within the Eckert Creek anabranch system.

The aim of this study is to assess the differences (changes over time) in fish abundance, species composition and diversity in response to increased connectivity, and more specifically, to determine changes in fish movement (emigration/immigration) in response to improved fish passage within the Eckert Creek anabranch system.

The Eckert Island complex was divided into four sections based on current meso-habitat types. Reaches potentially affected by the management intervention will be the 'impact' sites, while unaltered reaches will be the 'control' sites:

Impact:

1. Eckert Creek (Bank J to Wide Water) - fast flowing habitat;
2. Northern Arms (Eckert Creek) – slow flowing habitat;
3. Eckert Wide Water - backwater habitat;
4. Lower Splash - backwater habitat;
5. Lower Eckert (end of Wide Water to lower Splash) - slow flowing habitat.

Control:

6. Katarapko Creek.

Three sites are to be sampled in each of these six sections.

To assess fish movement (emigration/immigration), fish are to be sampled from all sites described as well as from the main river stem. More detail on the methodology and the recommended species selection is included in Section 4.

H8: Increasing connectivity (increase lotic habitats) will alter habitat availability and subsequently alter the habitat use by fish within the Eckert Creek anabranch system.

The aims of this study include the assessment of:
- changes in habitat diversity and abundance within the Eckert Creek anabranch system in response to increased connectivity; and
- changes in Fish-Habitat associations within the system.

The sites chosen for this hypothesis will be the same as for H7.

H9: Increasing connectivity will alter recruitment success in some fish species within the Eckert Creek anabranch system.

This study aims to assess the level of recruitment success within the Eckert Creek anabranch system for individual fish species and the potential changes in response to increased connectivity.

The sites chosen for this hypothesis will be the same as for H7.

H10: Increasing connectivity will reduce fish accumulations immediately below structures/barriers within the Eckert Creek anabranch system.

This study aims to assess the level of fish accumulations immediately below structures/barriers within the Eckert Creek anabranch system and the potential changes in response to increased connectivity.

To assess changes in fish accumulations, sampling will be focussed on locations directly below structures/barriers. Reaches potentially affected by the management intervention will be the 'impact' sites, while unaltered reaches will be the 'control' sites:

Impact:
1. Eckert Creek (Bank J to Wide Water): Bank J;
2. Northern Arms (Eckert Creek): Bank N;
3. Northern Arms (Eckert Creek): Bank K;
4. Lower Eckert (end of Wide Water to lower Splash): Log Crossing.

Control:
5. Eckert Wide Water - backwater habitat;
6. Lower Splash - backwater habitat;
7. Katarapko Creek.

3.4 Intervention 4

Intervention 4: Achieve fish passage and increased in-stream flow for Katarapko Creek.

ACTION: Modification and/or replacement of existing structures and the installation of new structures on Katarapko Creek. Includes fish passage structures on Katarapko stone weir and increasing flow velocity through Katarapko Creek by lowering the existing crest level.

A detailed overview of the mechanisms for potential responses and/or indicator behaviour is presented in the conceptual model for this intervention (Figure 4).

