EPBC 2019/8590 - Operation of Peel River Drought Protection Works, Tamworth, NSW.

Chaffey to Dungowan Pipeline:

Annual Compliance Report 2024

Author	Jeremy Stacy, Environmental Adviser
Review	Evan Webb, Manager Environmental Services
Revision history	V1 - 12 August 2024

Declaration of accuracy

In making this declaration, I am aware that sections 490 and 491 of the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) make it an offence in certain circumstances to knowingly provide false or misleading information or documents. The offence is punishable on conviction by imprisonment or a fine, or both. I declare that all the information and documentation supporting this compliance report is true and correct in every particular. I am authorised to bind the approval holder to this declaration and that I have no knowledge of that authorisation being revoked at the time of making this declaration.

Signed	
Full Name	Ronan Magaharan
Position	Executive Manager, Operations
Organisation (including ABN)	WaterNSW ABD 21 147 934 787
Date:	16 August 2024

Table of Contents

List of Tables

Appendices

1. Introduction

Chaffey Dam is located on the Peel River approximately 43 kilometres (km) south-east of Tamworth, between the towns of Nundle and Woolomin, NSW.

Water NSW obtained approval to operate a temporary drought mitigation pipeline to supply water directly from Chaffey Dam to the Tamworth water supply network via the Chaffey Dam to Dungowan Pipeline in June 2020. The pipeline extends underground approximately 18km from Chaffey Dam to Dungowan and connects with the existing Dungowan Dam to Calala water treatment plant pipeline operated by Tamworth Regional Council (TRC).

The pipeline was constructed to operate during severe drought to increase town water security for Tamworth when the Chaffey Dam storage fell below 20% capacity. During operation, water deliveries to TRC were made via the pipeline resulting in no water deliveries to TRC being made via releases to the Peel River.

On 3 June 2020, WaterNSW received authorisation by the NSW Minister for Water, Property and Housing under the *Water Supply (Critical Needs) Act 2019,* to operate the pipeline in accordance with the conditions of approval. Approval under NSW WSCN Act expired on 30 September 2021.

On 12 June 2020, WaterNSW received approval EPBC 2019/8590 with conditions, from the Commonwealth Minister for the Environment for the controlled activity to operate the pipeline during drought. The approval contained a number of conditions including, but not limited to; annual monitoring and compliance reporting; and the development and implementation of a Biodiversity Offset Plan (BOP, GHD 2022). The approval EPBC 2019/8590 to operate the temporary drought mitigation pipeline, has effect until 1 May 2030. The drought ceased September 2020 and the pipeline is not in operation.

WaterNSW (ABN: 21 147 934 787) is the approval holder for the Chaffey Dam to Dungowan Pipeline Drought Operation project (EPBC 2019/8590) approximately 43 km south-east of Tamworth. The construction was completed in March 2020. Operation of the pipeline to deliver water to Tamworth Regional Council's Calala water treatment plant commenced 17 June 2020 and continued to 29 July 2020. The delivery of water via the pipeline has not occurred since 29 July 2020.

This report has been prepared to fulfil the annual compliance reporting requirements of EPBC 2019/8590.

2. Description of Activities

This report relates to the activities undertaken during the reporting period from 17 June 2023 to 16 June 2024. Activities completed in response to EPBC2019/8590 approval include:

- Engage construction partner for snag installation works
    - Installation of snags commenced March 2024 with 45 of the 50 snags (90%) being installed by 16 June 2024.

- Baseline monitoring field surveys commenced October 2023 and were completed within the reporting period.
- Assessment of screens solutions for small pumps found on Peel River.
- Identification and assessment of candidate pump sites/owners on the Namoi and Peel that meet available screening solutions.
- Preparation of this annual compliance report.

3. Compliance Review – Conditions as per EPBC 2019/8590

The approval notice – to operate a temporary drought mitigation pipeline to supply water directly from Chaffey Dam to the Tamworth water supply network (EPBC 2019/8590) issued on 12 June 2020, requires annual reporting from the commencement of the action on 17 June 2020, against the conditions of consent. Table 2 below outlines these conditions and provides a statement of compliance for the reporting year to 16 June 2024. This report fulfils the requirements of EPBC 2019/8590 Condition 12.

Table 1: Compliance tracking 17 June 2023 to 16 June 2024

Condition	Source Section No.	Source Page No.	Condition	Action to achieve Compliance	Responsibility	Condition / Commitment Implemented?	Link to Evidence/Record	Status Review	
								June 2024	Evidence / Comments
n/a	**EPBC 2019/8590 Notice of Approval letter.**	**1**	EPBC notices to be available on WaterNSW website	Make EPBC approval available on WaterNSW website. Weblink to DCCEEW EPBC approval	WaterNSW	15/06/2020	EPBC 2019/8590 Approval Peel Valley - WaterNSW website	Compliant; complete	ARK reference D2020/58692 Approval link to DCCEEW EPBC website
1	Annexure A Part A	2	The approval holder must implement the Drought Operations - Delivery of Peel Environmental Water Plan for the life of the approval. In addition, the approval holder must comply with NSW conditions of authorisation where those conditions relate to environmental water releases and operation of the technical advisory group.	Submission of Delivery plan - submitted with referral Pipeline operated in accordance with State and Commonwealth approval conditions. PEWTAG provided monitoring data as available	WaterNSW, Operations	12 June 2020 until cessation of drought	Peel Valley - WaterNSW website	Compliant; complete	Implemented; incorporated into WSCN authorisation conditions; ARK D2020/58721 EPBC Approval D2020/58692 Monitoring data collected as requirement of NSW authorisation F2019/5571 Drought ceased September 2020 WSCN Authorisation expired 30 September 2021 Operation of pipeline ceased August 2020
2	Annexure A Part A	2	The approval holder must notify the technical advisory group at least five business days prior to commencing the next phase of operation.	Notice to be sent within time frame required and posted on project website	WaterNSW, Operations	17/06/2020	Peel Valley - WaterNSW website	Compliant; complete	Notices posted to website
3	Annexure A Part A	2	The approval holder must invite the Commonwealth Environmental Water Holder to nominate a representative to become a member of the technical advisory group.	Email invitation	WaterNSW, Operations	12/06/2020	ARK D2021/120098	Compliant; complete	D2021/120098 CEWH members identified in PEWTAG terms of reference, page 6
4	Annexure A Part A	2	To compensate for impacts to Murray Cod and Silver Perch, the approval holder must, within 20 business days of commencement of the action, submit a Biodiversity Offset Management Plan (BOMP) for approval by the Minister. If the Minister approves the BOMP, then the BOMP must be implemented.	Draft Biodiversity Offset Management Plan	WaterNSW - EnvServ	submitted 15/07/2020	ARK# D2021/119441	Compliant; Complete	Draft submitted to department 15/07/2020 D2021/119441
5	Annexure A Part A	2	The approval holder must make all reasonable efforts to ensure the BOMP (in full) meets the following requirements and promptly address any feedback from the Department on unapproved versions of the BOMP so that the BOMP is suitable for the Minister to approve within three months of the commencement of the action.	Biodiversity Offset Management Plan	WaterNSW - EnvServ	Plan approved 29 October 2020 Amended plan approved 3 November 2022	BOP ARK# D2022/109857 (Rev 4)	Compliant	BOP D2020/101647 (superseded) Plan approval D2020/116788 Amended approval D2022/152810 2023 Revision 5 Nov pending Departmental approval: The BOP has been amended to revise delivery timeframes due to ongoing delays due floods and persistent elevated river levels.

Condition	Source Section No.	Source Page No.	Condition	Action to achieve Compliance	Responsibility	Condition / Commitment Implemented?	Link to Evidence/Record	Status Review	
								June 2024	Evidence / Comments
6	Annexure A Part A	2	The BOMP must: **a.** be prepared by a suitably qualified ecologist, and be consistent with the Department's Environmental Management Plan Guidelines and the EPBC Act Environmental Offset Policy; **b.** propose an offset package, including direct habitat restoration works and conservation measures relevant to Murray Cod and Silver Perch **c**. include, but not be limited to: **i.** specific objectives to demonstrate improvements in habitat quality and conservation outcomes for Murray Cod and Silver Perch over the life of the approval; **ii**. specific management actions, and timeframes for implementation, to be carried out to meet the specific objectives to improve habitat quality and conservation outcomes for Murray Cod and Silver Perch; **iii**. key performance indicators to demonstrate the improvements in habitat quality and conservation outcomes for Murray Cod and Silver Perch; **iv**. the nature, timing and frequency of monitoring to determine the success of management actions against key performance indicators; **v**. indicative corrective actions that will be implemented in the event monitoring activities indicate key performance indicators are not or are unlikely to be achieved; **vi.** the roles and responsibilities for implementing the management actions; **vii.** evidence of consistency with relevant conservation advices, recovery plans and/or threat abatement plans; **viii**. commitments to maintain or improve the extent and quality of habitat and populations of other EPBC Act listed threatened species and ecological communities in the offset area; and a timeline and legal mechanism for implementing the offset(s).	Biodiversity Offset Management Plan Rev. 4 September 2022	WaterNSW - EnvServ JS	Amended Plan approved 3 November 2022	BOP ARK # D2022/109857 (Rev.4)	Compliant	BOP (Rev.4) approval D2022/152810 BOP November 2023 Revision 5 - Pending approval Variation request to the Department - D2023/158994 and D2024/28912 The BOP has been amended to revise delivery timeframes due to ongoing delays due floods and persistent elevated river levels.
7	Annexure A Part B	3	The approval holder must notify the Department in writing of the date of commencement of the action within 10 business days after the date of commencement of the action. The approval holder must notify the Department in writing of the date of commencement of each phase of operation within 10 business days after the date of commencement of each phase of operation.	Send advice via email at each change of operation phase.	WaterNSW, Operations - AS	Notice #1 - 17 June 2020 - Commencement of Action Notice #2 - 1 Juy 2020 Notice #3 - 29 July 2020	ARK D2021/120827 D2021/120845 D2021/120866	Compliant; Complete	Media Release - https://www.waternsw.com.au/about/newsroom/2020/chaffey-to-tamworth-pipeline-operational
8	Annexure A Part B	3	The approval holder must maintain accurate and complete compliance records.	Maintain approval tracking spreadsheet and identified records within	WaterNSW - EnvServ	Implemented compliance tracking	ARK D2022/18480	Compliant	ARK D2022/18480 - tracking of ongoing commitments and relevant records are updated within spreadsheet
9	Annexure A Part B	3	If the Department makes a request for compliance records in writing, the approval holder must provide electronic copies of compliance records to the Department within the timeframe specified in the request.	Notice from Department to be received	WaterNSW PM EnvServ	No requests received	N/A	Compliant	No requests received

Condition	Source Section No.	Source Page No.	Condition	Action to achieve Compliance	Responsibility	Condition / Commitment Implemented?	Link to Evidence/Record	Status Review	
								June 2024	Evidence / Comments
10	Annexure A Part B	3	The approval holder must: **a.** submit plans electronically to the Department; **b**. publish each plan on the website within 20 business days of the date of this approval, or the date that the plan is approved by the Minister or of the date a revised action management plan is submitted to the Minister or the Department, unless otherwise agreed to in writing by the Minister; **c**. exclude or redact sensitive ecological data from plans published on the website or provided to a member of the public; and **d.** keep plans published on the website until the end date of this approval.	Submit plans via email to Department Post Approval PostApproval@dcceew.gov.au Approved plans to be published to WaterNSW website https://www.waternsw.com.au/supply/drought-information/regional-nsw/peel-valley	WaterNSW - EnvServ JS	BOP submitted to DCCEEW; BOP published to WNSW project website	https://www.waternsw.com.au/__data/assets/pdf_file/0016/161620/Chaffey-to-Dungowan-Pipeline-EPBC-2019_8590-BOMP-Rev-4-30-Sept-2022.PDF	Compliant	BOP D2020/101647 Approval D2020/116788 Revised BOP November 2023 Pending approval
11	Annexure A Part B	3	The approval holder must ensure that any monitoring data (including sensitive ecological data), surveys, maps, and other spatial and metadata required under a plan, is prepared in accordance with the Department's Guidelines for biological survey and mapped data (2018) and submitted electronically to the Department in accordance with the requirements of the plan.	Submit with annual compliance report via email to Department epbcmonitoring@dcceew.gov.au	WaterNSW Project Delivery PM; EnvServ	Baseline monitoring completed within 2023-2024 reporting period	ARK# D2024/44694	Compliant	Baseline monitoring report prepared 2023-2024, spatial data not supplied ARK# D2024/44694
12	Annexure A Part B	3	The approval holder must prepare a compliance report for each 12 month period following the date of commencement of the action, or otherwise in accordance with an annual date that has been agreed to in writing by the Minister. The approval holder must: a. publish each compliance report on the website within 60 business days following the relevant 12 month period; b. notify the Department by email that a compliance report has been published on the website and provide the weblink for the compliance report within five business days of the date of publication; c. keep all compliance reports publicly available on the website until this approval expires; d. exclude or redact sensitive ecological data from compliance reports published on the website; and e. where any sensitive ecological data has been excluded from the version published, submit the full compliance report to the Department within five business days of publication.	Compliance report to be prepared and published to WaterNSW website https://www.waternsw.com.au/supply/drought-information/regional-nsw/peel-valley Biodiversity monitoring report to be prepared as per BOP requirements; Email notification to DCCEEW epbcmonitoring@dcceew.gov.au to advise of compliance report availability and link to publication on WaterNSW website	WaterNSW - EnvServ WQS	Annual compliance report to be prepared	2023-2024 Annual Compliance Report ARK# D2024/53418	Compliant	ARK# D2024/53418 2023-2024 Annual Compliance Report
13	Annexure A Part B	4	The approval holder must **notify** the Department in writing of any: incident; non-compliance with the conditions; or non-compliance with the commitments made in plans. The notification must be given as soon as practicable, and no later than two business days after becoming aware of the incident or non-compliance. The notification must specify: **a.** any condition which is or may be in breach; **b**. a short description of the incident and/or non-compliance; and **c.** the location (including co-ordinates), date, and time of the incident and/or non-compliance. In the event the exact information cannot be provided, provide the best information available.	Send advice via email to Department: epbcmonitoring@dcceew.gov.au	WaterNSW	Notification made to the Department 1 September 2023 regarding ability to deliver offsets within the timeframe of October 2023 and potential breach.	ARK# D2023/56383 - Potential Non-compliance ARK#D2024/55990 – Non-compliance notification	Compliant	Notification sent to the Department 1 September 2023 advising of a potential to be non-compliant with offset installation timeframes. D2024/55990 - Department advised of actual non-compliance October 2023

Condition	Source Section No.	Source Page No.	Condition	Action to achieve Compliance	Responsibility	Condition / Commitment Implemented?	Link to Evidence/Record	Status Review	
								June 2024	Evidence / Comments
14	Annexure A Part B	4	The approval holder must **provide** to the Department the details of any incident or noncompliance with the conditions or commitments made in plans as soon as practicable and no later than 10 business days after becoming aware of the incident or non-compliance, specifying: **a.** any corrective action or investigation which the approval holder has already taken or intends to take in the immediate future; **b**. the potential impacts of the incident or non-compliance; and **c.** the method and timing of any remedial action that will be undertaken by the approval holder.	Send advice via email to Department: epbcmonitoring@dcceew.gov.au	WaterNSW		ARK# D2024/55990	Compliant	Revised delivery timeframe identified within amended biodiversity offset management plan submitted for approval November 2023. ARK# D2023/158994 and D2024/28912
15	Annexure A Part B	4	The approval holder must ensure that independent audits of compliance with the conditions are conducted as requested in writing by the Minister.	N/A	WaterNSW	Nil to date	N/A	Not applicable	Nil requests to date
16	Annexure A Part B	4	For each independent audit, the approval holder must: **a**.provide the name and qualifications of the independent auditor and the draft audit criteria to the Department; **b**.only commence the independent audit once the audit criteria have been approved in writing by the Department; and **c**.submit an audit report to the Department within the timeframe specified in the approved audit criteria.		WaterNSW	Nil to date	N/A	Not applicable	No audits undertaken to date
17	Annexure A Part B	4	The approval holder must publish the audit report on the website within 10 business days of receiving the Department's approval of the audit report and keep the audit report published on the website until the end date of this approval.	Nil to date	WaterNSW	Nil to date	N/A	Not applicable	No reports prepared to date
18	Annexure A Part B	4	The approval holder may, at any time, apply to the Minister for a variation to an action management plan approved by the Minister under condition 4, or as subsequently revised in accordance with these conditions, by submitting an application in accordance with the requirements of section 143A of the EPBC Act. If the Minister approves a revised action management plan (RAMP) then, from the date specified, the approval holder must implement the RAMP in place of the previous action management plan.	Application to Minister to amend Biodiversity Offset Plan	WaterNSW	Request to amend Biodiversity Offset Plan made in accordance with approval condition requirements November 2023.	Variation request sent 21 November 2023	Compliant	Variation to Biodiversity Offset Plan requested 21/11/2023 ARK# D2024/28912
19	Annexure A Part B	4	Within 30 days after the completion of the action, the approval holder must notify the Department in writing and provide completion data.	notification letter/email epbcmonitoring@dcceew.gov.au	WaterNSW - EnvServ	Nil to date	Department notified of completion of the action 30 July 2020 ARK# D2021/120866	Compliant; complete	Operation of the pipeline is not permitted outside of the drought which ceased September 2020 and the action is no longer occurring.

'Compliance' is achieved when all the requirements of a condition have been met, including the implementation of management plans or other measures required by those conditions.

A designation of 'non-compliance' should be given where the requirements of a condition or elements of a condition, including the implementation of management plans and other measures, have not been met.

A designation of 'not applicable ' should be given where the requirements of a condition or elements of a condition fall outside of the scope of the current reporting period. For example, a condition which applies to an activity that has not yet commenced.

4. Implementation of Offset Plan

The revised Biodiversity Offset Plan (GHD 2022) outlines the key management actions required to achieve the objectives of improving habitat for Murray Cod and Silver Perch. Table 2 below outlines the activities undertaken in order to implement the management actions identified within the BOP.

The baseline survey was undertaken prior to the installation of the offset measures and field surveys commenced in October 2023. The survey and report were completed by May 2024.

On ground re-snagging works commenced in March 2024. At the time of commencement of the installation works, it was expected that the 50 snag installations would be completed by mid-2024, (as advised November 2023). Installation of the snags progressed ahead of schedule, with 45 snags (90%) installed by 16 June 2024[1].

The following actions in Table 2 have been undertaken during the reporting period 17 June 2023 to 16 June 2024;

Table 2: Summary of actions undertaken during reporting period.

Offset Measure	Actions Undertaken	Performance in accordance with BOMP
1 – Re-snagging Develop plan to install up to 50 snags as habitat for Murray Cod and Silver Perch	**Installation** Contractor engaged and installation of snags within the Peel River commenced March 2024. (installation 90% completed as of 16 June 2024)	Compliant
Baseline and Monitoring Survey	Baseline monitoring completed: Field surveys undertaken during October 2023 and March 2024 and report submitted	Compliant
2 – Self-cleaning Pump Screens Install self-cleaning pumps screens on extraction points to seven licenced pumps downstream from Chaffey Dam	Undertake further assessments of Peel and Namoi pumps to assess suitability to receive either type of self-cleaning pump screens, including: - identify site constraints and installation requirements, e.g. access, electrical, safety, pump/screen retrieval systems - specify pump screen requirements for manufacture - assess suitability of small pump screening solutions	Compliant

[1] All 50 snags were completed and installed by 24 June 2024

Investigation of alternate screen manufacturers was undertaken to identify self-cleaning pumps screens that are suited to the smaller capacity licenced pumps found on the Peel River.

To ensure that the requirement of installing self-cleaning pumps screens on seven licenced water pumps is achieved by June 2025 (revised timeframe), investigations along both the Peel and Namoi Rivers were undertaken.

4.1 Impacts to Implementation

Reported in previous years, significant delays to undertaking the actions required to progress the implementation of the Biodiversity Offset Plan were significant.

WaterNSW submitted a variation request in November 2023 to the Department regarding offset delivery and requesting further revision to the implementation dates.

Confirmation from the Department of the acceptance of the revised implementation dates has not been received prior to preparation of this report[2].

Based on the revised implementation dates, WaterNSW is confident of being able to fully implement the biodiversity offset plan measures, re-snagging and self-cleaning pumps screens by June 2025.

[2] Correspondence from the department during July has been received that indicates acceptance of proposed changes

APPENDICES

Appendix 1 – EPBC 2019/8590 Notice of Approval

Australian Government
Department of Agriculture, Water and the Environment

APPROVAL

Operation of Peel River Drought Protection Works, Tamworth, NSW (EPBC 2019/8590)

This decision is made under sections 130(1) and 133(1) of the *Environment Protection and Biodiversity Conservation Act 1999 (Cth)*. Note that section 134(1A) of the **EPBC Act** applies to this approval, which provides in general terms that if the approval holder authorises another person to undertake any part of the action, the approval holder must take all reasonable steps to ensure that the other person is informed of any conditions attached to this approval, and that the other person complies with any such condition.

Details

Person to whom the approval is granted (approval holder)	WATER NSW
ACN or ABN of approval holder	ABN: 21 147 934 787
Action	To operate a temporary drought mitigation pipeline to supply water directly from Chaffey Dam to the Tamworth water supply network [See **EPBC Act** referral 2019/8590].

Approval decision

My decision on whether or not to approve the taking of the action for the purposes of the controlling provision for the action is as follows.

Controlling Provisions

Listed Threatened Species and Communities	
Section 18	Approve
Section 18A	Approve

Period for which the approval has effect

This approval has effect until 01 May 2030

Decision-maker

Name and position

The Hon Sussan Ley MP
Minister for the Environment

Signature Sussan Ley

Date of decision 12 June 20

Conditions of approval

This approval is subject to the conditions under the EPBC Act as set out in ANNEXURE A.

