Commonwealth Environmental Water Office Long Term Intervention Monitoring: Standard Methods

Prepared by: Jennifer Hale, Rick Stoffels, Rhonda Butcher, Michael Shackleton, Shane Brooks, Ben Gawne and Michael Stewardson

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Commonwealth Environmental Water Holder
GPO Box 787
Canberra ACT 2601

John Gorton Building
King Edward Terrace
Parkes ACT 2600
Ph: (02) 6274 1111

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For further information contact:

Ben Gawne

The Murray-Darling Freshwater Research Centre
PO Box 991
Wodonga VIC 3689
Ph: (02) 6024 9650; Fax: (02) 6059 7531

Email: B.Gawne@latrobe.edu.au
Web: www.mdfrc.org.au
Enquiries: info@mdfrc.org.au

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Authors: Jennifer Hale, Rick Stoffels, Rhonda Butcher, Michael Shackleton, Shane Brooks, Ben Gawne, Michael Stewardson

Author affiliation(s): Independent Ecologist**,** MDFRC, Water's Edge Consulting, MDFRC, Lite PC, MDFRC, The University of Melbourne

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1 Introduction

The Commonwealth Environmental Water Office (CEWO) Long Term Intervention Monitoring (LTIM) Project seeks to quantify the outcomes of the management of Commonwealth environmental water and its contribution to achieving the requirements of the Basin Plan. Basin-scale evaluation is pivotal to the LTIM Project, and is to be informed by monitoring at each of the seven Selected Areas. Three categories of indicators have been developed to ensure that M&E Plans at each Selected Area aligns with the needs of the Basin-scale evaluation. These include:

- Category I – Mandatory indicators and standard protocols which are required to inform quantitative Basin-scale evaluation. Indicators have been identified for each Selected Area in this category and must be applied in a consistent manner following standard protocols;
- Category II – Optional indicators with mandatory standard protocols which may be used to inform quantitative Basin-scale evaluation in the future. In the event that any of these indicators is selected by Monitoring and Evaluation Providers for implementation at the Selected Area, the standard protocol must be implemented; and
- Category III – Optional indicators with Selected Area specific protocols and mandatory reporting requirements. This includes Selected Area specific monitoring using locally appropriate methods. Reporting requirements for Basin Scale Evaluation must also be implemented.

This report provides the standard methods for indicators across all categories as indicated in Table 1.

Table 1: Indicators for each of the Selected Areas

Standard Method	**Goulburn**	**Edward-Wakool**	**Lower Murray**	**Lachlan**	**Murrumbidgee**	**Gwydir**	**Warrego/Darling**
LTIM Standard Protocol: Ecosystem Type	I	I	I	I	I	I	I
LTIM Standard Protocol: Tree Stand Condition	III	III	III	III	III	III	III
LTIM Standard Protocol: Vegetation Diversity	II	II	II	II	II	II	II
LTIM Standard Protocol: Fish (River)	I	I	I	I	I	I	I
LTIM Standard Protocol: Fish (Wetland)	III	III	III	III	III	III	III
LTIM Standard Protocol: Fish (Larvae)	III	III	III	III	III	III	III
LTIM Standard Protocol: Fish (Movement)	II	II	II	II	II	II	II
LTIM Standard Protocol: Waterbird Breeding	II	II	II	II	II	II	II
LTIM Standard Protocol: Waterbird Diversity	II	II	II	II	II	II	II
LTIM Standard Protocol: Macroinvertebrate Diversity	III	III	III	III	III	III	III
LTIM Standard Protocol: Stream Metabolism	I	I	I	I	I	II	I
LTIM Standard Protocol: Water quality	II	II	II	II	II	II	II
LTIM Standard Protocol: Hydrology (River)	I	I	I	I	I	I	I
LTIM Standard Protocol: Hydrology (Wetland)	II	II	II	II	II	II	II

2 Ecosystem Type

2.1 Evaluation questions

This is a protocol to validate the interim Australian National Aquatic Ecosystems (ANAE) classification at monitoring sites. The interim ANAE ecosystem typology and classification are relevant to the following Basin scale evaluation questions:

- **Short-term (one-year) and long-term (five year) questions:**
  - What did Commonwealth environmental water contribute to sustainable ecosystem diversity?
  - Were ecosystems to which Commonwealth environmental water was allocated sustained?
  - Was Commonwealth environmental water delivered to a representative suite of ecosystem types?

The process for evaluating these questions is illustrated in Figure 1, with components covered by this protocol highlighted in blue.

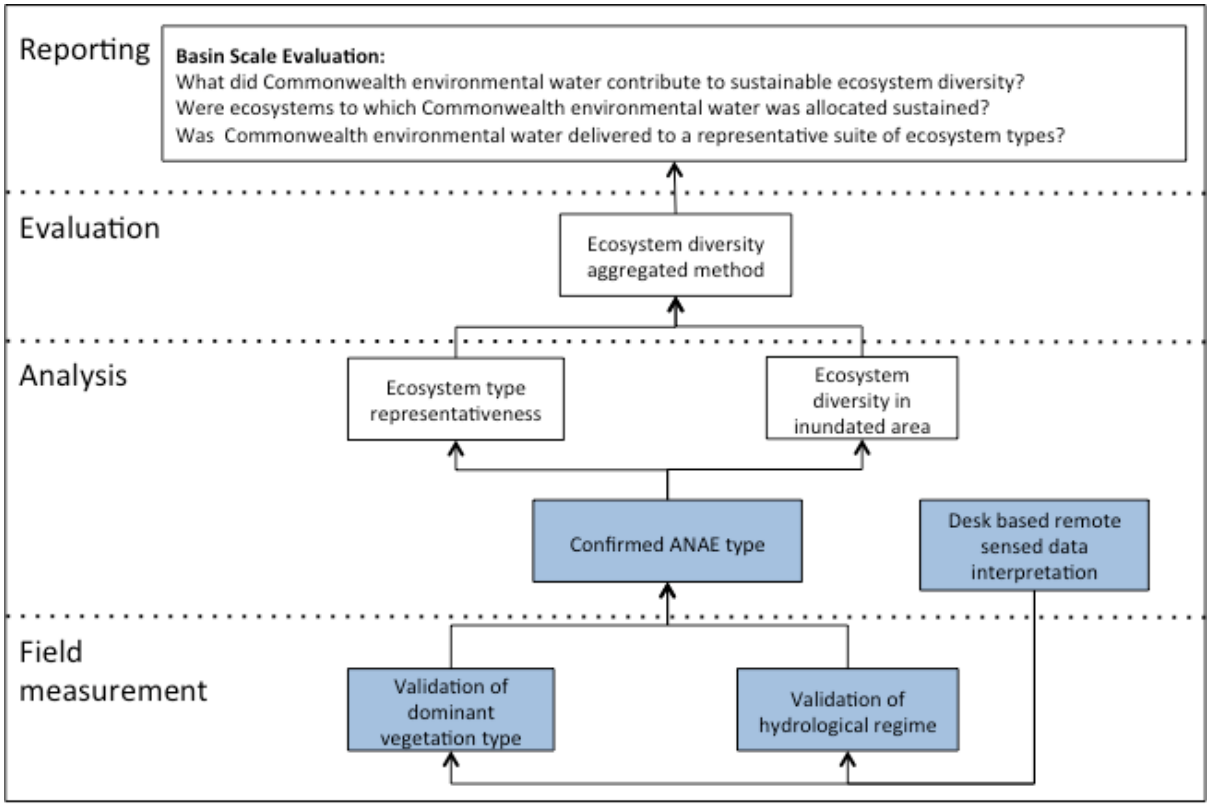

Figure 1: Schematic of key elements of the LTIM Standard Protocol: Ecosystem type.

2.2 Relevant ecosystem types

Rivers and wetlands. Note that the definition of wetland used in the Logic and Rationale for the LTIM project incorporates palustrine and lacustrine systems as defined in the interim Australian National Aquatic Ecosystem (ANAE) classification. Also note, that while the protocol is to be applied to wetlands on floodplains, it is not currently recommended for broader areas of the floodplain surface.

2.3 Relevant flow types

All.

2.4 Overview and context

This method is the field validation if the ANAE classification that is required for the Basin Scale evaluation of ecosystem diversity for the LTIM project. Brooks et al. (2013) applied the interim ANAE framework to aquatic ecosystems across the Murray Darling Basin using the best available mapping and attribute data. Wetland polygons, riverine polygons, and river centre lines were attributed with the majority coverage of each attribute without dividing them further. The scale and coverage of available mapping and attribute data varied considerably across the MDB has not yet been validated by the contributing jurisdictions. There is a need to validate the mapping outputs from Brooks et al. (2013) as they relate to specific sampling sites, and the Selected Areas. The current mapping may be useful within the LTIM project but should not be relied upon until validated. This validation must be carried out at all Selected Areas for each ecosystem type that falls within an assessment unit for all other on-ground monitoring programs:

- LTIM Standard Protocol: Fish (River)
- LTIM Standard Protocol: Fish (Wetland)
- LTIM Standard Protocol: Fish (Larvae)
- LTIM Standard Protocol: Hydrology (River)
- LTIM Standard Protocol: Hydrology (Wetland)
- LTIM Standard Protocol: Macroinvertebrates
- LTIM Standard Protocol: Stream metabolism
- LTIM Standard Protocol: Tree stand condition
- LTIM Standard Protocol: Vegetation diversity
- LTIM Standard Protocol: Waterbirds breeding
- LTIM Standard Protocol: Waterbirds diversity
- LTIM Standard Protocol: Water quality

2.5 Complementary monitoring and data

Mapping output from Brooks et al. (2013) or any regional sources with updated feature mapping for the Selected Area, any fine scale resolution vegetation mapping and/or remote sensed data, current aerial photography, satellite imagery (e.g. SPOT6 – panchromatic resolution 1.5 m, multispectral resolution 8 m) and NVIS41_MDB vegetation mapping (NVIS v4.1 updated with CMA mapping by Brooks et al. 2013). These should be used in the first instance to aid in identifying aquatic ecosystem types prior to the field validation.

2.6 Interim ANAE classification

Terminology

For the purposes on the LTIM project aquatic ecosystems have been described in the Logic and Rational document as rivers, floodplains and wetlands. This is a simplification of four ecosystem classes into three common terms. For the validation protocol the terminology defined by the interim ANAE classification (Aquatic Ecosystem Task Group 2012) is to be applied. The ecosystem classes relevant to the LTIM project are as follows:

- **Floodplain systems** are those aquatic systems that are either seasonally or intermittently flooded flat areas that are outside the riverine channels or palustrine/lacustrine systems but

that display characteristics of hydric soils or vegetation that are characteristically adapted to the seasonal or intermittent presence of water. ***Excluded from this protocol.***

- **Lacustrine systems** (lakes) are open-water dominated systems, characterised by deep, standing or slow-moving water with little or no emergent vegetation (<30% cover). (Included as wetlands in Logic and Rational document).
- **Palustrine systems** are primarily shallow, vegetated, non-channel environments, including billabongs, bogs, swamps, springs, soaks etc. (Included as wetlands in Logic and Rational document).
- **Riverine systems** are those that are contained within a channel and its associated streamside vegetation. This definition refers to both single channel and multi-channel systems e.g. braided channel networks. The beds of channels are not typically dominated by emergent vegetation, may be naturally or artificially created, periodically or continuously contain moving water, and may form a connecting link between two bodies of standing water (Aquatic Ecosystem Task Group 2012). (Includes riparian systems).

The typology used to assign ecosystem types is presented as a dichotomous key in section 2.11 and as an extract from Brooks et al. (2013) in section 2.12.

An example of the mapping output from Brooks et al (2103) for some saline Victorian systems is shown in Figure 2. This highlights some of the potential validation issues that may be encountered. In some cases the data provided for the MDB mapping project included situations were multiple polygons were sub-units of larger polygons. In most cases this is likely to represent a different habitat/vegetation type within a single wetland. In this case, as illustrated below, it is advised to use the larger ecosystem and unique identifier as the assessment ecosystem. Attribute mapping that overlays these polygons (e.g. vegetation, hydrological regime, salinity) may also contain inaccuracies. Confidence measures included in the Brooks et al (2103) mapping product should be used to guide interpretation. Note that it is expected that updated mapping will be made available in coming years as attribute data improves, however the ecosystem typology is considered robust and is less likely to change significantly.

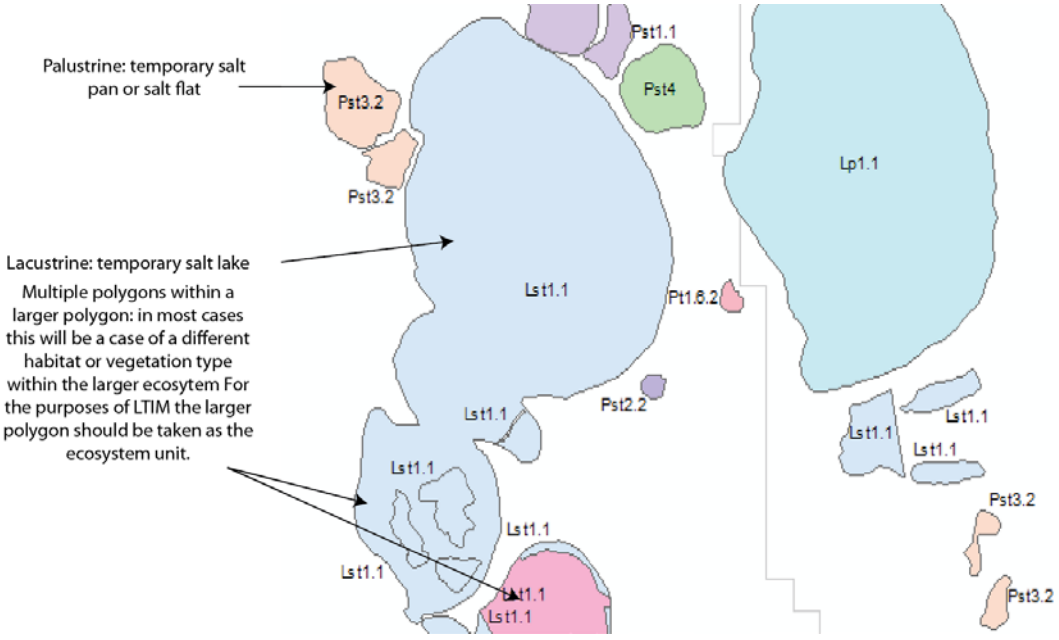

Figure 2: Example of mapping output from Brooks et al. (2013) with areas requiring validation.

A unique number (SYSID) for each polygon (wetland, lake, floodplain) or line (river, creek, stream) identifies each mapped unit (Brooks et al. 2013). On ground validation of the interim ANAE classification is required to confirm the aquatic ecosystem types for use in the LTIM program.

Validation sites are to be determined by Monitoring Evaluation Providers and will include all sites for other monitoring protocols (i.e. waterbird breeding sites, tree stand condition sites, fish sites, etc.).

Where a site has not been mapped the typology developed by Brooks et al. (2013) should be used to assign an ecosystem type *de novo* (Protocol step 3 below).

Equipment

- Maps of Selected Area including assessment site information
- Aerial imagery should be as current as possible and of sufficient resolution to identify vegetation
- Satellite imagery – e.g. SPOT6
- GPS
- Datasheets and/or field computer
- Appropriate safety gear
- Copy of this protocol
- Appropriate plant identification field guides.

Protocol

1. Prior to field visit, source and review all relevant information relevant to the potential area of influence of Commonwealth environmental water.
    - This will include, but not necessarily be limited to, mapping output from Brooks et al. (2013) for the selected area, current aerial imagery, satellite imagery, and any fine scale mapping (aquatic ecosystem type and or vegetation mapping).
2. Prior to field visit, source and review all relevant information relevant to the potential area of influence of Commonwealth environmental water.
    - This will include, but not necessarily be limited to, mapping output from Brooks et al. (2013) for the selected area, current aerial imagery, satellite imagery, and any fine scale mapping (aquatic ecosystem type and or vegetation mapping).
3. Identify the ecosystems to be assessed and record/locate their unique identifier code.
    - If mapped by Brooks et al. (2013) use the SYSID as the unique identifier for each mapped ecosystem.
    - If the ecosystem is not mapped then record coordinates (GDA94) of the centre of the ecosystem and either locate compatible GIS mapping or delineate the boundary of the ecosystem using remote sensed data. Contact your Selected Area M&E Advisor to obtain a unique identifier for the ecosystem.
4. Using the dichotomous key presented in Appendix A assign an ecosystem type and code to each assessment ecosystem, noting any knowledge gaps that relevant unambiguous classification
    - If the aquatic ecosystem is mapped then check if the interim ANAE type allocated to the polygon/line feature representing the ecosystem (see Appendix A) is correct. (Note that is it possible to have lacustrine and palustrine systems located on floodplains and some, or potentially many, of these may not have been captured in the interim ANAE mapping).
    - Record the correct interim ANAE type as per the typology in Appendix A.
5. Determine locations for ground-truthing, mark on map and note GPS co-ordinates. The ground truthing should be designed to:
    - Confirm / identify dominant vegetation type (note the typology is based on dominant vegetation type only, so not all habitat/ vegetation types require ground-truthing).
    - Fill any knowledge gaps identified in step 2.
    - Be easily and safely accessible.

6. Use the information collected in the field to update (if necessary) the ecosystem type as identified in step 4.

2.7 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the MEP for all Selected Areas.

2.8 Data Description

All data provided for this indicator must conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this validation is an ANAE feature identified by the ANAE SYSID.

Each row of data provided for this validation will identify the ANAE SYSID, the original classification, and the revised classification. The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

It is strongly recommended that Monitoring and Evaluation Providers make themselves familiar with the data standard requirements for this standard method prior to detailed monitoring program design and implementation.

2.9 Health and safety

As with all programs that include field based methods, a Health Safety and Environment Plan (HSEP) must be developed. The HSEP must include an assessment of all identified potential risks and a plan on how these risks will be managed in the field.