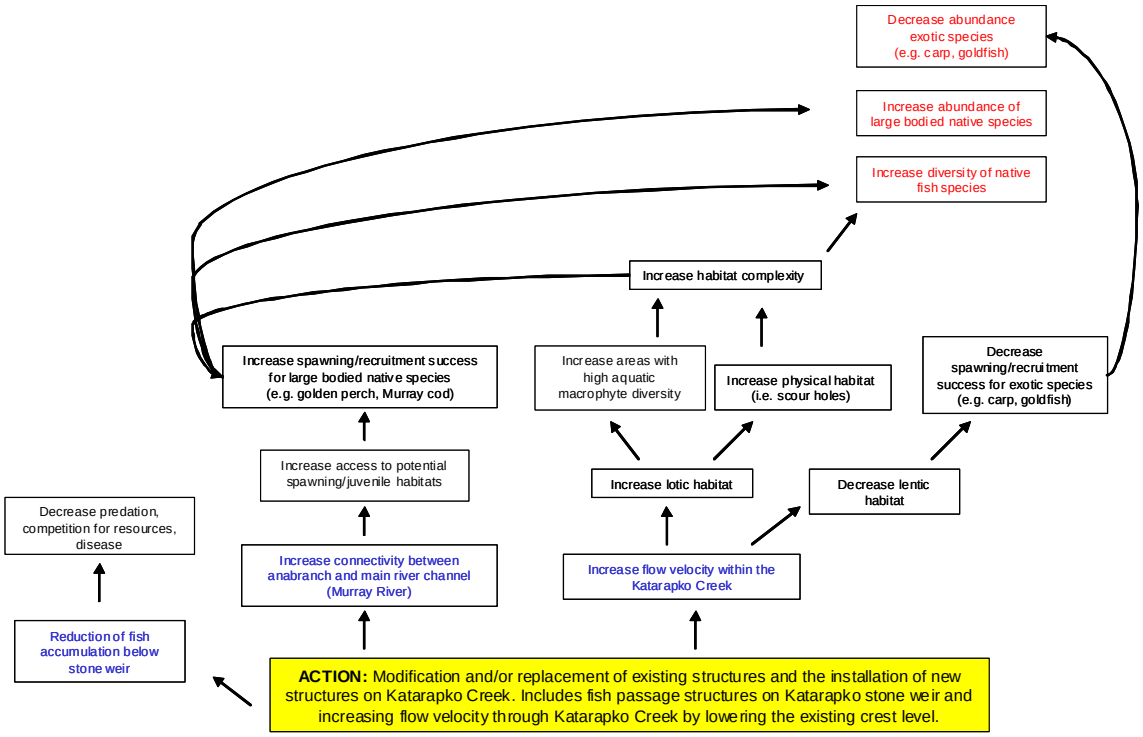

Figure 4: Conceptual model detailing the mechanisms for potential responses and/or indicator behaviour related to Intervention 4.

H11: Increasing connectivity will alter the structure of the fish community within Katarapko Creek.

The aim of this study is to assess the differences (changes over time) in fish abundance, species composition and diversity in response to increased connectivity, and more specifically, to determine changes in fish movement (emigration/immigration) in response to improved fish passage within Katarapko Creek.

Reaches potentially affected by the management intervention will be the 'impact' sites, while unaltered reaches will be the 'control' sites:

Impact:

1. Katarapko Creek.

Control:

2. Eckert Creek (Bank J to Wide Water) - fast flowing habitat;
3. Northern Arms (Eckert Creek) – slow flowing habitat;
4. Eckert Wide Water - backwater habitat;
5. Lower Splash - backwater habitat;
6. Lower Eckert (end of Wide Water to lower Splash) - slow flowing habitat.

Three sites are to be sampled in each of these six sections.

Fish are to be sampled from all sites described above as well as the main river stem. More detail on the methodology and the recommended species selection is included in Section 4.

H12: Increasing connectivity (increase lotic habitats) will alter habitat availability and subsequently alter the habitat use by fish within Katarapko Creek.

The aims of this study include the assessment of:

- changes in habitat diversity and abundance within Katarapko Creek in response to increased connectivity; and
- changes in Fish-Habitat associations within the system.

The sites chosen for this hypothesis will be the same as for H11.

H13: Increasing connectivity will alter recruitment success in some fish species within Katarapko Creek.

This study aims to assess the level of recruitment success within Katarapko Creek for individual fish species and the potential changes in response to increased connectivity.

The sites chosen for this hypothesis will be the same as for H11.

H14: Increasing connectivity will reduce fish accumulations immediately below structures/barriers within Katarapko Creek.

This study aims to assess the level of fish accumulations immediately below structures/barriers within Katarapko Creek and the potential changes in response to increased connectivity.

To assess changes in fish accumulations, sampling will be focussed on locations directly below structures/barriers. Reaches potentially affected by the management intervention will be the ‘impact’ sites, while unaltered reaches will be the ‘control’ sites:

Impact:

1. Katarapko Creek: Stone Weir;

Control:

2. Eckert Creek (Bank J to Wide Water) - fast flowing habitat;
3. Northern Arms (Eckert Creek) – slow flowing habitat;
4. Eckert Wide Water - backwater habitat;

5. Lower Splash - backwater habitat;
6. Lower Eckert (end of Wide Water to lower Splash) - slow flowing habitat.

To assess fish movement (emigration/immigration), fish are to be sampled from all sites described as well as from the main river stem. More detail on the methodology and the recommended species selection is included in Section 4.

3.5 Intervention 5

Intervention 5: Improve flows, carp control and fish passage at Ngak Indau Wetland.

ACTION: The inlet and outlet structures of the Ngak Indau Wetland will be replaced. All structures will be fitted with carp screens.

A detailed overview of the mechanisms for potential responses and/or indicator behaviour is presented in the conceptual model for this intervention (Figure 5).