ANNEXURE A – CONDITIONS OF APPROVAL

Part A – Conditions specific to the action

1. The approval holder must implement the **Drought Operations – Delivery of Peel Environmental Water Plan** for the life of the approval. In addition the approval holder must comply with **NSW conditions of authorisation** where those conditions relate to environmental water releases and operation of the **technical advisory group**.
2. The approval holder must notify the **technical advisory group** at least five **business days** prior to commencing the next **phase of operation**.
3. The approval holder must invite the **Commonwealth Environmental Water Holder** to nominate a representative to become a member of the **technical advisory group**.
4. To compensate for impacts to **Murray Cod** and **Silver Perch**, the approval holder must, within 20 **business days** of **commencement of the action**, submit a Biodiversity Offset Management Plan (BOMP) for approval by the **Minister**. If the **Minister** approves the BOMP, then the BOMP must be implemented.
5. The approval holder must make all reasonable efforts to ensure the BOMP (in full) meets the following requirements and promptly address any feedback from the **Department** on unapproved versions of the BOMP so that the BOMP is suitable for the **Minister** to approve within three months of the **commencement of the action.**
6. The BOMP must:
    a. be prepared by a **suitably qualified ecologist**, and be consistent with the **Department's Environmental Management Plan Guidelines** and the **EPBC Act Environmental Offset Policy**;
    b. propose an offset package, including direct habitat restoration works and conservation measures relevant to **Murray Cod** and **Silver Perch**;
    c. include, but not be limited to:
        i. specific objectives to demonstrate improvements in habitat quality and conservation outcomes for **Murray Cod** and **Silver Perch** over the life of the approval;
        ii. specific management actions, and timeframes for implementation, to be carried out to meet the specific objectives to improve habitat quality and conservation outcomes for **Murray Cod** and **Silver Perch**;
        iii. key performance indicators to demonstrate the improvements in habitat quality and conservation outcomes for **Murray Cod** and **Silver Perch**;
        iv. the nature, timing and frequency of monitoring to determine the success of management actions against key performance indicators;
        v. indicative corrective actions that will be implemented in the event monitoring activities indicate key performance indicators are not or are unlikely to be achieved;
        vi. the roles and responsibilities for implementing the management actions;
        vii. evidence of consistency with relevant conservation advices, recovery plans and/or threat abatement plans;
        viii. commitments to maintain or improve the extent and quality of habitat and populations of other **EPBC Act** listed threatened species and ecological communities in the offset area; and
        ix. a timeline and legal mechanism for implementing the offset(s).

Part B – Standard administrative conditions

Notification of date of commencement of the action

7. The approval holder must notify the **Department** in writing of the date of **commencement of the action** within 10 **business days** after the date of **commencement of the action.** The approval holder must notify the **Department** in writing of the date of **commencement** of each **phase of operation** within 10 **business days** after the date of **commencement** of each **phase of operation**.

Compliance records

8. The approval holder must maintain accurate and complete **compliance records**.
9. If the **Department** makes a request for **compliance records** in writing, the approval holder must provide electronic copies of **compliance records** to the **Department** within the timeframe specified in the request.

Note: **Compliance records** may be subject to audit by the **Department** or an independent auditor in accordance with section 458 of the **EPBC Act**, and or used to verify compliance with the conditions. Summaries of the result of an audit may be published on the **Department's website** or through the general media.

Preparation and publication of plans

10. The approval holder must:
    a. submit **plans** electronically to the **Department**;
    b. publish each **plan** on the **website** within 20 **business days** of the date of this approval, or the date that the **plan** is approved by the **Minister** or of the date a revised action management **plan** is submitted to the **Minister** or the **Department**, unless otherwise agreed to in writing by the **Minister**;
    c. exclude or redact **sensitive ecological data** from **plans** published on the **website** or provided to a member of the public; and
    d. keep **plans** published on the **website** until the end date of this approval.
11. The approval holder must ensure that any **monitoring data** (including **sensitive ecological data**), surveys, maps, and other spatial and metadata required under a **plan**, is prepared in accordance with the **Department's** *Guidelines for biological survey and mapped data* (2018) and submitted electronically to the **Department** in accordance with the requirements of the **plan**.

Annual compliance reporting

12. The approval holder must prepare a **compliance report** for each 12 month period following the date of **commencement of the action**, or otherwise in accordance with an annual date that has been agreed to in writing by the **Minister**. The approval holder must:
    a. publish each **compliance report** on the **website** within 60 **business days** following the relevant 12 month period;
    b. notify the **Department** by email that a **compliance report** has been published on the **website** and provide the weblink for the **compliance report** within five **business days** of the date of publication;
    c. keep all **compliance reports** publicly available on the **website** until this approval expires;
    d. exclude or redact **sensitive ecological data** from **compliance reports** published on the **website**; and
    e. where any **sensitive ecological data** has been excluded from the version published, submit the full **compliance report** to the **Department** within five **business days** of publication.

Note: The first **compliance report** may report a period less than 12 months so that it and subsequent **compliance reports** align with the similar requirement under state approval. **Compliance reports** may be published on the **Department's website**.

Reporting non-compliance

13. The approval holder must notify the **Department** in writing of any: **incident;** non-compliance with the conditions; or non-compliance with the commitments made in **plans**. The notification must be given as soon as practicable, and no later than two **business days** after becoming aware of the **incident** or non-compliance. The notification must specify:
    a. any condition which is or may be in breach;
    b. a short description of the **incident** and/or non-compliance; and
    c. the location (including co-ordinates), date, and time of the **incident** and/or non-compliance. In the event the exact information cannot be provided, provide the best information available.
14. The approval holder must provide to the **Department** the details of any **incident** or non-compliance with the conditions or commitments made in **plans** as soon as practicable and no later than 10 **business days** after becoming aware of the **incident** or non-compliance, specifying:
    a. any corrective action or investigation which the approval holder has already taken or intends to take in the immediate future;
    b. the potential impacts of the **incident** or non-compliance; and
    c. the method and timing of any remedial action that will be undertaken by the approval holder.

Independent audit

15. The approval holder must ensure that **independent audits** of compliance with the conditions are conducted as requested in writing by the **Minister**.
16. For each **independent audit**, the approval holder must:
    a. provide the name and qualifications of the independent auditor and the draft audit criteria to the **Department**;
    b. only commence the **independent audit** once the audit criteria have been approved in writing by the **Department**; and
    c. submit an audit report to the **Department** within the timeframe specified in the approved audit criteria.
17. The approval holder must publish the audit report on the **website** within 10 **business days** of receiving the **Department's** approval of the audit report and keep the audit report published on the **website** until the end date of this approval.

Revision of action management plans

18. The approval holder may, at any time, apply to the **Minister** for a variation to an action management **plan** approved by the **Minister** under condition 4, or as subsequently revised in accordance with these conditions, by submitting an application in accordance with the requirements of section 143A of the **EPBC Act**. If the **Minister** approves a revised action management **plan** (RAMP) then, from the date specified, the approval holder must implement the RAMP in place of the previous action management **plan**.

Completion of the action

19. Within 30 days after the **completion of the action**, the approval holder must notify the **Department** in writing and provide **completion data**.

Part C - Definitions

In these conditions, except where contrary intention is expressed, the following definitions are used:

Business day means a day that is not a Saturday, a Sunday or a public holiday in the state or territory of the action.

Commencement / Commencement of the action means the first instance of any specified activity associated with the action.

Commonwealth Environmental Water Holder means as established under the *Water Act 2007* (Cth.) to manage water acquired by the Australian Government as part of a suite of national water reforms, including the Murray-Darling Basin Plan.

Completion data means an environmental report and spatial data clearly detailing how the conditions of this approval have been met. The **Department**'s preferred spatial data format is **shapefile**.

Completion of the action means all specified activities associated with the action have permanently ceased.

Compliance records means all documentation or other material in whatever form required to demonstrate compliance with the conditions of approval in the approval holder's possession or that are within the approval holder's power to obtain lawfully.

Compliance report(s) means written reports:

i. providing accurate and complete details of compliance, **incidents**, and non-compliance with the conditions and the **plans**;

ii. consistent with the **Department's** *Annual Compliance Report Guidelines* (2014);

iii. include a **shapefile** of any clearance of any **protected matters**, or their habitat, undertaken within the relevant 12 month period; and

iv. annexing a schedule of all **plans** prepared and in existence in relation to the conditions during the relevant 12 month period.

Department means the Australian Government agency responsible for administering the **EPBC Act**.

Department's Environmental Management Plan Guidelines means the *Environmental Management Plan Guidelines, Commonwealth of Australia*, 2014.

Drought Operations – Delivery of Peel Environmental Water Plan means the environmental management plan submitted to the **Department** on 20 April 2020 as Appendix C to the finalised preliminary documentation.

EPBC Act means the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

EPBC Act Environmental Offset Policy means *EPBC Act Environmental Offsets Policy, Commonwealth of Australia*, 2012.

Incident means any event which has the potential to, or does, impact on one or more **protected matter(s)**.

Independent audit: means an audit conducted by an independent and **suitably qualified person** as detailed in the *Environment Protection and Biodiversity Conservation Act 1999 Independent Audit and Audit Report Guidelines* (2019).

Monitoring data means the data required to be recorded under the conditions of this approval.

Minister means the Australian Government Minister administering the **EPBC Act** including any delegate thereof.

Murray Cod means the Murray Cod (*Maccullochella peelii*), listed as a vulnerable species under the **EPBC Act**.

NSW conditions of authorisation means the conditions set out in the NSW authorisation under the NSW *Water Supply (Critical Needs) Act 2019*.

Phase of operation means each discrete phase of the action as specified in Table 1 in the **Drought Operations – Delivery of Peel Environmental Water Plan**.

Plan(s) means any of the documents required to be prepared, approved by the **Minister**, and/or implemented by the approval holder and published on the **website** in accordance with these conditions (includes action management plans and/or strategies).

Protected matter means a matter protected under a controlling provision in Part 3 of the **EPBC Act** for which this approval has effect.

Sensitive ecological data means data as defined in the Australian Government Department of the Environment (2016) *Sensitive Ecological Data – Access and Management Policy V1.0*.

Shapefile means location and attribute information of the action provided in an Esri shapefile format. Shapefiles must contain '.shp', '.shx' , '.dbf' files and a '.prj' file that specifies the projection/geographic coordinate system used. Shapefiles must also include an '.xml' metadata file that describes the shapefile for discovery and identification purposes.

Silver Perch means the Silver Perch (*Bidyanus bidyanus*), listed as a critically endangered species under the **EPBC Act**.

Suitably qualified ecologist means a person who has professional qualifications and at least three (3) years of work experience designing and implementing surveys and management plans for **Murray Cod** and **Silver Perch**, and can give an authoritative assessment and advice on the presence and environmental requirements of **Murray Cod** and **Silver Perch** applying relevant protocols, standards, methods and literature.

Suitably qualified person means a person who has professional qualifications, training, skills and/or experience related to the nominated subject matter and can give authoritative independent assessment, advice and analysis on performance relative to the subject matter using the relevant protocols, standards, methods and/or literature.

Technical advisory group means the Technical Advisory Group established as specified in the **Drought Operations – Delivery of Peel Environmental Water Plan** and is the same as the Peel Environmental Water Technical Advisory Group established under the **NSW conditions of authorisaton**.

Website means a set of related web pages located under a single domain name attributed to the approval holder and available to the public.

Appendix 2 – Baseline Monitoring Report

Chaffey Dam downstream offset monitoring baseline survey

WaterNSW

ecological AUSTRALIA
A TETRA TECH COMPANY

1300 646 131
www.ecoaus.com.au

DOCUMENT TRACKING

Project Name	Chaffey Dam downstream offset monitoring baseline survey
Project Number	22ARM4391
Project Manager	Peter Hancock
Prepared by	Peter Hancock, Jessica York, Alice Bauer and Lily Tonks
Reviewed by	Ian Dixon
Approved by	Ian Dixon
Status	**Final**
Version Number	**2**
Last saved on	**28 May 2024**

This report should be cited as 'Eco Logical Australia 2024. *Chaffey Dam downstream offset monitoring baseline survey*. Prepared for WaterNSW.'

ACKNOWLEDGEMENTS

This document has been prepared by Eco Logical Australia Pty Ltd with support from WaterNSW

Template 2.8.1

Contents

List of Figures

List of Tables

Abbreviations

Abbreviation	Description
ANOSIM	Analysis of Similarities
ANZG	Australian and New Zealand Guidelines
BACI	Before-After-Control-Impact study design
EIS	Environmental Impact Statement
ELA	Eco Logical Australia Pty Ltd
EPT	The ratio of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) to other taxa
FM Act	*Fisheries Management Act 1994*
nMDS	Non-Metric multidimensional scaling
SIGNAL	Stream Invertebrate Grade Number - Average Level
SIMPER	Similarity Percent

Executive Summary

As part of their approval to operate a pipeline between Chaffey Dam and Dungowan, WaterNSW are required to offset reduced flow in the Peel River with a re-snagging program, and to monitor the effectiveness of snag installation on improving aquatic ecological communities. Eco Logical Australia Pty Ltd (ELA) has been engaged by WaterNSW to collect baseline aquatic ecological data from refuge pools along the Peel River, downstream of Chaffey Dam, in which snag installation is proposed. Baseline samples of macroinvertebrate communities, biofilm communities, and fish communities on and around existing snags were collected from 16 pools in the Peel and Cockburn Rivers to assess the current ecological condition. Follow-up monitoring over the next 5 years will indicate how well the introduced snags are improving river ecology. As snags age, it is expected that macroinvertebrates and biofilm communities will come to resemble those of nearby natural snags, and that the overall native fish populations will increase. Three species of threatened fish are known in the Peel River, and should benefit either directly or indirectly from the snag installation. These are Murray cod (*Maccullochella peelii peelii*), silver perch (*Bidyanus bidyanus*), and eel-tailed catfish (*Tandanas tandanas*).

The Peel River downstream of Chaffey Dam showed evidence of cold water pollution, with a temperature difference of 9.1 °C between upstream and downstream sites. This resulted in differences in the macroinvertebrate and biofilm communities upstream of Dungowan Creek (the first large tributary to enter the Peel downstream of Chaffey Dam) and those communities downstream. Likewise, cold water pollution affected fish communities immediately downstream of the dam, with no fish caught with electrofishing or fyke nets at Site 1 (closest to dam outlet) despite fish being detected with eDNA.

Snag biofilm in the Peel River downstream of Chaffey Dam consisted of 14 species of Bacillariophytes (diatoms), 13 species of Chlorophytes (green algae), 13 species of Cyanophytes (blue-green algae), 1 species of golden/yellow-green algae and 2 species of flagellates. Taxonomic richness was highest at Site 1 (the upstream site) with 35 taxa, then declined with distance downstream to 15 taxa at Site 14, downstream of the Dungowan Creek confluence. All sites downstream of Dungowan Creek had 14 or 15 taxa. Sites upstream of Dungowan Creek differed to those downstream sites upstream, having greater densities of *Pseudobaena* spp., *Scenedemus* spp., *Phormidium* spp. (>5µm), and *Aulacoseira* spp. There were 18 taxa that occurred at sites upstream of Dungowan Creek that did not occur downstream.

There were 39 macroinvertebrate families on snags, with communities dominated by Chironomidae, Ecnomidae, and Oligochaeta. Invertebrates consisted of taxa that bore into wood, or require a solid substrate for attachment, and the community resemble snag-dwelling macroinvertebrate communities in other locations of the Murray-Darling Basin. Macroinvertebrate communities differed between sites upstream of the Dungowan Creek confluence and those downstream. The difference was driven by higher numbers of Micronectidae in the lower reaches, and more Simuliidae in the upper reaches.

Baseline surveys found 13 species of fish near the snags sampled using eDNA (October 2023) and 12 species using the combined electrofishing and fyke netting approach. Murray cod, golden perch, silver perch, carp gudgeon, Australian smelt, and European carp were detected at all 10 sites where eDNA was collected, but none of these species was collected at all sites using electrofishing/fyke netting. Murray cod and river blackfish are the two most snag-dependent species as they both use snags for spawning and refuge. Five river blackfish were collected from Site 3, although the species was detected at this,

and four other sites using eDNA. A total of 21 Murray cod were collected from nine sites in the Peel and Cockburn Rivers, with two of these being young-of-year.

While the snag bag was suitable for sampling natural snags, it will not work with the snags being installed because of their large diameter. A different method that can measure macroinvertebrate samples reliably should be identified and tested before the next round of surveys.

Using young-of-year sampling is a relatively coarse way to assess spawning efficiency. Cod collected inside the young-of-year length range may have spawned elsewhere (tributary, fish hatchery) and moved to the site of capture. Larval fish sampling around snags, and downstream of re-snagged pools will be a less ambiguous way of detecting whether the introduced snags are improving spawning rates for cod in the Peel River.

Some of the sites initially planned for re-snagging could not have snags introduced into their pools, and alternatives had to be found. Once all 50 snags have been installed, the list of survey sites should be revised to incorporate factors such as the number of installed snags per site, and the location of the site in relation to confluences. This will help to appropriately ground control and impact locations to account for any variation caused by cold water pollution or the influence of tributary streams.

1. Introduction

As part of their Peel River Drought Protection Works, WaterNSW were granted short-term approval to operate a pipeline between Chaffey Dam and Dungowan during the prevailing drought at the time (2017-2020). Operation of the pipeline caused a reduction in flows to the Peel Rivers, potentially impacting threatened fish species including Murray cod (*Maccullochella peelii peelii*), silver perch (*Bidyanus bidyanus*), and eel-tailed catfish (*Tandanas tandanas*). In addition to a reduction in water volume, water pump offtakes entrain and impinge larval and young-of-year fish, specifically Murray cod (Stocks et al. 2024). These impacts are to be offset by a re-snagging program along the Peel River and the installation of self-cleaning screens on selected offtake pumps in the river.

WaterNSW began installing the first of 50 snags (Figure 1), including many with root balls intact, in March 2024 and this is scheduled for completion in late 2024. Eco Logical Australia Pty Ltd (ELA) has been engaged by WaterNSW to collect baseline aquatic ecological data from refuge pools along the Peel River, downstream of Chaffey Dam, in which snags are proposed to be installed (Figure 2). Baseline monitoring includes survey of freshwater macroinvertebrates communities and fish species present on and around existing snags in these pools, as an assessment of the current ecological condition of the Peel River.

Following snag installation, WaterNSW would continue monitoring ecological communities in refuge pools and on snags for a period of 5 years. During this period it is anticipated that self-cleaning screens will be installed on pumps, and sampling will be designed to test the effectiveness of these on the intake of larval fish to the pumps.

Figure 1. Snags stockpiled downstream of Chaffey Dam awaiting installation in the Peel River

2. Desktop assessment

2.1.1. Threatened species and communities

The Peel River is part of the 'Lowland Darling River aquatic ecological community', which is an endangered ecological community in NSW. This means that all native fish and other aquatic animal life are given the status of endangered species. In addition, the Peel River potentially contains four species or populations of fish listed as threatened. These are the Murray cod (*Maccullochella peelii*) and silver perch (*Bidyanus bidyanus*), listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and the southern purple-spotted gudgeon (*Mogurnda adspersa*), and Murray-Darling Basin population of eel-tailed catfish (*Tandanus tandanus*), listed under the *Fisheries Management Act 1994* (FM Act).

2.1.2. Macroinvertebrate communities

Macroinvertebrate communities in the Peel River have previously been surveyed as part of an aquatic ecology assessment for the Dungowan Dam Environmental Impact Statement (EIS) (EMM 2022). The average SIGNAL score for pool/edge habitat at the seven sites was 5.51, indicating that ecology in the river is in a mildly disturbed condition (Table 1). Each site had between 10 and 27 families for the riffle and edge habitats (EMM 2022). These surveys provide a baseline understanding of aquatic invertebrate communities of the Peel River, but the macroinvertebrate communities in edges and riffles generally differ slightly to those of snag habitats, which often contain more wood boring taxa (Humphries et al. 1998, Growns et al. 1999). Although previous sampling does not give a direct indication of the invertebrate communities on snags, the data is useful in demonstrating the overall diversity of the river, and an indication of the invertebrate community condition.

Table 1: Aquatic macroinvertebrate data from Edge and Riffle samples along the Peel River from 2020 and 2022 (EMM 2022)

Site	Latitude	Longitude	Sampled year	SIGNAL	No. Families	EPT	SIGNAL	No. Families	EPT
				Edge			Riffle		
Site	Latitude	Longitude	Sampled year	SIGNAL	No. Families	EPT	SIGNAL	No. Families	EPT
PHF01	-31.34457	151.14294	2022	5.4	10	3	5	9	3
PHF06	-31.30382	151.14787	2022	5.47	19	6			
PR01	-31.21750	151.10889	2020	5.38	27	7			
PHF11	-31.22030	151.11203	2022	5.88	16	4	5.35	6	5
PHF14	-31.18256	151.06658	2022	5.43	21	7			
PR03	-31.16054	151.03759	2022	5.59	19	5			
PHF19	-31.13366	150.96620	2022	5.42	19	7			
			Average	5.51	19	6	5.18	8	4

2.1.3. Fish communities

Twelve fish species occurred in the Peel River during the EIS surveys (EMM 2022). This included the threatened species Murray cod, silver perch and eel-tailed catfish. Silver perch occurred only at 2 sites, Murray cod at 9 sites, and catfish at 11 sites. Other species present include river blackfish (*Gadopsis marmoratus*), carp gudgeon (*Hypseleotris* sp.), mountain galaxias (*Galaxias olidus*), golden perch (*Macquaria ambigua*), bony bream (*Nematalosa erebi*) and Australian smelt (*Retropinna semoni*). Three exotic species were also present, including common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), and eastern mosquitofish (*Gamusia holbrooki*).