2.10 References

Aquatic Ecosystem Task Group. (2012). Aquatic Ecosystems Toolkit: Module 2, Interim Australian National Aquatic Ecosystem Classification Framework. Australian Government Department of Sustainability, Environment, Water, Population and Communities, Canberra.

Batzer, D.P. and Sharitz, R. (2006). Ecology of freshwater and estuarine wetlands. University of California Press.

Boulton, A.J. and Brock, M.A. (1999). Australian freshwater ecology : processes and management / Andrew J. Boulton, Margaret A. Brock. Gleneagles Publishing, Mt Osmond, S. Aust. :

Brooks, S., Cottingham, P., Butcher, R., and Hale, J. (2013). Murray-Darling Basin aquatic ecosystem classification: Stage 2 report. Peter Cottingham & Associates report to the Commonwealth Environmental Water Office and Murray-Darling Basin Authority, Canberra.

Brooks, S. and Wealands, S.R. (2014). Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Data Standard. Report prepared for the Commonwealth Environmental Water Office by The Murray-Darling Freshwater Research Centre. MDFRC Publication 29.3/2013 Revised Jan 2014.

Cowardin, L.M., Carter, V., Golet, F.C., and LaRoe, E.T. (1979). Classification of Wetlands and Deepwater Habitats of the United States. US Department of the Interior, Fish 7 Wildlife Service, Office of Biological Services, Washington DC 20240.

Example Ecosystem Type Validation field sheet

ECOSYSTEM TYPE VALIDATION FIELD SHEET: Page ---------- of ----------			Selected Area:	
Date:			Name of recorder:	
Mapped ecosystems				
SYSID	ANAE Type (code and name)	Valid Y/N	Correct ANAE type (code and name)	Relevant assessment protocol
e.g. 123456	Lst1.1: Temporary saline lakes	N	Lst1.2: Temporary saline lakes with aquatic beds	Waterbird breeding

ECOSYSTEM TYPE VALIDATION FIELD SHEET: Page ---------- of ----------	Selected Area:
Date:	Name of recorder:

New ecosystems (not mapped by Brooks et al. 2013)			
Unique identifier	Location GDA94	ANAE Type (code and name)	Relevant assessment protocol

2.11 Key to MDB interim ANAE Typology

The following terminology explains some of the descriptors used in the typology, and some of the assumptions made in order to simplify the naming convention (modified from Brooks et al. 2013):

Energy (high, low) – pertains to the relative energy of riverine flows resulting from the slope or steepness of the terrain.

Fen and bogs – peatlands (bogs and fen) are created under a range of hydrological and physical conditions. Fens are formed where mineral rich groundwater flows sustain vegetation such as grasses, sedges, reeds, shrubs and trees (Batzer and Sharitz 2006). The alkaline nature of fens and the fact that their primary water source is groundwater, with some surface and rainfall inputs, distinguishes them from bogs, which are dominated by surface water inputs. Bogs are further characterised as supporting Sphagnum moss.

Freshwater – unless specified, aquatic ecosystems are assumed to be freshwater (salinity <3000 mg/L).

Intermittent – used to describe the water regime of periodically inundated types in which inundation is known to be less frequent than annual or seasonal inundation, but more frequent than episodic and ephemeral inundation. Flooding may persist from months to years (Boulton and Brock 1999). Only used in the type name when the inundation requirements of the dominant vegetation associated with the system are able to inform the frequency of inundation, or when waterholes have been identified as being present in a stream.

Lake – an inland body of water, predominantly still or lentic in nature. Cowardin et al. (1979) defines them as being situated in a topographic depression or a dammed river channel, and having less than 30 per cent emergent vegetation. Size may vary but most will exceed eight hectares; those with similar habitats but less than eight hectares can also be included, however, if active wave-formed or bedrock shoreline features makes up all or part of the boundary, or their depth is greater than 2 meters. Ocean-derived salinity is always less than 0.5 parts per thousand, thus separating them from lagoons.

Marsh – a wetland dominated by non-woody emergent vegetation such as sedges, reeds and rushes. Marshes can be shallow or deep with a combination of emergent and submergent vegetation types. They may also have areas of open water in deeper systems, up to 70 per cent of wetland area. Marshes are typically between 0.5 to 2 meters depth, but depth can be highly variable.

Meadow – a wetland dominated by grasses (excluding Phragmites which is typically found in deeper marsh environments) and forbs. Meadows typically have shallow depths in the order of 10 to 50 centimeters. They are rarely permanent, often being filled on a seasonal basis.

Permanent – used to describe the water regime of commonly wet systems (wet >70 per cent of the time). This assumes that for commonly wet lakes, for example, that they have water all year round except during extreme droughts, when they can dry out. Permanent is used as a commonly accepted term (e.g. Ramsar and Queensland typologies).

Saline – ecosystems with a salinity >3000 mg/L.

Streams – 'streams' is taken to include rivers, streams and creeks for the purposes of simplifying the naming convention. Rivers are large natural in-channel bodies of moving water (lotic) which have the capacity to structure the surrounding landscape (i.e. alluvial processes). This includes large anabranching systems (e.g. Edward-Wakool Rivers are major anabranches of the River Murray). Streams and creeks, both of which are typically smaller in-channel bodies of moving water, can be either a tributary or distributary of a river.

Swamp – a wetland dominated by woody vegetation, either shrubs and or trees.

Temporary – used to describe the water regime of periodically inundated types when the frequency of inundation is not known, but is less than commonly wet (wet <70% of the time).

Key to MDB interim ANAE types

This typology can be used to validate ecosystem types at which assessments are made for both mapped and unmapped features. It can also be used to identify ecosystems that have not been mapped. For greater detail see section 2.12.

1a	Ecosystem being validated/classified is a line feature, has flowing water and a defined channel……	***Riverine systems*** got to 2
1b	Ecosystem being validated/classified is a polygon feature, typically lacks flowing water and a defined channel……	go to 5
2a	Water regime permanent (surface water >70% of time) ……	go to 3
2b	Water regime temporary (surface water present <70% of time)……	go to 4
3	Landform for ANAE was derived in GIS by intersecting features with the 3sec CSIRO Valley Bottom Flatness and does not require field validation…	
Rp1.1: Permanent high energy upland streams		
Rp1.2: Permanent transitional zone streams		
Rp1.3: Permanent low energy upland streams		

Rp1.4: Permanent lowland streams	
4	Landform for ANAE was derived in GIS by intersecting features with the 3sec CSIRO Valley Bottom Flatness and does not require field validation…
Rt1.1: Temporary high energy upland streams	
Rt1.2: Temporary transitional zone streams	
Rt1.3: Temporary low energy upland streams	
Rt1.4: Temporary lowland streams	
5a.	Ecosystem with less than 30% emergent vegetation, large enough to support wave action ……..***Lacustrine systems*** go to 6
5b.	Ecosystem with more than 30% emergent vegetation, or no vegetation. If no vegetation typically shallow and doesn't develop wave action (i.e deflation basins, salt flats, clay pans etc.). ……..go to 17
6a	Water type: fresh ……go to 7
6b	Water type: saline……go to 10
7a	Permanent (surface water >70% of time)……go to 8
7b	Temporary (surface water <70% of time)……go to 9
8a	Permanent floodplain lakes, with or without submergent aquatic macrophyte……..
……	**Lp2.1: Permanent floodplain lakes**
……	**Lp2.2: Permanent floodplain lakes with aquatic beds**
8b	Permanent non-floodplain lakes, with or without submergent aquatic macrophytes……
……	**Lp1.1: Permanent lakes**
……	**Lp1.2: Permanent lakes with aquatic beds**
9a	Floodplain lakes, with or without submergent aquatic macrophytes……..
……	**Lt2.1: Temporary floodplain lakes**
……	**Lt2.2: Temporary floodplain lakes with aquatic beds**
9b	Non- floodplain lakes, with or without submergent aquatic macrophytes ……

……**Lt1.1: Temporary lakes**

……**Lt1.2: Temporary lakes with aquatic beds**

10a Permanent saline lakes (surface water >70% of time)……go to 11

10b Temporary saline lakes (surface water <70% of time)……go to 12

11a Floodplain saline lakes, with or without submergent aquatic macrophytes……..

……**Lsp2.1: Permanent saline floodplain lakes**

……..**Lsp2.2: Permanent saline floodplain lakes with aquatic beds**

11b Non-floodplain saline lakes, with or without submergent aquatic macrophytes……..

……**Lsp1.1: Permanent saline lakes**

…….. **Lsp1.2: Permanent saline lakes with aquatic beds**

12a Temporary saline floodplain lakes, with or without submergent aquatic macrophytes ……

……**Lst2.1: Temporary saline floodplain lakes**

……..**Lst2.2: Temporary saline floodplain lakes with aquatic beds**

12b Temporary saline non-floodplain lakes, with or without submergent aquatic macrophytes……..

……**Lst1.1: Temporary saline lakes**

……**Lst1.2: Temporary saline lakes with aquatic beds**

13a The ecosystem is a wetland depression ……***Palustrine systems*** go to 14

14a Water type: fresh……go to 15

14b Water type: saline……go to 20

14c Unspecified, no data…… **Pu1: Unspecified wetland**

15a Permanent springs…… **Pp5: Permanent springs**

15b Permanent (surface water >70% of time), non-springs……go to 16

15c Temporary (surface water <70% of time)……go to 23

16a Permanent floodplain wetlands……go to 19

16b Permanent non-floodplain wetlands……go to 18

17a Floodplain swamps - dominated by woody vegetation ……**Pp1.1.1: Permanent floodplain paperbark swamps**

17b Floodplain marshes – dominated by non-woody vegetation……

(e.g. Typha, Phragmites, Baumea, Juncus: tall spp typically>1m)……**Pp2.1.1: Permanent floodplain tall emergent marshes**

(species typically <1m)……**Pp2.2.1: Permanent floodplain sedge/grass/forb marshes**

……**Pp2.3.1: Permanent floodplain grass marshes**

……**Pp2.4.1: Permanent floodplain forb marshes**

17c Floodplain wetland, unspecified vegetation……**Pp4.1: Permanent floodplain wetland**

18a Non-floodplain swamps- dominated by woody vegetation ……**Pp1.1.2: Permanent paperbark swamps**

18b Non-floodplain marshes, bogs and fens – dominated by non-woody vegetation……

(e.g. Typha, Phragmites, Baumea, Juncus: tall spp typically>1m)……**Pp2.1.2: Permanent tall emergent marshes**

(species typically <1m)……**Pp2.2.2: Permanent sedge/grass/forb marshes**

……**Pp2.3.2: Permanent grass marshes**

……**Pp2.4.2: Permanent forb marshes**

(fen marshes dominant water source is groundwater)…… **Pp3: Peat bogs and fen marshes**

18c Non-floodplain wetland, unspecified vegetation……**Pp4.2: Permanent wetland**

19a Temporary floodplain swamps and marshes, identified by dominant vegetation type……

……**Pt1.1.1: Intermittent River red gum floodplain swamp**

……**Pt1.2.1: Intermittent Black box floodplain swamp**

……**Pt1.3.1: Intermittent Coolibah floodplain swamp**

……**Pt1.4.1: Intermittent River Cooba floodplain swamp**

……**Pt1.5.1: Temporary paperbark floodplain swamp**

(tree species unidentified)……**Pt1.6.1: Temporary woodland floodplain swamp**

……**Pt1.7.1: Intermittent Lignum floodplain swamps**

(e.g. Typha, Phragmites, Baumea, Juncus: tall spp typically>1m)……**Pt2.1.1: Temporary tall emergent floodplain marsh**

(species typically <1m)……**Pt2.2.1: Temporary sedge/grass/forb floodplain marsh**

(water typically <50cm, often seasonally inundated)……**Pt2.3.1: Floodplain freshwater meadow**

……**Pt3.1.1: Floodplain clay pan**

(unspecified vegetation)……**Pt4.1: Temporary floodplain wetland**

19b Temporary non-floodplain swamps, marshes, identified by dominant vegetation type……

……**Pt1.1.2: Intermittent River red gum swamp**

……**Pt1.2.2: Intermittent Black box swamp**

……**Pt1.3.2: Intermittent Coolibah swamp**

……**Pt1.4.2: Intermittent River Cooba swamp**

……**Pt1.5.2: Temporary paperbark swamp**

(tree species unidentified)……**Pt1.6.2: Temporary woodland swamp**

……**Pt1.7.2: Intermittent Lignum swamps**

(e.g. Typha, Phragmites, Baumea, Juncus: tall spp typically>1m)…… **Pt2.1.2: Temporary tall emergent marsh**

(species typically <1m)……**Pt2.2.2: Temporary sedge/grass/forb marsh**

(water typically <50cm, often seasonally inundated)……**Pt2.3.2: Freshwater meadow**

(lacks vegetation, shallow)……**Pt3.1.2: Clay pan**

(unspecified vegetation)……**Pt4.2: Temporary wetland**

20a Permanent saline palustrine systems (surface water >70% of time), identify by dominant vegetation type……

……**Psp1.1: Saline paperbark swamp**

(e.g. samphire)……**Psp2.1: Permanent salt marsh**

……**Psp3.1: Permanent seagrass marsh**

……**Psp4: Permanent saline wetland (vegetation not specified)**

20b Temporary saline palustrine systems (surface water <70% of time) identify by dominant vegetation type ……..

……**Pst1.1: Temporary saline swamp**

(e.g. samphire)……**Pst2.2: Temporary salt marsh**

……**Pst3.2: Salt pans and salt flats**

(vegetation unspecified)……**Pst4: Temporary saline wetland**

2.12 Typology (extract from Brooks et al. 2013)

Water regime, water type and vegetation are the main attributes used throughout the typology developed by Brooks et al. (2013). It should be noted that only vegetation structure (not dominant vegetation) has been used to help distinguish types for lacustrine and riverine classes. 'Non-vegetated' is a valid category for riverine systems as it can represent areas of settlement, or cleared areas. As lacustrine systems are defined on the basis of having less than 30 per cent emergent vegetation, 'only water' is considered as a valid attribute category for the dominant vegetation attribute in the typology for lakes. For example, it would not be appropriate to describe a type on vegetation that only occurred over, say, 5 per cent of the site.

Lacustrine systems

The typology proposed for lacustrine systems (Table 30) is based on the following Level 3 ANAE attributes:

- Water type;
- Water regime (water permanency);
- Dominant vegetation (water only);
- Finer vegetation (aquatic bed).

The typology for lacustrine systems also captures if the system is located on a floodplain. A number of types can be aggregated (for example permanent lakes with or without submerged macrophytes can be aggregated up to being called just permanent lakes) and this is explained in the descriptions for each combination of attributes in **Table 2**. In the typology lacustrine systems are considered freshwater unless stated otherwise in the naming convention. Also lakes are assumed to have no submergent vegetation unless stated in the name convention.

Table 2: Lacustrine types using Level 3 attributes and a location descriptor (floodplain) (from Brooks et al. 2013).

Note: Dominant vegetation and fringing vegetation do not provide any greater separation of types. Codes: Lp = permanent freshwater lacustrine/lakes, Lt = temporary freshwater lacustrine/lakes, Lsp = permanent saline lacustrine/lakes, Lst = temporary saline lacustrine/lakes

Water type	Water regime	Dominant vegetation	Finer scale vegetation	Located on floodplain	Type			Description
Fresh	Commonly wet	Water	No vegetation	No	Lakes	Lp1: Permanent lakes	Lp1.1: Permanent lakes	Includes volcanic lakes, dune lakes, crater lakes, alpine lakes and other inland lakes. Typically greater than 2 metres deep with substantial areas of open water – may have fringing vegetation in littoral zone, but are defined as having less than 30 per cent emergent vegetation and no to limited submergent vegetation. Often greater than 8 ha in size, but smaller systems are also included if they are greater than 2m deep and support wave action.
			Aquatic bed				Lp1.2: Permanent lakes with aquatic beds	As for Lp1.1 but have substantial areas of submergent macrophytes (e.g. Hattah Lakes). This type of lake is likely to be shallow in areas which support macrophytes.
			No vegetation	Yes		Lp2: Permanent floodplain lakes	Lp2.1: Permanent floodplain lakes	As for Lp1.1, but lakes located on floodplains.
			Aquatic bed				Lp2.2: Permanent floodplain lakes with aquatic beds	As for Lp1.2, but lakes located on floodplains.
	Periodic inundation	Water	No vegetation	No		Lt1: Temporary lakes	Lt1.1: Temporary lakes	As for Lp1.1 but tend to be shallower and periodically dries (temporary).
			Aquatic bed				Lt1.2: Temporary lakes with aquatic beds	As for Lp1.2; but lakes are temporary.
			No vegetation	Yes		Lt2: Temporary floodplain lakes	Lt2.1: Temporary floodplain lakes	As for Lt1.1, with main distinction being location on floodplain with dominant

Water type	Water regime	Dominant vegetation	Finer scale vegetation	Located on floodplain	Type			Description
								water source assumed to be from parent stream.
			Aquatic bed				Lt2.2: Temporary floodplain lakes with aquatic beds	As for Lt1.2, with main distinction being location on floodplain with dominant water source assumed to be from parent stream.
Saline	Commonly wet	Water	No vegetation	No	Saline lakes	Lsp1: Permanent saline lakes	Lsp1.1: Permanent saline lakes	As for Lp1.1, but saline.
			Aquatic bed				Lsp1.1: Permanent saline lakes with aquatic beds	As for Lp1.2, but saline. Examples of typical aquatic vegetation include systems with *Ruppia*.
			No vegetation	Yes		Lsp2: Permanent saline floodplain lakes	Lsp2.1: Permanent saline floodplain lakes	As for Lp2.1 but saline.
			Aquatic bed				Lsp2.2: Permanent saline floodplain lakes with aquatic beds	As for Lp2.2 but saline.
	Periodic inundation	Water	No vegetation	No		Lst1: Temporary saline lakes	Lst1.1: Temporary saline lakes	As for Lt1.1, but saline
			Aquatic bed				Lst1.2: Temporary saline lakes with aquatic beds	As for Lt1.2, but saline.
			No vegetation	Yes		Lst2: Temporary saline floodplain lakes	Lst2.1: Temporary saline floodplain lakes	As for Lt2.1, but saline.
			Aquatic bed				Lst2.2: Temporary saline floodplain lakes with aquatic beds	As for Lt2.2, but saline.