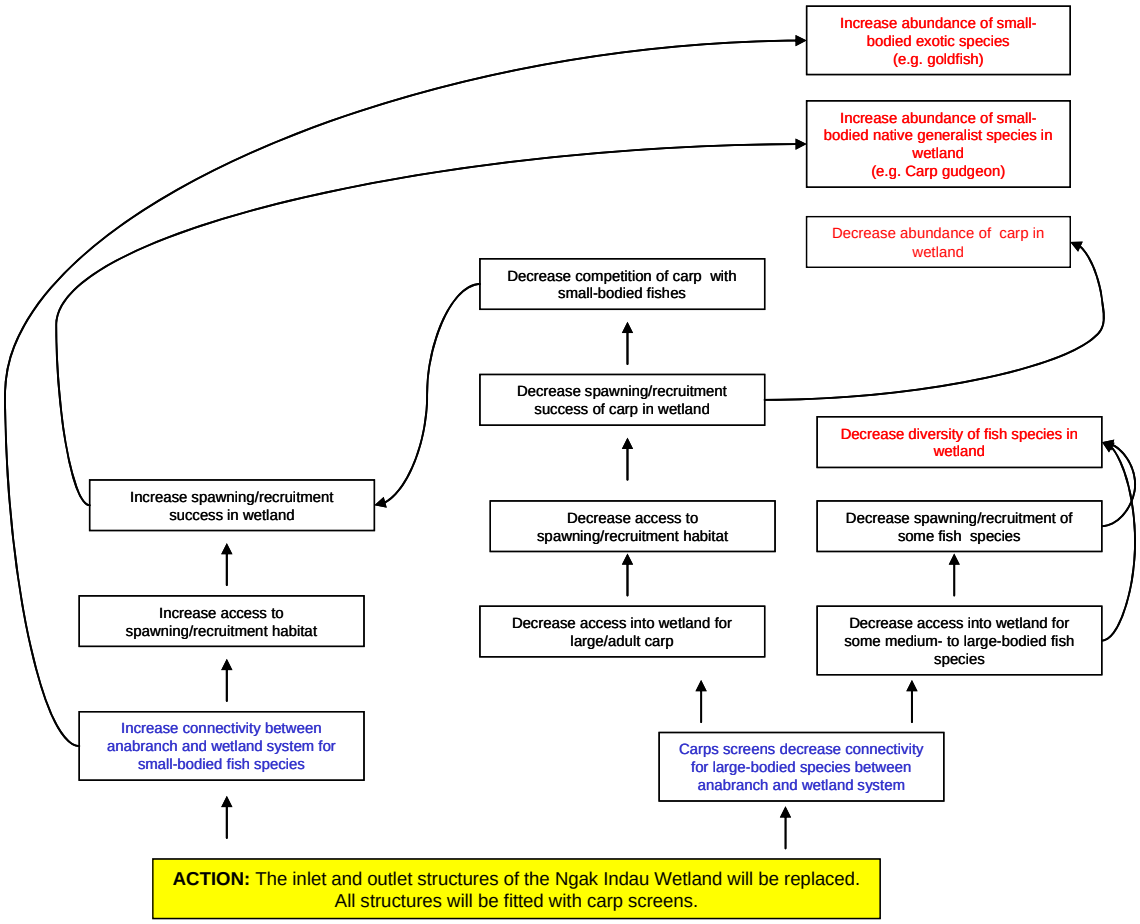

Figure 5: Conceptual model detailing the mechanisms for potential responses and/or indicator behaviour related to Intervention 5.

H15: Replacing in- and outlet structures (increasing connectivity) will alter the structure of the fish community within the Ngak Indau Wetland.

The aim of this study is to assess the differences (changes over time) in fish abundance, species composition and diversity in response to increased connectivity, and more specifically, to determine changes in fish movement (emigration/immigration) in response to improved fish passage through the inlet and outlet structures of the Ngak Indau Wetland.

Areas potentially affected by the management intervention will be the 'impact' sites, while unaltered reaches will be the 'control' sites:

Impact:

1. Ngak Indau Wetland.

Control:

2. Temporary Wetland 1541;
3. Temporary Wetland 408;
4. Temporary Wetland 399;
5. Temporary Wetland 900;
6. Katarapko Island Saline Water Disposal Basin.

A minimum of three sites are to be sampled in each of these 6 wetlands.

To assess fish movement (emigration/immigration), fish are to be sampled from all sites described as well as from the main river stem. More detail on the methodology and the recommended species selection is included in Section 4.

H16: Fitting carp screens to all in- and outlet structures will alter the structure of the fish community (decrease influx of large-bodied fish species) within the Ngak Indau Wetland.

The aim of this study is to assess the differences (changes over time) in fish abundance, species composition and diversity in response to fitting carp screens to all in- and outlet structures, and more specifically, to determine changes in fish movement (emigration/immigration) in response to improved fish passage through the inlet and outlet structures of the Ngak Indau Wetland.

The sampling sites chosen for this hypothesis will be the same as for H15.

To assess fish movement (emigration/immigration), fish are to be sampled from all sites described as well as from the main river stem. More detail on the methodology and the recommended species selection is included in Section 4.

H17: Increasing connectivity by replacing in- and outlet structures (increasing lotic habitats) will alter habitat availability and subsequently alter the habitat use by fish within the Ngak Indau Wetland.

The aims of this study include the assessment of:

- changes in habitat diversity and abundance within Ngak Indau Wetland in response to increased connectivity; and

• changes in Fish-Habitat associations within the system.

The sampling sites chosen for this hypothesis will be the same as for H15.