Of the Peel River sites sampled for the EIS, four correspond to sites which are being considered for snag introduction (Table 2). Fish diversity at the four sites was between 3 and 7 species. Site 7 had the highest fish diversity, with seven species, including two that are threatened (Table 2). Murray cod were collected at all four sites proposed for snagging, and at five of the other sites.

Table 2: Fish communities at EIS sites, and sites nominated for snag installation (EMM 2022)

EIS site number	Re-snag site number	Australian smelt	Carp gudgeon	River blackfish	Murray cod	Eel-tailed catfish	Mountain galaxias	Silver perch	Golden perch	Bony bream	Common carp	Goldfish	Eastern mosquitofish
PHF01	10	Y	Y	Y	Y	Y							
PHF04		Y	Y	Y		Y					Y		
PHF06		Y	Y	Y		Y							
PHF 08		Y	Y	Y	Y	Y							Y
PHF 09	9	Y	Y	Y	Y	Y							
PHF 11			Y	Y	Y	Y							Y
PHF 12			Y		Y	Y							
PHF 13			Y			Y							Y
PHF 14			Y		Y								
PHF 15	8		Y		Y	Y							
PRO3	7	Y	Y	Y	Y			Y	Y				Y
PHF 17		Y	Y			Y	Y						
PHF 19			Y										
PHF 23A		Y	Y					Y	Y	Y	Y	Y	Y
PHF 23B		Y	Y		Y	Y			Y	Y	Y	Y	

3. Methods

The methods described below address the 'before' phase of the Before-After-Control-Impact (BACI) study designed to evaluate responses in the fish community to re-snagging. Survey data were obtained from 10 sites, which act as pre-installation control sites (Figure 2). Sites for the baseline survey of macroinvertebrate, biofilm, and fish environmental DNA communities were selected from those nominated as potential snagging sites in Geolink (2022). Fish community survey (using electrofishing and fyke netting) sites were initially based on the sites sampled for macroinvertebrates. However, between macroinvertebrate sampling in May, and fish sampling in March 2024, some difficult-to-access pools were removed from the list of snagging sites. This meant that some of the fish community sites differed to the macroinvertebrate community sites (Table 3, Figure 2). Impact sites will be selected once snags are installed by WaterNSW in 2024.

3.1. Site Description

A description for all sites surveyed are presented below, and photographs are included in Appendix A: Site photos. A map showing site location is given in Figure 2.

Table 3: Description of sites sampled in October 2023 and March 2024

Site	Site description	Samples collected	Status (as of 30/04/24)
Site 1	Small pool with gravel bar on right bank and bedrock bar on left bank. All snags present at this site are *Casuarina*. Still backwater on left side of bank with lots of woody debris and sticks. Snags cross down-stream end of pool. Pool approximately 10 m wide by 16 m long. Some willows in riparian zone. Bank opposite the gravel bar is steep. Bed is cobble/gravel covered in silt. Underwater - no snags mid-stream, apart from those visible from land. Depth approximately 2 m.	Snag invertebrates, biofilm, water quality, eDNA, fish	Snag installed
Site 2	This pool, upstream of a small crossing, is 12 m wide by 50 m long. Numerous *Casuarina* logs occur downstream and several occur upstream. The pool consists of a cobble bed, water speed is moderate, and a pump is present. Two piles of woody debris occur upstream of the pump. The pool is approximately 1.6 m deep.	Snag invertebrates, biofilm, water quality, eDNA, fish	Snag installed
Site 3	Broad pool, measuring 12 m by 80 m long. It features a cobble bed, with a steep bank on right-hand side and a gravel bar on the left bank. Banks on both sides are largely undercut. *Casuarina* occur in the riparian zone, with several small snags visible. Very few of these snags are suitable for snag bag or biofilm collection. The site resembles more of a run than a pool, with a depth of 1.2 m.	Snag invertebrates, biofilm, water quality, eDNA	Snag installed
Site 13	This site consists of a small pool at the bottom of a steep bank. The pool is approximately 15 m by 14 m and it contains a pump. Snags occur upstream and downstream of the pool, and there are riffles mark the start and end of the pool. *Casuarina* and *Eucalyptus camaldulensis* (red gum) occur in the riparian zone. There were not many snags suitable for sampling with the snag	Snag invertebrates, biofilm, water quality, eDNA, fish	Snag to be installed

Site	Site description	Samples collected	Status (as of 30/04/24)
	bag, but plenty of large woody debris downstream of the pool. Bedrock occurs upstream and downstream of pool. Pool bed consists of gravel, sand, and cobble substrate, and it is approximately 2 m deep.		
Site 14	Site 14 is an elongated pool with a pump present. A gravel bar occurs on the right bank, and the left bank is steep. *Casuarina* and *Salix* (willow) dominate riparian the zone. The pool consists of a gravel bed, is approximately 100 m long and with a riffle occurring at the downstream end of the pool. Woody debris occurs upstream and along the left bank and mid-stream at the downstream end of the pool, the latter debris being suitable for sampling.	Snag invertebrates, biofilm, water quality, eDNA, fish	Snag installed
Site 16	Site 16 is a broad, shallow pool in a bend of the river, with riffles occurring downstream and upstream of pool. A gravel bar occurs on the right bank. Several small and narrow snags are present. Pool is approximately 18 m by 20 m, and 2 m deep, with a substrate of sand and gravel. Cows were present at the water's edge. *Potomagenton* sp. beds present.	Snag invertebrates, biofilm, water quality, eDNA, fish	Snag to be installed
Site 24	The pool is approximately 20 m wide, located in a bend of the Peel River. It has a gentle current, with numerous snags, both in the pool and upstream of the pool. The riparian zone consists mostly of weedy species, with *Phragmites* (common reed) occurring in dense stands. *Salix* and *Casuarina* dominate the riparian tree community. A shallow median bar is present, and the left bank is steep and undercut. Banks are very steep.	Snag invertebrates, biofilm, water quality, eDNA	No snag will be installed due to steep banks and lack of access.
Site 28	This pool is about 20 m across and 30 m long, the banks on both sides of this pool are steep. The pool has lots of snags, and the water was turbid. Steel girders held logs against the left bank as a stabilisation measure. Samples were collected upstream of this in flowing water because there were no suitable snags in pool. Riparian vegetation mainly *Casuarina* and *Salix*. The deepest part of the pool was approximately 2.2 m.	Snag invertebrates, biofilm, water quality, eDNA, fish	Snag to be installed
Site 32	The left bank and a significant portion of the right bank exhibit erosion, exposing steep cliffs that rise approximately four meters above the water level. A few snags and a small gravel bar are evident. The water was turbid, with riffles observed upstream of the pool, situated within a bend of the river. The riverbed predominantly consists of silted gravel and sand.	Snag invertebrates, biofilm, water quality, eDNA	Snag to be installed
Site 42	This pool spans approximately 25 meters in width and extends for a length of 300 meters. Predominantly shallow, the deepest section reaches 1.2 meters. The water was turbid and had a lot of snags. The pool substrate primarily comprises silt-covered sand and gravel. The riparian zone was vegetated with a mix of *Salix* and exotic vegetation, with some *Casuarina*. Both banks had significant erosion and were steep.	Snag invertebrates, biofilm, water quality, eDNA, fish	Snag to be installed
CRCON1	The Cockburn River was not flowing at CRCON1 and consisted of a series of shallow pools. The substrate consisted of cobble and boulder. The riparian zone was intact in areas and absent in	Water quality, fish	Resnagging not planned for this site

Site	Site description	Samples collected	Status (as of 30/04/24)
	others and was dominated by *Casuarina* sp. in the intact areas. Banks were undercut in areas and extensive algal mats were present. Macrophytes were present in the form of Knotweed and *Cyperus* sp. Only a few snags were present at this site.		
CRCON2	CRCON2 was located under a bridge and included a fishway immediately downstream of the bridge. Substrate consisted of sand and gravel, and the site was dominated by pool habitat. Depth reached 1.5 m. The riparian zone was largely intact and was dominated by *Casuarina* sp. and willow. Macrophytes were present in the form of knotweed, *Potamogeton* sp. and *Myriophyllum* sp. A large algal mat dominated the pool above the fishway. Fish habitat was present in the form of large woody debris and undercut banks.	Water quality, fish	Resnagging not planned for this site
CRCON3	CRCON3 consisted of a long pool on the Cockburn River. Both banks were heavily vegetated with trees and shrubs with *Casuarina* sp. dominating. Peppercorn (*Schinus* sp.) was the dominant exotic at this site in addition to some willow. The substrate was dominated by cobble and sand and deeper pool areas also supported some silt substrate. Fish habitat was present in the form of undercut banks, snags and dumped concrete rubble. Algae was present in the shallows. Depth ranged from 0.5 to 1.5 m.	Water quality, fish	Resnagging not planned for this site
USCONT1	This is an upstream control site on the Peel River. The river was flowing at the time of the surveys and consisted of large pools with riffle and run habitat. River width ranged from 3 to 15 m and was up to 1.5 m in depth. Substrate consisted of pebble, gravel and sand overlaid with silt. The riparian zone was largely intact and was dominated by *Casuarina* sp. with sections of exotics. The understory was dominated by exotic vegetation. Macrophytes were present in the form of *Cyperus* sp., *Potamogeton* sp., *Juncus* sp. and water speedwell (*Veronica anagallis-aquatica*). Banks were on a steep incline and were undercut.	Water quality, fish	Resnagging not planned for this site
DSCONT1	Riverine habitat was present at DSCONT1 in the form of long pools and shorted sections of run and riffle habitat. Banks were heavily incised with areas of erosion observed during the survey. Banks were also undercut in areas. The river width ranged from 5 to 15 m and was up to 1.2 m in depth. Substrate was dominated by clay and silt with some gravel and pebble present. The riparian zone consisted of scattered *Eucalyptus* sp., *Casuarina* sp. and Willow with a weedy understory and groundcover. Fish habitat was present in the form of CPOM, woody debris and algal mats. Macrophytes were present in the form of *Cyperus* sp., common reed and *Juncus* sp.	Water quality, fish	Resnagging not planned for this site
DSCONT3	The river was flowing at the time of the surveys with large pools and run and riffle habitat. River width ranged from 3 to 12 m with depth up to 1.5 m in some areas. The substrate consisted of clay/silt with some sand, gravel, pebble and a small amount of cobble present. The channel was heavily incised with areas of prominent erosion observed during the survey. Banks were	Water quality, fish	Resnagging not planned for this site

Site	Site description	Samples collected	Status (as of 30/04/24)
	undercut and the site supported a significant amount of coarse particulate organic matter (CPOM) and large woody debris (LWD). The riparian zone was present in patches with an overstory of *Eucalyptus* sp., *Casuarina* sp. and willow (*Salix* sp.). The understory was dominated by weed species as was the groundcover. Macrophytes were present in the form of *Cyperus* sp. and common reed (*Phragmites australis*).		

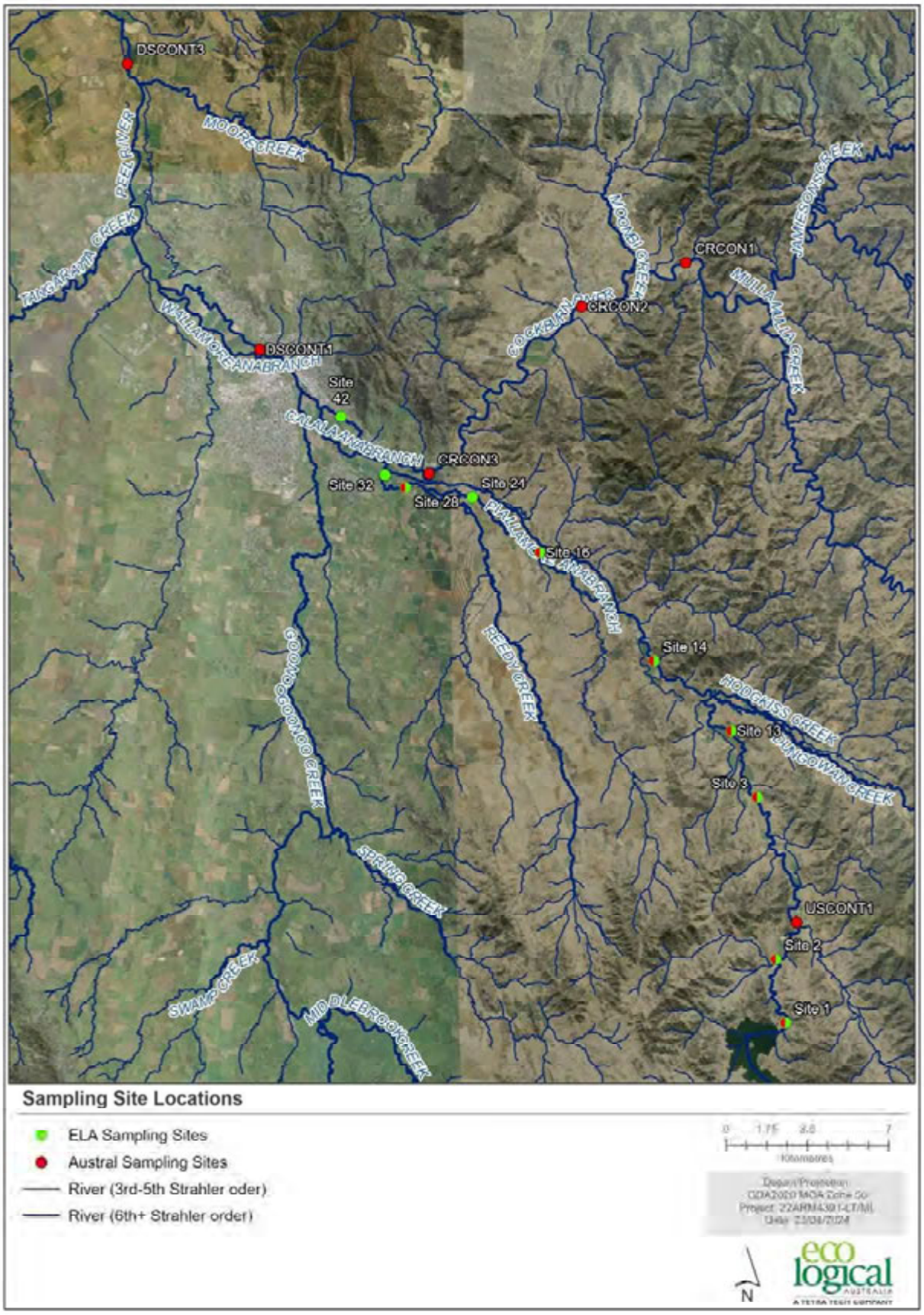


Figure 2: Map of survey sites sampled for macroinvertebrates, fish eDNA, and diatom community (green) and fish communities (red)

Only sites sampled in March 2024 using electrofishing and fyke net have been nominated as 'Control' (sites where snags are not being introduced) or 'Snag' (sites where snags will be introduced) sites. Sites sampled in October 2023 were chosen from the list of locations nominated by GeoLink (2022). However, this list changed in the period prior to the commencement of snag installation in March 2024. Some of the sites on the list were replaced with others because of problems with access. The final list of sites for the non-fish sampling will be made after snag installation is complete but before the next survey round in October 2024.

3.2. Habitat assessment and photo points

Observations of changes in habitat features were conducted for each site. Although snags were the primary focus of the study, other features in the stream could also impact fish habitat. The collected data included overview photographs of each site, and any significant habitat features or erosion. In addition, a description was provided for the following:

- Debris (instream and riparian woody debris)
- Aquatic habitat features likely to be present (substrate, woody debris, overhanging vegetation, etc.)
- Instream habitat (riffles, runs, pools, backwaters, etc.)
- Physico-chemical parameters (dissolved oxygen, temperature, electrical conductivity, pH, turbidity)
- Observations of bank erosion or debris scattering caused by flooding in the past 12 months.

3.3. Physico-chemical and flow data

To complement biological data, physico-chemical parameters were measured at each site. ELA used a calibrated Horiba U52 multi-parameter meter to measure temperature, dissolved oxygen (DO), electrical conductivity (EC), turbidity, and pH. The meter was calibrated in the laboratory before the field survey and DO was calibrated at the beginning of each field survey day.

Nearest gauging stations were 419045 Peel River D/S Chaffey Dam, 419015 Peel River at Piallamore and 419009 Peel River at Tamworth (Figure 3). River level began to rise at the downstream Chaffey gauge in early September 2023, and plateaued at around 1.2 m at the end of October, then fell again to around 1 m near mid-January 2024. The gauge at Piallamore showed a less distinct increase in flow, and a lot of erratic small-scale rises and falls in river level (Figure 3).

Gauging station 419045 is approximately 770 m downstream of Chaffey Dam and has measured water temperature since late October 1992 (Figure 4). The average temperature since the start of records is 16.9°C, with a range of 6.3 to 30.1°C.

Physico-chemical measurements were also conducted at each site by ARC in autumn 2024. At each of the fish survey sites, water temperature, DO saturation, conductivity, pH and turbidity were measured.

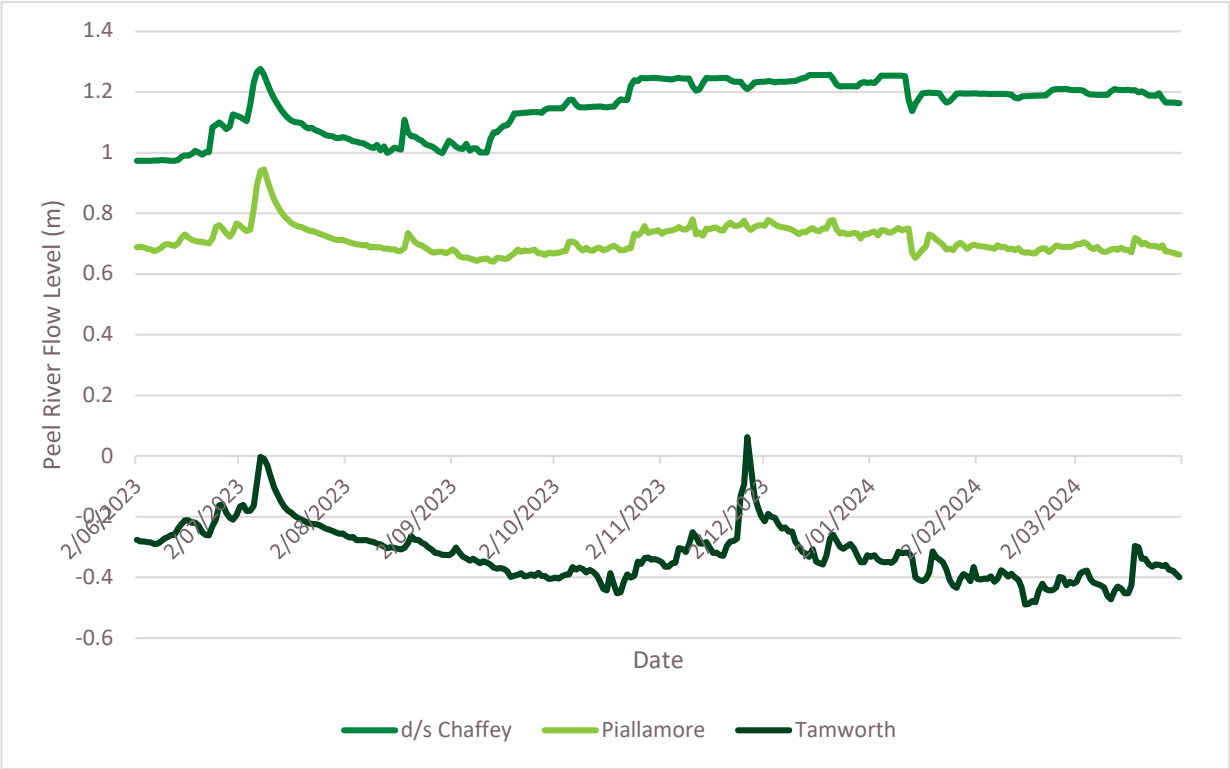


Figure 3: River level at three gauging stations in the Peel River

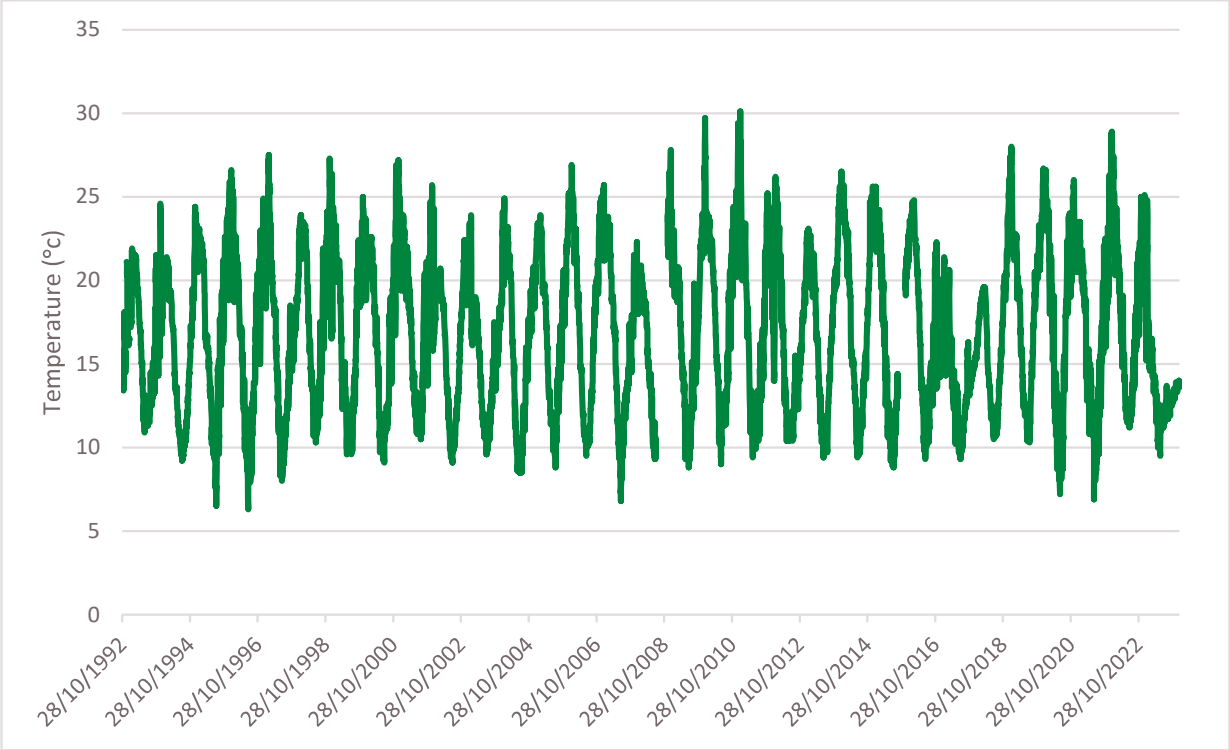


Figure 4: Water temperature measurements at Peel River d/s Chaffey (Gauging Station 419045)

3.4. Snag biofilm

Sampling occurred for macroinvertebrate at three snags per site. The same snags that were sampled for macroinvertebrates were also used for biofilm sampling, but the biofilm was collected from an area not scrubbed for macroinvertebrates.