Palustrine systems

The typology proposed for palustrine systems (Table 31) is based on the following Level 3 ANAE attributes:

- Water type;
- Water regime;
- Dominant vegetation (structure);
- Finer scale vegetation (dominant species) **(Note this equates to vegetation type/habitat type in LTIM).**

The typology for palustrine systems also captures if the system is located on a floodplain. The typology for palustrine systems includes a greater number of types as the potential range of vegetation associations/attributes is greater, as these reflect the greater range or variability in water regime encountered in this ecosystem class. Springs were assigned to individual features as designated in jurisdictional data sets and were assumed to be commonly wet.

Table 3: Palustrine types using Level 3 attributes (from Brooks et al. 2013).

Codes Pp = permanent wetland types, Pt = temporary wetland types, Psp = permanent saline wetland types, Pst = temporary saline wetland types, Pu = unknown

Water type	Water regime	Dominant vegetation	Finer scale vegetation	Located on floodplain	Type			Description
Fresh	Commonly wet	Tree	Paperbark	Yes	Pp1: Permanent swamp forest	Pp1.1: Permanent paperbark swamps	Pp1.1.1: Permanent floodplain paperbark swamps	Permanent wetlands on floodplains; vegetation is emergent and dominated by paperbark.
				No			Pp1.1.2: Permanent paperbark swamps	As for Pp1.1.1, but not on floodplains.
		Sedge	Tall emergent aquatic	Yes	Pp2: Permanent marsh	Pp2.1: Permanent tall emergent marshes	Pp2.1.1: Permanent floodplain tall emergent marshes	Permanent wetlands on floodplains; vegetation is dominated by emergent aquatic species, including *Typha*, *Phragmities*, *Eleocharis*, some *Juncus* species, Includes species ≥1m in height.
				No			Pp2.1.2: Permanent tall emergent marshes	As for Pp2.1.1, but not on floodplains.
		Sedge	Aquatic sedge/grass/forb	Yes		Pp2.2: Permanent sedge/grass/forb marshes	Pp2.2.1: Permanent floodplain sedge/grass/forb marshes	Permanent wetlands on floodplains; vegetation is emergent, but can also include submergent species as well. Height of emergent species is typically ≤1m – can include species from *Carex*, *Cyperus*, *Myriophyllum*, *Triglochin*, *Eleocharis*,

Water type	Water regime	Dominant vegetation	Finer scale vegetation	Located on floodplain	Type			Description
								Sporobolus, Amphibromus, Pseudoraphis spinescens etc. Includes obligate aquatics as well as amphibious species in littoral zones.
				No			Pp2.2.2: Permanent sedge/grass/forb marshes	As for Pp2.2.1, but not on floodplains.
		Grass/forb	Freshwater grasses	Yes		Pp2.3: Permanent grass marshes	Pp2.3.1: Permanent floodplain grass marshes	Permanent wetlands on floodplains; vegetation is emergent grass species.
				No			Pp2.3.2: Permanent grass marshes	As for Pp2.3.1, but not on floodplains.
		Grass/forb	Freshwater forb	Yes		Pp2.4: Permanent forb marshes	Pp2.4.1: Permanent floodplain forb marshes	Permanent wetlands on floodplains; vegetation is emergent forb species.
				No			Pp2.4.2: Permanent forb marshes	As for Pp2.4.1, but not on floodplains.
		Sedge/Grass/ forb	Bogs and fen	No	Pp3: Peat bogs and fen marshes			Permanent wetlands with emergent sedge, grass or forb. Fen marshes are separated from bog by the presence of Sphagnum and groundwater being the dominant water source.
		All remaining	Not specified	Yes	Pp4.1: Permanent floodplain wetland			Permanent wetlands on floodplains with unspecified vegetation.

Water type	Water regime	Dominant vegetation	Finer scale vegetation	Located on floodplain	Type			Description
				No	Pp4.2: Permanent wetland			As per Pp4.1 but not on floodplains.
			Not specified	All	Pps5: Permanent springs			Permanent freshwater wetlands in groundwater discharge areas.
	Periodic inundation	Tree	River red gum	Yes	Pt1:Temporary swamps	Pt1.1:Intermittent River red gum swamp	Pt1.1.1: Intermittent River red gum floodplain swamp	Intermittent River red gum wetland on floodplains; can include both woodland and forest forms.
				No			Pt1.1.2: Intermittent River red gum swamp	As for Pt1.1.1, but not on floodplains.
		Tree	Black box	Yes		Pt1.2:Intermittent Black box swamp	Pt1.2.1: Intermittent Black box floodplain swamp	Intermittent Black box wetlands on floodplains; have predominantly woodland structure. Occurs on infrequently flooded outwash areas, as a narrow fringe around intermittent lakes, as a woodland across the floor of some deflation basins and as a string of trees following a palaeo-channel (Roberts and Marston 2011).
				No			Pt1.2.2: Intermittent Black box swamp	As for Pt1.2.1, but not on floodplains.

Water type	Water regime	Dominant vegetation	Finer scale vegetation	Located on floodplain	Type			Description
		Tree	Coolibah	Yes		Pt1.3:Intermittent Coolibah swamp	Pt1.3.1: Intermittent Coolibah floodplain swamp	Intermittent Coolibah wetlands on floodplains; mainly restricted to the north-west of the Basin. Often the dominant tree in infrequently inundated floodplains of northern rivers such as the Darling and Gwydir; forming extensive woodlands. This type may also occur as a riparian fringe beside river channels and around waterholes (Roberts and Marston 2011).
				No			Pt1.3.2: Intermittent Coolibah swamp	As for Pt1.3.1, but not on floodplains.
		Tree	River Cooba	Yes		Pt1.4:Intermittent River Cooba swamp	Pt1.4.1: Intermittent River Cooba floodplain swamp	Intermittent River Cooba wetlands on floodplains. River Cooba is also known as Belalie and Eumong (Roberts and Marston 2011). Common in the northern Basin.
				No			Pt1.4.2: Intermittent River Cooba swamp	As for Pt1.4.1, but not on floodplains.

Water type	Water regime	Dominant vegetation	Finer scale vegetation	Located on floodplain	Type			Description
		Tree	Paperbark	Yes		Pt1.5:Temporary paperbark swamp	Pt1.5.1: Temporary paperbark floodplain swamp	As for Pp1.1.1 but temporary.
				No			Pt1.5.2: Temporary paperbark swamp	As for Pp1.2.1 but temporary.
		Tree	Other aquatic trees	Yes		Pt1.6:Temporary swamp	Pt1.6.1: Temporary woodland floodplain swamp	Temporary wetlands on floodplain with a range of aquatic trees such as *Casuarina*, *Allocasuarina*, *Eucalyptus ovata*.
				No			Pt1.6.2: Temporary woodland swamp	As for Pt1.6.1, but not on floodplains.
		Shrub	Lignum	Yes		Pt1.7:Intermittent Lignum swamps	Pt1.7.1: Intermittent Lignum floodplain swamps	Temporary Lignum swamps on floodplains.
				No			Pt1.7.2: Intermittent Lignum swamps	As for Pt1.7.1, but not on floodplains.
		Sedge	Tall emergent aquatics	Yes	Pt2: Temporary marshes	Pt2.1: Temporary tall emergent marshes	Pt2.1.1: Temporary tall emergent floodplain marsh	Temporary floodplain wetlands dominated by *Phragmites*, *Juncus Typha*, *Eleocharis*, *Baumea,* etc.
				No			Pt2.1.2: Temporary tall emergent marsh	As for Pt2.1.1, but not on floodplains.
		Sedge/grass/ forb	Aquatic sedge/grass/forb	Yes		Pt2.2: Temporary sedge/grass/forb marsh	Pt2.2.1: Temporary sedge/grass/forb floodplain marsh	Temporary sedge/grass/forb marshes on floodplains. Marshes tend to be

Water type	Water regime	Dominant vegetation	Finer scale vegetation	Located on floodplain	Type			Description
								deeper than meadows, ranging anywhere from 20-30 centimetres in depth to up to two metres in depth. Can be vegetated across the whole system or include areas of open water (deeper areas). Includes systems with *Eragrostis*, *Eleocharis*, *Carex*, *Cyperus*, *Paspalum*, etc
				No			Pt2.2.2: Temporary sedge/grass/forb marsh	As for Pt2.2.1, but not on floodplains.
		Grass/forb	Freshwater grasses, Freshwater forbs	Yes		Pt2.3: Freshwater meadow	Pt2.3.1: Floodplain freshwater meadow	Temporary meadows on floodplains, which tend to be shallow typically ranging between 20 to 40 centimetres in depth. Meadows are typically vegetated across whole system, may have scattered trees, shrubs, and or sedges, but are dominated by grasses and forbs.
				No			Pt2.3.2: Freshwater meadow	As for Pt2.3.1, but not on floodplains.

Water type	Water regime	Dominant vegetation	Finer scale vegetation	Located on floodplain	Type			Description
		No vegetation/ Water	n/a	Yes	Pt3: Freshwater playas	Pt3.1:Clay pans	Pt3.1.1: Floodplain clay pan	Floodplain clay pans typically less than eight hectares and less than two metres deep. Lack wave action characteristic of lacustrine systems
				No			Pt3.1.2: Clay pan	As for Pt3.1.1, but not on floodplains.
		All remaining	Not specified	Yes	Pt4.1: Temporary floodplain wetland			Temporary wetlands on the floodplain with unspecified vegetation.
				No	Pt4.2: Temporary wetland			As for Pt4.1, but not on floodplains.
Saline	Commonly wet	Tree	Paperbark	All	Psp1: Saline swamps	Psp1.1: Saline paperbark swamp		Permanent saline paperbark swamps, including *Melaleuca halmaturorum.*
		Shrub/sedge/ grass/forb	Saltmarsh	All	Psp2: Salt marsh	Psp2.1: Permanent salt marsh		Permanent inland saltmarsh.
		Grass	Seagrass	All	Psp3: Seagrass marsh	Psp3.1: Permanent seagrass marsh		Permanent saline marshes dominated by seagrass.
		All remaining	Not specified	All	Psp4: Permanent saline wetland			Permanent saline wetlands with unspecified vegetation.
	Periodic inundation	Tree	All trees	All	Pst1: Saline swamp	Pst1.1: Temporary saline swamp		Temporary saline wetlands with tree species.
		Shrub/sedge/ grass/forb	Saltmarsh	All	Pst2: Salt marsh	Pst2.2: Temporary salt marsh		Temporary inland saltmarsh wetlands.

Water type	Water regime	Dominant vegetation	Finer scale vegetation	Located on floodplain	Type		Description
		No vegetation/ water	n/a	All	Pst3: Saline playas	Pst3.2: Salt pans and salt flats	Temporary saltpans and playas typically less than eight hectares and less than two metres deep. Lack wave action characteristic of lacustrine systems.
		All remaining	Not specified	All	Pst4: Temporary saline wetlands		Temporary saline wetlands with unspecified vegetation.
Unknown	Unknown	Unknown	Unknown	All	Pu1: Unspecified wetland		There is no information with which to assign a type.

Riverine systems

The typology for palustrine systems (**Table 4**) is based on the following Level 3 ANAE attributes:

- Water source,
- Water regime, and
- Landform.

The riverine confinement attribute was also considered for the typology but was found to be highly correlated with the landform attribute and so provided no additional ecological information.

Waterholes are assumed to have been identified in temporary or periodically inundated streams. However, approaches such as designating permanent palustrine features that intersect steams as 'waterholes' resulted in a vast (unrealistic) number of features being so assigned. The designation of a feature as a 'waterhole' therefore relies on designations from jurisdiction databases.

Including substrate as an attribute in the typology for riverine systems would be informative; however, there is insufficient information available for the MDB to include it at this stage. It may be considered in future iterations of the ANAE framework as it would add useful information on the characteristics of a riverine system (e.g. help define sandy bottom, cobble, boulder or bedrock streams).

Table 4: Riverine types using Level 3 attributes(from Brooks et al. 2013).

Codes: Rp = riverine – permanent streams, Rt = riverine – temporary streams, Rw = riverine – waterholes, Ru = unspecified streams.

Water source	Water regime	Landform	Type		Description
Surface	Commonly wet	High energy upland	Rp1: Permanent streams	Rp1.1: Permanent high energy upland streams	Fast flowing streams with steep gradient (>6%), and dominated by riffles and runs. Often with coarse substrate. Base flow typically maintained except in extreme droughts.
		Transitional		Rp1.2: Permanent transitional zone streams	Intermediate slope (4-6%) with long runs and riffle zones; pools are infrequent.
		Low energy upland		Rp1.3: Permanent low energy upland streams	Low gradient (<4%), slow flowing systems, often with a narrow channel on relatively flat land. May lack extensive riffle areas.
		Lowland		Rp1.4: Permanent lowland streams	Low gradient (<4%),systems that can include both narrow and relatively shallow flowing systems with pool, riffle, run sequences, and large deeper lowland systems with slow flow and no riffle areas. Base flow is maintained in dry periods, except in extreme drought.

Water source	Water regime	Landform	Type		Description
	Periodic inundation	High energy upland	Rt1: Temporary streams	Rt1.1: Temporary high energy upland streams	As for Rp1.1, but may be systems which rise and fall rapidly, wetting and drying for varying lengths of times.
		Transitional		Rt1.2: Temporary transitional zone streams	As for Rp1.2, but are only periodically wet.
		Low energy upland		Rt1.3: Temporary low energy upland streams	As for Rp1.3, but are only periodically wet.
		Lowland		Rt1.4: Temporary lowland streams	As for Rp1.4, but are only periodically wet.
All	Commonly wet	All	Rw1: Waterholes		Commonly wet remnant pools that are located on periodically wet riverine segments.
	Unknown	Unknown	Ru1: Unspecified river		There is no information with which to assign a type.

3 Tree stand condition

3.1 Evaluation questions

This monitoring protocol addresses the following Basin scale evaluation questions:

Long-term (five-year) question:

- What did Commonwealth environmental water contribute to populations of long-lived organisms?

Short-term (one-year) and long-term (five year) questions:

- What did Commonwealth environmental water contribute to condition of floodplain and riparian trees?

The process for evaluating these questions is illustrated in Figure 3, with components covered by this protocol highlighted in blue.

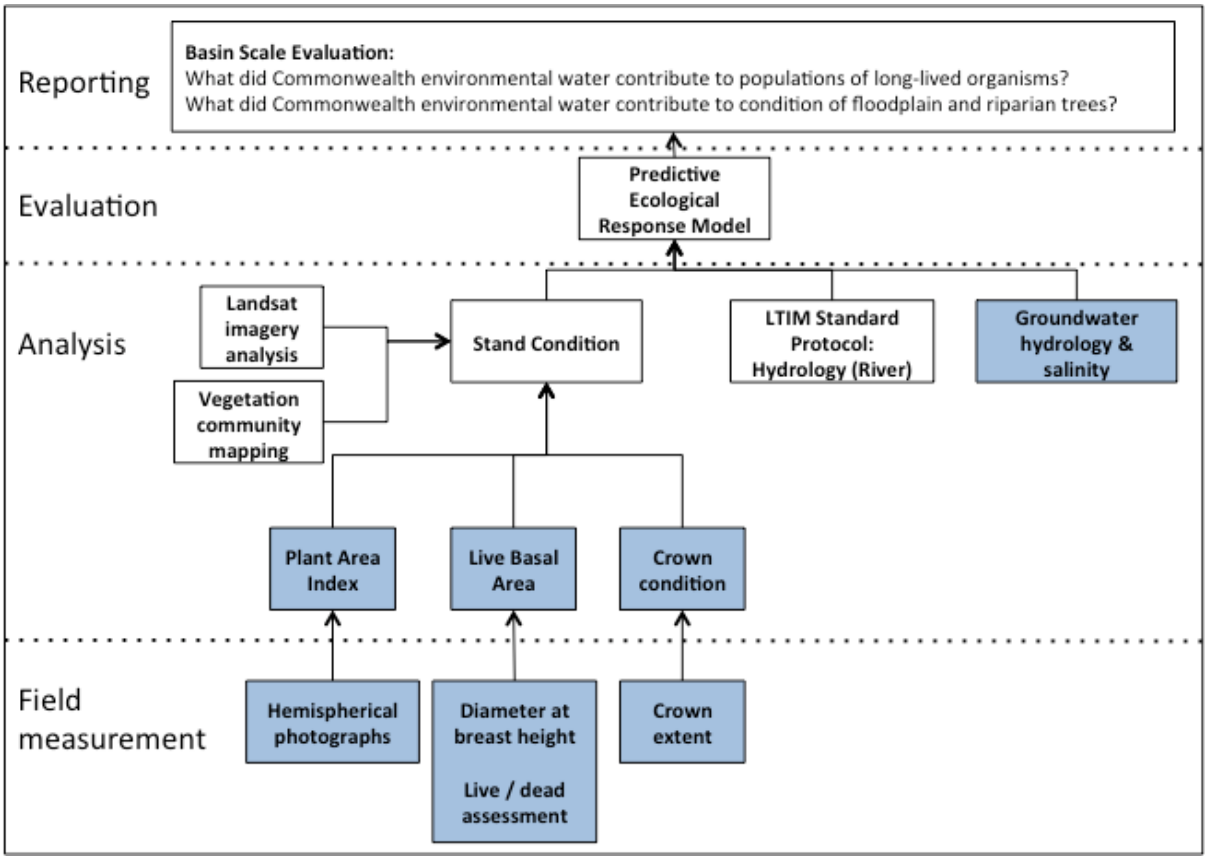

Figure 3: Schematic of key elements of the LTIM Standard Protocol: Tree stand condition.