H18: Increasing connectivity by replacing in- and outlet structures will alter recruitment success in some fish species within the Ngak Indau Wetland.

This study aims to assess the level of recruitment success within the Ngak Indau Wetland for individual fish species and the potential changes in response to increased connectivity.

The sampling sites chosen for this hypothesis will be the same as for H15.

3.6 Intervention 6

Intervention 6: Improve opportunities for wetland inundation frequency and duration at temporary Wetlands 1541, 408, 399 & 900 and the Katarapko Island Saline Water Disposal Basin.

ACTION: Increase frequency and extent of inundation at selected priority wetlands. Modification/replacement of existing regulatory structures and/or the lowering of wetland inlet sills. Carp screens will be fitted to inlet structures at each wetland.

A detailed overview of the mechanisms for potential responses and/or indicator behaviour is presented in the conceptual model for this intervention (Figure 6).

H19: Replacing in- and outlet structures (increasing connectivity) will alter the structure of the fish community within the temporary wetlands and the Katarapko Island Saline Water Disposal Basin.

The aim of this study is to assess the differences (changes over time) in fish abundance, species composition and diversity in response to increased connectivity, and more specifically, to determine changes in fish movement (emigration/immigration) in response to improved fish passage through the inlet and outlet structures the temporary wetlands and the Katarapko Island Saline Water Disposal Basin.

Areas potentially affected by the management intervention will be the ‘impact’ sites, while unaltered reaches will be the ‘control’ sites:

Impact:

1. Temporary Wetland 1541;
2. Temporary Wetland 408;
3. Temporary Wetland 399;
4. Temporary Wetland 900;
5. Katarapko Island Saline Water Disposal Basin.

Control:

6. Ngak Indau Wetland;
7. Eckert Creek system;

8. Katarapko Creek.

A minimum of three sites are to be sampled in each of these locations.

To assess fish movement (emigration/immigration), fish are to be sampled from all sites described as well as from the main river stem. More detail on the methodology and the recommended species selection is included in Section 4.

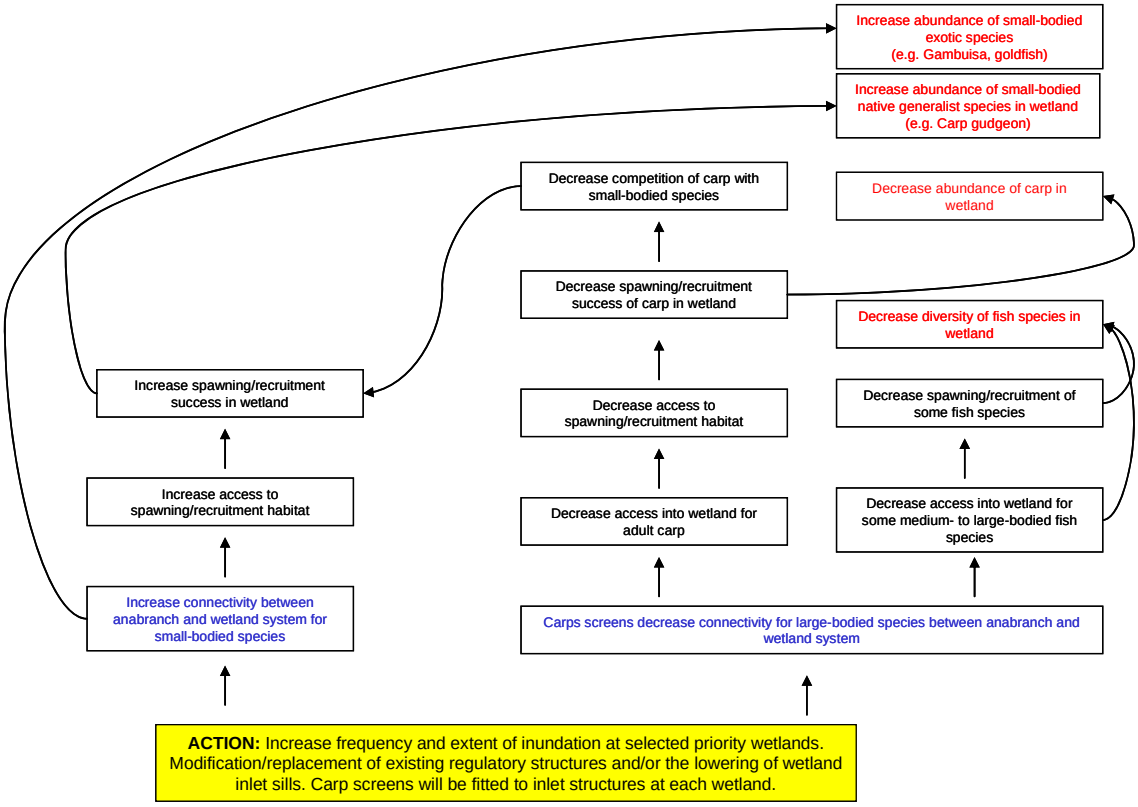

Figure 6: Conceptual model detailing the mechanisms for potential responses and/or indicator behaviour related to Intervention 6.