Samples were collected using a length of 90 mm diameter PVC pipe that was pushed firmly against the snag to create a seal at the base of the pipe. The snag surface inside the pipe was scrubbed with a small stiff-bristled brush to dislodge the biofilm, and this was sucked into a syringe through 3 mm diameter tubing. Three samples were collected from the top of each snag at most sites, and these were combined into a single sample container, providing a total area of 63.6 cm^2. The samples were preserved in 1% Lugols Iodine Solution for identification. Three snags were sampled at most sites, although it was possible only to do two at Sites 16 and 32, and one at Sites 14, 24, 28, and 42.

The samples were sent to ALS Environmental for identification, and the data were analysed for green filamentous algae, diatoms, blue-green algae (cyanophyta), and detritus. To allow comparisons between sites, data were converted to cells/mL/cm^2.

Biofilm community data was used do generate a non-Metric Multidimensional Scaling (nMDS) plot to show similarities between sites. Sites that have similar species in their biofilm community will appear close to each other in nMDS space, and those that have different species will be further apart. Prior to analysis, data were transformed by Log(x+1), then a Bray-Curtis similarity matrix was developed. This was used to generate the nMDS plot, and also to conduct an ANOSIM (Analysis of Similarity) analysis to compare communities upstream of Dungowan Creek to those downstream. The separation between upstream and downstream of Dungowan Creek was selected after viewing the nMDS plot and seeing that these groupings appeared to be largely separated from each other. The main taxa contributing to each grouping were identified using SIMPER (Similarity Percent). All multivariate analysis was completed using the software package Primer 7 (PRIMER-e Pty Ltd).

3.5. Macroinvertebrate communities

Macroinvertebrate sampling occurred at all sites. Macroinvertebrate samples were collected from individual snags using the snag bag method (Growns et al. 1999). This method requires snags to be less than 30 cm in diameter and free of branches to ensure a complete seal with the snag bag. Measurements of snag diameter and the length of the sampled area were taken to determine the surface area for estimating invertebrate density.

The enclosed section of the snag was gently scrubbed with a small brush to dislodge macroinvertebrates into the bag (Figure 5), which was later concentrated into the sample jar. The samples were preserved in 70% ethanol for identification to the family level. Identification was done in the laboratory using a Leica M80 dissecting microscope. Total invertebrate abundance and taxa richness (the number of different invertebrate families) was documented for each snag, with the expectation that as the snags age, their invertebrate community increases in diversity and abundance. For snags introduced to the river, the invertebrate community would start simple, then become more diverse and support more individuals over time, and eventually the structure of the community will resemble that of naturally occurring snags.

During sample collection, the circumference and length of snag spanned by the snag bag were measured. These measurements were then used to determine the area sampled and calculate a ratio for multiplying macroinvertebrate counts by to give densities per m^2. Macroinvertebrate data was scaled up from raw count data for each snag bag sample, to give densities per m^2 of snag.

Figure 5: Using the snag bag to sample macroinvertebrates in the Peel River. Arm reaches in through the black sleeve at top of picture to scrub the snag inside the snag bag.

3.5.1. SIGNAL Score

Each family was assigned a SIGNAL (Stream Invertebrate Grade Number - Average Level) score based on Chessman (2003). The SIGNAL score served as an indicator of how sensitive an invertebrate family was to disturbance, providing insights into habitat health. Families with scores between 6 and 10 were considered sensitive to pollution and were likely to occur in healthy habitats, while those with scores below 6 could tolerate pollution and were found in impacted stream habitats.

3.5.2. EPT Ratio

The EPT taxa richness is the number of Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) taxa present in each sample. The families in these three insect orders are generally sensitive to disturbance so will be absent in degraded water bodies. The EPT Ratio is the total number of EPT taxa expressed as a proportion of the total taxonomic richness at each site.

3.5.3. Macroinvertebrate community data

Similarities between macroinvertebrate communities were displayed graphically using nMDS plots. Snags with similar invertebrate communities are close to each other in nMDS plots, and clusters of points indicate that multiple snags have similar invertebrate communities. The objective of sampling macroinvertebrate communities on natural snags is to collect baseline data for future comparisons to communities on installed snags. As the installed snags increase in age, invertebrate communities would come to resemble those of natural snags.

3.6. Fish community surveys

3.6.1. Fish environmental DNA sampling

Environmental DNA (eDNA) samples were collected from 10 survey pools from 31st October to 2nd November 2023, with three replicates gathered from each pool around snag habitat (Figure 2). For each sample, 520 – 1000 mL (mean = 860 mL) of water was filtered through a 1.2 µm disk filter. The volume of water filtered was dependent on turbidity, with less water filtered at turbid sites. The filters were then stored in a cool container before being dispatched to the laboratory for analysis. Throughout the sample preparation, collection, and storage phases, care was taken to minimise contamination between sites.

Environmental DNA (eDNA) samples, collected at the same time as the macroinvertebrate samples, were sent to EnviroDNA Pty Ltd for analysis. DNA sequences were matched to known fish species using a general 12S "Fish" primer. Fish community data from eDNA sampling was compared to the community data generated using other survey methods.

3.6.2. Fish community sampling

Fish communities were sampled directly at 6 control sites and 8 re-snagging impact sites (Figure 2) using backpack electrofishing and fyke nets. Electrofishing surveys were conducted by Austral Research and Consulting (ARC) between 12 and 18 March 2024. Fish measurements from specimens collected by electrofishing, were used to assess recruitment rates for young-of-year Murray cod and other species.

Fish communities were sampled around snags using a backpack electrofisher between 12th and 18th March 2024. Each pool was shocked for 6 (3 sites) or 8 (11 sites) sessions of 150 seconds each, with a focus on snag habitats, depending on their availability. Electrofisher settings are shown in Table 4. Fish were captured with a fish-friendly Environet, identified, measured, then placed in a recovery well until they resumed normal swimming behaviour. They were subsequently released at the capture location. Additional electrofishing efforts were directed towards specific snags to enhance the collection of young-of-year Murray cod (<120 mm). Similarly, increased efforts were made around areas where silver perch were observed.

Smaller fish were also collected using fyke nets, with two large single-wing nets and two small single-wing nets deployed at each site around snags. The captured fish were identified, measured, and subsequently released.

Fish data are reported as total fish captured per site, with electrofishing results combined with fyke net totals.

Table 4. Backpack electrofisher settings for March 2024

Site	Frequency (Hz)	Volts	Duty Cycle (%)	Time on (sec)
DSCONT1	80	180	30	1200
DSCONT3	80	180	30	1200
CRCONT1	80	180	30	1200
CRCON2	80	240	30	1200
CRCON3	80	240	30	1200
Site 1	80	180	30	900
Site 3	80	220	30	1200
Site 13	80	180	30	1200
Site 14	80	180	30	1200
Site 16	80	220	30	1200
Site 28	80	220	30	1200
Site 42	80	180	30	900

4. Results

4.1. Physico-chemistry

4.1.1. Water quality in October 2023

Physico-chemical measurements taken during the macroinvertebrate and eDNA surveys indicated **exceedances** of Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) recommended ranges at all sites for at least one variable, but often more. Turbidity generally increased with distance downstream, with a measurement of 1.9 at Site 1 and 25.3 at Site 42. Turbidity at Sites 1 was just below the recommended ANZG range for upland streams, while Site 42 was just above this range (Table 5). Likewise, temperature also increased with distance downstream of Chaffey Dam. At Site 1, temperature was 13.2°C, while at Site 42 it was 23.5°C (Table 5). pH exceeded ANZG recommended range for all 10 sites except Site 2 (Table 5). Apart from Site 2, all sites had pH between 8.15 and 8.43 (Table 5). Dissolved Oxygen concentration was within ANZG recommended range for all sites except four, where it was low (Table 5).

Table 5: Physico-chemical measurements at sites sampled along Peel River in October 2023. Red figures are those that exceed water quality guidelines as per the ANZG range for upland rivers >150 m altitude.

Site	Temperature	pH	EC	Turbidity	DO	DO
(Unit)	°C		µS/cm	NTU	% saturation	mg/L
(ANZG range)		6.5-8.0	125-350	2-25	85-110	
1	13.2	8.41	365	1.9	108.1	11.36
2	14.8	7.75	365	2.3	101.5	10.3
3	17.7	8.15	374	4.1	94.3	8.98
13	15.9	8.34	379	6	80.1	7.92
14	17.4	8.29	365	5.1	70.4	6.81
16	19.6	8.43	382	13.5	105.1	9.6
24	19.5	8.51	388	12.2	93.7	8.56
32	18.2	8.40	374	21.6	71.6	6.72
28	19.2	8.46	403	12.9	97.2	8.96
42	23.5	8.37	446	25.3	79.9	6.9

4.1.2. Water quality in March 2024

Water temperature in the Cockburn River (23.5 to 30.9°C) was higher than that of the Peel River (14.0 to 24.8°C; Table 6). In the Cockburn River, water temperature decreased with distance downstream, possibly due to the uppermost pool being isolated from continuous flow. Temperature in the Peel River increased along the river, with lower temperatures at the base of Chaffey Dam and higher temperatures at the downstream control sites, downstream of Tamworth. pH was between 7.04 and 8.67, with measurements at all but two Peel River sites exceeding the ANZG recommended range. All sites in the Cockburn River were within ANZG range. EC was between 302 and 1010 µS/cm at all sites, with only Sites 1 and 2 falling within the ANZG range for upland streams. Turbidity was between 4.43 NTU (Site 1)

and 27.4 NTU (DSCONT3) in the Peel River, and 5.9 and 23.5 NTU in the Cockburn River (Table 6). DO was either too low or too high to fit within ANZG Range for most sites except three (Table 6).

Table 6: Physico-chemical measurements at sites sampled along Peel and Cockburn Rivers in April 2024. Red figures are those that exceed water quality guidelines as per the ANZG range for upland rivers >150 m altitude.

Site	Temperature	pH	EC	Turbidity	DO	DO
(Unit)	°C		µS/cm	NTU	% saturation	mg/L
(ANZG range)		6.5-8.0	125-350	2-25	85-110	
1	14.9	8.3	337	4.43	103.3	9.47
2	14	7.94	302	5.82	72.6	7.43
13	19.3	8.64	381	7.39	82.3	7.36
14	19.9	8.46	390	8.19	87.9	7.06
16	22.1	8.12	392	9.7	86.2	7.26
28	21.9	7.99	421	10	77.1	6.75
42	20.8	8.66	493	16.7	75.6	6.47
CRCON1	30.9	7.83	858	17.8	118	8.62
CRCON2	24.1	7.04	685	5.9	83	7.45
CRCON3	23.5	7.9	818	23.5	47.1	4.31
USCONT1	15.1	8.34	394	4.58	71.8	7.28
DSCONT1	24.8	8.67	829	5.6	121.5	9.85
DSCONT3	24	8.17	1010	27.4	132.9	10.88

4.2. Snag biofilm

4.2.1. Phycology results

Snag biofilm in the Peel River downstream of Chaffey Dam consisted of 14 species of Bacillariophytes (diatoms), 13 species of Chlorophytes (green algae), 13 species of Cyanophytes (lue-green algae), 1 species of golden/yellow-green algae and 2 species of flagellates (Appendix B). The results showed Bacillariophytes (diatoms) were the most prevalent algae at all sites (range = 508–2848 cells/ml/cm^2) with Cyanophytes (blue-green algae) (range = 67–467 cells/ml/cm^2) the second-most prevalent at all sites (Figure 6). The least common algae at all sites were golden/yellow-green algae, which only occurred at Site 13 in one sample at 1 cells/mL/cm^2 (Figure 6).

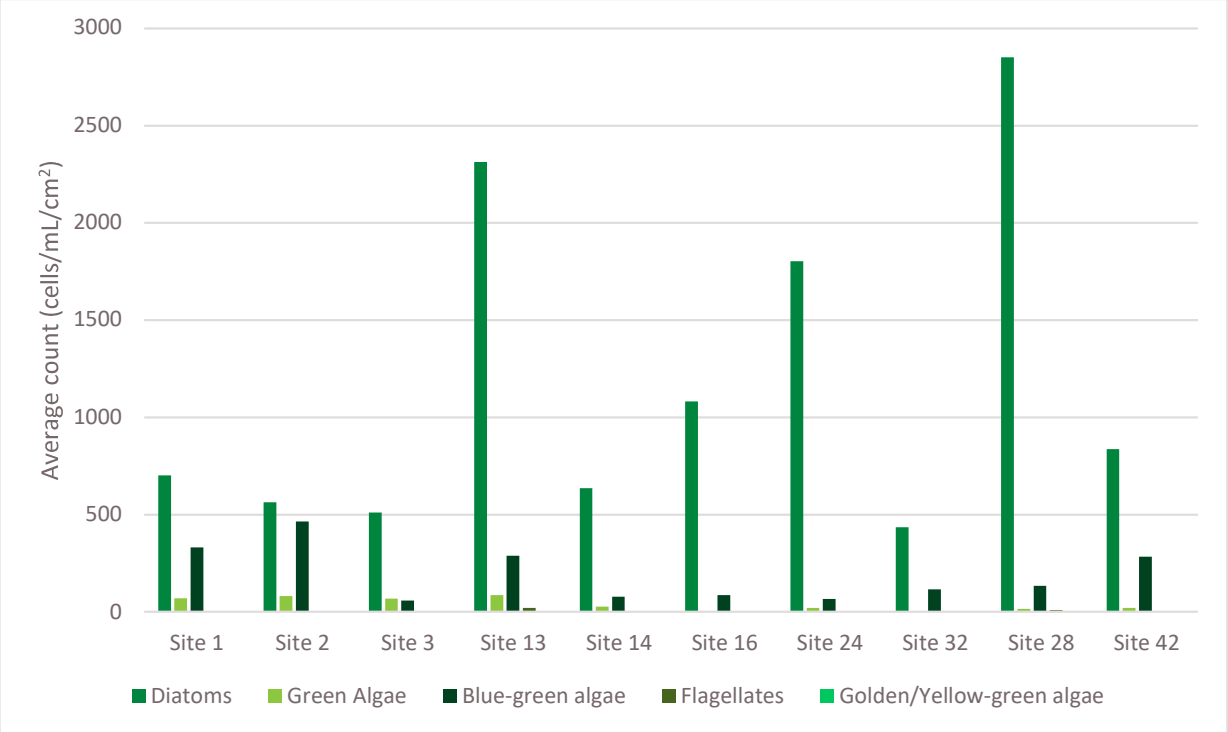


Figure 6: Average algae count (cells/ml) per site for each algae type.

Upstream sites had between 21 and 35 different biofilm taxa per snag, while those downstream had only 14 or 15 taxa (Figure 7). There were 18 taxa that occurred upstream of Dungowan Creek and not downstream. Of these, the most prominent were cyanophytes *Phormidium* spp. >5µm and *Planktothrix* spp. and the chlorophyte *Stigeoclonium* spp. Conversely, only two taxa occurred downstream and not upstream. These were the cyanophyte *Merismopedia* spp. and the diatom *Cocconeis* spp.

Diatoms dominated biofilm assemblages, occurring at all sites with richness of between 8 and 13 taxa (Figure 8). There were more green algae taxa at sites upstream of Dungowan Creek (6-9 taxa) than at downstream sites (1-4 taxa), and the pattern was similar for blue-green algae, except for Site 32. Flagellates occurred at every site upstream of Dungowan Creek, but at only two downstream sites.

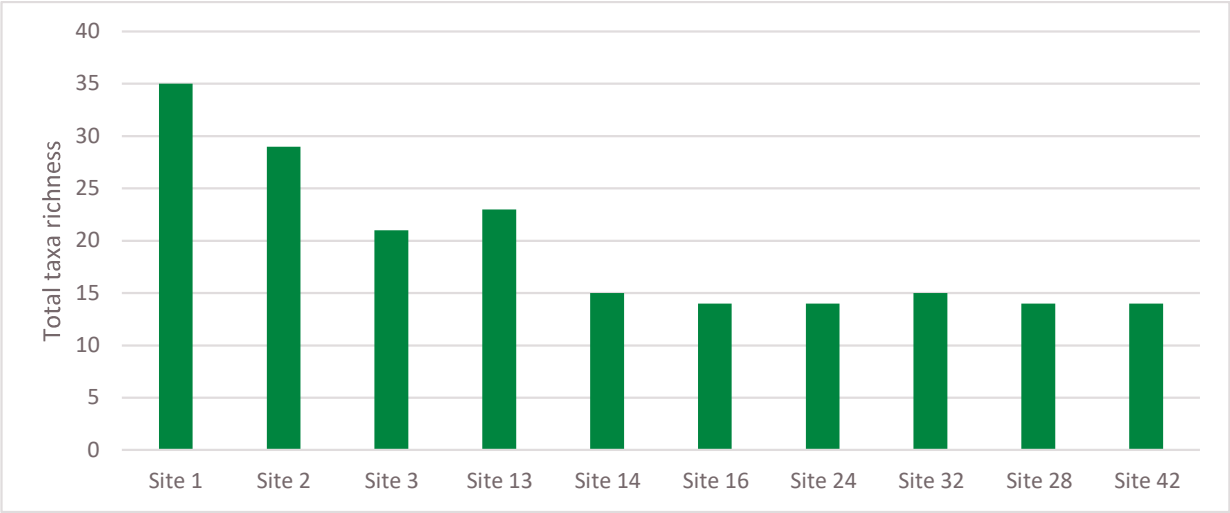


Figure 7: Total species richness in the Peel River at sites downstream of Chaffey Dam

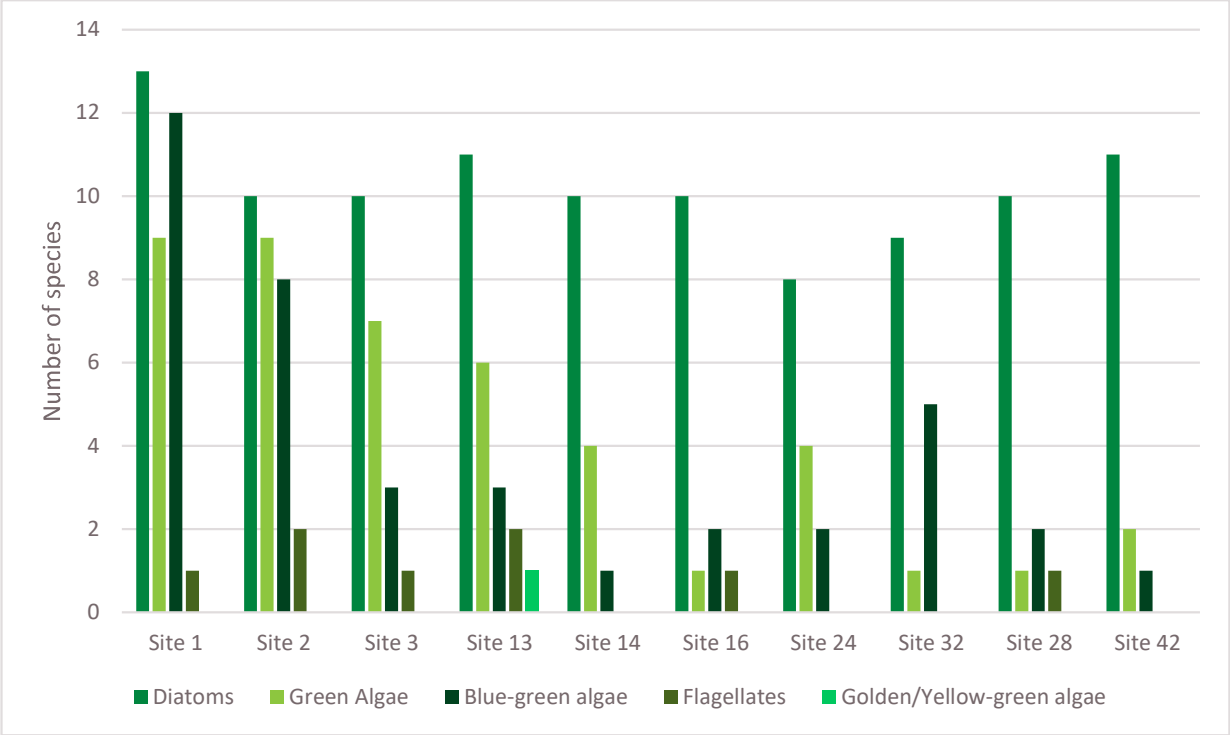


Figure 8: Species richness for each biofilm group.

A total of 14 cyanophyte taxa (blue-green algae) were collected from the Peel River during sampling. They occurred at all sites (Figure 8), with between 1 and 12 cyanophyte taxa per site. Potentially toxic cyanophyte taxa occurred at all sites except Site 14 (Figure 9). There were four different taxa: *Limnothrix* spp., *Micricystis* cf. *aeruginosa, Phormidium* spp. <5µm, and *Phormidium* spp. >5µm, all of which were in relatively low densities. *Phormidium* spp. <5µm were most abundant, with densities of 17 to 283 cells/mL/cm^2.