3.2 Relevant ecosystem types

River, wetland and floodplain

3.3 Relevant flow types

This method is not event based, but an annual assessment conducted between January and April of each year; and so is relevant to all flow types.

3.4 Overview and context

This method is the field validation required for the Basin Scale evaluation of tree condition for the CEWH LTIM project. Tree condition will be assessed via the Living Murray Stand Condition Model (Souter et al. 2010) based on a combination of remotely sensed data (LANDSAT) and field measurements of tree community stands by the MDBA and provided to Monitoring and Evaluation Providers annually. The field measurements to be completed by Monitoring and Evaluation Providers comprise:

- Live basal area
- Crown extent (percentage of crown that contains foliage)
- Plant area index (area of leaves and stems).

In addition the protocol for establishing sites is provided.

The method follows that of (Souter et al. 2012), the relevant sections of which are reproduced here.

3.5 Complementary monitoring and data

The field measures required for the assessment of tree stand condition are unique to this protocol. However, existing vegetation community mapping should be used in the first instance to aid in identifying potential monitoring locations and establishing permanent sites as detailed in section 1.6. In addition, in some instances (where groundwater is believed to be a strong influence on tree stand condition) groundwater measures (depth and salinity) will be required for evaluation. In these instances, existing groundwater monitoring networks are required (see section 1.6.2 below).

3.6 Establishing sites

A minimum of 25 permanent sites are to be established in each Selected Area. The following protocol explains the procedure for establishing those sites, which will be conducted in the first year of the LTIM implementation. Subsequent monitoring annual monitoring is undertaken at these sites following the procedures described in sections 1.7 and 1.8.

Site locations will be stratified to cover stand condition and the range of tree communities covered by the MDBA tree stand condition model (river red gum forest, river red gum woodland, black box woodland, coolibah woodland).

Sites are to be determined by Monitoring and Evaluation Providers from stand condition mapping, which will be provided by the MDBA in the first quarter of 2014. The selection of sites will be at the discretion of Monitoring and Evaluation Providers but must, as stated above, be distributed to cover the range of communities and stand condition in their Selected Area.

Each site is defined at this initial planning stage by a single point location (GDA 94). It may be necessary to validate these in the field and adjust where necessary. However, once sites are established, these should be marked permanently following the procedure outline below (recorded in the Stand Condition Site Establishment Sheet) and repeat surveys undertaken at these exact locations. Each site should be attributed to a unique identification code from the MDBA ANAE database, with riparian sites attributed to the adjacent Streamid.

3.6.1 Site selection in groundwater dependent systems

In some parts of the Basin, groundwater is a strong influence on tree stand condition. In these circumstances, measures not only of river hydrology (as per LTIM Standard Protocol: Hydrology (River)) but also of groundwater (depth and salinity) will be required to inform evaluation. To obtain this groundwater data, every effort should be made to utilise existing groundwater monitoring

networks. Figure 4 provides the decision process that is to be implemented with respect to groundwater measures as they relate to Tree Stand Condition.

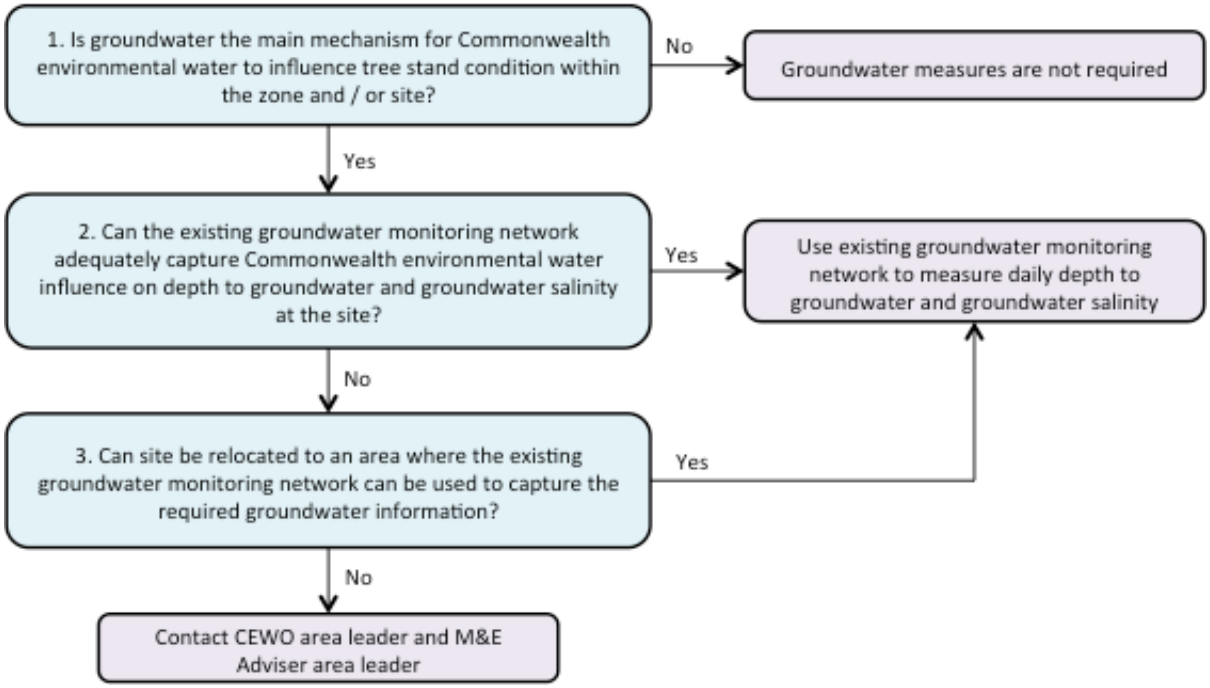

Figure 4: Decision process for groundwater monitoring at tree stand condition sites.

3.6.2 Equipment

- GPS and spare batteries
- Compass
- Maps of Selected Area including assessment site information
- 100 m surveyor's measuring tape(s)
- DBH tape
- Plastic cattle tags or stamped metal tags pre-prepared as unique identifiers of surveyed trees
- Aerosol can of blue tree marking paint
- Tags
- Fasteners
- Hammer
- Permanent marker pens
- Datasheets and/or field computer

3.6.3 Protocol

1. Find the site using the point location established in the Monitoring and Evaluation Plan.
2. Identify an site of 0.25 hectares. The shape of the site can vary according to the vegetation distribution at the site being assessed. The optimum shape and size is a 50 x 50 metre square, or circle with a radius of 28.2 metres. However, rectangular sites of 100 m x 25 metres can be used to assess linear stands.
3. Mark the corners of the site using a marker that is easily seen during assessments such as large, white painted surveyor's pegs, and record the GPS locations of all corners of a site, or centre of a circular area.
4. Determine and record the tree community type (river red gum forest, river red gum woodland, black box woodland, river red gum / black box mixed woodland, coolibah woodland, river cooba

woodland). If this does not match what was expected, then consideration should be given to moving the site into the target community type.

5. All trees with a diameter at breast height (DBH) ≥ 10 cm that are located within the site and included in the Live Basal Area Assessment. A tree is to be included in the if its trunk originates wholly or partly from within the boundaries of the site. All trees that fit these are permanently marked with blue plastic cattle tags, or alternatively marked annually with blue tree marking paint.
6. Individual crown extent is measured at 30 trees within an site (with a DBH ≥ 10 cm). These are selected as follows:

    - Trees are to be randomly selected from within the site to reach the 30 tree quota.
    - If the 0.25 hectare site contains fewer than 30 trees, additional representative trees are to be chosen within 20 metres of the edge of the site until the 30 tree quota is reached. These additional trees must be noted on the datasheet as 'outside' the 0.25 hectare site.
    - Each tree is given a number (1-30) and permanently marked using plastic cattle tags.
    - Record the GPS locations of the 30 individual trees.
    - Upon completion of the site setup and selection of trees, a mud map of the site is created. This will help clarify approximately where each marked tree is. Mud maps can be based on aerial photos, GIS maps with GPS coordinates, a sketch on a grid, or sketches with bearings and approximate distances from centre point (for circular plots).

7. Plant Area Index is assessed from digital hemispherical photographs. Permanent photo points must be established in each site. A single photo point is sufficient for sites < 70 metres in length. Two photo points are required for sites > 70 metres in length. Photo points are evenly spaced along the length of the site so that they provide representative coverage (e.g. at 100 x 25 metres sites photo points should be at 33.3 and 66.6 metres). Photo points must not be established within 3 metres of the trunk of a large tree. Record the location of photo point(s) and permanently mark. Mark the position of the photo points on the mud map.

3.7 Live basal area and crown extent

Every tree ≥ 10 cm DBH within the defined site must be assessed as live or dead and have DBH recorded. The 30 marked trees at the site must also be assessed for crown extent.

3.7.1 Equipment

- GPS and spare batteries
- Compass
- Maps of Selected Area including assessment site information
- DBH tape
- Aerosol can of blue tree marking paint
- Permanent marker pens
- Datasheets and/or field computer
- Copy of this protocol

3.7.2 Protocol

1. Find the site using the point location established in the Monitoring and Evaluation Plan.
2. Conduct a rapid assessment of disturbance at the site noting the presence and extent of natural and/or man-made disturbances within the site (e.g. fire, logging, grazing, flooding etc.) on the datasheet.
3. Select the first tree to be assessed. All trees within the 0.25 hectare site are to be assessed as part of the Live Basal Area assessment. Crown assessment is conducted at 30 tagged trees.

4. Trees marked for crown extent should be re-marked on both sides of the tags using permanent marker to prevent fading of the tree identifier.
5. Measure the DBH of the tree according to the following rules:

    - Breast height is 1.3 metres above ground measured along the stem.
        - Where the tree is on a slope, 1.3 metres is measured on the uphill side of the tree.
        - Where the tree is on a lean, 1.3 metres is measured on the underside of the lean.
        - Where a swelling occurs at 1.3 metres, two points unaffected by swellings or limbs equally spaced above and below 1.3 metres should be selected, measured then averaged to give an estimate of DBH.
    - The DBH tape must be at 90 ☐ to the axis of the stem at 1.3 metres.
    - Measure DBH to the nearest millimetre.
    - If DBH is less than 10 cm, ignore and move to the next tree.
    - If DBH is at least 10 cm record the measurement on the datasheet.
    - If the tree has multiple stems at 1.3 metres, the DBH of each stem greater than 5 cm is to be recorded. Where trees have a high number of stems with small diameters, assessors should ensure they capture a minimum of 80% of the basal area of the tree.
    - The point(s) on the tree where the diameter measurement(s) have been made are marked with blue paint.

Every tree in the 0.25 hectare site is to be assessed as above, regardless of species and the species noted.

6. Assess the tree as live or dead based on the following definitions and record the assessment on the datasheet, applying the following definitions:

    - "Dead" tree is defined as a tree that has no live (green) foliage;
    - "Live" tree is classed as a tree that does have live foliage.

7. If the tree is one of the 30 trees tagged for crown extent assessment, apply the following method:

    - 'Assessable Crown' is defined as the crown that is/was supported by all existing branches on the tree. This includes live branches, recently dead branches, long-term dead branches, and branches in the lower crown that possibly died because they were redundant (see Figure 5).
    - Crown extent is the percentage of the assessable crown in which there are live leaves. This includes branches that have leaves at their base and middle but not at their tips, including epicormic growth.
    - Consider the tree from several angles and make your final decision of what the crown extent is, standing where you have a clear view of the whole crown.
    - Crown extent is assessed using the scale presented in Table 5 and the category recorded on the datasheet.
    - Also record an actual (numerical) estimate of crown extent percentage value (to within five percent).

All 30 marked trees in the 0.25 hectare site are to be assessed as above, regardless of species and the species noted.

Figure 5: Illustration of area of "assessable crown" (From Souter et al. 2012).

Table 5: Category scale for reporting crown extent (Souter et al. 2012).

Score	Description	Percentage of assessable crown (%)
0	None	0
1	Minimal	1-10
2	Sparse	11-20
3	Sparse-medium	21-40
4	Medium	41-60
5	Medium-major	61-80
6	Major	81-90
7	Maximum	91-100

3.8 Plant Area Index hemispherical photographs

Plant Area Index (PAI) is defined as the area of leaves and stems per unit ground area without adjustment for clumping of canopy components. Plant Area Index is estimated from digital hemispherical photographs taken using a digital camera and fisheye lens or adaptor with full 180 degree field of view. Timing of photograph collection is critical to ensure highest possible accuracy.

Photographs must be collected in the January to April sampling window to align with satellite imagery.

3.8.1 Equipment

- GPS and spare batteries
- Maps of Selected Area including assessment site information
- Digital camera and spare battery
- Fish eye lens or adaptor with full 180 degree field of view
- Tripod
- Datasheets and/or field computer
- Copy of this protocol

3.8.2 Protocol

1. Photographs must be taken during the two hours after sunrise or the two hours before sunset to avoid direct sunlight on the canopy.
2. Locate the established assessment site using the location information provided.
3. Locate the marked camera position.
4. View the canopy and trunks of nearby trees, excessive sunlight in the canopy or on the trunks will lead to substantial underestimates of PAI. If the level of light in the canopy or on the trunks of trees is deemed too great, postpone collection of photographs to another time.
5. If conditions are suitable to continue, set up and level the tripod and camera at 1.3 metre height.
6. Photographs must be taken with the lens pointing at 90 □ to the horizontal plane
7. Best results are achieved using AV mode where aperture and ISO can be set, and the camera auto adjusts the shutter speed:

    - F-value (aperture) set to 16 (higher F-value increases depth of field/focus but too high can reduce photo quality e.g. specs of dust on lens can come into focus
    - ISO set to 800 for limited light (1600 increases the exposure and allows for faster shutter speed at higher F-value but increases 'noise' that may reduce image quality.
    - For brightness – metering mode set to 'evaluate'
    - To reduce camera shake – enable mirror lockup
    - Set Picture style to landscape
    - Use a remote shutter activator to eliminate any hands on 'shake' and set a timer (for a couple of seconds) to allow the photographer to move from view.
    - Use manual focus as auto focus may be unreliable particularly in lower light situations

8. Capture the photograph and record the required information including the filename/number on the hemispherical photograph record sheet
9. Where the photographer believes image quality can be improved, take additional photos using different F-value and ISO settings (and hence shutter speed).
10. Move to the next camera position and repeat.

3.9 Groundwater

In the event that groundwater monitoring is required (see section 1.6.2), then daily salinity and depth to groundwater measures are required. The collection of groundwater data should be consistent with standard methods as documented in (Feitz et al. 2009) Groundwater Sampling and Analysis – A Field Guide http://www.ga.gov.au/image_cache/GA15501.pdf

3.10 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the MEP for all Selected Areas (insert reference to QA/QC requirements).

All tree condition assessments within a Selected Area, where possible, should be undertaken by the same experienced observers to maintain consistency over time. All observers must undergo training prior to undertaking monitoring surveys, including calibration against experienced observers to ensure standardisation of measurements. Training and calibration procedures must be documented in the Monitoring and Evaluation Plan and relevant records maintained.

Visual assessments of tree condition will often differ between observers. To minimise the variance associated with different observers, a minimum of two staff are assigned to tree assessments. Where there are significant differences in original observer scores, observers will discuss their rationale and where appropriate adjust scores to mutually agreed values.

3.11 Data analysis and reporting

3.11.1 Live Basal Area

1. Calculate the Basal Area (BA) of each stem using the following formula:
    - $BA(cm^2) = \pi \times [DBH(cm)/2]^2$
2. Calculate total Live Basal Area for the site by calculating the sum of the basal areas for all "Live" trees.
3. Calculate total Dead Basal Area for the site by calculating the sum of the basal areas for all "Dead" trees.
4. Calculate % Live Basal Area (LBA) for the site using the following formula:
    - %LBA = [total live BA / (total live BA + total dead BA)] x 100

3.11.2 Crown extent

The crown extent is reported as the score for each tree in each assessment site according to the values in Table 5.

3.11.3 Plant Area Index

Calculation of Plant Area Index from digital hemispherical photographs is a two stage process. First, images must be thresholded in the program MulitSpec Application Version 3.1 (Purdue University, Indiana) to improve the contrast between vegetation and sky. This program is freeware and can be downloaded from: http://cobweb.ecn.purdue.edu/~biehl/MultiSpec/download_win.html

Plant Area Index is then calculated from thresholded images using the program Winphot 5.00 (ter Steege, 1996). This program is also freeware and can be downloaded from: http://www.bio.uu.nl/~herba/Guyana/winphot/wp_index.htm

MultiSpec procedure:

1. MultiSpec requires images as tiff files (.tiff). Microsoft Photo Editor (or an equivalent photographic program) can be used to crop the black areas outside of the circular image and convert the photographs to tiff files.
2. Open the tiff file in MultiSpec (File>Open Image).
3. Start processing the image (Processor>Cluster).
4. In the 'Set Cluster Specifications' window tick 'ISODATA'.

5. In the ‘Set ISODATA Cluster Specifications’ window make the number of clusters 15 and then click OK.
6. In the ‘Set Cluster Specifications’ window tick ‘Cluster mask file’.
7. Name and save the cluster mask file.
8. Classification of clusters will begin.
9. When the classification is finished, open the cluster mask file. You should see a multicoloured classification of the hemispherical photograph.
10. Change the colour of vegetation clusters to black and sky clusters to white. On the left of the window there is a legend of the clusters. By clicking on the coloured square for each cluster you can change its colour.
11. Save the reclassified image as a tiff file (File>Save Image To TIFF As).