H20: Fitting carp screens to the inlet structures will alter the structure of the fish community (decrease influx of large-bodied fish species) within the temporary wetlands and the Katarapko Island Saline Water Disposal Basin.

The aim of this study is to assess the differences (changes over time) in fish abundance, species composition and diversity in response to fitting carp screens to all in- and outlet structures, and more specifically, to determine changes in fish movement (emigration/immigration) in response to improved fish passage through the inlet and outlet structures the temporary wetlands and the Katarapko Island Saline Water Disposal Basin.

The sampling sites chosen for this hypothesis will be the same as for H19.

To assess fish movement (emigration/immigration), fish are to be sampled from all sites described as well as from the main river stem. More detail on the methodology and the recommended species selection is included in Section 4.

H21: Replacing in- and outlet structures (increasing connectivity & lotic habitats) will alter habitat availability and subsequently alter the habitat use by fish within the temporary wetlands and the Katarapko Island Saline Water Disposal Basin.

The aims of this study include the assessment of:

- changes in habitat diversity and abundance within the temporary wetlands and the Katarapko Island Saline Water Disposal Basin in response to increased connectivity; and
- changes in Fish-Habitat associations within these systems.

The sampling sites chosen for this hypothesis will be the same as for H19.

H22: Replacing in- and outlet structures (increasing connectivity) will alter recruitment success in some fish species within the temporary wetlands and the Katarapko Island Saline Water Disposal Basin.

This study aims to assess the level of recruitment success within the temporary wetlands and the Katarapko Island Saline Water Disposal Basin for individual fish species and the potential changes in response to increased connectivity.

The sampling sites chosen for this hypothesis will be the same as for H19.

3.7 Intervention 7

Intervention 7: Reduce and control carp populations in the Katfish Reach area.

ACTION: Carp screens on inlet regulators at the Ngak Indau, 1541, 408, 399 & 900 wetlands under managed wetting events (it is proposed that under natural flooding the screens be decommissioned). A carp separation cage is to be fitted to the structure at the main Eckert Creek inlet (Bank J). 'Carp buster' events will be held (timing/locations of these not having been identified).

A detailed overview of the mechanisms for potential responses and/or indicator behaviour is presented in the conceptual model for this intervention (Figure 7).

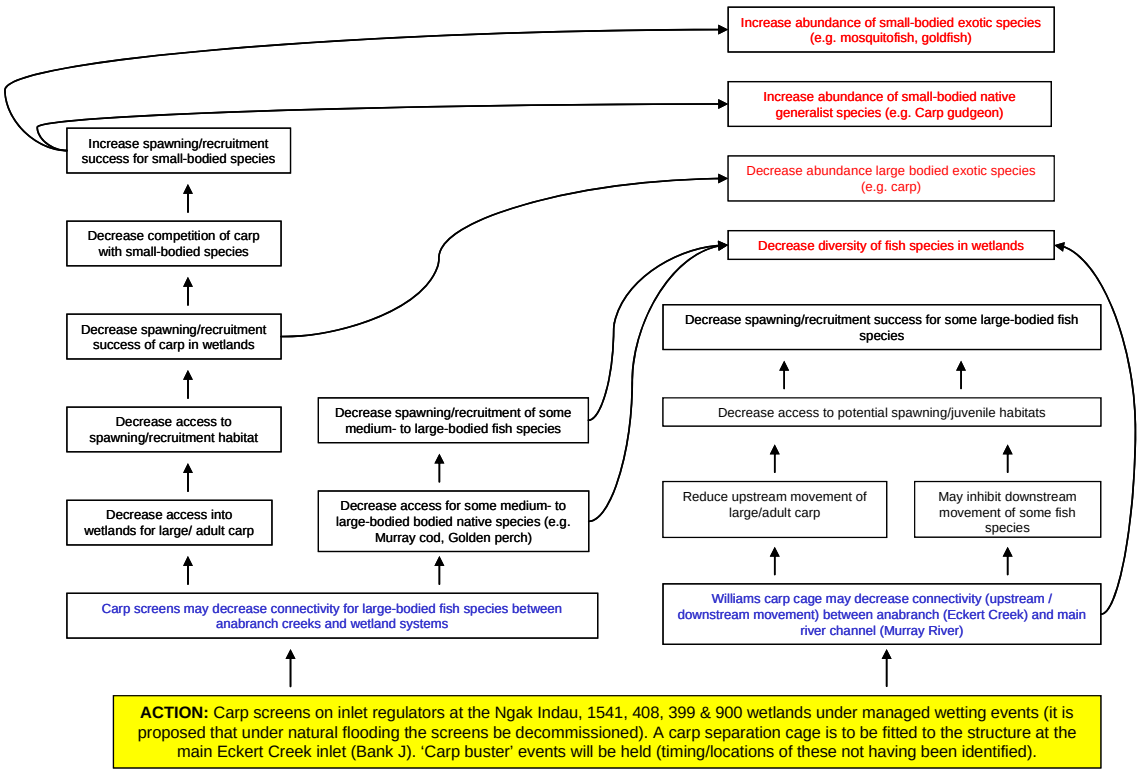

Figure 7: Conceptual model detailing the mechanisms for potential responses and/or indicator behaviour related to Intervention 7.