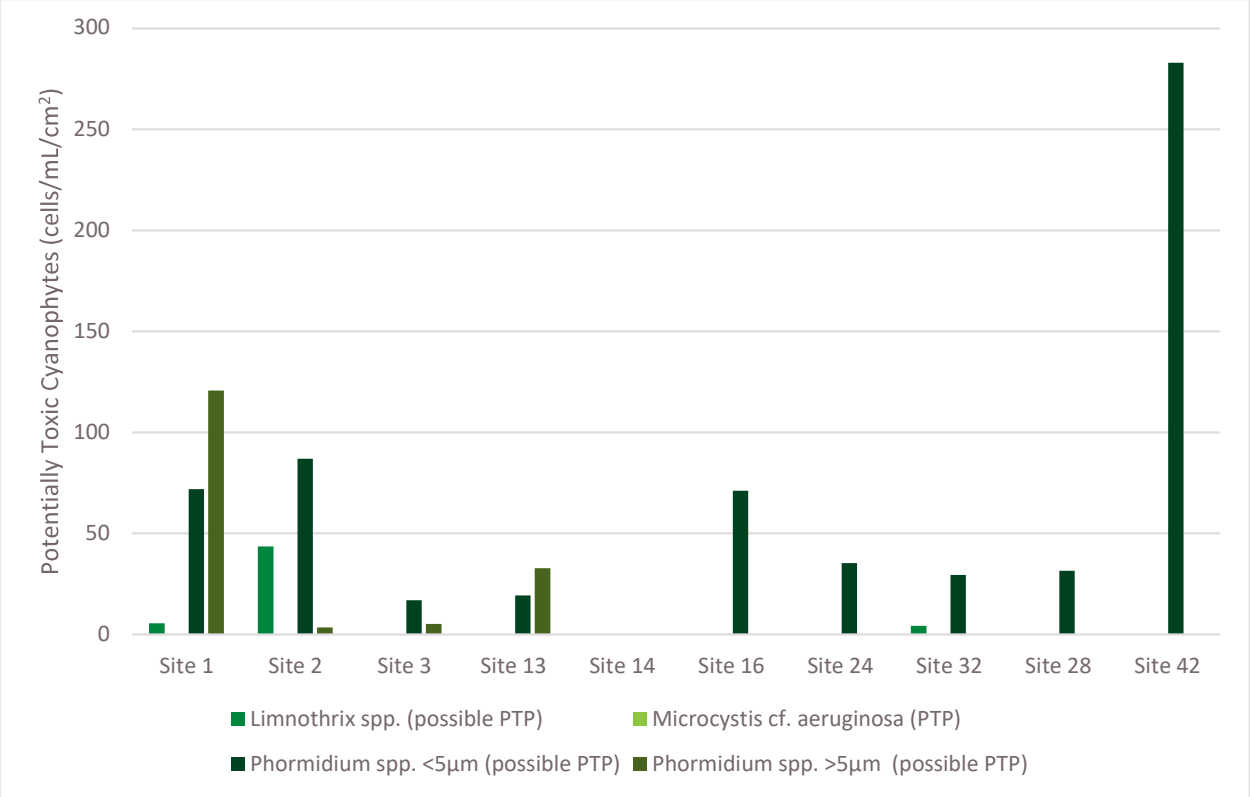


Figure 9: Density of potentially toxic cyanophytes at sites on the Peel River

4.2.2. Biofilm communities

Biofilm communities differed between those sites upstream of Dungowan Creek confluence, and those downstream (ANOSIM R=0.23, P<0.001). This is shown in the nMDS plot (Figure 10). SIMPER analysis indicates that sites upstream had greater densities of *Pseudobaena* spp., *Scenedemus* spp., *Phormidium* spp. (>5µm), and *Aulacoseira* spp.

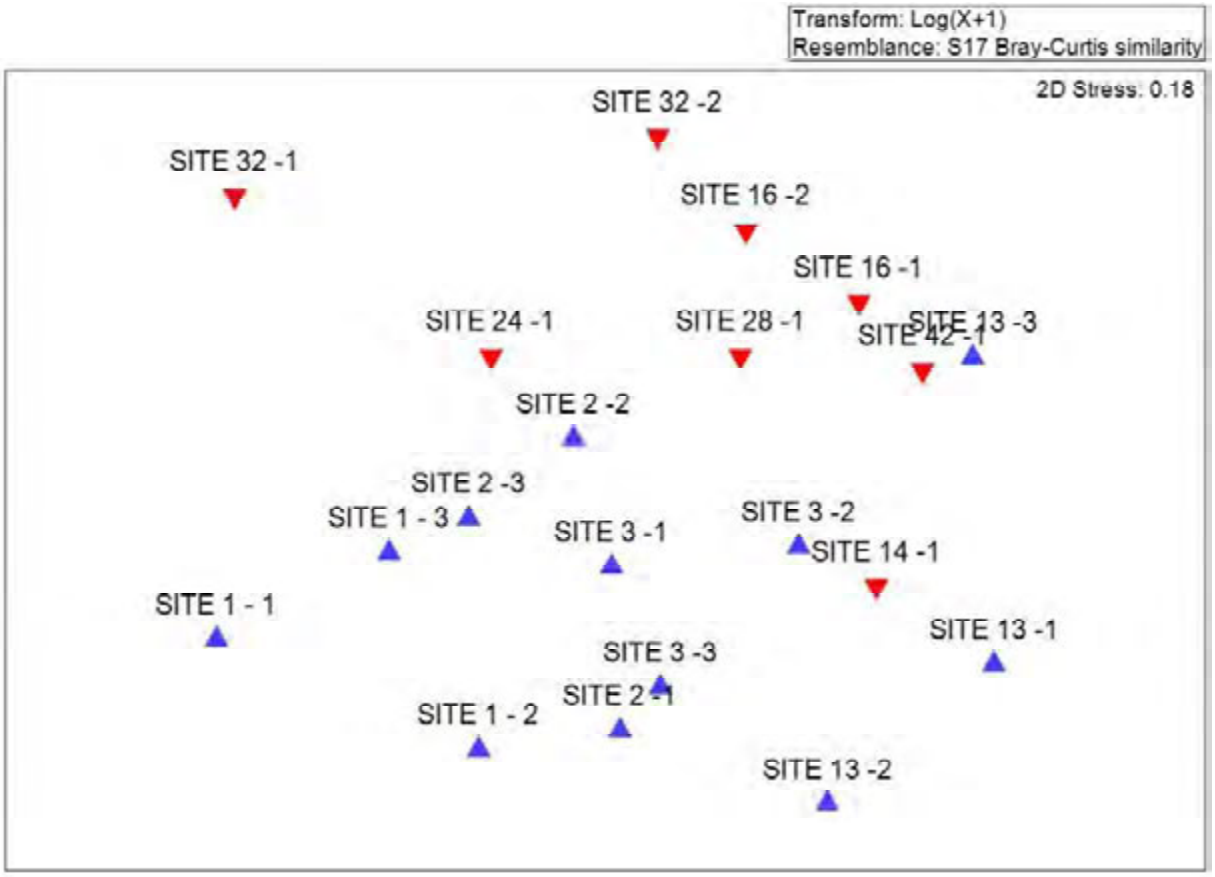


Figure 10: nMDS plot of biofilm communities at sites upstream (blue) and downstream (red) of Dungowan Creek confluence.

4.3. Macroinvertebrate communities

Macroinvertebrate data is presented in Appendix C.

4.3.1. Macroinvertebrate indices

Abundance/Density

The total density of macroinvertebrates ranged from 2937 ± 156 (at Site 2) to 19,358 ± 9054 individuals/m^2 of snag across all sites (Figure 11). The average across all sites was 8378 ± 5718 individuals/m^2.

Chironomidae was the family with the highest density on snags, averaging 5019 individuals/m^2. Oligochaetes had the second-highest densities, with an average of 2034 individuals/m^2, then Elmidae (742 individuals/m^2). All other taxa, apart from Tipulidae, Philopotamidae, Hydridae, Ecnomidae, and Cladocera averaged fewer than 200 individuals/m^2.

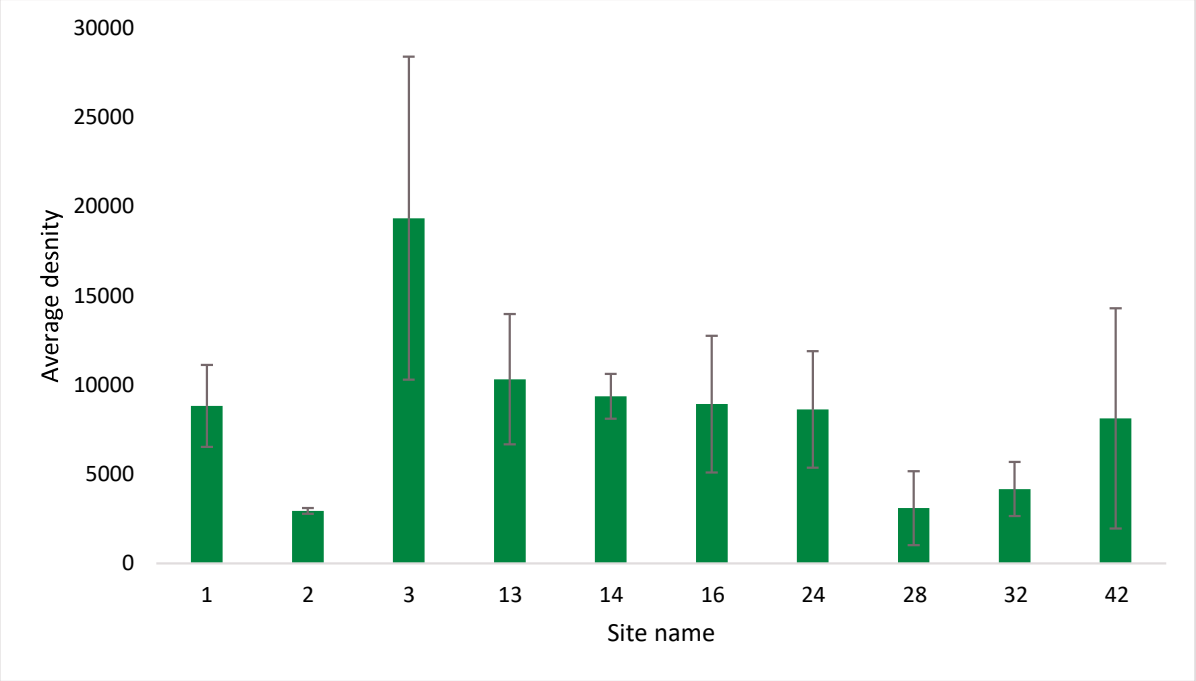


Figure 11: Average density of macroinvertebrates sampled for each snag per site.

Taxonomic richness

There were 39 macroinvertebrate taxa collected from snags during the spring 2023 survey. Average macroinvertebrate taxonomic richness per site was between 8 at Site 42, and 22 at Site 3 (Figure 12, Table 7). Of the 26 taxa, only Chironomidae, Ecnomidae, and Oligochaeta occurred at all sites, while Elmidae and Hydroptilidae occur at 9 sites. 31% of taxa occurred only at one site.

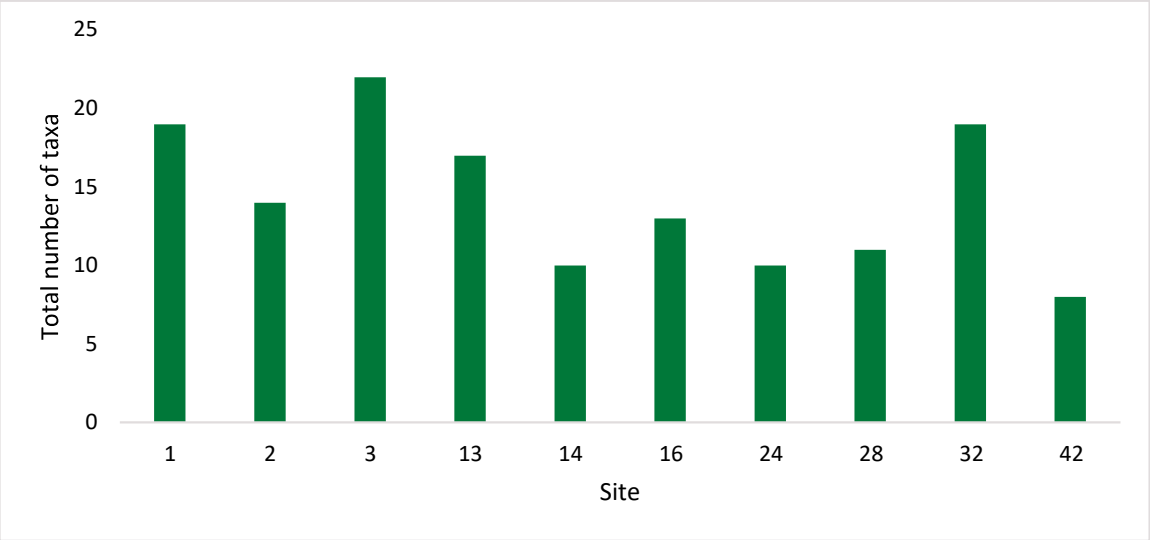


Figure 12: The total number of macroinvertebrate taxa present (richness) per site from sampling by ELA in spring 2023

SIGNAL Score

SIGNAL Scores for snag macroinvertebrate communities averaged between 3.2 ± 1.1 at Site 2, to 4.8 ± 0.1 at Site 13 (Figure 13). SIGNAL Scores indicated that Sites 1-3, 24, and 42 were severely disturbed (SIGNAL Score <4), while the remaining sites were moderately disturbed (Score 4 to 5). The factor contributing to disturbance in the upper three sites is likely to be cold-water released from Chaffey Dam.

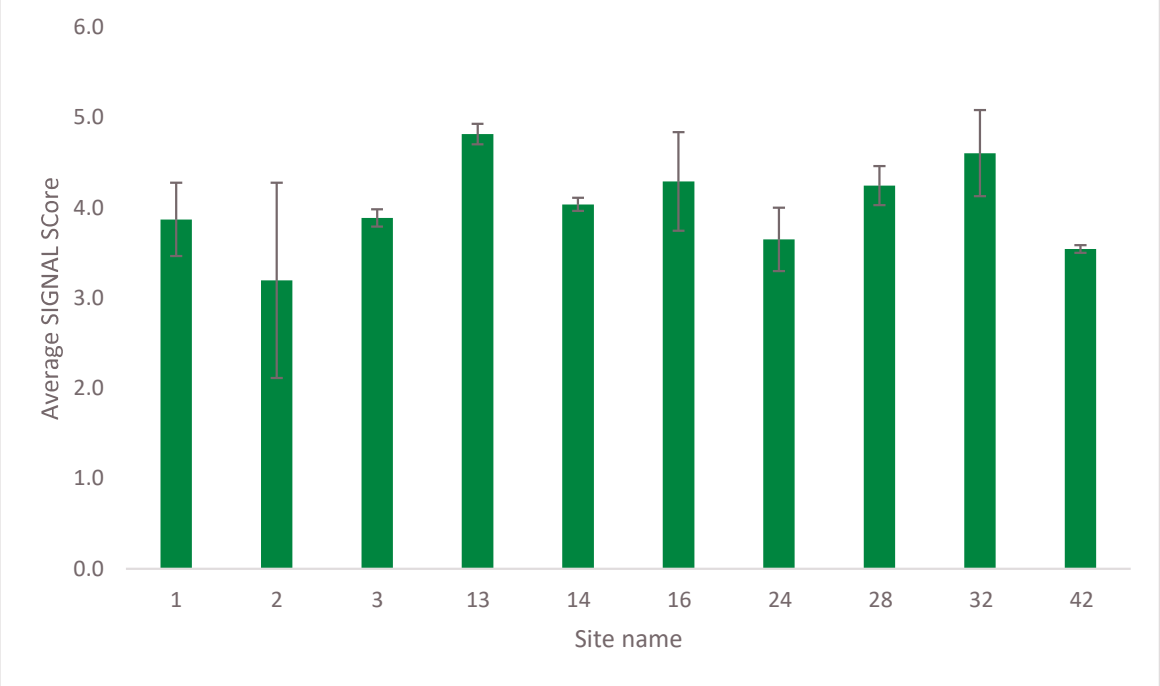


Figure 13: The average SIGNAL score of all taxa observed from each snag (total of 3) per site.

Ephemeroptera, Plecoptera, Trichoptera (EPT) ratio

There were three families of Ephemeroptera in the Peel River samples (Baetidae, Caenidae, Leptophlebiidae) and 6 families of Trichoptera (Antipodeciidae, Ecnomidae, Hydropsychidae, Hydroptilidae, Leptoceridae, Philopotamidae). No Plecoptera were collected, but members of this order are more likely to be collected from cobbles or gravel beds than from snags. Ratios of EPT to other taxa across each site was between 6.9 and 32.4% (Figure 14, Table 7). Apart from Site 14, EPT showed an increasing trend with distance downstream to Site 16, then it began to decline.

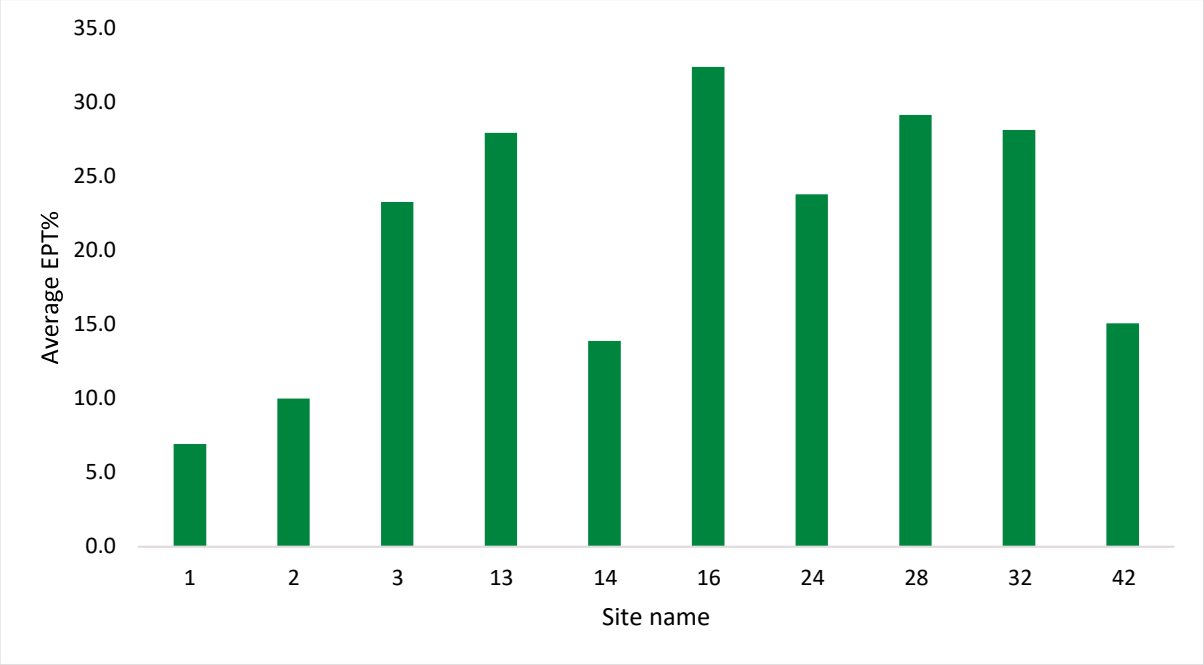


Figure 14. The average EPT % observed from each snag (total of 3) per site.

Table 7. Macroinvertebrate community indices for sites sampled in spring 2023.

Site	1	2	3	13	14	16	24	28	32	42
Richness	19	14	22	17	10	13	10	11	19	8
EPT Ratio	6.9	10.0	23.3	27.9	13.9	32.4	23.8	29.2	28.1	15.1
SIGNAL	3.9	3.2	3.9	4.8	4.0	4.3	3.7	4.3	4.6	3.5

4.3.2. Community similarity

Macroinvertebrate communities on snags within sites were similar to each other at most sites except Sites 2, 3 and 24. This is shown in nMDS space, where similar snag communities are plotted close to each other (Figure 15). Sites 14, 16, 24, 28, and 42 are clustered together, indicating the macroinvertebrate communities on snags in the middle and lower reaches of the project area, downstream of the Dungowan Creek confluence, differ to those in the upper reaches (ANOSIM R=0.4, P<0.001). Both groupings had snag communities dominated by Chironomidae, Oligochaeta, and Elmidae. Taxa that contributed most to differences between upstream sites and downstream sites were Micronectidae (more abundant in lower reaches) and Simuliidae (more common in upper).