Winphot procedure:

1. Winphot 5.00 requires that images are bitmaps (.bmp), 256 colour (8 bit) and no greater than 1000 pixels in length. Using Microsoft Photo Editor (or an equivalent photographic program) convert the tiff image to the required format.
2. Open the Converted images in Winphot 5.00.
3. Define the extent of the hemispherical photograph using the ‘align image’ tool (arrow pointing at circle symbol) by clicking at the top edge of the circle and dragging down.
4. Calculate the PAI of an aligned image by clicking on the ‘LAI’ tool (leaf symbol). Further information can be found in the Help menu of the program

3.11.4 Data management

All data provided for this indicator must conform to the data structure defined in the LTIM Data Standard. The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an ‘assessment unit’. The assessment unit for this indicator is: the site (quadrat).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

It is strongly recommended that Monitoring and Evaluation Providers make themselves familiar with the data standard requirements for this standard method prior to detailed monitoring program design and implementation.

3.12 Health and safety

As with all programs that include field based methods, a Health Safety and Environment Plan (HSEP) must be developed. The HSEP must include an assessment of all identified potential risks and a plan on how these risks will be managed in the field.

3.13 References

Brooks, S., Cottingham, P., Butcher, R., and Hale, J. (2013). Murray-Darling Basin aquatic ecosystem classification: Stage 2 report. Peter Cottingham & Associates report to the Commonwealth Environmental Water Office and Murray-Darling Basin Authority, Canberra.

Brooks, S. and Wealands, S.R. (2014). Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Data Standard. Report prepared for the Commonwealth

Environmental Water Office by The Murray-Darling Freshwater Research Centre. MDFRC Publication 29.3/2013 Revised Jan 2014.

Souter, N.J., Cunningham, S., Little, S., Wallace, T., McCarthy, B., and Henderson, M. (2010). Evaluation of a visual assessment method for tree condition of eucalypt floodplain forests. Ecological Management & Restoration **11**(3): 210–214.

Souter, N.J., Cunningham, S., Little, S., Wallace, T., McCarthy, B., Henderson, M., and Bennets, K. (2012). Ground-based Survey Methods for the Living Murray Assessment of Condition of River Red Gum and Black Box Populations. Murray-Darling Basin Authority.

Stand Condition Site Establishment Sheet

ANAE id:		Dimensions:		Forest type:	
Location (mark central point for circular sites and four corners for square / rectangular sites): GDA94					
Latitude		Longitude			

Hemispherical photopoint locations:

Zone	Latitude	Longitude

Crown extent tree locations (30 trees per site):

Tree number	Tree species	Latitude	Longitude

Stand Condition Data Collection Sheet

Stream ID:		Dimensions:		Date:	
Observer 1:			Observer 2:		
Disturbance(s):					
Notes:					

Key:
Tree species: RRG = River red gum; BB = Black Box; C = Coolibah; RC = River Cooba; GB = Grey box
Live / Dead assessment: L = Live; D = Dead
Crown extent:

Score	Description	Percentage of assessable crown (%)
0	None	0
1	Minimal	1-10
2	Sparse	11-20
3	Sparse-medium	21-40
4	Medium	41-60
5	Medium-major	61-80
6	Major	81-90
7	Maximum	91-100

Note: Trees outside the 0.25 hectare when less than 30 trees occur within the site are marked with an * next to the tree number

Tree number	Tree species	DBH (mm)	Live/Dead	Marked tree? (Y/N)	Crown extent score	Crown extent value (%)

Tree number	Tree species	DBH (mm)	Live/Dead	Marked tree? (Y/N)	Crown extent score	Crown extent value (%)

Hemispherical photograph record sheet

Site ID	Date	Time	Photo 1 filename	Photo 2 filename	Photographer

4 Vegetation diversity

4.1 Evaluation questions

This monitoring protocol addresses the following Basin scale evaluation questions:

- **Short-term (one-year) and long-term (five year) questions:**
  - What did Commonwealth environmental water contribute to vegetation species diversity?
  - What did Commonwealth environmental water contribute to vegetation community diversity?

The process for evaluating these questions is illustrated in Figure 6, with components covered by this protocol highlighted in blue. The red boxes for tree recruitment and structure indicate that these are optional parts of the protocol that may not be relevant to every situation and can be implemented at the discretion of Monitoring and Evaluation Providers.

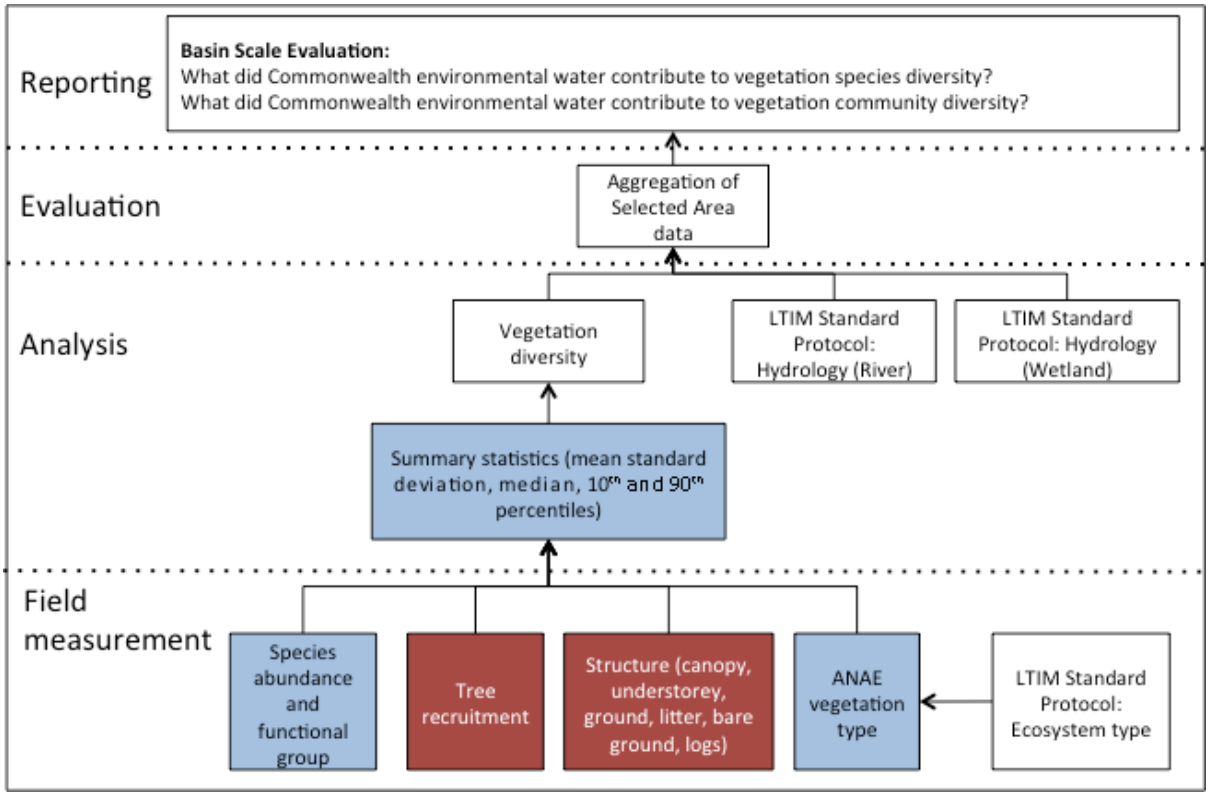

Figure 6: Schematic of key elements of the LTIM Standard Protocol: Vegetation diversity.

4.2 Relevant ecosystem types

River and wetland

4.3 Relevant flow types

Fresh, bankfull, overbank (infrastructure assisted).

4.4 Overview and context

Vegetation diversity is an event based monitoring program to assess the responses of vegetation species and community diversity to Commonwealth Environmental Water (CEW). At this stage

CEWO is not intending to provide uncontrolled overbank releases of environmental water onto the broad floodplain surface, and as such this protocol is limited to assessing riverine (to top of bank) and inundation of wetland and floodplain vegetation primarily through infrastructure assisted flows.

In recognition of the diversity and variability in water dependent vegetation communities across the Basin, a flexible approach is proposed. Site appropriate methods are to be developed for specific Selected Areas. However, to inform Basin scale evaluation they must meet the minimum requirements detailed below with respect to:

- Site establishment
- Timing of field sampling
- Field measures
- Reporting of results

4.5 Complementary monitoring and data

The field measures required for the assessment of vegetation diversity are largely unique to this protocol. However, it is possible that existing vegetation monitoring programs may collect data in a compatible manner and be adapted to suit Basin scale evaluation.

4.6 Establishing sites

4.6.1 Overview

LTIM for Basin-scale evaluation has adopted a hierarchical approach to sample design (see (Gawne et al. 2013). Briefly, the spatial hierarchy for vegetation monitoring is as follows:

- Selected Area
    - Zone
        - Site
            - Habitat (vegetation type, open water)

Selection of zone(s)

A 'zone' is a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. For example, separate river systems, sub-catchments or large groups of wetlands.

For Basin-scale evaluation, we require selection of a single zone for monitoring of vegetation diversity as follows:

- The zone must be likely to receive Commonwealth environmental water at least once in the next five years;
- The zone must have an expected outcome related to the indicator in question (in this instance vegetation).

The zone selected is to be included in monitoring throughout the five year LTIM program. Monitoring and Evaluation Providers may wish to include wetlands from other zones in their area-specific monitoring and analysis, and the number of zones selected will be determined by area-specific constraints and requirements, as well as fiscal constraints.

Selection of sites

Sites may be a single large wetland, a complex of wetlands or a stream segment within a zone. It is not possible to be prescriptive about the selection of sites within zones. Aquatic ecosystems

targeted for watering and monitoring will vary immensely in surface area, volume and shape as well as landscape position and connectivity. Site selection within a zone is therefore at the discretion of Monitoring and Evaluation Providers. However, sites should have the following characteristics:

- Each site should be accessible and representative of the zone—one's site should not be an obvious ecological aberration for that zone.
- Sites should adequately represent the range of inundation dependent vegetation characteristic of the Selected Area and zone.
- The site must be highly likely to receive Commonwealth environmental water at least once in the next five years.
- Preference should be given to sites with known bathymetry (or DEM) and water level recording infrastructure (otherwise a bathymetric survey, DEM and installation of water level recorders will be required, see LTIM Standard Protocol: Hydrology (Wetland)).

Fixed or flexible site locations among years? This will depend on what questions / hypotheses are developed at the Selected Area scale. **Site locations should be fixed *within years*, but we do not specify they should be fixed *among years* at this stage**. One cautionary note is warranted, however:

- With respect to Basin-scale objectives, we require an accurate description of the inundation dependent vegetation diversity within and among years, across the diversity of aquatic ecosystem types within an area. Aquatic ecosystems are notoriously variable in space, so if sample size is not large and the sites selected change among years, inter-annual differences may be due to spatial heterogeneity, not temporal effects. Such space-time confounding is undesirable, so if Monitoring and Evaluation Providers wish to change sites among years, the number of sites sampled will have to be sufficiently large to eliminate this space-time confounding. Fixing sites among years may be a more cost-effective solution. Alternatively, a combination of fixed and variable site locations may be appropriate.

Location of transects / quadrats

Sample locations must be selected to cover the range of water dependent vegetation communities likely to be affected by Commonwealth Environmental Water within a given Selected Area. Vegetation types to be identified using the interim ANAE typology developed for the MDB (see (Brooks et al. 2013), and includes the following choices:

- River red gum forest
- River red gum woodland
- Black box forest
- Black box woodland
- Coolibah
- River Cooba
- Unidentified aquatic trees
- Lignum
- Other shrub
- Tall emergent aquatic (reeds, phragmities, cumbungi, etc)
- Aquatic sedge/grass/forb
- Freshwater grasses
- Freshwater forb

The choice of transects or quadrats and the physical locations of these are dependent on the system and must be documented in the Monitoring Evaluation Plan. It is expected that sampling design will capture different vegetation communities at different elevations and locations within the wetland

and / or river from submerged communities in the river or wetland bed through to emergent or littoral vegetation at the edges of aquatic ecosystems.

4.6.2 Sample size

The size and number of quadrats or transects must be determined objectively. It is suggested that species area curves based on data collected in previous monitoring programs be used to determine adequate sample sizes (Figure 7). Alternative, objective methods can be used, but must be documented and justified in the Monitoring Evaluation Plan.

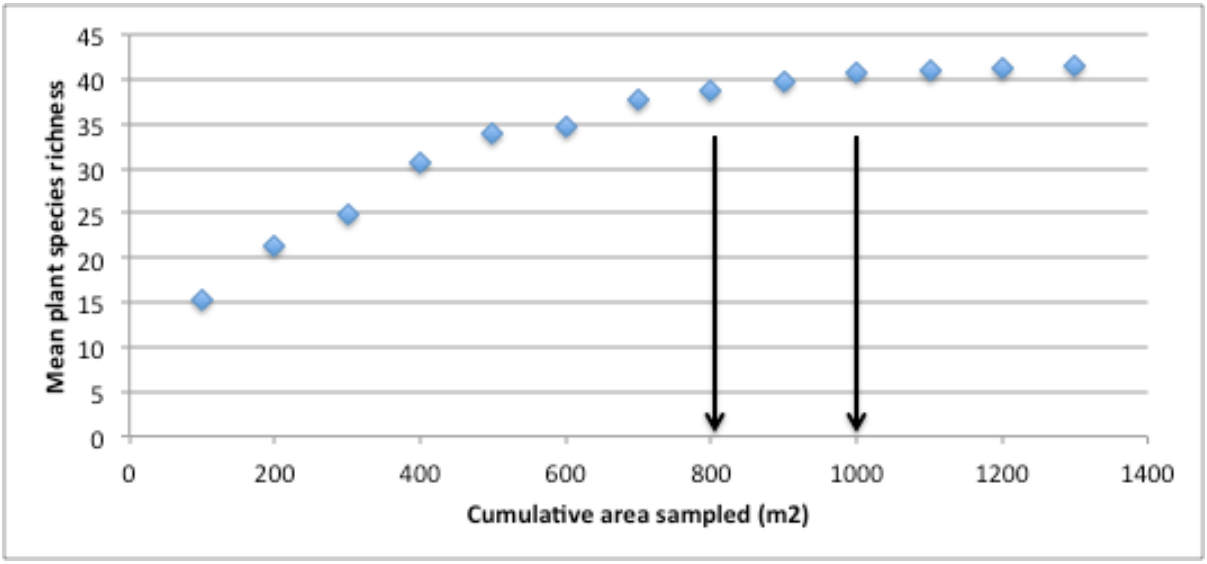

Figure 7: Example cumulative species area curve showing potential sample sizes to adequately capture species richness (data from Roberts and Hale 2013).

4.7 Timing of field sampling

The purpose of this protocol is the measure the response of inundation dependent vegetation to environmental water. Therefore it is suggested that sampling will be required both before and at some time following delivery of Commonwealth environmental water. The exact timing of sampling will be largely dependent on the target vegetation communities and expected lag time for response to watering. Details of sample timing and frequency are to be provided in the Monitoring Evaluation Plan.

4.8 Field measures

Site appropriate measures are to be developed for vegetation field measures. However, to inform Basin scale evaluation there are requirements with respect to:

- Structure (optional)
- Tree recruitment (optional)
- Species abundance
- Function group

4.8.1 Measures of cover

Cover is measured as “projected foliage cover”” and is the area that is covered by a vertical projection of the plants foliage. This is applied to **ALL** vegetation measures in the monitoring (e.g. trees, shrubs, ground, individual species, etc.). An example of “projected foliage cover” is provided in Figure 8.

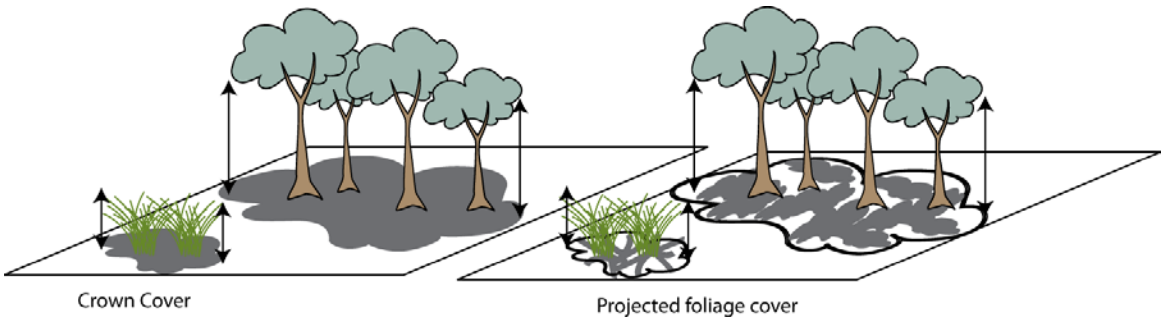

Figure 8: Example of crown cover (left) NOT used in this monitoring program and "projected foliage cover" as used in this monitoring program (Roberts and Hale 2013).

4.8.2 Tree recruitment

Tree recruitment density is an optional indicator and is measured as counts of riparian tree species (river red gum, black box, coolibah, river cooba), in each of three height classes (Do not include seedlings smaller than 20 cm tall):

- 20 – 50 cm
- 50 – 130 cm
- 1.3 – 3 m

Recruits are individual plants, which may be seedlings or re-growth from a woody rootstock after grazing.

4.8.3 Structure

Structure is an optional indicator and is measured as percentage projected foliage cover of:

- Canopy (trees > 5 m tall);
- Understorey (trees and shrubs and non-woody plants 1 – 5 m tall);
- Groundcover layer (plants shorter than 1 m tall);
- Litter (bark, leaves and twigs on ground);
- Lichen crusts and mosses;
- Bare ground.

Also included in structure are:

- Counts of standing dead trees
- Linear metres of fallen logs > 10 cm diameter.

4.8.4 Species abundance

Species abundance is measured as % cover (Figure 8) of each live species recorded within the quadrat. Cover is recorded to the nearest 5% for cover 100 – 5%; to the nearest 1% for cover < 5% and "trace" records (i.e. all those that have cover < 1%) should be recorded as 0.5%. Note that the total can be > 100% due to overlapping structural layers.