H23: Reducing the numbers of mature large-bodied carp (reduced competition during early life for native species) will alter recruitment success in some fish species within the Ngak Indau, 1541, 408, 399 & 900 wetlands under managed wetting events, and within the Eckert Creek anabranch system.

This study aims to assess the level of recruitment success for individual fish species and whether this changes in response to the reduced number of mature large-bodied carp potentially resulting from the fixing of carp screens to the inlets of Ngak Indau, 1541, 408, 399 & 900.
Areas potentially affected by the management intervention will be the 'impact' sites, while unaltered reaches will be the 'control' sites:

Impact:

1. Temporary Wetland 1541;
2. Temporary Wetland 408;
3. Temporary Wetland 399;
4. Temporary Wetland 900;
5. Ngak Indau Wetland.

Control:

6. Katarapko Island Saline Water Disposal Basin;
7. Eckert Creek system;
8. Katarapko Creek.

A minimum of three sites are to be sampled in each of these locations.

H24: Fitting carp screens to inlet regulators structures will alter the structure of the fish community (decrease influx of large-bodied fish species) within the Ngak Indau, 1541, 408, 399 & 900 wetlands under managed wetting events.

The aim of this study is to assess the differences (changes over time) in fish abundance, species composition and diversity in response to fitting carp screens to all in- and outlet structures, and more specifically, to determine changes in fish movement (emigration/immigration) in response to improved fish passage through the inlet and outlet structures of Ngak Indau, 1541, 408, 399 & 900 wetlands.

The sampling sites chosen for this hypothesis will be the same as for H23.

To assess fish movement (emigration/immigration), fish are to be sampled from all sites described as well as from the main river stem. More detail on the methodology and the recommended species selection is included in Section 4.

H25: Fitting a 'Williams carp cage' to the inlet structure (Bank J) of Eckerts Creek will alter the structure of the fish community (decreased influx of large-bodied fish species) into the Eckert Creek anabranch system.

The aim of this study is to assess the differences (changes over time) in fish abundance, species composition and diversity in response to fitting Williams carp cage' to the inlet structure (Bank J) of Eckert Creek, and more specifically, to determine changes in fish movement (emigration/immigration) within the Eckert Creek anabranch system.

Areas potentially affected by the management intervention will be the 'impact' sites, while unaltered reaches will be the 'control' sites:

Impact:

1. Eckert Creek;

Control:

2. Katarapko Creek.

A minimum of five sites are to be sampled in each of these locations.

To assess fish movement (emigration/immigration), fish are to be sampled from all sites described as well as from the main river stem. More detail on the methodology and the recommended species selection is included in Section 4.

4. Methodology

The 25 different hypotheses have been developed to monitor and evaluate the implementation of seven interventions within the Katfish Demonstration Reach. These hypotheses address the following main issues relating to fish ecology in the Katarapko Anabranch System (associated hypotheses codes are indicated in brackets):

1. Fish community structure (H1, H4, H7, H11, H15, H19, H24, H25),
2. Habitat availability (H2, H5, H8, H12, H17, H21),
3. Fish habitat use (H2, H5, H8, H12, H17, H21),
4. Recruitment success (H3, H6, H9, H13, H18, H22, H23),
5. Fish movement (H7, H10, H11, H14, H15, H19, H20, H24, H25),
6. Fish accumulations below in-stream barriers (H10, H14), and
7. Non-native species, notably carp (H16, H20, H23, H24, H25).

To address these main issues similar methods will be used across all of the interventions and these can be grouped into the following general methods:

1. Electro fishing surveys (to assess fish community structure, fish-habitat associations, recruitment success, fish accumulations, fish movement, non-native fish species);
2. Habitat assessment (to assess habitat availability and habitat use); and
3. Telemetry (to assess fish movement, emigration/immigration).

An overview of the sampling methodology for each hypothesis is given is Table 2, while the specific nature of these methods will vary according to the indicator/s to be measured.

4.1 Electro fishing surveys

Boat electro fishing has previously been used in the Katarapko system in 2007 and 2009 (Leigh *et al.,* 2008, 2009) and is commonly used to address similar fish ecology research questions (Baumgartner *et al.,* 2008; Zampatti *et al.*, 2008; Henderson *et al.*, 2008).