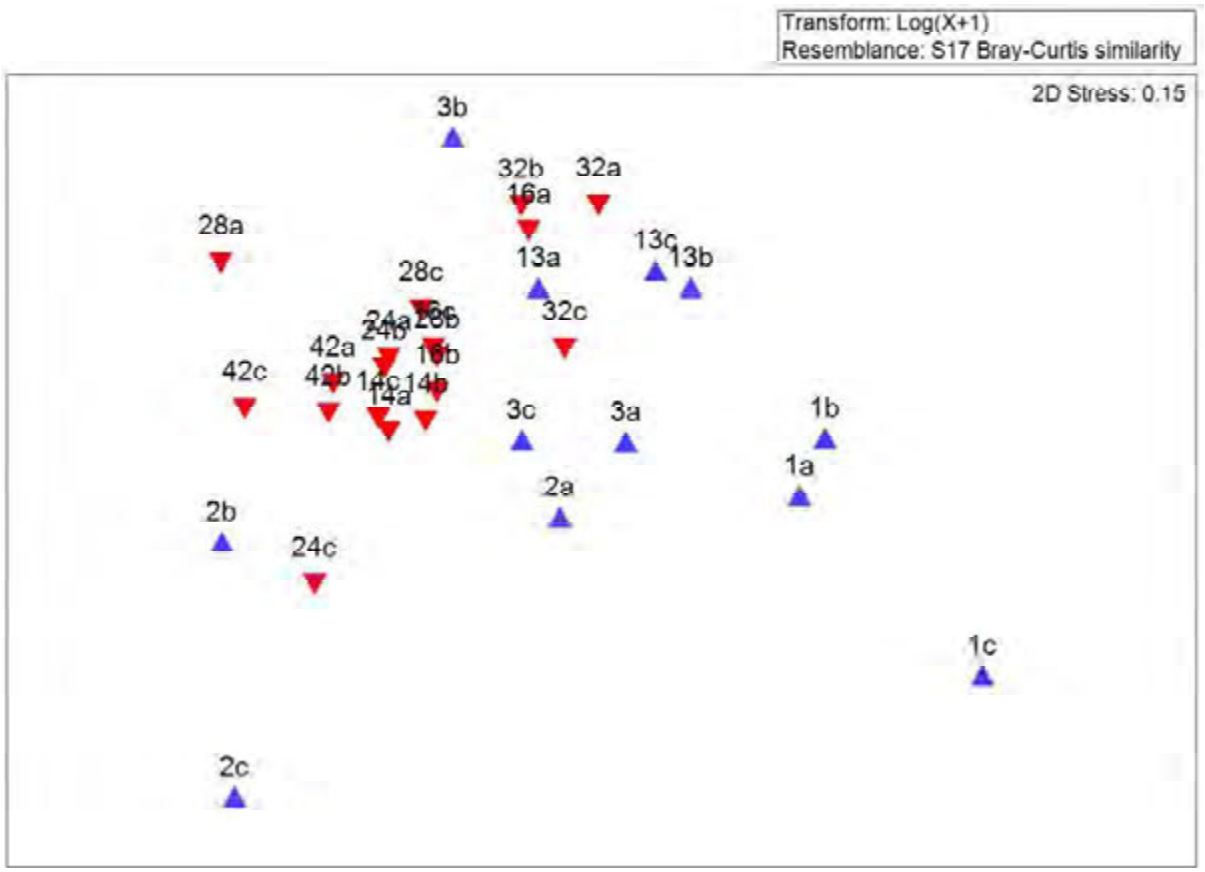


Figure 15: Macroinvertebrate communities on at sites in the Peel River. Red triangles represent snags downstream of Dungowan Creek, while blue snags represent sites upstream

4.4. Fish communities

4.4.1. Environmental DNA sampling

A total of 30 samples were analysed from 10 sites in the Peel River between Chaffey Dam and Tamworth. Thirteen fish taxa were detected. Of these, 10 were native taxa, 3 were introduced (Table 8, Appendix D).

DNA from cod, golden perch, silver perch, European carp, carp gudgeon and Australian smelt were detected at all sites compared to Murray River rainbowfish DNA which was only detected at Site 14, and eastern gambusia and freshwater catfish DNA at Site 28 (Table 8). Each site (across all replicate samples) had between 6 to 9 fish species (Figure 16). The number of native taxa per site varied from 6 to 7 (Table 8).

Table 8: eDNA results for each where Y= fish species DNA was detected by eDNA sampling in at least one of the three samples from that site, N= native species, I= introduced species, CE= Critically Endangered, V= Vulnerable, TP= Threatened Population.

Common name	Status	EPBC listing	NSW FM Act	Site 1	Site 2	Site 3	Site 13	Site 14	Site 16	Site 24	Site 28	Site 32	Site 42
Flyspecked hardyhead	N											Y	Y
Murray river rainbowfish	N							Y					
River blackfish	N				Y	Y	Y	Y	Y				
Murray cod	N	CE		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Golden perch	N			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Silver perch	N	CE	V	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Goldfish	I			Y									Y
European carp	I			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Eastern gambusia	I										Y		
Mountain galaxias	N					Y	Y	Y					
Carp gudgeon	N			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Australian smelt	N			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Freshwater catfish	N		TP								Y		
Total fish taxa				7	6	7	7	7	6	6	8	6	7

The frequency of occurrence for each fish species showed that European carp, carp gudgeons, cod, golden perch and Australian smelt had the highest number of detections (range = 29 – 30) with silver perch detected to a lesser degree (21 detections). The remaining taxa (flyspecked hardyhead, goldfish, galaxiids, Murray River rainbowfish, freshwater catfish and eastern gambusia) had lower number of detections (range = 1 – 10) with Murray River rainbowfish and freshwater catfish each only detected once. Taxa with higher detections (range = 21 – 30) occurred at more sites (n= 10) compared to taxa with fewer detections (range = 1 – 10) which occurred at fewer sites (range = 1 – 5) (Table 9).

Table 9: Number of detections (N detections) and number of occupied sites (N sites) for each fish taxon.

Family	Species	Common Name	N detections	N sites
Atherinidae	*Craterocephalus stercusmuscarum*	Flyspecked hardyhead	3	2
Cyprinidae	*Carassius auratus*	Goldfish	4	2
	Cyprinus carpio	European carp	30	10
Eleotridae	*Hypseleotris* sp.	Carp gudgeon	30	10
Galaxiidae	*Galaxias maculatus*	Mountain galaxias	4	3
Melanotaeniidae	*Melanotaenia fluviatilis*	Murray River rainbowfish	1	1
Percichthyidae	*Gadopsis marmoratus*	River blackfish	10	5
	Maccullochella peelii	Murray cod	30	10
	Macquaria ambigua	Golden perch	29	10
Plotosidae	*Tandanus tandanus*	Freshwater catfish	1	1
Poeciliidae	*Gambusia holbrooki*	Eastern gambusia	2	1
Retropinnidae	*Retropinna semoni*	Australian smelt	30	10
Terapontidae	*Bidyanus bidyanus*	Silver perch	21	10

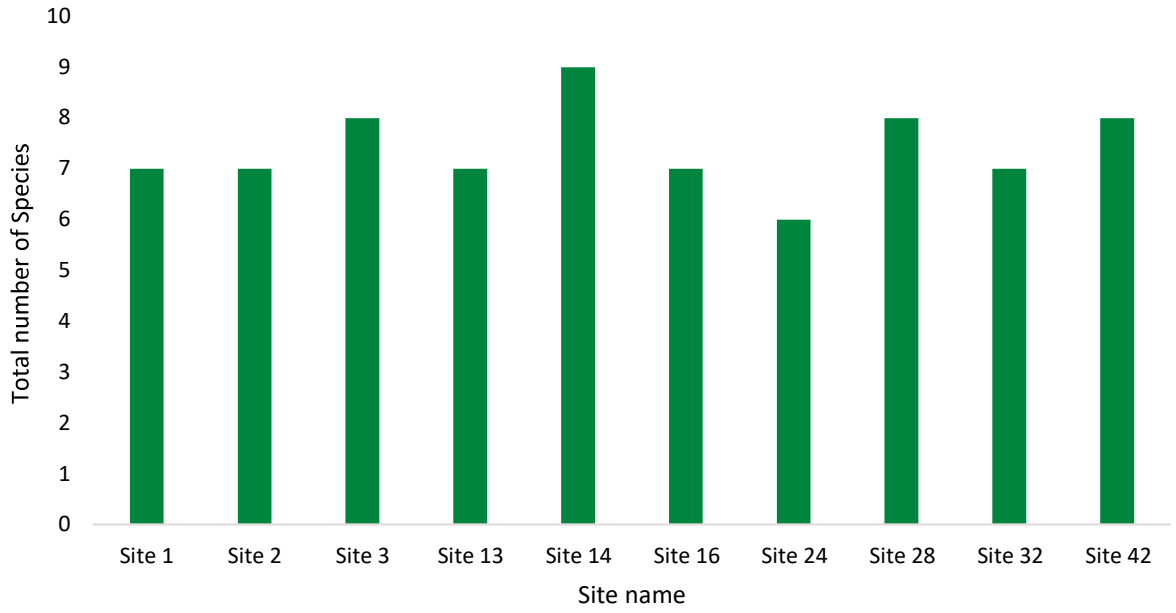


Figure 16: The total number of species present (species richness) per site from eDNA sampling results taken in Spring 2023

4.4.2. Electrofishing and fyke net surveys

Fish surveys using electrofishing and fyke netting collected 12 species of fish across 12 sites (Figure 17, Table 10). Site 1 was the only site that had no fish when sampled in March 2024. This site was very close

to the release from Chaffey Dam. For the other sites, the number of species ranged from 3 to 8 in Control sites, and 2 to 6 in sites along the Peel River where snagging is planned. CRCON1 on the Cockburn River had the highest species diversity, with seven native species and one exotic.

There were species of exotic fish (goldfish, European carp, eastern mosquitofish) across all samples. *Gambusia holbrooki* was the most abundant species, although more occurred in the Control sites than the Peel River sites (Table 10). Carp gudgeon (*Hypseleotris* sp.) was the most abundant and widespread native species, occurring at all snagging sites except Site 1, and all Control sites except DSCONT1 and DSCONT3. Goldfish (*Carassius auratus*) and river blackfish (*Gadopsis marmoratus*) were collected only at Site 3. Spangled perch (*Leioptherapon unicolor*) was another species that occurred at only one site, with one individual collected at DSCONT1. Australian smelt (*Retropinna semoni*) were only collected from Cockburn Creek (Table 10).

Freshwater catfish (*Tandanas tandanas*) occurred at all Control sites, with abundances between one and four individuals. Only three of the Snag sites had catfish, with abundances ranging from 2 to 7. Site 16 had the most individuals (Table 10).

A total of 21 Murray cod (*Maccullochella peelii*) were collected during the survey (Figure 18, Table 11). All of these except for one at USCONT1 were collected using electrofishing, and all except two were collected from the Peel River. Cod were collected from 10 sites, with DSCONT3, downstream of Tamworth, having the most with 6 individuals. Sites 2, 13, 16, and 18 had 3 each (Table 11). Cod were between 93 mm and 710 mm long, with a median length of 420 mm. Two of the fish were less than 120 mm long (Figure 18, Table 11), indicating that they had hatched in the past year. One of these was at Site 16, and the other at DSCONT3. The largest size cohort was between 400 and 499 mm, followed by the 300-399 mm group. Three mature adult cod were sampled at Site 3, Site 28, and CRCON3 (Table 11).

There was no significant difference in fish communities between Control and Snag sites (ANOSIM R= 0.25, P=0.07). Instead, there were distinct groupings of sites with distance relative to the Cockburn River confluence. Sites in the Cockburn River had similar fish communities to sites in the Peel River downstream of the confluence (lower left cluster in Figure 19), and these differed to sites upstream of the confluence (cluster on right, plus Site 14 and, ANOSIM R=0.85, P=0.002). The fish community at Site 42 was more similar to the control sites in the Cockburn River and downstream reaches of the Peel River than it was to upstream reaches of the Peel River.

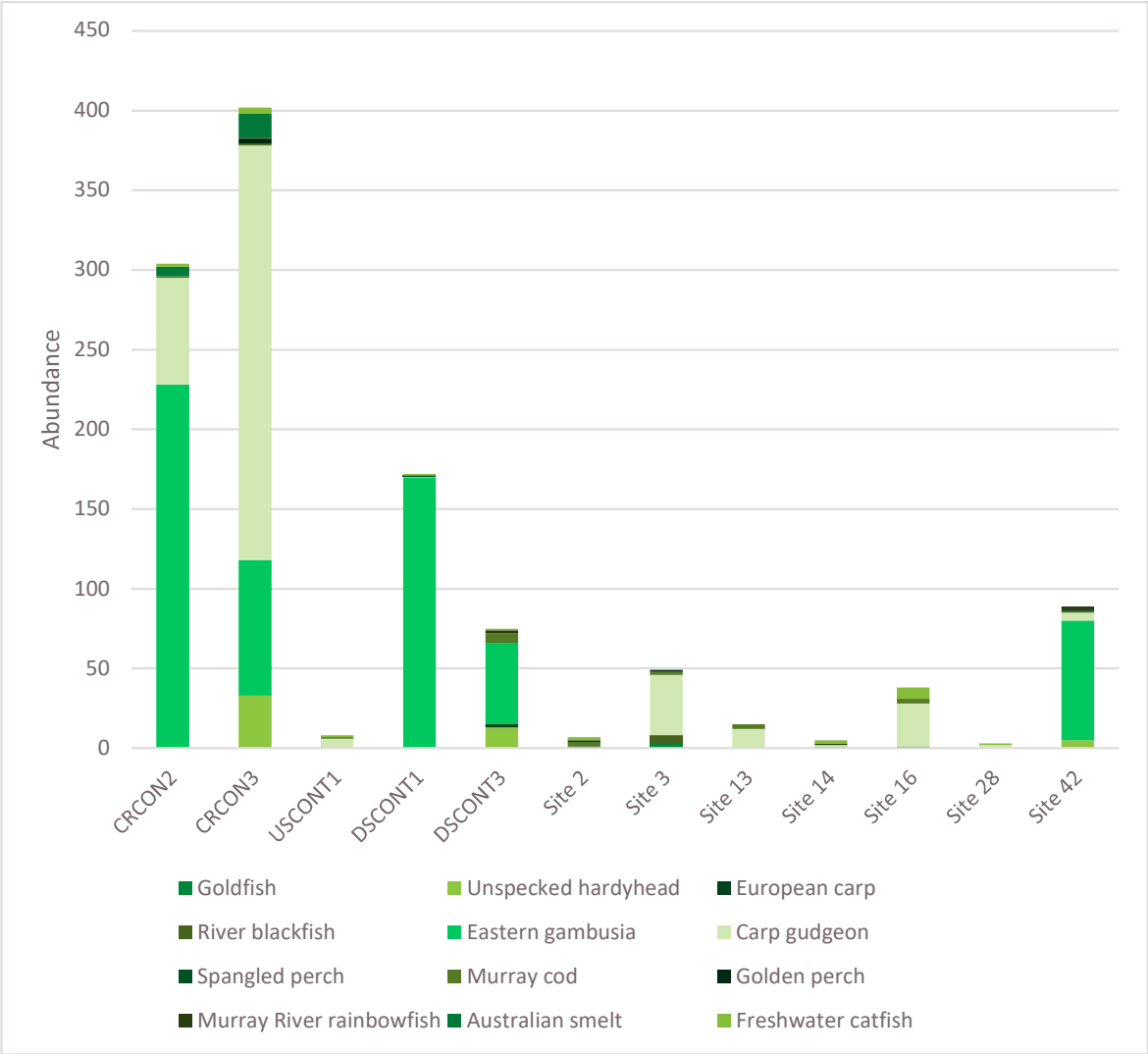


Figure 17: The total abundance of fish identified per site with species differentiated per site by the coloured sections of each bar

Table 10. Fish caught using comined fyke netting and electrofishing.

Scientific Name	Common Name	Control Sites						Snag Sites							Grand Total
		CRCONT1	CRCON2	CRCON3	USCONT1	DSCONT1	DSCONT3	Site 2	Site 3	Site 13	Site 14	Site 16	Site 28	Site 42	
Carassius auratus	Goldfish								3						3
Craterocephalus stercusmuscarum fulvus	Unspecked hardyhead			33			13							5	51
Cyprinus carpio	European carp	15					2	1				1			19
Gadopsis marmoratus	River blackfish								5						5
Gambusia holbrooki	Eastern gambusia	1461	228	85		170	51				1			75	2071
Hypseleotris sp.	Carp gudgeon	10	67	260	6				38	12	1	27	2	5	428
Leiopotherapon unicolor	Spangled perch					1									1
Maccullochella peelii	Murray cod		1	1	1		6	3	2	3		3		1	21
Macquaria ambigua	Golden perch			3				1	1					1	6
Melanotaenia fluviatilis	Murray River rainbowfish			1			2				1			2	6
Retropinna semoni	Australian smelt		6	15											21
Tandanus tandanus	Freshwater catfish	3	2	4	1	1	1	2			2	7	1		24
	Total Fish	**1489**	**304**	**402**	**8**	**172**	**75**	**7**	**49**	**15**	**5**	**38**	**3**	**89**	**2656**

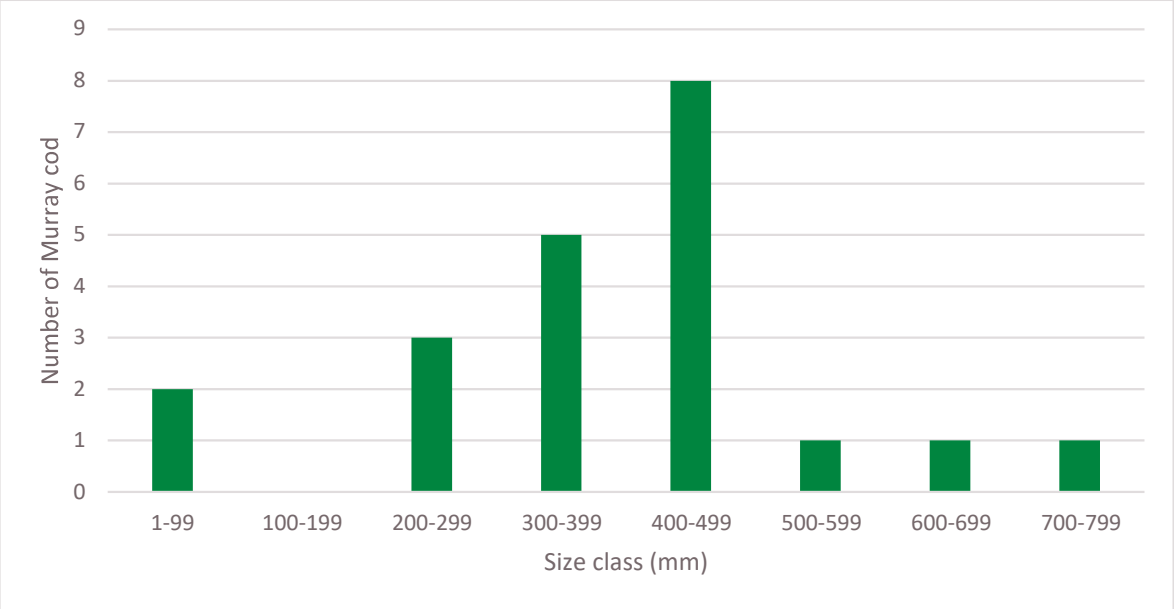


Figure 18: Size class of cod captured during March 2024 surveys

Table 11: Murray cod *(Maccullochella peelii*) at sites in the Peel and Cockburn Rivers

Sample Start Date	Site	Site Status	N detections young-of-year Murray cod (<120 mm length)	Length young-of-year Murray cod (mm)	N detections adult Murray cod (>500 mm length)	Length for adult cod (mm)
12/03/2024	CRCON2	Control	0	-	0	-
12/03/2024	CRCON3	Control	0	-	1	570
13/03/2024	3	Snag	0	-	1	620
15/03/2024	13	Snag	0	-	0	-
16/03/2024	DSCONT3	Control	1	87	0	-
13/03/2024	16	Snag	1	93	0	-
13/03/2024	2	Snag	0	-	1	710
17/03/2024	42	Snag	0	-	0	-

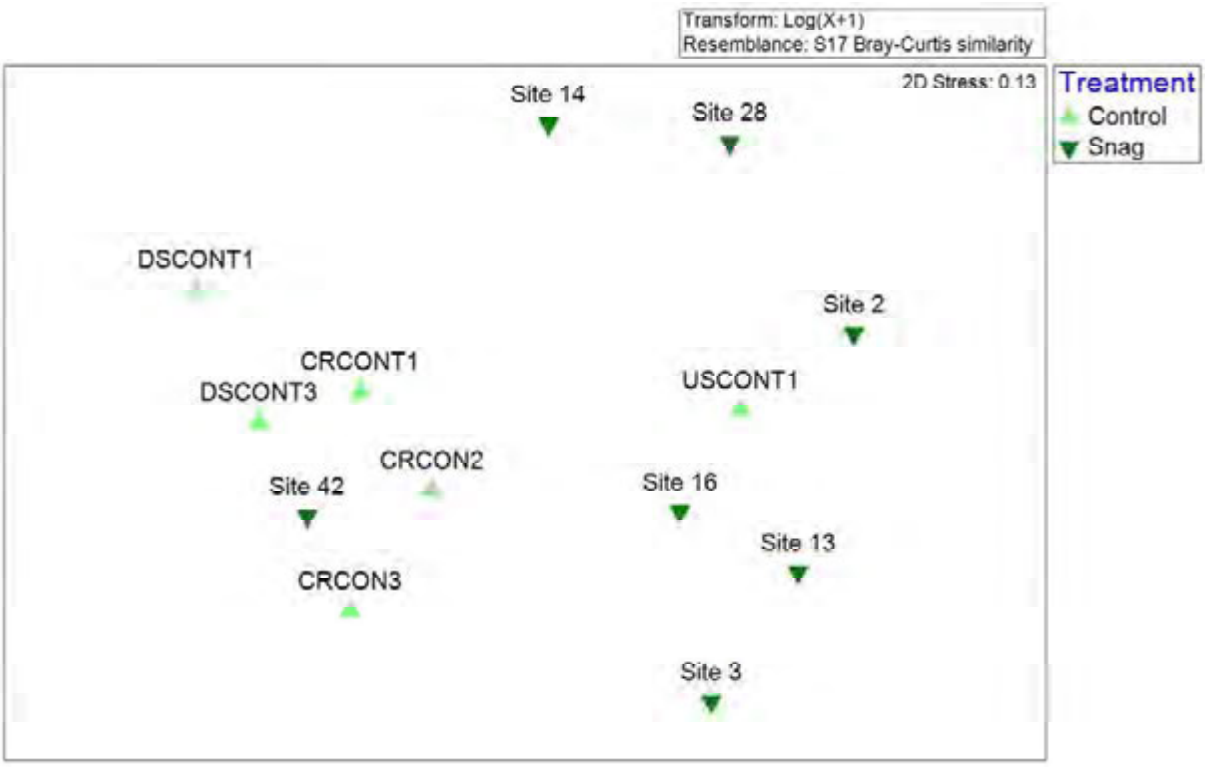


Figure 19: Nonmetric multi-dimensional scaling plot for fish communities captured at Control and Snag sites

5. Discussion

The purpose of the current round of sampling was to collect baseline data from the Peel River prior to the installation of snags by WaterNSW. Sites for the macroinvertebrate, biofilm, and fish eDNA sampling were selected based on the list of sites nominated by Geolink (2022). These were sampled in October 2023 and the intention was to also sample fish communities from the same sites in March 2024. However, when snag installation began in March 2024, it became apparent that not all sites would be suitable for installation due to steepness of banks and limited access. Therefore, some of the sites selected for fish sampling differed to those of the macroinvertebrate sampling sites. Of the 16 sites, 3 were sampled for macroinvertebrates, biofilm and eDNA; 7 were sampled for macroinvertebrates, biofilm, eDNA and fish community, and 6 were sampled only for fish community. Once re-snagging has been completed, the list of sites for ongoing post-installation monitoring should be revised so that all variables are sampled from the same sites.