4.8.5 Functional groups

Plant species are to be grouped into the four following functional groups (Brock and Casanova 1997):

- Amphibious responders (AmR) – plants which change their growth form in response to flooding and drying cycles;
- Amphibious tolerators (AmT) – plants which tolerate flooding patterns without changing their growth form;
- Terrestrial damp plants (Tda) – plants which are terrestrial species but tend to grow close to the water margin on damp soils; and
- Terrestrial dry plants (Tdr) - those which are terrestrial species which don't normally grow in wetlands but may be encroaching into the area due to prolonged drying.

4.9 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the Monitoring and Evaluation Plan for all Selected Areas.

Visual assessments of cover will often differ between observers. Measures to limit this variance should be documented in the Quality Plan.

4.10 Data analysis and reporting

4.10.1 Tree recruitment density

Tree recruitment density is reported as mean (and standard deviation) number of seedlings of each species in each of the height categories:

- 20 – 50 cm
- 50 – 130 cm
- 1.3 – 3 m

4.10.2 Structure

Structure is reported as summary statistics (mean, standard deviation, median, 10^{th} and 90^{th} percentiles) for the following:

- Cover of structural layers (Canopy, understorey, groundcover, litter, lichen and mosses, bare ground);
- Counts of standing dead trees;
- Linear metres of fallen logs.

4.10.3 Species abundance

Species data is reported as summary statistics (mean, standard deviation, median, 10^{th} and 90^{th} percentiles) for the following:

- Cover of individual species in each vegetation community type
- Species richness in each vegetation community type
- Identification of non-native species
- Identification of function group for each species

4.10.4 Data management

All data provided for this indicator must conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is equivalent to the site.

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

It is strongly recommended that Monitoring and Evaluation Providers make themselves familiar with the data standard requirements for this standard method prior to detailed monitoring program design and implementation.

4.11 Health and safety

As with all programs that include field based methods, a Health Safety and Environment Plan (HSEP) must be developed. The HSEP must include an assessment of all identified potential risks and a plan on how these risks will be managed in the field.

4.12 References

Brock, M.A. and Casanova, M.T. (1997). Plant life at the edge of wetlands: ecological responses to wetting and drying patterns. *In* Frontiers in Ecology: Building the Links. *Edited by* N. Klomp and Lunt. Elsevier Science, Oxford. pp. 181–192.

Brooks, S., Cottingham, P., Butcher, R., and Hale, J. (2013). Murray-Darling Basin aquatic ecosystem classification: Stage 2 report. Peter Cottingham & Associates report to the Commonwealth Environmental Water Office and Murray-Darling Basin Authority, Canberra.

Brooks, S. and Wealands, S.R. (2014). Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Data Standard. Report prepared for the Commonwealth Environmental Water Office by The Murray-Darling Freshwater Research Centre. MDFRC Publication 29.3/2013 Revised Jan 2014.

Gawne, B., Brooks, S., Butcher, R., Cottingham, P., Everingham, P., Hale, J., Nielsen, D.L., Stewardson, M., and Stoffels, R. (2013). Long Term Intervention Monitoring Logic and Rationale Document Final Report prepared for the Commonwealth Environmental Water Office by The Murray-Darling Freshwater Research Centre.

Roberts, J. and Hale, J. (2013). Monitoring Riparian Zones in the Western Catchment: Round 2 – 2012. A report to the Western Catchment Management Authority.

Example vegetation diversity monitoring sheet

Stream or wetland ID:			Date:	
Observer 1:		Observer 2:		
Notes:				

Location

Sample unit code (quadrat / transect number)	Location (GDA94)		Vegetation community: River red gum forest; river red gum woodland; black box forest; black box woodland; coolibah; river cooba; lignum; other shrub; tall emergent aquatic; aquatic sedge/grass/forb; freshwater grasses; freshwater forb
	Latitude	Longitude	

Tree recruitment density

Sample unit code	Tree species	Height class		
		20-50cm	50-130cm	1.3-3m

Structure

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
CANOPY: Trees taller than 5m (% cover)										
UNDERSTOREY: Plants 1-5m tall (% cover)										
GROUND LAYER: plants shorter than 1 m (% cover)										
BARE: unvegetated area (% cover)										
Lichen crust, mosses (% cover)										
LITTER on ground: bark, leaves, fine twigs (% cover)										
STANDING DEAD TREES: more than 20 cm dbh (count)										

Species abundance

Species name	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10

5 Fish (River)

5.1 Evaluation questions

Long-term (five-year) question:

- What did Commonwealth environmental water contribute to native fish populations?
- What did Commonwealth environmental water contribute to native fish diversity?

Short-term (one-year) questions:

- What did Commonwealth environmental water contribute to native fish community resilience?
- What did Commonwealth environmental water contribute to native fish survival?

The process for evaluating these questions is illustrated in Figure 9, with components covered by this protocol highlighted in blue.

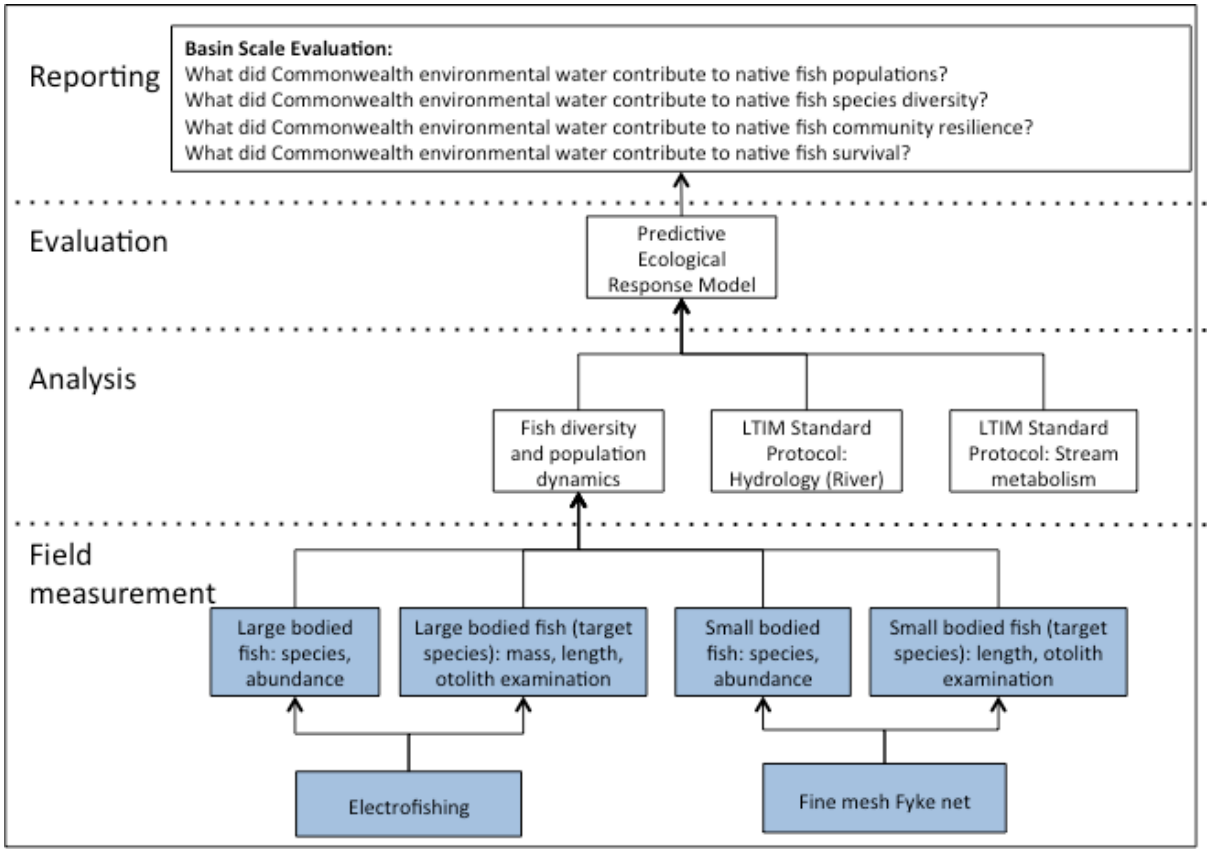

Figure 9: Schematic of key elements in LTIM Standard Protocol: Fish (River).

5.2 Relevant ecosystem types

Rivers.

5.3 Relevant flow types

These methods describe annual monitoring conducted during March of each year independent of specific watering events. The methods are therefore relevant to all flow types.

5.4 Overview and context

These standard methods describe monitoring required for the Basin Scale evaluation of the response of river fish to Commonwealth environmental water. The methods describe the sampling design and protocol for small- and large-bodied fishes in river channels for the LTIM project.

This protocol describes sampling once each year during Autumn to measure:

- Catch-per-unit-effort (CPUE) of each fish species for:
    - Electrofishing
    - Small-meshed fyke nets
- Population structure data for target species:
    - Length
    - Weight
    - Approximate age structure (from otolith examination)

5.5 Establishing sites

5.5.1 Equipment

- Boat
- GPS

5.5.2 Protocol

LTIM for Basin-scale evaluation has adopted a hierarchical approach to sample design (see Figure 10 and Gawne et al. 2013). The spatial hierarchy for fish (river) monitoring is as follows:

- Selected Area
    - Zone
        - Site

Zone placement within Selected Areas

A 'zone' is a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. For example, separate river systems, sub-catchments or large groups of wetlands.

For Basin-scale evaluation, M&E Advisors require selection of one or more zones for monitoring of fish in rivers channels as follows:

- Different zones within Selected Areas represent spatially-, geomorphologically- and/or hydrologically-distinct units;
- Zones must be likely to receive Commonwealth environmental water at least once in the next five years;
- Zones must have an expected outcome related to the indicator in question (in this instance fish);

For **Basin-scale analysis one zone must be monitored within each Selected Area**. If area providers wish to monitor fishes from the channel(s) of several zones, we encourage them to use the same sampling design and monitoring protocols and contribute additional data to the basin scale analysis.

The zone selected for basin-scale data should have the following characteristics:

- The zone should be situated on a single river channel within a Selected Area, and the zone should contain channel habitat that is generally representative of the Selected Area as a whole;
- Within the channel of this zone there should ideally be a flow gauging station measuring height and discharge (otherwise a manual gaging station must be established (see LTIM Standard Protocol: Hydrology (River);
- If possible, the zone should contain relatively high abundances of the target species (Section 5.6), to maximise potential to obtain powerful age- or stage-structure data.
- This zone must be among the zones of an Selected Area most likely to receive Commonwealth environmental water, towards some significant change in river hydrology during that Commonwealth environmental water delivery event;
- The zone must contain channel habitat that can be readily accessed—either by boat or car—for sampling using the full suite of active and passive gears detailed below;

Site placement within zones

A 'site' is defined as follows:

- An **800 m reach of channel within a zone** (Figure 10).
- Site location for channel sampling should be fixed throughout the LTIM program.
- Each site should be accessible and be representative of the zone.
- Ideally, each site will coincide with a pre-existing discharge and river height gauging station. In the event a site does not contain a gauging station, new gauging stations (and associated rating curves etc.) may have to be established.
- Each site should not be within 1 km of a significant tributary and/or distributary.

The below specifications for site number and distribution apply to all areas.

- **Ten channel sites** should be located within the zone targeted for Basin-scale monitoring/analysis.
- All ten sites for Basin-scale data should be located on a single channel.
- These sites should be distributed randomly throughout the zone selected for Basin-scale data collection, such that the samples collected are representative of that zone. However, they should not be spread over a distance farther than 100 km.
- Note that larval fish sampling will occur at three of the 10 sites between September and February (*specific Selected Areas only*).

Sample placement within sites

A sampling grid will be established within each site to ensure individual samples can be randomly sampled from that site, and are therefore representative of that site as a whole**. Sampling should be *random with respect to the environment* to avoid temporal and spatial biases**:

- Focusing sampling on particular habitat types that are easiest to sample (e.g. slackwaters) may bias our 'whole-site' sample towards particular fish assemblages associated with those habitats. Further, if Commonwealth environmental water flows are affecting fish community structure by altering the availability of non-target habitat types (e.g. those habitats poorly represented within a Selected Area at the inception of the long-term program), then *a priori* focus on particular habitat types yields very low power to detect such temporal changes.
- A stratified-random design may seem like a solution to the above problem. By 'stratified-random' we mean a sampling design whereby individual samples are taken randomly not from the site as a whole, but within each key habitat at a site. This design requires *a priori* specification of what the key habitats of the river channel are, which may be difficult given one of the objectives of this program is to search for common responses to flow across

seven Selected Areas throughout the Basin, each of which may have unique habitat composition. Perhaps more importantly, a stratified-random design does not fix the problem mentioned above; Commonwealth environmental water creating/restoring important habitat types, which may not have been targeted from the beginning.

We propose that a totally random sampling design is most appropriate for detecting flow-induced temporal trends within zones and Selected Areas, and spatiotemporal trends among zones and Selected Areas. Each 800m site is subdivided by fixed transects spaced 50 m apart. Points of intersection between the transects and the river bank define the sampling grid (Figure 10).

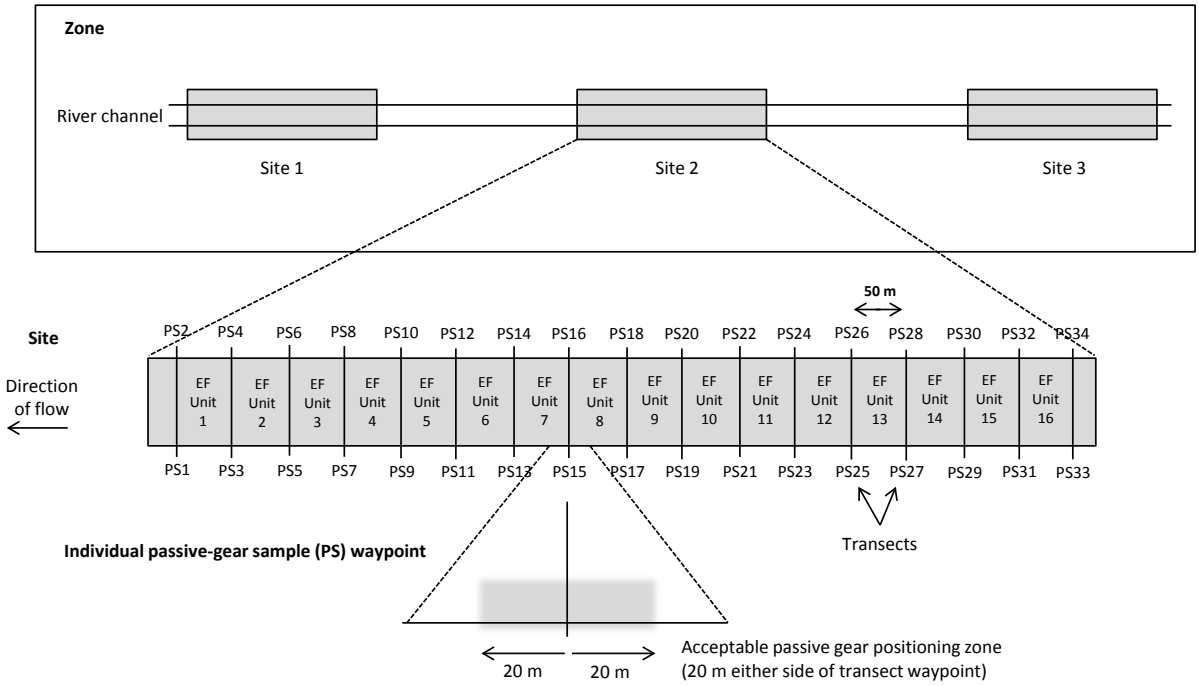

Figure 10: Diagram of hierarchical sample design illustrating zones, sites and sample locations.

The sample design specified in Figure 10 defines two key sampling locations: electrofishing (EF) units (16 in total), and passive-gear sample (PS) waypoints (34 in total). Use of these EF units and PS waypoints will be explained in Section 5.7, below.

To establish the PS grid, providers should save each PS waypoint in a GPS, so that the GPS can be used to locate each PS waypoint over the monitoring period. That is, it is not necessary to establish visible transects and physically label each PS waypoint (with, say, a stake, floats or flagging tape), but if service providers wish to use physical markers in addition to GPS coordinates, then they may do so.

5.6 Representative species from life-history guilds

5.6.1 Overview

Fishes belonging to different life history guilds may respond in different ways to managed and natural flows. Towards a more complete knowledge of fish population response to flows, monitoring will target representatives of the three primary life history guilds: equilibrium, periodic and opportunistic. **We request additional data collected from these target species.**

5.6.2 Protocol

Within each Selected Area we request providers identify **six target species, two from each guild**. Within each guild, one of the two species will be fixed, and common to all Selected Areas (as much as practicable), while the identity of the other species will be flexible across Selected Areas.

Across all Selected Areas the equilibrium life history species targeted for detailed data collection will be **Murray cod**. The second equilibrium species should be selected on the basis of how well it is represented within a Selected Area (is there a reasonable chance of obtaining quality data?), as well as conservation concern. Examples include freshwater catfish and river blackfish.

Across all Selected Areas the periodic life-history species targeted will be **golden perch**. The basis for selection of a second, Selected Area-specific periodic species is similar to that outlined above for equilibrium species. Examples include silver perch and bony herring.

Across all Selected Areas the opportunistic life-history species targeted will be **carp gudgeon**, *Hypseleotris* spp. Several options exist for selection of a second opportunistic species within Selected Areas: smelt, Murray rainbowfish, fly-specked hardyhead, and *Ambassis* spp., for example.