To assess the **fish community structure** and **non-native species (notably carp)** electro fishing surveys should be carried out using a boat mounted electro fishing system. At each sampling site, an equal number of electro fishing shots on each side of the river/creek should be undertaken during daylight hours. All fish are to be dip netted and placed in a recirculating well. Fish from each shot are identified and a sub sample of 20 individuals measured for length. Any positively identified fish unable to be dip netted should be recorded as 'observed'. For each sampling site, water quality data (pH, turbidity, temperature, conductivity, dissolved oxygen) should be collected using a hand-held water quality meter at all fish survey sites.

To assess **fish habitat use** (fish-habitat associations), electro fishing surveys described above should be combined with habitat assessment surveys discussed in Section 4.2.

To detect **recruitment success** for individual fish species, length distributions will be generated from data collected from the electro fishing surveys described above. Alternatively, for species where there is high variability in length at age (e.g. golden perch *Macquaria ambigua*), age may be determined using ageing techniques from a sub sample of fish.

To **assess fish movement**, electro fishing surveys will be used to capture suitable species for tagging (tag-outs). Two different tagging technologies are recommended namely battery powered radio frequency transmitters (Radio tags) and/or passive integrated transponder tags (PIT). More detail on the telemetry methodology is presented in Section 4.3.

To assess potential changes in **fish accumulations below in-stream barriers** in response to management interventions, site selection must include sites directly below in-stream barriers.

4.2 Habitat assessment

To assess **habitat availability**, quantitative habitat assessments should be carried out simultaneously to the electro fishing surveys (Zampatti *et al.* 2006; Leigh *et al.* 2008). The percentage cover of each plant species, large woody debris (loading and complexity) and open water in the area covered by each electro fishing shot is recorded by an observer. Submerged vegetation can be sampled using a van Veen grab to enable identification to species where possible.

4.3 Telemetry

To assess potential changes in **fish movement** in response to improved fish passage within the system, large-bodied potamodromous native fish species such as golden perch and Murray cod *Maccullochella peelii peelii* are recommended for use in telemetry investigations. Both species are known to occur in the Katarapko system (Leigh *et al.,* 2007, 2009) and undertake up- and downstream movements within the Murray River (Jones & Stuart, 2007; O'Connor *et al.*, 2005). They are also assumed to occur in sufficient numbers within the Katarapko anabranch system to allow the capture of a suitable number of individuals to allow the appropriate assessment of their emigration/immigration into/out of the system.

We would also recommend the inclusion of non-native common carp *Cyprinus carpio* in the telemetry study, due to their abundance in the Katarapko system and their known migratory behaviour (Jones & Stuart, 2007). Investigating spatial and temporal variability in common carp movement will enable the confirmation of not only the reinstatement of connectivity within the system but also the functionality of any carp control methodology that may be applied as part of the management interventions.

Two different tagging technologies are recommended:

1. Passive integrated transponder tags (PIT) (Gibbons & Andrews, 2004; Skov *et al.* 2005; Park & Park, 2009); and/or
2. Battery powered radio frequency transmitters (Radio tags) (Crossman 1977; O'Connor *et al.*, 2005; Jones & Stuart, 2007).

For the application of both, PIT and Radio tags, fish should be collected using the electro fishing survey technique described in Section 4.1. Monitoring of the movement of tagged fish within the Katarapko anabranch system may take place using handheld receivers and *via* permanently fixed receiving stations.

Table 2: Summary of the monitoring methods recommended across the seven interventions and associated hypotheses.

Method	Intervention 1			Intervention 2			Intervention 3				Intervention 4				Intervention 5				Intervention 6				Intervention 7		
	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23	H24	H25
Electro-fishing: fish community structure																									
Electro-fishing: recruitment success																									
Electro-fishing: fish-habitat associations																									
Electro-fishing: fish movement/tag-out																									
Electro-fishing: fish accumulations																									
Electro-fishing: non-native fish (notably carp)																									
Habitat assessment: habitat availability																									
Habitat assessment: fish-habitat associations																									
Telemetry: fish movement																									

6. Resource requirements

The resource requirements presented here are estimated on an annual basis, and independent of each other (Table 3). Each of the respective surveys is assumed to be done separately while expenditure could be reduced if these were done in a combined manner, i.e. when using the same methods to address different hypotheses. The estimated requirements include the number of days and staff required for the respective field surveys, project management, data entry, data analysis, report writing and are presented for each of the 25 hypotheses. For equipment requirements please refer to Section 5, which presents details on the methodology used to address the hypotheses.

Table 3: Overview of the event based resource requirements estimated for each of the 25 proposed hypotheses. n, denotes the number of staff required for this task.