Once this re-snagging project is complete, WaterNSW will have introduced 50 large tree stumps/root balls into the Peel River downstream of Chaffey Dam. Snags are critical components of inland rivers, providing many benefits to aquatic ecosystems (DEW 2021, Hrodey et al 2018), including:

- Refuge habitat and breeding locations for native fish
- Increased habitat for bacteria, algae, biofilm, and invertebrates, some of which are specialised for living/feeding on woody debris
- Perching and basking sites for aquatic birds, reptiles, and mammals
- Increased feeding areas for native fish
- Stabilising stream channel and dictate morphological changes, and
- Retention of organic matter in the stream.

The Peel River currently has many naturally occurring snags between Chaffey Dam and Tamworth. There were multiple snags at each of the sites visited during the baseline survey, some of which were sampled for macroinvertebrates and snag biofilm. However, most of the snags observed were *Casuarina* spp. rather than *Eucalyptus* spp. *Casuarina cunninghamiana* (river sheoak) has a dry wood density of approximately 770 kg/m^3 while *Eucalyptus camaldulensis* has a density of 900 kg/m^3 (Brooks et al 2006). The higher density of *Eucalyptus* wood over *Casuarina* means that the introduced snags will be more resilient to both biological breakdown by invertebrates and microbial activity, and physical breakdown by the movement of water and entrained solids. The large snags would also have more impact in driving geomorphological processes over time, such as the scouring of pools. To complement this, the softer *Casuarina* snags would provide a more ready food source for wood-boring invertebrates such some aquatic beetle larvae.

5.1. Snag biofilm

Snag biofilms are assemblages of microbial cells, including algae, diatoms, bacteria, flagellates and fungi in an extracellular polymeric matrix and attached to large woody debris. River biofilms dominate the microbial life in stream and can contribute significantly to biogeochemical processes that affect water chemistry (Battin et al. 2016). On snags, biofilms develop over time, with the type of microbial cells changing with the age of the snag, flow velocity, nutrient content of the river, and other physico-

chemical parameters (Boulton et al. 2014). Snag biofilms are also important processers of dissolved organic carbon in lowland rivers (Baldwin et al 2013). In turbid, silt-laden rivers biofilm also needs to contend with the accumulation of silt on the snag, which can contribute nutrients but also block light for some algae.

Generally, more mature biofilm communities will have a higher biological diversity than younger communities (Rather et al. 2021). Initially, planktonic microorganisms attach to the surface and form the early stages of the extracellular matrix. More microorganisms join the biofilm and begin dividing to form microcolonies, until the biofilm matures and sends planktonic bacteria off to colonise other locations.

These surveys provide the first assessment of snag biofilm communities in the Peel River. Across all sites, there were 44 taxa in the snag biofilm community, consisting of:

- Bacillariophytes (diatoms)- Centrales: 3 taxa, with at least one taxon on all snags sampled except for one at Site 32
- Bacillariophytes (diatoms)- Pennales: 11 taxa, with four taxa occurring on every snag sampled
- Chlorophytes (green algae): 13 taxa
- Cyanophytes (blue green algae): 14 taxa, including the 4 potential toxic taxa *Limnothrix* spp., *Microcistis* cf. *aeruginosa, Phomidium* spp. <5 µm and *Phomidium* spp. >5 µm
- One taxon each of Cryptophyte Flagellates, Euglenophyte Flagellates, and Golden/yellow-green algae.

Biofilm communities in the Peel River showed a general decrease in diversity along the river until Site 14, when diversity generally levelled out at 15 or 14 taxa downstream of Cockburn River confluence. The higher diversity in upstream reaches may be due to the greater fluctuations experienced in temperature, water level, velocity, and physico-chemistry. Sites 1 to 13 also had less turbid water than downstream sites, allowing better light penetration and subsequently a more diverse community of Chlorophytes and Cyanophytes than downstream sites.

Snags newly introduced to the Peel River are unlikely to have a diverse biofilm community, but this would develop the longer the snag stays underwater. As biofilm community develops on new snags, it should gradually build up to resemble that of snags in similar reaches of the river. There is some possibility that there will be differences between natural snags and introduced snags because of the different wood type (*Casuarina* vs *Eucalyptus*) and their respective hardness, but the taxa present should be relatively similar in the long term.

5.2. Macroinvertebrate communities

In inland rivers, snags constitute one of the main types of solid substrate, and so have a unique invertebrate fauna that differs from other riverine habitats (Growns et al. 1999). Snag macroinvertebrates are important as food for fish and other aquatic predators, so play an important role in the ecological community.

Snag macroinvertebrate communities in the Peel River consisted of 8 to 22 invertebrate families per site, which is similar to other Peel River habitats sampled for macroinvertebrates. During the aquatic

ecology assessment for the Dungowan Dam pipeline project, the Peel River had 10 to 27 invertebrate families in edge habitats, and 6 to 9 families in riffle habitats (EMM 2022).

Snag macroinvertebrate communities in the Peel River had an average density of 2937 ± 156 to 19,358 ± 9054 individuals/m^2 of snag. These numbers are comparable to snag communities collected from the Campaspe and Broken Rivers in Victoria using the same methods (Growns et al. 1999). In these rivers, the median value across 8 sites was between 4676 and 12,568 individuals/m^2 of snag.

Snags introduced into pool and riffle habitats of the Hunter River increased both abundance and taxa richness after just 30 days (Scealy et al. 2007), highlighting the rapid ability of snags to impact on the aquatic community. This study found that complex woody debris structures were more effective than simple structures at enhanced macroinvertebrate community composition in pools and riffles.

5.3. Fish communities

The Peel River is part of the Lowland Darling River Endangered Ecological Community (EEC) has a relatively diverse fish community similar to other similar catchments in the upper Murray-Darling Basin. Previous surveys by EMM (2022) in 2020 and 2022 found 12 species, including two threatened species (Murray cod, silver perch) a species from a threatened population (Eel-tailed catfish of the Murray-Darling Basin), as well as the non-threatened native species bony bream, carp gudgeon, river blackfish, golden perch, Australian smelt, and mountain galaxias. Three non-native, exotic species were also collected: goldfish, common carp, and eastern mosquitofish.

Baseline surveys found 13 species of fish near the snags sampled using eDNA (October 2023) and 12 species using the combined electrofishing and fyke netting approach. Fish communities collected in the most recent surveys were similar to those reported by EMM (2022), although the EMM survey did not include any flyspeckled hardyheads or Murray River rainbowfish.

Two of the fish species, Murray cod and river blackfish, use snags as major nesting sites (Table 12). River blackfish were detected at Sites 3, 13, 14 and 16 using eDNA, and Site 3 using electrofishing. This species usually spawns inside hollow logs between October and January when temperature is above 16°C, although may use undercut banks or rocks as alternatives (Lintermans 2023). Females lay 200-500 adhesive eggs inside the nest, which are guarded by the male until they hatch after 14 days. This species may benefit from re-snagging at the upper sites in the Peel River, particularly if the snags have hollow limbs.

Table 12. Fish detected in Peel River, and how they use snags

Scientific Name	Common Name	Snag use
Native species		
Galaxias olidus	Mountain galaxias	Minimal
Craterocephalus stercusmuscarum fulvus	Unspecked hardyhead	Use snags opportunistically as refugia
Gadopsis marmoratus	River blackfish	Use snags opportunistically as refugia, and hollow logs for spawning
Bidyanus bidyanus	Silver perch	Minimal

Scientific Name	Common Name	Snag use
Hypseleotris sp.	Carp gudgeon	Uses hard substrates (including snags) for laying eggs, source of macroinvertebrate food
Leiopotherapon unicolor	Spangled perch	Minimal
Maccullochella peelii	Murray cod	Nesting, cover, source of macroinvertebrate food
Macquaria ambigua	Golden perch	Refugia, source of food
Melanotaenia fluviatilis	Murray River rainbowfish	Minimal
Retropinna semoni	Australian smelt	Minimal
Tandanus tandanus	Freshwater catfish	Minimal, may use snags for cover
Exotic species		
Carassius auratus	Goldfish	Minimal
Cyprinus carpio	European carp	Minimal
Gambusia holbrooki	Eastern gambusia	Minimal

Murray cod were detected at all sites sampled with eDNA during October 2023, and at all sites on the Peel River except 3 during March 2024. Cod were also collected from most sites along the Cockburn River. The data indicate that cod occur in low numbers all along the Peel River upstream of Tamworth, and potentially use snags as refuge habitat. Cod were between 93 mm and 710 mm long, with representatives in most size classes within this range.

Murray cod spawn in spring and early summer (August to October in the northern Murray-Darling Basin), when water temperature exceeds 15°C (Lintermans 2023), so spawning may be affected by cold water pollution in the reach immediately downstream of Chaffey Dam (see *Cold Water Pollution* section below). Cod lay adhesive eggs that are deposited on hard surfaces such as rocks or snags (Lintermans 2023). Stocks (2021) suggests that hydrographs designed to enhance cod spawning success in the Macquarie River should include a pulse or bank-full flow event in August/early September, followed by a period of moderately stable flow from mid-September to early December. As Murray cod in the northern Murray-Darling Basin generally lay their eggs in water less than 1 m deep, river level should not drop more than 0.3 m, nor have significant increases in flow so that disturbance to nests is minimised (Butler et al. unpublished, in Stock 2021).

Recruitment of Murray cod in the Peel River appears low. Of the 21 cod collected in the Peel and Cockburn Rivers, only two were less than 120 mm long and hatched in the last year. While this indicates that recruitment is occurring in the Peel River, it does not indicate spawning success for Murray cod, as mortality of larval fish in their first year can be high (Stocks 2021). A more effective way of assessing hatch success would be to conduct targeted sampling for larval fish around natural and installed snags during the spawning period.

Silver perch were detected at all Peel River sites using eDNA, but no individuals were collected at any sites using electrofishing or fyke nets. The non-detection of silver perch in March may be due the preference of this species for riffle and run habitats, and the focus of survey effort around snags. Without capture data, there is no indication of spawning or young-of-year in the Peel River. Silver perch spawn in spring and summer, when water temperatures are between 16 and 28°C, or in the mid-Murray, above 20°C (Lintermans 2023). Silver perch eggs are non-adhesive and semi-buoyant, so the species is not directly reliant on snags for spawning habitat.

Four other native species detected in the Peel River use snags for cover, or as sources of food such as macroinvertebrates (Table 12). Even those native species which do not directly use snags for habitat or food will benefit from the secondary geomorphic impacts that snags have on rivers. These include an increase in the morphological and flow diversity in the river, as well as the retention of other organic matter to assist in breakdown (Anlanger et al 2021).

5.4. Cold water pollution

Rivers downstream of some large dams in NSW are vulnerable to cold water pollution, particularly in warmer months when dams stratify (Chaaya and Miller 2002). Koehn et al (2023) modelled the impacts of cold-water pollution on Murray cod and golden perch downstream of Copeton and Pindari Dams in the northern Murray-Darling Basin. The study analysed daily flow and temperature data from gauging stations along the Gwydir and Severn Rivers, for the spawning periods of both species (October to December for cod, August to February for golden perch). Population models using minimum spawning temperatures for both species (18°C for Murray cod, and 20°C for golden perch) indicated that Murray cod populations were largely unaffected by cold water pollution downstream of Pindari Dam in Severn River, but that golden perch populations were significantly affected, with numbers declining almost to zero. In the Gwydir River, downstream of the larger Copeton Dam, Murray cod and golden perch populations both declined severely with modelled cold water pollution.

Impacts were greater on golden perch than Murray cod because of their need for water spawning water. Pindari Dam had a smaller impact on Murray cod populations than did Copeton Dam. This was partly attributed to the smaller size of Pindari Dam (312 GL compared to 1364 GL). Chaffey Dam has a storage volume of 100.5 GL, so the impact from coldwater pollution in the Peel River would likely be less than it is in Gwydir and Severn River. Nevertheless, there were noticeable impacts to the aquatic community from data collected in the baseline surveys.

In the Peel River, the two upstream sites (Site 1 and 2) show clear signs of cold-water pollution with temperatures at least two degrees cooler than the next site, and up to 20 degrees cooler than sites further downstream at the dates of our surveys. Turbidity was also much lower at the two most upstream sites. The ecological community at these two sites, and Site 3, appears to also have been affected by cold water pollution, with depauperate macroinvertebrate communities featuring few taxa and low numbers of individuals.

The impact of cold water pollution on fish communities is more ambiguous in the Peel River immediately downstream of Chaffey Dam. Although no fish were caught at Site 1 in March 2024, 4 species (7 individuals) were caught at Site 2, including Murray cod, golden perch and freshwater catfish. Environmental DNA collected from downstream of Chaffey Dam in October indicated that there were at least 7 species of fish at Sites 1 and 2, including Murray cod, golden perch, and silver perch. However,

while cold water pollution may not prevent fish from being present at the upstream sites, there is plenty of evidence that it may limit spawning success for native species that prefer warmer water. Data from 1992-2023 at the gauging station downstream of Chaffey Dam show water in the Peel River has its first day exceeding 15°C (minimum spawning temperature reported in Lintermans 2023) somewhere between 19 August and 28 December (Figure 4). More frequently, temperature doesn't get above 15°C until late September. This means that cod in the Peel River between Chaffey Dam and Dungowan Creek would have a restricted window of suitable spawning temperature from approximately mid-September to end of October, but that this period may be truncated if temperature is low in the earlier dates. Downstream of the Dungowan Creek confluence, water temperatures in the spawning period will be higher so temperature should not be a limiting factor.

5.5. Recommendations for future monitoring

The use of the snag bag was an effective and quantitative way to sample macroinvertebrate communities during this baseline assessment. However, this method is designed for snags no greater than approximately 30 cm diameter (Growns et al 1999), so while it is possible to sample the natural snags with the snag bag, this is not feasible for sampling the introduced snags because some of these have diameters of up to 2 m, which is too large to be encapsulated by the snag bag. A suitable replacement method would need to allow macroinvertebrate densities on both the introduced (large diameter) and natural (smaller diameter) snags to be calculated and would need to sample a known area of snag. While it may be possible to continue sampling the natural snags with the snag bag, it would be best for comparability if the same method was used for both the natural and introduced snags.

One possible alternative could be a modified Hess sampler (Hauer and Lamberti 2017). Hess samplers are constructed from a cylindrical frame (or bucket) that is pushed against the stream bed to seal off a standardised area from flow. The area of bed inside the frame is agitated, and macroinvertebrates are collected either with a pump or by passing through a net. This method could be applied to large snags, but would be limited to only sampling the top of the snag and only when water is less than 40 cm over the snag (which is a similar depth limitation for sampling with the snag bag). Samples could be collected by scrubbing the enclosed section of snag with a stiff-bristled brush to dislodge invertebrates, then these could be collected with a small 250 µm-mesh net, or the water collected using a hand-held pump then filtered through the net. For flowing water, another alternative could be to position a D-frame kick net downstream of the area of snag to be sampled, then scrub the snag with a brush and allow the current to carry macroinvertebrates downstream to the net (Hrodey et al 2008). If feasible, different methods should be trialled on some of the snags installed in the Peel River so that their effectiveness can be assessed prior to the next round of survey in October 2024.

Only two young-of-year Murray cod, and no juvenile silver perch were collected from snags during the baseline survey. While this may indicate juvenile recruitment of cod, a more effective method of assessing spawning rates would be to specifically target larval fish. Targeting larval fish also removes the uncertainty about whether young-of-year spawned in the river or originate as stocked individuals. Over a five week period between mid-October to mid-November, Stocks (2021) collected 645 Murray cod larvae and 91 larvae or eggs from at least 5 other species using larval drift and light trap. It is recommended that at least two rounds of larval fish sampling occur in the Peel River, if not every year, then in the first- and fifth-years post-installation. This will allow spawning success to be tracked, and it will also remove some uncertainty about whether the fish spawned in the Peel or elsewhere and then

moved into the Peel in their first year. Larval sampling will also provide good baseline data for assessing the effectiveness of pump screens at protecting larval fish. Larval light traps and plankton tow nets can be used around natural and introduced snags to monitor the immediate larval community, and drift nets can be set at the downstream end of pools at selected sites to determine the rate at which species are dispersing along the river.

Some of the sites used for baseline macroinvertebrate and biofilm will not have snags installed in them. While the list of sites has not been finalised, at least Sites 42, 32, and 24 have been removed from the program. Prior to the next survey round, the monitoring program will need to be modified to account for this either by reducing the total number of sites, or finding replacements. There were seven sites where all variables (fish community, eDNA, macroinvertebrates, diatoms, water quality) were collected and these should be retained. At these sites, it will be possible to collect invertebrates and diatoms from both natural and installed snags, with the expectation that communities on the installed snags will gradually come to resemble those on natural snags. Pairing natural and installed snags within sites will also help reduce the influence of longitudinal differences between sites, such as the difference in communities upstream and downstream of tributaries.

Fish are not attached to individual snags, and are much more mobile than macroinvertebrates and diatoms, fish communities in the same pool are unlikely to differ around individual snags. During the baseline fish survey, control sites were established in the Peel River and Cockburn River where no snags are intended. If resnagging increases populations of native fish species in the Peel River, it is likely that there will be flow-on increases in tributaries over time as fish spawned in the Peel grow to adults and swim into other waterways.

6. References

Anlanger, C., Attermeyer, K., Hille, S., Kamjunke, N. Koll, K., Konig, M., Schnauder, I., Tavares, C.N., Weitere, M. and Brauns, M. 2022. Large wood in river restoration: A case study on the effects on hydromorphology, biodiversity, and ecosystem functioning. *International Review of Hydrobiology* 107:34-45.

ANZG. 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. https://www.waterquality.gov.au/anz-guidelines/about

Baldwin, D.S., Whitworth, K.L. and Hockley, C.L. 2013. Uptake of dissolved organic carbon by biofilms provides insights into the potential impact of loss of large woody debris on functioning of lowland rivers. *Freshwater Biology* 59:692-702.

Battin, T., Besemer, K., Bengtsson, M., Romanis, A.M., and Packmann, A.I. 2016. The ecology and biogeochemistry of stream biofilms. *Nature Reviews Microbiology,* 14, 251–263 (2016). https://doi.org/10.1038/nrmicro.2016.15

Boulton, A.J., Brock, M.A., Robson, B.J., Ryder, D.S., Chambers, J.M., and Davis, J.A. 2014. *Australian Freshwater Ecology: Processes and Management, Second Edition*. Wiley Blackwell.

Brooks, A., Abbe, T., Cohen, T., Marsh, N., Mike, S., Boulton, A., Broderick, T., Borg, D., and Rutherfurd, I. 2006., *Design guideline for the reintroduction of wood into Australian streams*, Land & Water Australia, Canberra

Chaaya, F.C. and Miller, B. 2022. *A review of artificial destratification techniques for cold water pollution mitigation*. UNSW Water Research Laboratory.

Chessman, B.C. 2003. New sensitivity grades for Australian river macroinvertebrates. *Marine and Freshwater Research*, 54, 95-103.

Department for Environment and Water, 2021. *Resnagging Guidelines for the Lower River Murray.* South Australian Government, March 2021.

Dec, E. and Marklund, M. 2021. *Resnagging Guidelines for the Lower River Murray*, DEW Technical report 2021/04, Government of South Australia, Department of Environment and Water, Adelaide.

EMM 2022. *Dungowan Dam and pipeline project: Aquatic Ecology Assessment*. Prepared for Water Infrastructure NSW, September 2022.

GeoLINK Consulting Pty Ltd. 2022. *Biodiversity Assessment: Chaffey to Dungowan Pipeline EPBC Offset-River Re-snagging*. Report for WaterNSW.

Growns, J.E., King, A.J., and Betts, F.M. 1999. The Snag Bag: a new method for sampling macroinvertebrate communities on large woody debris. *Hydrobiologia*, 405:67-77.

Humphries, P., Growns, J.E., Serafini, L.G., Hawking, L.G., Chick, A.J. and P.S. Lake, 1998. Macroinvertebrate sampling methods for lowland Australian rivers. *Hydrobiologia*, 364: 209–218.

Hrodey, P.J., Kalb, B.J., and Sutton, T.M. 2008. Macroinvertebrate community response to large-woody debris additions in small warmwater streams, *Hydrobiologia* 605: 193-207.

Lintermans, M. 2023. *Fishes of the Murray-Darling Basin*. Second Edition. Australian River Restoration Centre.