5.7 Sampling protocol

5.7.1 Equipment

- Backpack or boat electrofisher, including nets, storage and processing equipment;
- Ethics and fisheries permits from relevant institutions;
- GPS;
- GPS coordinates of site structure (PS waypoints and EF units; Figure 10);
- PS waypoints determined using random number generator (sample locations within sites);
- 12 fine-mesh fyke nets (10 for use; 2 spare) per site;
- Anchoring devices for fyke nets (stakes, chains, etc.);
- Large (1000 mm) and small (300 mm) measuring boards;
- Scales, either quality hanging scales with bag or bench scales with bucket/tray for fish;
- Data sheets

5.7.2 Protocol

Timing of sampling

The channel sites of each Selected Area should be sampled once each Autumn (March-May inclusive). In the event that more than the one required zone is proposed for monitoring within a Selected Area, sites sampled should be dispersed across zones in any one sampling trip, so that any inter-zone differences are not confounded by sampling time. For example, if the Selected Area Monitoring and Evaluation Plan is designed with two channel zones, each containing ten sites (twenty sites total), multiple trips might be appropriate, whereby sites from each zone are sampled on each trip.

Large-bodied species

Sampling

Large-bodied species will be sampled using either boat or backpack electrofishing, depending on the size of the river and approach of the area providers.

Sustainable Rivers Audit (SRA) electrofishing protocol will be a subset of what is described here, so that data collected as part of the CEWO LTIM Program can be compared and contrasted with SRA

large-bodied fish data. Do not collect small-bodied species for processing using electrofishing, but collect all stages (including juveniles) of large-bodied species for processing.

Herein, 'small-bodied' species are those belonging to the following families:

- Galaxiidae;
- Retropinnidae;
- Atherinidae;
- Melanotaeniidae;
- Ambassidae;
- Nannopercidae;
- Eleotridae;
- Gobiidae;
- Poecilidae;

All other fish families of the Basin are considered 'large-bodied'.

The entire 800m site will be electrofished. Within each electrofishing unit of a site (EF unit; Figure 10) two 'shots' of 90 s 'on-time' should be carried out. This results in a total of 2880 s (48 min on-time) for each site. No more than 180 s of shocking should be allocated to each EF unit, such that electrofishing effort is spread out across the entire site, thus giving a more random sample with respect to the (site's) environment. Note that, *within* EF units the location of shots is left to the discretion of the service provider.

We cannot stress enough how important it is we obtain a sample that is, as much as possible, representative of the population structure within the zone selected for 'Basin-scale' monitoring. **If area providers suspect that boat electrofishing alone results in a sample biased towards larger and/or older individuals, then they should carefully consider, say, splitting the effort in half, across both boat and backpack methods.** Perhaps, for example, 50% of the EF units might be shallow enough to be intensively fished (still 180 s) with backpack electrofishing, thus enabling fishers to target the shallower (< 40 cm deep), more structurally complex habitats where 0+ and 1+ individuals might reside. Or maybe a certain proportion of the 16 (EF units) x 2 (90 s shots per EF unit) = 32 shots should be allocated to backpack electrofishing the shallow margins.

It is difficult to standardise electrofishing across areas towards meeting the objective of a robust sample that is representative of the population present. We can merely request that area providers objectively consider the above paragraph and select the appropriate balance of boat and backpack electrofishing that suits their particular area. **Once a certain 'balance' or partitioning of boat and backpack electrofishing is devised—within the constraints of the general 'shot structure' laid out above—area providers should maintain that design over the entire five years.**

Processing - electrofishing

For every individual belonging to a **target** large-bodied species, the following should be obtained or implemented:

1. Identified to species;
2. Total (TL; round or square caudal fin species) OR fork (FL; fork-tailed species) lengths, in millimetres (mm);
3. Mass in grams (g) (use scales that have been recently calibrated);

If > 20 individuals are obtained within a 90 s shot, record the above information on a random sub-sample of 20 individuals only. The random sub-sample should be the first 20 individuals sampled during a 90 s shot. That is, if 20 individuals from a target species are obtain in less than 90 s,

sampling should cease until the above statistics are obtained, or service providers should have some way of separating the first 20 individuals from those caught subsequently during that 90 s shot.

Identify and enumerate non-target species; there is no need to obtain lengths and masses of these non-target species. Return all individuals (including alien species) to the water.

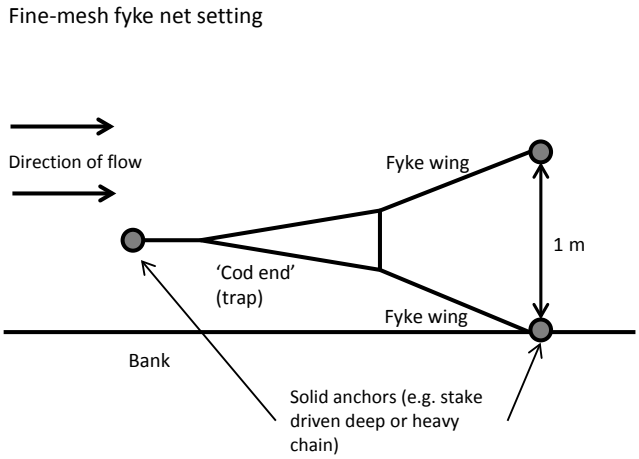

Figure 11. Diagram indicating the positioning of fine-mesh fyke nets in river channels, relative to the bank and direction of water flow. Cod-end should face upstream so as to not collect debris and act as a water velocity 'parachute'.

Small-bodied species

Sampling

Small-bodied species will be sampled using a passive technique only; fine-mesh fyke nets. The fine-mesh fyke nets (2 mm mesh) should be double wing (Figure 11) (each wing: 2.5 m × 1.2 m), with a first supporting hoop covered by a plastic grid (5 cm x 5 cm) to keep large aquatic vertebrates out of the trap.

A random number generator should be used to randomly select a subset of 10 PS waypoints (Figure 10) from the total of 34. As noted in Figure 10, a waypoint encompasses a total of 40 m of bank (20 m either side of specific waypoint), so providers should endeavour to find the point on the bank as close to the exact waypoint as possible. The purpose of this system is to ensure sampling is random with respect to the environment, so providers should not simply ignore a waypoint if setting of a net is not as leisurely as they would like. If it is impossible (in the strict sense, not just inconvenient) to set a fyke net at a certain waypoint (current is too fast; bank is far too steep; water too deep; too many emergent macrophytes to be an effective fish sample), then an adjacent, unoccupied waypoint should be used.

Fine-mesh fyke nets should be set in the afternoon and retrieved the following morning. Set and retrieval times should be recorded for each individual net/trap, so that abundances can be expressed as rates (see Section 5.8.4).

Past monitoring programs have not used fine-mesh fyke nets in the channel. In many (most?) cases, however, fine-mesh fyke nets can be set in certain locations within river channels. Fine-mesh fyke nets sample a much broader subset of the overall fish community than minnow traps, and are effective for estimating relative abundances of active, pelagic species such as smelt and hardyhead. Furthermore, use of fyke nets in the river channel and in wetlands may allow comparisons of community and population structure among these two major habitat types.

Fine-mesh fyke nets should be set with the cod end facing the current, so that water velocity is deflected around the net and wings (Figure 11). For the net to be effective both wings and the cod end need to be anchored to the bottom very well using, say, steel stakes. So that sampling effort is held constant across nets, the wings should have an aperture of 1 m (Figure 11).

Processing

The following measurements should be made for non-target, small-bodied species:

1. Identify (to species) and enumerate all individuals. Random sub-samples may be used if nets capture too many fish for complete processing, as long as proportion of total sample sub-sample represents is recorded;

Further measurements are required for those small-bodied species targeted as part of the opportunistic guild (see Section 5.6):

2. Obtain total (TL; round or square caudal fin species) OR fork (FL; fork-tailed species) lengths, in millimetres (mm), of up to the first 10 individuals from both target species, from each net. Ensure the first ten are randomly selected from the overall sample. This may be achieved, for example, by using an aquarium net to 'blindly' sub-sample from a bucket until 10 individuals have been measured.

Example approach to a typical site

Electrofishing should interfere with passive sampling as little as possible. Fyke nets should not be set while electrofishing is taking place (and vice versa). Accordingly, Monitoring and Evaluation Providers might adopt a 'per site' itinerary similar to the following:

1. Day 1 morning – travel to site;
2. Day 1 afternoon – set fine-mesh fyke nets;
3. Day 2 – retrieve and process fyke nets;
4. Day 3 – electrofish;

Otolith collection and analysis

Otoliths should be collected from target species (Section 1.6) populations for the following purposes:

1. Estimation of von Bertalanffy (vB) growth parameters, such that we have a vB model for each target species, for each area. These models will be used to coarsely approximate the age distribution (in years) of target species, based on their lengths, within each of the monitoring years. Age distributions will subsequently be used to coarsely approximate survivorships, hence year-class strength, in the absence of capture-mark-recapture data. Furthermore, otoliths may be used to back-calculate temporal variance in growth rates, in response to changes in flow.
2. For periodic and equilibrium targets, determine the relationship between age and length of (approximate, or what one assumes to be) 0+ and 1+ individuals within each year, to reduce uncertainty of age prescription during early life history.
3. For opportunistic species, determine the age composition (in years) of the populations within each area.

The otolith collection and reading protocol is dependent on which life-history guild the species belongs to:

Opportunistic species

During each annual census, retain a minimum of 6 individuals of each of the two species (*Hypseleotris* sp. + one other) from each of the 10 sites, giving a minimum of 60 pairs of otoliths for

each opportunistic species, each year, per area. The 6 individuals collected within each site should, as much as practicable, span the entire length range observed at that site, for that species.

Otolith removal, storage, mounting and reading methods are now very broadly tested and used (e.g. Campana 2001; Secor et al. 1992, and references therein). Accordingly, we request that service providers utilise published protocols for these procedures.

Periodic and Equilibrium species

We do not request *annual* otolith samples from these life-history guilds, due to the relatively small sizes of their populations within many monitoring zones. Instead, **we request two comprehensive otolith samples from these target species over the course of the 5-year program**; one at the beginning of the program (**Year 1**) and one at the end of the program (the winter of **Year 5**, following autumn censuses). Accordingly, we will use these data to obtain two vB growth curves for each of the four target species of an area: one at the beginning of the program and one at the end of the program. The vB curves from Year 1 will give the modelling team some idea of how variable length-age relationships are between areas, and this will, in turn, improve their ability to progress population models as annual census data arrives. The vB curves from Year 5 will improve our area-specific vB curves, while also enabling service providers to explore the possibility of back-calculating growth rates in response to flow events over the 5-year period.

Please obtain otoliths from **at least 50 individuals** of each target species. **Samples for estimating the parameters for vB curves should not be random with respect to the structure of the population**. Instead, what we really require are samples containing representatives across the full range of lengths within the population (ideally), and approximately equal numbers of individuals within each length-class.

One strategy providers might use to achieve this is as follows: Suppose we are to obtain a sample size of n = 50 individual fish. If l_{min} and l_{max} are the approximate minimum and maximum lengths (mm) of individuals obtainable within a zone, respectively, then $w = (l_{max} - l_{min})/50$ defines an increment (mm) that can be used to define intervals within which one sample should be sought. For example, the first approximate length we then should try to obtain falls in the first bin, $b_1 = [l_{min}, l_{min} + w)$. The second sample should then be sought within the interval $b_2 = b_1 + w = [l_{min} + w, l_{min} + 2w)$; the third sample from within $b_3 = b_2 + w = [l_{min} + 2w, l_{min} + 3w)$; the ith sample (i goes from 1 to 50) from within $b_i = [l_{min} + (i-1)w, l_{min} + iw)$, such that for the last bin, $b_{50} = [l_{min} + 49w, l_{min} + 50w) = [l_{min} + 49w, l_{max})$.

Please obtain otolith samples from within the zone targeted for Basin-scale data collection, but not at the same 10 sites selected for annual censuses. If that zone does not yield an appropriate sample, sample from within the broader monitoring area, but please note location of capture.

Use any sampling method you feel is most appropriate for obtaining the representative size distribution specified above—the collection method is immaterial.

Note:

- If service providers already have a good vB model for any of the target periodic and/or equilibrium species of their area, based on otoliths collected within the 10 years preceding Year 1 of this program, then they should submit those vB statistics and refrain from collecting more otoliths from those populations during Year 1.
- For both the Year 1 and Year 5 samples, otoliths retained from angler catch can and should be used—obtain as many as possible—as long as service providers are sure the samples are from within the 100 km reach of river that circumscribes the 10 sites (Section 5.5). Note, however, that we still need a sample containing even representation of individuals across

the approximate range of lengths in the population of the zone. It is therefore unlikely that angler catch alone can be used.

5.8 Data analysis and reporting

5.8.1 Relative abundance estimation

Abundances should be recorded as 'catch-per-unit-effort' (CPUE). Data should be structured in spreadsheets by individual 'samples', which are individual net hauls, or abundances within discrete electrofishing shots (see Section 5.7). Units will depend on sampling method—electrofishing versus trapping. **Electrofishing CPUE will have units** number of individuals per unit on-time for each shot. **Passive trap CPUE units** will be number of individuals per net per hour.

5.8.2 Population structure data for target species

Additional data is required for target species:

- Total length or fork length (mm), depending on species (see Section 5.7).
- Mass (gm).
- Length-age data:
    - Year 1 and Year 5 data sets for the four species belonging to the Periodic and Equilibrium guilds;
    - Annual data sets for the opportunistic species;
    - Raw data required, not just von Bertalanffy parameter estimates, since we need to devise a stochastic model of age at length to accommodate strong inter-individual variation in growth, common in fish populations, particularly those with protracted spawning seasons in Mediterranean climates.
    - Yearly ages of fish (0+, 1+,…x+), should be tagged by their species identity, place and date of capture, total or fork length (mm), and mass (g).

5.8.3 Community data

We will also be conducting Basin-scale analyses of community response to Commonwealth environmental water. For these analyses we require CPUE data at the level of the site (species by site matrices) corresponding to each sampling method:

1. Electrofishing (large-bodied species; target + non-target);
2. Coarse-mesh fyke nets (large-bodied species; target + non-target);
3. Fine-mesh fyke nets (small-bodied species; target + non-target);

5.8.4 Data management

All data provided for this indicator must conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is: the site (river section).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

It is strongly recommended that Monitoring and Evaluation Providers make themselves familiar with the data standard requirements for this standard method prior to detailed monitoring program design and implementation.

5.9 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the Monitoring and Evaluation Plan for all Selected Areas. QA/QC activities specific to this protocol include:

- Electrofishers must be experienced operators of units. They should be supervised by Senior Operators on-site, and have obtained their electrofishing certificates through a reputable course.
- Monitoring and Evaluation Providers must have relevant boat licenses.
- It is the responsibility of the Monitoring and Evaluation Providers to have specific fisheries and ethics permits with them while sampling.
- Monitoring and Evaluation Providers must also have experience with appropriate PIT implantation procedures.
- Fyke nets should be checked for holes in either wing- or cod-ends prior to every field trip. Any net with a hole should be repaired or replaced.

5.10 Health and safety

As with all programs that include field based methods, a Health Safety and Environment Plan (HSEP) must be developed. The HSEP must include an assessment of all identified potential risks and a plan on how these risks will be managed in the field.

5.11 References

Brooks S and Wealands S (2014) Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Data Standard. Report prepared for the Commonwealth Environmental Water Office by The Murray-Darling Freshwater Research Centre, MDFRC Publication 29.3/2013 Revised Jan 2014

Campana, S.E. 2001. Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. J. Fish Biol. **59**(2): 197-242.

Secor, D.H., Dean, J.M., and Laban, E.H. 1992. Otolith removal and preparation for microstructural examination. *In* Otolith Microstructure Examination and Analysis. *Edited by* D.K. Stevensen and S.E. Campana. Canadian Special Publication in Fisheries and Aquatic Science. 117. pp. 19-57.

LTIM Monitoring – Electrofishing data sheet

Date**:** _____ Selected Area: _____

Zone: _____ Site: _____

EF Unit	Shot	Species	TL (mm)	SL (mm)	FL (mm)	Weight (g)	Recapture (0,1)	Tag #

Example: LTIM Monitoring – Fine-mesh fyke field data

Date**:** _____ Selected Area: _____

_____

Zone: _____ Site: _____

Fyke 1 of 10 PS waypoint: _____

Time set: _____ Time retrieved: _____

Abundances:

Species	Sub-sample (proportion)	Count

Standard lengths of two target small-bodied species (refer to LTIM protocol)

Species	Standard lengths (mm) of first (random) 20 individuals
Hypseleotris	

Fyke 2 of 10 PS waypoint: _____

Time set: _____ Time retrieved: _____

Abundances:

Species	Sub-sample (proportion)	Count

Standard lengths of two target small-bodied species (refer to LTIM protocol)

Species	Standard lengths (mm) of first (random) 20 individuals
Hypseleotris	

6 Fish (Wetland)

6.1 Evaluation questions

Long-term (five-year) question:

- What did Commonwealth environmental water contribute to native fish populations?
- What did Commonwealth environmental water contribute to native fish species diversity?

Short-term (one-year) questions:

- What did Commonwealth environmental water contribute to native fish community resilience?
- What did Commonwealth environmental water contribute to native fish survival?

The process for evaluating these questions is illustrated in Figure 12, with components covered by this protocol highlighted in blue.