Hypothesis	Survey Days (n)	Project Management Days (n)	Data Entry Days (n)	Data Analysis Days (n)	Report Writing Days (n)
H1 (Fish community)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H2 (Habitat assessment)	15 (2)	5 (1)	3 (1)	10 (1)	10 (1)
H2 (Fish-Habitat Associations)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H3 (Recruitment success)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H4 (Fish community)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H5 (Habitat assessment)	15 (2)	5 (1)	3 (1)	10 (1)	10 (1)
H5 (Fish-Habitat Associations)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H6 (Recruitment success)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H7 (Fish community)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H7 (Tag-out)	15 (3)	5 (1)	3 (1)	–	–
H7 (Fish movement)	21 (2)	5 (1)	5 (1)	10 (1)	10 (1)
H8 (Habitat assessment)	15 (2)	5 (1)	3 (1)	10 (1)	10 (1)
H8 (Fish-Habitat Associations)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H9 (Recruitment success)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H10 (Fish community)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H10 (Tag-out)	15 (3)	5 (1)	3 (1)	–	–
H10 (Fish movement)	21 (2)	5 (1)	5 (1)	10 (1)	10 (1)
H10 (Fish accumulations)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H11 (Fish community)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H11 (Tag-out)	15 (3)	5 (1)	3 (1)	–	–
H11 (Fish movement)	21 (2)	5 (1)	5 (1)	10 (1)	10 (1)
H12 (Habitat assessment)	15 (2)	5 (1)	3 (1)	10 (1)	10 (1)
H12 (Fish-Habitat Associations)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H13 (Recruitment success)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H14 (Fish community)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H14 (Tag-out)	15 (3)	5 (1)	3 (1)	–	–
H14 (Fish movement)	21 (2)	5 (1)	5 (1)	10 (1)	10 (1)
H14 (Fish accumulations)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H15 (Fish community)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H15 (Tag-out)	15 (3)	5 (1)	3 (1)	–	–
H15 (Fish movement)	21 (2)	5 (1)	5 (1)	10 (1)	10 (1)
H16 (Fish community, e.g. Carp)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H17 (Habitat assessment)	15 (2)	5 (1)	3 (1)	10 (1)	10 (1)
H17 (Fish-Habitat Associations)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)

H18 (Recruitment success)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H19 (Fish community)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H19 (Tag-out)	15 (3)	5 (1)	3 (1)	–	–
H19 (Fish movement)	21 (2)	5 (1)	5 (1)	10 (1)	10 (1)
H20 (Fish community, e.g. Carp)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H20 (Tag-out)	15 (3)	5 (1)	3 (1)	–	–
H20 (Fish movement)	21 (2)	5 (1)	5 (1)	10 (1)	10 (1)
H21 (Habitat assessment)	15 (2)	5 (1)	3 (1)	10 (1)	10 (1)
H21 (Fish-Habitat Associations)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H22 (Recruitment success)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H23 (Fish community, e.g. Carp)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H23 (Recruitment success)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H24 (Fish community, e.g. Carp)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H24 (Tag-out)	15 (3)	5 (1)	3 (1)	–	–
H24 (Fish movement)	21 (2)	5 (1)	5 (1)	10 (1)	10 (1)
H25 (Fish community, e.g. Carp)	15 (3)	5 (1)	3 (1)	10 (1)	10 (1)
H25 (Tag-out)	15 (3)	5 (1)	3 (1)	–	–
H25 (Fish movement)	21 (2)	5 (1)	5 (1)	10 (1)	10 (1)

7. Summary and conclusions

To address the seven interventions proposed for the Katarapko anabranch system, a large number of hypotheses were developed. Of these, a total of 25 hypotheses were chosen as they were deemed the most suitable hypotheses for this monitoring program. The hypotheses associated with each intervention are presented in detail together with the linked goals, response scales and the indicators to be measured (Section 2; Table 1). The experimental approach and methodology is described with the associated resource requirements presented on an annual basis (Section 3 and 4; Table 2; Table 3).

All hypotheses are based on the current knowledge of fish ecology and the intervention management options for the Katarapko anabranch system (Katfish Reach Steering Group, 2008a, b). We have assumed that there will be a time lag before any of the interventions are implemented. This assumption was of importance in hypothesis development and the associated experimental designs (Paired Before-After-Control-Impact Design (BACIP); see design options in Boys *et al*., 2008). If conditions for the BACIP monitoring design are not met, the 'fallback' design to be used is the 'Control-Intervention' design, which is less powerful to show responses to interventions in fish (Boys *et al*., 2008).

For the purpose of this report the seven interventions and associated hypotheses were treated independently (i.e. as single units). Nevertheless, the Katarapko Anabranch ecosystem is connected to the River Murray and is thus influenced by river management and broader scale ecological processes. Furthermore, the range of proposed interventions in the Katfish Reach may eventually be undertaken simultaneously. A combination of these factors may potentially confound the determination of causality with respect to individual interventions and objective judgement will need to be used when designing and interpreting monitoring programs.

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