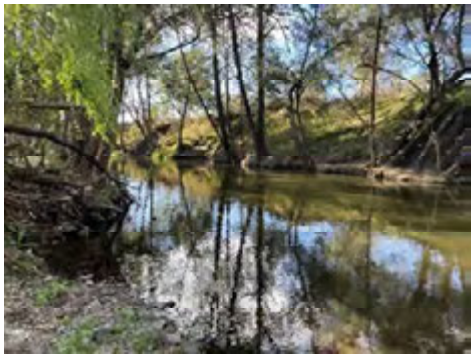
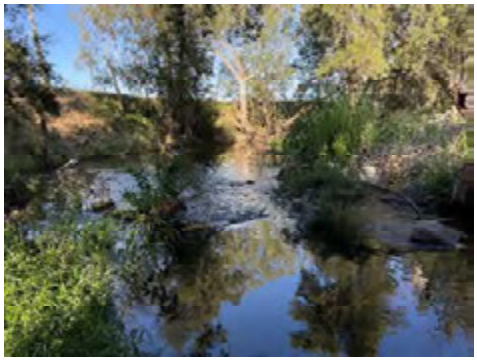
Scealy, J.A., Mika, S.J., and Boulton, A.J. 2007. Aquatic macroinvertebrate communities on wood in an Australian lowland river: experimental assessment of the interactions of habitat, substrate complexity and retained organic matter. *Marine and Freshwater Research* 58: 153-165.

Stocks, J. 2021. *Monitoring Murray cod spawning and recruitment in response to spring 2020 Macquarie River environmental water flows.* Final report to the Commonwealth Environmental Water Office. NSW Department of Primary Industries.

Stocks, J.R., Walsh, C.T., Rayner, T.S. and C.A. Boys, 2024. Murray cod and modern fish screens: influence of water velocity and screen design on the entrainment and impingement of larval and young-of-year fish at water offtakes. *Marine and Freshwater Research*, 75(4).

Appendix A: Site photos

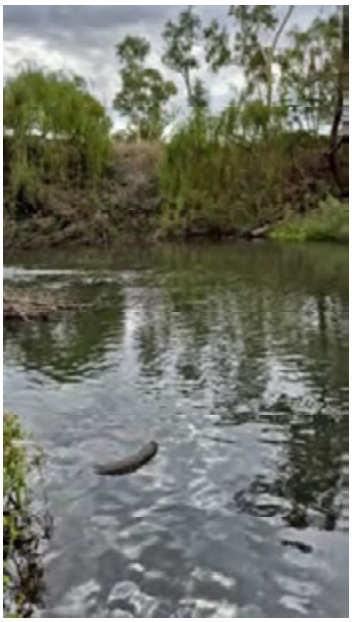
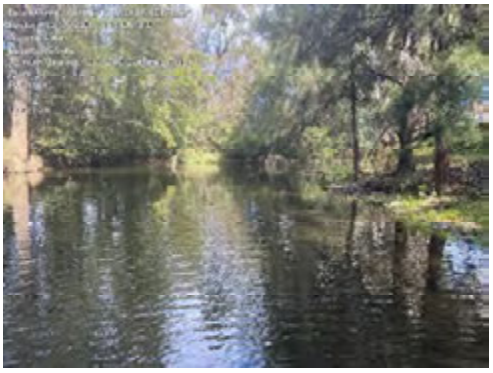
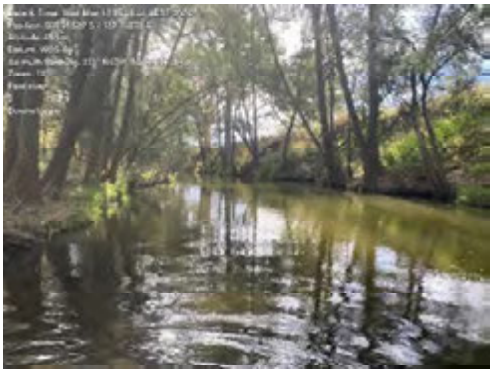
October 2023

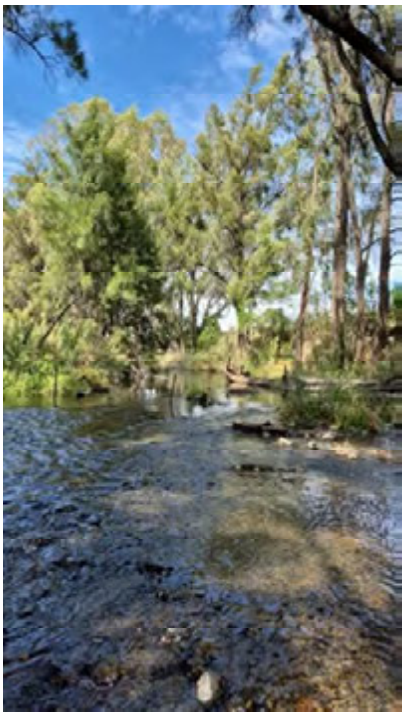
Site	Upstream	Downstream
Site 1		
Site 2		
Site 3		
Site 13		

Site	Upstream	Downstream
Site 14		
Site 16		
Site 24		
Site 28		

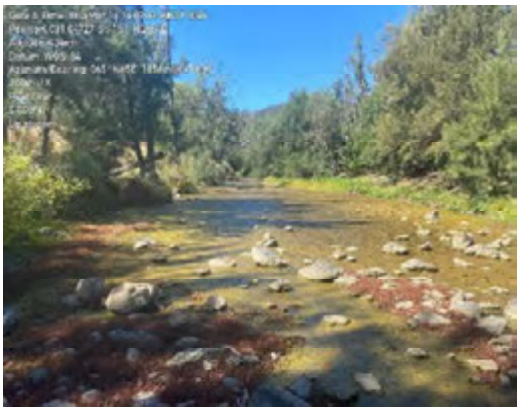
Site	Upstream	Downstream
Site 32		
Site 42		

April 2024

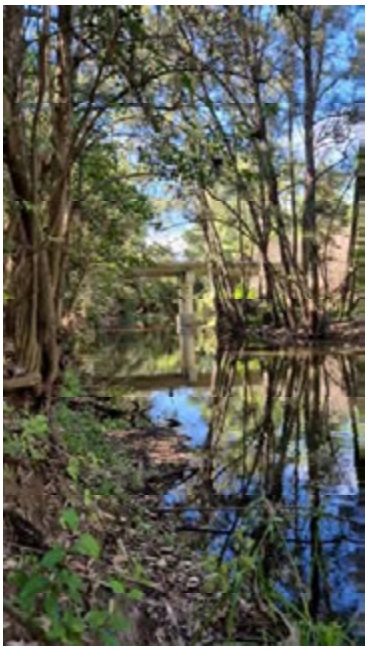
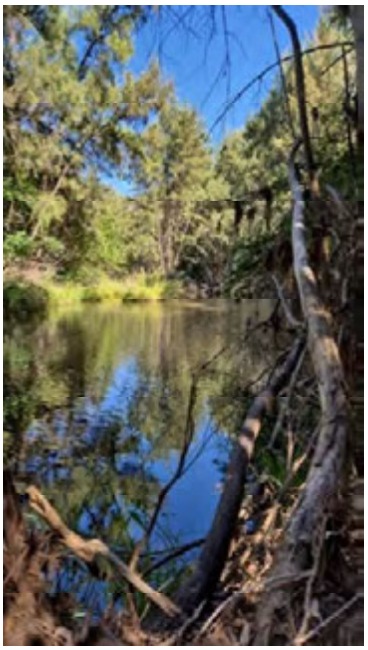
Site	Upstream	Downstream
Site 1		
Site 2		
Site 3		

Site	Upstream	Downstream
Site 13		
Site 14		

Site	Upstream	Downstream
Site 16		
Site 28		
Site 42		

Site	Upstream	Downstream
CRCON1		
CRCON2		
CRCON3		

Site	Upstream	Downstream
DSCONT1		
DSCONT3		

Site	Upstream	Downstream
USCONT1		

Appendix B: Snag biofilm communities

Site:	Site 1			Site 2			Site 3			Site 13			Site 14	Site 16		Site 24	Site 32		Site 28	Site 42
Snag:	1a	1b	1c	2a	2b	2c	3a	3b	3c	13a	13b	13c	14a	16a	16b	24a	32a	32b	28a	42a
MW024: Bacillariophytes (Diatoms) - Centrales																				
Aulacoseira spp.	525	2000	1120	1120	125	375	4500	250	3000	2500	1250		500			200	150		500	750
Cyclotella spp.	25	250	125	125	125	375	750			1500		250	500	750	250	250			1500	1000
Melosira spp.	425	4000	875	625	375	875	500	125	1500	11000		500	1750	250		1250	6250		21000	500
MW024: Bacillariophytes (Diatoms) - Pennales																				
Amphora spp.	75	2500	250	125	2000	500	1500	2750	2000	4500	500	1250	1250	1500	750	250		750	1000	2500
Cocconeis spp.														750	1250					250
Cymbella spp.		250																		
Diatoma spp.	3170	13800	4380	3250	2750	5620	5750	1500	3000	88600	5250	31000	5250	3500	15600	17400	14000	1250	22300	250
Fragilaria spp.	475	3000	1250	500	500	2250	1000	250	6000	15000	2250	5000	4750	2000	5000	2000	650	750	18500	6500
Gomphonema spp.		1750		500	1250	1120	3000	1500	2500	11000	1000	3500	1750	2750	2750			250	4500	750
Navicula spp.	9000	15300	8120	5870	15600	16900	9640	875	9000	104000	2750	52000	11200	3750	10400	56000	3750	8960	7500	13300
Nitzschia spp.	2250	52000	4810	7100	14400	20700	7650	2500	20800	60000	3250	24500	11800	10400	74000	37100	4000	13500	93300	27000
Pinnularia spp.	100									500		500								250
Rhopalodia spp.	25																			
Synedra spp.	50	1250	125	375	625	1000	1500	500	3000	4500	1500	1500	1500	1000	750			750	11000	750
MW024: Chlorophytes (Green Algae)																				
Chlamydomonas spp.	100			250						1000		250								
Desmodesmus spp.										4000	1000	250	750							1000

Site:	Site 1			Site 2			Site 3			Site 13			Site 14	Site 16		Site 24	Site 32		Site 28	Site 42
Dictyosphaerium spp.	25	500	250			875														
Elakatothrix spp.								125												
Kirchneriella spp.	25															250				
Monoraphidium spp.	25		125			125						500	250			250			1000	250
Oedogonium spp.						175														
Oocystis spp.	750	1500				250	750		1000		250				250			250		
Other green cells	525	3250	2000	1250	2000	4820	5000	500	500	6500	1250		250			500				
Scenedesmus spp.	100	750	500	250		375	1000	125	500	1500			500			250				
Sphaerocystis spp.		500	250			250	250													
Stigeoclonium spp.		2250		3880	875		500		2500											
Tetraedron spp.							250													
MW024: Cyanophytes (Blue Green Algae)																				
Anabaena spp. (straight)		950																		
Aphanocapsa spp. <2µm	250		1880			1750				45000							3250			
Limnothrix spp. *			1050		4980	3320												550		
Merismopedia spp.													5000							
Microcystis cf. aeruginosa *					25															
Other *Nostocales*		2000																		
Phormidium spp. <5µm *	865	7200	5650		3380	13200	2850	375				3700		1250	7800	2250	2800	950	2000	18000

Site:	Site 1			Site 2			Site 3			Site 13			Site 14	Site 16		Site 24	Site 32		Site 28	Site 42
Phormidium spp. >5µm *	3400	19200	425	675					1000		6250									
Planktolyngbya limnetica	1620																			
Planktothrix spp. <5 µm	750	2000	1200		4000	4000											3250			
Pseudanabaena spp.	1200	9500	2120	8500	1500	43100	5000		2000						2000	2000	2250	1600	6500	
Rhabdoderma spp.	1300																			
Synechococcus spp.	50																			
cf. *Synechococcus* spp.		500		125																
MW024: Flagellates - Cryptophytes																				
Cryptomonas spp.					125					3000									500	
MW024: Flagellates - Euglenophytes																				
Euglena spp.	25	250	125	125		125	50				250	500			250					
MW024: Golden/Yellow-Green Algae																				
Dinobryon spp.												250								
Total cells	18785	115000	32760	25220	49010	74855	46390	11375	55300	361100	20250	124700	47000	27900	118800	117950	34850	27960	184100	73050
No. taxa	27	25	21	18	18	23	19	13	15	17	13	16	15	11	13	14	10	11	14	15
* Potentially toxic Cyanophytes																				

Appendix C: Snag macroinvertebrate communities

Macroinvertebrate densities (individuals/m^2 of snag)

Site:	1			2			3			13			14		
Snag:	1a	1b	1c	2a	2b	2c	3a	3b	3c	13a	13b	13c	14a	14b	14c
Acarina	12			8				43			39	70	26		19
Atyidae							67		9				3		
Baetidae				8			34	43			19	139			
Caenidae		8		39			67	299	19	45		70			
Ceratopogonidae	130	95	33				34				443	139			
Chironomidae	6810	5425	8928	2217	672	552	10070	13072	4759	2649	5167	5672	6406	7419	4550
Cladocera	546	71	535												
Collembola						53									
Dugesiidae								43							
Dytiscidae						9		43							
Ecnomidae	52	32		16			219	85	303	521	19	348	153	255	326
Elmidae				8	78		505	1324	1308	1675	116	174	638	796	499
Empididae		8									39				
Glossiphoniidae	26														
Gyrinidae							67					35			
Hydracarina		16								45					
Hydridae	884	32	1070				34	171	19						
Hydrobiosidae											77	35			
Hydropsychidae										23	58	70			

Site:	1			2			3			13			14		
Hydroptilidae	26	16	33	47			168	43	133	45	19			32	
Isostictidae								128							
Leptoceridae															
Leptophlebidae								43							
Lymnaeidae				8											
Mesostigmata								43							
Micronectidae							135	85	57				77	159	19
Muscidae			33				34								
Oligochaeta	598	190		668	2150	2111	6669	13371	3583	1585	713	7308	2526	1528	2515
Oridbatida	52	55	67							23					
Ostracoda		8				53									
Palaemonidae															
Philopotamidae							202								
Platycnemididae														32	
Psychodidae			67												
Simuliidae	26	317	134	71			101		133		19	35			
Stratiomyidae					45										
Tanyderidae	26	32					34		474				51	64	
Tardigrada		8													
Tipulidae	52	40								566	2738	244			
Total	9239	6352	10901	3089	2946	2777	18440	28836	10798	7177	9466	14338	9879	10284	7930
Taxa richness	13	16	9	10	4	5	16	15	11	10	13	13	8	8	6
No. EPT	2	3	1	4	0	0	5	5	3	4	5	5	1	3	1

Site:	16			24			28			32			42		
Snag:	16a	16b	16c	24a	24b	24c	28a	28b	28c	32a	32b	32c	42a	42b	42c
Acarina															
Atyidae													64	104	784
Baetidae			15	43	25				10	67	7				
Caenidae	24			22					10	54	14				
Ceratopogonidae												25	16		
Chironomidae	1979	7388	5914	6124	3919	6849	461	2901	2966	2844	1577	3198	13871	3041	3174
Cladocera															
Collembola						23									
Dugesiidae															
Dytiscidae															
Ecnomidae	203	159	216	411	56		50	208	482	391	63	202	338	78	23
Elmidae	715	2092	1401	2380	393	204	190	710	461	1078	482	1075	725	164	116
Empididae	12									27	14				
Glossiphoniidae															
Gyrinidae									10						
Hydracarina										94					
Hydridae															
Hydrobiosidae															
Hydropsychidae	370		123					12		310	161	13			

Site:	16			24			28			32			42		
Hydroptilidae	60	132	31		6		9	12	21	27	14	13			
Isostictidae															
Leptoceridae	12														
Leptophlebidae	24									13					
Lymnaeidae															
Mesostigmata										13	28	13			
Micronectidae		583	31	130	156			37				25	177	562	357
Muscidae												13			
Oligochaeta	727	2092	1725	1601	312	3249		526	210	94	35	76	64	691	39
Oridbatida															
Ostracoda						11									
Palaemonidae														2	
Philopotamidae															
Platycnemididae															
Psychodidae												13			
Simuliidae										27					
Stratiomyidae															
Tanyderidae											21	63			
Tardigrada															
Tipulidae	739	26						12		216	14	76			
Total	4863	12472	9456	10712	4867	10335	710	4419	4171	5257	2429	4804	15256	4642	4493
Taxa richness	11	7	8	7	7	5	4	8	8	14	12	13	7	7	6
No. EPT	6	2	4	3	3	0	2	3	4	6	5	3	1	2	1

Appendix D: Fish eDNA samples around snags

eDNA results for fish community sampling around snags. Figures represent the number of sequences read per species per sample.

Site:		Site 1			Site 2			Site 3			Site 13			Site 14		
Sample Number:		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Species	Common Name															
Craterocephalus stercusmuscarum	Flyspecked hardyhead	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melanotaenia fluviatilis	Murray River rainbowfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	77
Gadopsis marmoratus	River blackfish	0	0	0	291	0	217	93	0	949	0	777	401	195	641	461
Maccullochella peeli	Murray cod	815	971	4108	1277	227	1374	1519	3904	3457	5580	19590	2259	3097	4482	2064
Macquaria ambigua	Golden perch	4111	8896	4615	1195	2670	2110	0	1212	838	1213	570	102	1009	661	650
Bidyanus bidyanus	Silver perch	0	592	107	371	509	80	444	0	944	1732	0	0	695	1510	38
Carassius auratus	Goldfish	149	102	184	0	0	0	0	0	0	0	0	0	0	0	0
Cyprinus carpio	European carp	32213	42042	38363	38207	47539	39742	26233	32347	41010	50197	45265	27746	44423	47899	24781
Gambusia holbrooki	Eastern gambusia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Galaxias olidus	Mountain galaxias	0	0	0	0	0	0	2060	0	696	0	0	311	89	0	0
Hypseleotris sp.	Carp gudgeon	5381	5131	3540	2778	3132	4413	5775	9233	6293	9989	4171	3146	9865	10158	6325
Retropinna semoni	Australian smelt	6546	7206	2873	5554	9112	4331	12494	15428	13143	6699	5112	1519	20127	16113	11772
Tandanus tandanus	Freshwater catfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Site:		Site 16			Site 24			Site 28			Site 32			Site 42		
Sample Number:		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Species	Common Name															
Craterocephalus stercusmuscarum	Flyspecked hardyhead	0	0	0	0	0	0	0	0	0	134	0	0	0	706	72
Melanotaenia fluviatilis	Murray River rainbowfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gadopsis marmoratus	River blackfish	0	0	7716	0	0	0	0	0	0	0	0	0	0	0	0
Maccullochella peeli	Murray cod	7926	4567	2389	11737	17218	14806	11624	11822	20081	9862	10937	14432	3154	2291	3597
Macquaria ambigua	Golden perch	3041	436	2065	367	904	94	1536	456	1133	796	1535	1254	1529	817	1684
Bidyanus bidyanus	Silver perch	254	739	0	300	0	0	0	411	270	151	141	352	185	0	292
Carassius auratus	Goldfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	265
Cyprinus carpio	European carp	31756	34661	57496	27451	32543	42965	19788	21360	24279	36725	25916	32653	32157	34103	32499
Gambusia holbrooki	Eastern gambusia	0	0	0	0	0	0	232	120	0	0	0	0	0	0	0
Galaxias olidus	Mountain galaxias	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypseleotris sp.	Carp gudgeon	6021	5195	6223	11503	8298	7907	2730	5609	6141	2413	4253	4600	18199	25508	19575
Retropinna semoni	Australian smelt	23102	12973	16283	11725	10508	15164	10542	15334	16556	19887	25367	34046	38603	35586	27127
Tandanus tandanus	Freshwater catfish	0	0	0	0	0	0	42	0	0	0	0	0	0	0	0

Appendix E: Electrofishing and fyke netting data

		Control Sites						Snag Sites							Grand Total
Scientific Name	Common Name	CRCONT1	CRCON2	CRCON3	USCONT1	DSCONT1	DSCONT3	Site 2	Site 3	Site 13	Site 14	Site 16	Site 28	Site 42	
Carassius auratus	Goldfish								3						3
Craterocephalus stercusmuscarum fulvus	Unspecked hardyhead			33			13							5	51
Cyprinus carpio	European carp	15					2	1				1			19
Gadopsis marmoratus	River blackfish								5						5
Gambusia holbrooki	Eastern gambusia	1461	228	85		170	51				1			75	2071
Hypseleotris sp.	Carp gudgeon	10	67	260	6				38	12	1	27	2	5	428
Leiopotherapon unicolor	Spangled perch					1									1
Maccullochella peelii	Murray cod		1	1	1		6	3	2	3		3		1	21
Macquaria ambigua	Golden perch			3				1	1					1	6
Melanotaenia fluviatilis	Murray River rainbowfish			1			2				1			2	6
Retropinna semoni	Australian smelt		6	15											21

		Control Sites						Snag Sites							Grand Total
Scientific Name	Common Name	CRCONT1	CRCON2	CRCON3	USCONT1	DSCONT1	DSCONT3	Site 2	Site 3	Site 13	Site 14	Site 16	Site 28	Site 42	
Tandanus tandanus	Freshwater catfish	3	2	4	1	1	1	2			2	7	1		24
	Total Fish	1489	304	402	8	172	75	7	49	15	5	38	3	89	2656
	Total species	4	5	8	3	3	6	4	5	2	4	4	2	6	
Non-fish captures															
Cherax destructor	Common Yabby		2												2
Ornithorhynchus anatinus	Platypus				1										1
Chelodina expansa	Broad-shelled Turtle										1				1
Chelodina longicollis	Eastern Snake-necked Turtle	4	3	1	1	1	1								11
Emydura macquarii	Murray River Turtle						4			3				1	8
Myuchelys latisternum	Saw-shelled Turtle										1		2		3
	Total	4	5	1	1	1	5	0	0	3	1	0	2	1	26

ecological AUSTRALIA
A TETRA TECH COMPANY

1300 646 131
www.ecoaus.com.au