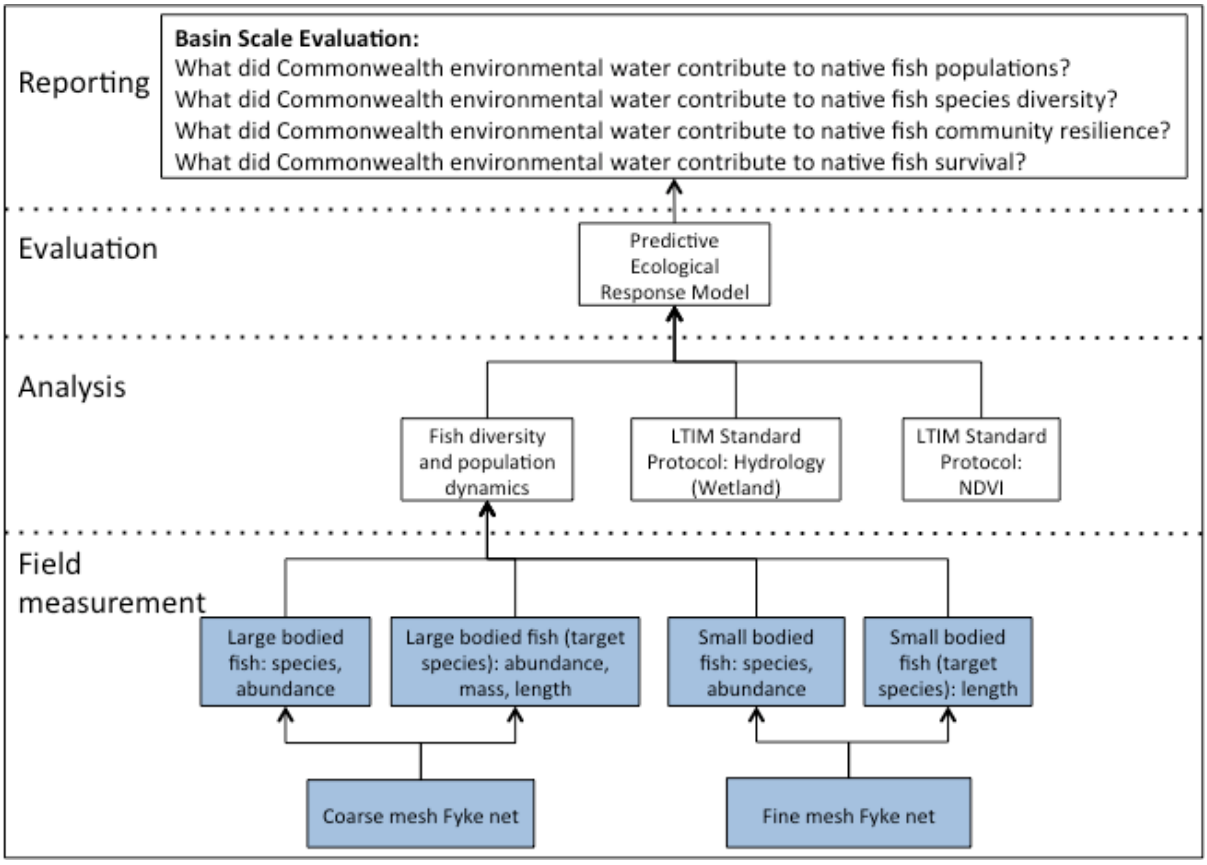

Figure 12: Schematic of key elements in LTIM Standard Protocol: Fish (Wetland).

6.2 Relevant ecosystem types

Wetlands

6.3 Relevant flow types

These methods describe annual monitoring conducted during the period September to March of each year independent of specific watering events. The methods are therefore relevant to all flow types.

6.4 Overview and context

These standard methods describe monitoring required for the Basin Scale evaluation of the response of wetland fish to Commonwealth environmental water. The methods describe the sampling design and protocol for small- and large-bodied fishes in floodplain wetlands for the LTIM project.

This protocol describes sampling four times per year in September, November, January, March to measure:

- Catch-per-unit-effort (CPUE) of each fish species for:
    - Large meshed fyke nets
    - Small-meshed fyke nets
- Population structure data for target species (length, weight)

6.5 Establishing assessment sites

6.5.1 Equipment

- GPS
- Map of floodplain wetlands in area or zone
- Possibly a boat, depending on access

6.5.2 Protocol

LTIM for Basin-scale evaluation has adopted a hierarchical approach to sample design (see Gawne et al. 2013). The spatial hierarchy for fish (river) monitoring is as follows:

- Selected Area
    - Zone
        - Site

Please refer to LTIM Fish (River) Standard Protocol for more detail on the nested hierarchical approach design adopted for all fish sampling.

Zone placement within Selected Areas

A 'zone' is a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. For example, separate river systems, sub-catchments or large groups of wetlands.

For Basin-scale evaluation, M&E Advisors require selection of one or more zones for monitoring of fish in wetlands as follows:

- Different zones within Selected Areas represent spatially-, geomorphologically- and/or hydrologically-distinct units;
- Zones must be likely to receive Commonwealth environmental water at least once in the next five years;
- Zones must have an expected outcome related to the indicator in question (in this instance fish);

For **Basin-scale analysis a minimum of one zone must be monitored within each Selected Area**. As much as is practicable, **the zone targeted for Basin-scale analysis of wetland fishes is the same zone selected for river channel monitoring**. Our rationale underlying this request is as follows:

In temperate-climate river-floodplain systems our understanding of which subset of stages (population level) and which subset of species (community level) from the river channel use the

floodplain habitats during a flood pulse. Towards improving our understanding of lateral population and community processes it would be wise to have channel sites (ultimate sources) immediately adjacent to floodplain sites (ultimately sinks, in the absence of hydrological connectivity).

Site placement within zones

A minimum of three wetland sites is required for Basin-Scale evaluation. Although it was possible to be quite prescriptive—only with respect to Basin-scale analysis requirements—for the layout of channel sites within a Selected Area, it is not possible to be prescriptive with respect to the layout of wetland sites within Selected Area. Wetlands that may be targeted for monitoring are likely to vary immensely in surface area, volume and shape, among other things. The following broad requirements should guide site selection:

1. Wetland sites within the zone selected for Basin-scale monitoring and analysis of channel fishes are preferred;
2. A 'site' is defined as an individual wetland that is large enough to contain **no less than three samples taken using both coarse- and fine-mesh fyke nets** (see Section 6.7). Three replicate gear pairs may seem like a very small sample from an individual site, however, if the wetland is very small (e.g. radius of 10 m, surface area approximately 314 m^2 (assume round)), one could suggest that three pairs of these very effective passive gears may be sufficient.
3. Monitoring and Evaluation Providers should select sites that are representative of the floodplain wetlands of a zone. That is, the wetlands selected should be a random sample from the zone, with respect to the full diversity of permanence, connectivity and geomorphological form, but with the following caveat:
    - Wetland sites should be likely to receive Commonwealth environmental water at least once over the monitoring period (five years).
4. **Fixed or flexible site locations among years?** This will depend on what questions / hypotheses individual Monitoring and Evaluation Providers wish to test. **Site locations should be fixed *within years*, but there is no specific requirement for sites to be fixed *among years* at this stage**. One cautionary note is warranted, however:
    - With respect to Basin-scale objectives, we require an accurate description of the floodplain fish assemblage within and among years, across the diversity of wetland types within a Selected Area (within the zone containing the channel sites, preferably (see 'Zone placement within areas')). Wetlands are notoriously variable in space, so if sample size is not large and the sites selected change among years, inter-annual differences may be due to spatial heterogeneity, not temporal effects. Such space-time confounding is undesirable, so if area providers wish to change wetland sites among years, the number of wetlands sampled will have to be sufficiently large to eliminate this space-time confounding. Fixing sites among years may be a more cost-effective solution. Alternatively, **a combination of fixed and variable site locations may be appropriate**.

Sample placement within sites

Samples (nets) will be placed within the littoral zone of each wetland.

Unlike river channels (LTIM Standard Protocol: Fish (River)), the extremely high variation in shape and size of wetland sites prohibits the establishment of a simple, common protocol of sample placement within sites. **Monitoring and Evaluation Providers should devise a method for randomly positioning individual sample gears within the littoral zone** that is appropriate for the wetlands being considered.

The unit of inference will be the individual wetland. Sufficient sampling effort must be allocated to characterise the fish community of each wetland, within any given sampling event. The sampling effort required will depend on how spatially heterogeneous the fish communities are during the

sampling event. Monitoring and Evaluation Providers should use pilot studies or historical data to determine what constitutes an appropriate sample size for the wetlands that are to be monitored. The required data are species x site abundance matrices, so it will be important to assess how estimates of species abundance stabilise with increasing sample size.

6.6 Representative species from life-history guilds

6.6.1 Overview

Fishes belonging to different life history guilds may respond in different ways to managed and natural flows. Monitoring will target representatives of the three primary life history guilds: equilibrium, periodic and opportunistic. **We request additional data collected from these target species.**

6.6.2 Protocol

For selection of target species, please refer to LTIM Standard Protocol: Fish (River). Wetland sampling will likely be most relevant for target species of the Opportunistic guild (small-bodied species). Certain life-stages of periodic species may also exhibit significant and strong use of floodplain habitats during lateral hydrological connectivity events (e.g. bony herring, golden perch).

6.7 Sampling protocol

6.7.1 Equipment

- Ethics and fisheries permits from relevant institutions;
- Coarse-mesh fyke nets;
- Fine-mesh fyke nets;
- Anchoring devices for fyke nets (stakes, chains, etc.);
- Large (1000 mm) and small (300 mm) measuring boards;
- Scales, either quality hanging scales with bag or bench scales with bucket/tray for fish;
- Data sheets

6.7.2 Protocol

Timing of sampling

The wetland sites will be sampled **four times per year: September, November, January, March**. We will refer to these as the four **'sampling events'** below. Within any given sampling trip (there may be numerous 'trips' within a sampling event), the sites sampled should be randomly selected (don't sample all the large wetlands on one trip, then all the small wetlands on the next).

Large-bodied species

Sampling

Large-bodied species will be sampled in wetlands with a passive technique only: coarse-mesh fyke nets. The number of coarse-mesh fyke nets set per wetland will vary, depending on the size of the wetland and logistical constraints. As stated above, however, an accurate species x abundance matrix is required from each site, each event, so sample size will vary positively with wetland size, to a point (see 'Sample placement within sites'). The *minimum* number of nets for wetlands of different areas, per sampling event, is provided below.

Wetland surface area	< 1,500 m^2	1,500 – 5,000 m^2	5000 – 20,000 m^2	> 20,000 m^2
Minimum number of coarse mesh fykes	1	3	5	7

The coarse-mesh fyke nets most commonly used are single-wing (8 m × 0.65 m) fyke nets (28 mm stretched mesh). Providers should use nets of very similar construction, or purchase such nets. Floats should be positioned within the final chamber of the nets, in accordance with fisheries permits, so that air breathing aquatic vertebrates can access the surface of the water.

Coarse-mesh fyke nets should be set in the afternoon and retrieved the following morning. Set and retrieval time should be recorded for each individual net, so that relative abundance can be expressed as a rate (see Section 6.8.4). Coarse-mesh fyke nets should be oriented perpendicular to the bank, such that the wing intercepts any fish moving parallel with the shoreline (Figure 13a). Water depth should be at least 50 cm at the location of the first supporting hoop (the entrance to the cod end; Figure 13b).

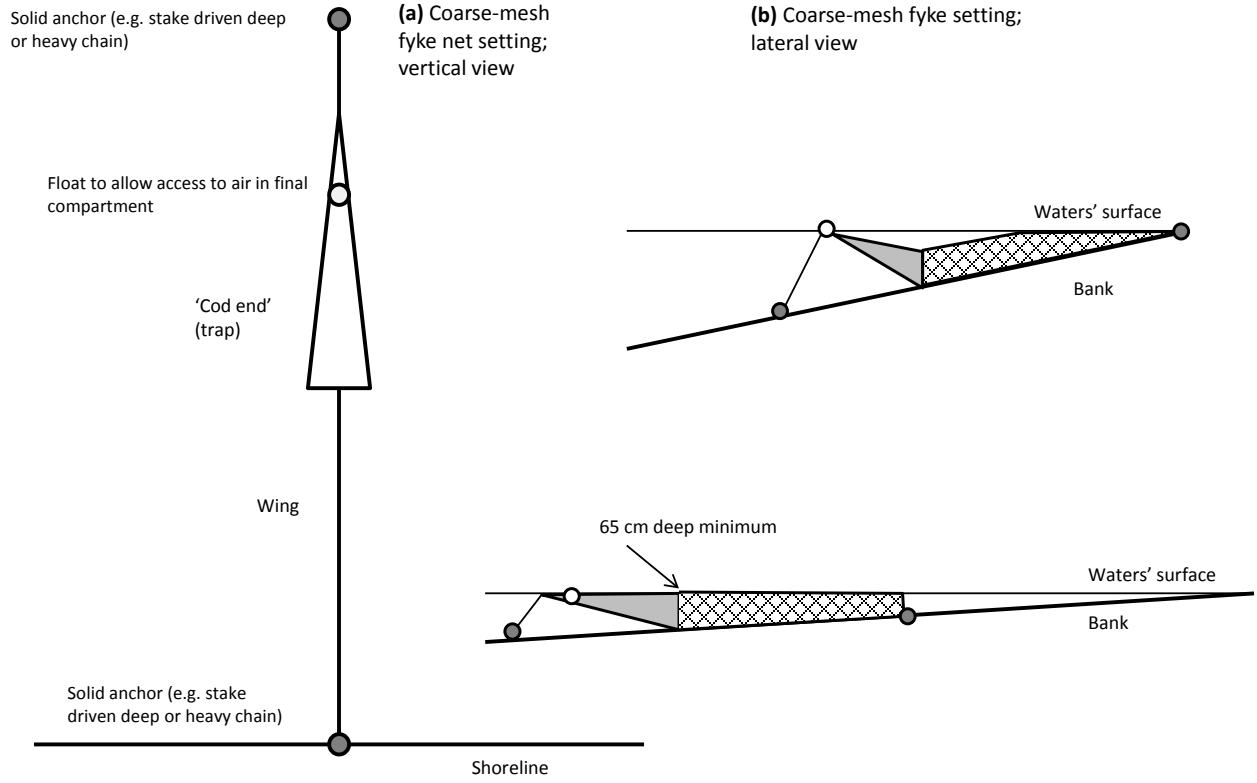

Figure 13. Diagrams indicating the positioning of coarse-mesh fyke nets in wetlands, relative to the bank / shoreline. Vertical and lateral views are indicated. Water depth at first supporting hoop must be a minimum of first supporting hoop height (65 cm). Longer cords to anchors may be required on steep banks, so that the float is allowed to reach the surface (b; upper panel).

Processing

For individuals belonging to a **target** large-bodied species, the following should be obtained or implemented:

4. Identified to species;
5. Total (TL; round or square caudal fin species) OR fork (FL; fork-tailed species) lengths, in millimetres (mm);
6. Mass in grams (g) (use scales that have been recently calibrated);

Identify and enumerate **non-target species**; there is no need to obtain lengths and masses of these non-target species.

Process individuals after each net is retrieved, to avoid excessive storage time in containers. Random sub-samples may be used if nets capture too many fish for complete processing, as long as

proportion of total sample sub-sample represents is recorded. Area providers are experienced professionals, so we leave derivation of the exact sub-sampling method to them. Release all individuals unharmed, including alien species.

Small-bodied species

Sampling

Small-bodied species will be sampled using fine-mesh fyke nets. The fine-mesh fyke nets (2 mm mesh) should be double wing (Figure 14) (each wing: 2.5 m × 1.2 m), with a first supporting hoop covered by a plastic grid to keep large aquatic vertebrates out of the trap. Wings should be set 1 m apart, to standardise sampling effort among fyke nets (Figure 14).

As for coarse-mesh fykes the number of fine-mesh fyke nets set per wetland will vary, depending on the size of the wetland and logistical constraints. As stated above, however, an accurate species x abundance matrix is required from each site, each event, so sample size will vary positively with wetland size, to a point (see 'Sample placement within sites'). The *minimum* number of fine-mesh fykes for wetlands of different areas, per sampling event, is provided below:

Wetland surface area	< 1,500 m^2	1,500 – 5,000 m^2	5000 – 20,000 m^2	> 20,000 m^2
Minimum number of fine-mesh fykes	3	5	8	10

Fine-mesh fyke nets should be set in the afternoon and retrieved the following morning. Set and retrieval times should be recorded for each individual net/trap, so that abundances can be expressed as rates (see Section 6.8.4). If overnight setting is deemed unnecessary and potentially harmful to small-bodied fishes (e.g. extremely high densities) then area providers should adjust duration accordingly. In this case the set times will enable standardisation to a common rate, but consideration should be given to potential biases induced by varying set times across areas (e.g. are some small bodied fishes more active at night?).

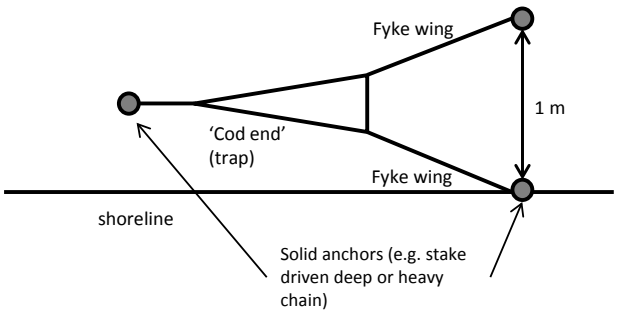

Figure 14. Vertical view of a fine-mesh fyke net.

Processing

The following measurements should be made for non-target, small-bodied species:

1. Identify (to species) and enumerate all individuals. Random sub-samples may be used if nets capture too many fish for complete processing, as long as proportion of total sample sub-sample represents is recorded. Area providers are experienced professionals, so we leave derivation of the exact sub-sampling method to them. Release all individuals unharmed, including alien species.

Further measurements are required for those small-bodied species targeted as part of the opportunistic guild (see Section 6.6):

2. Obtain TL (mm) or FL (mm), depending on species, of up to the first 20 individuals from both target species, from each net.

6.8 Data analysis and reporting

6.8.1 Relative abundance estimation

Abundances should be recorded as 'catch-per-unit-effort' (CPUE). Raw data for target species should be structured by individual 'samples', which are individual net hauls, or abundances within discrete electrofishing shots (see Section 6.7). **Passive trap CPUE units** will be number of individuals per net per hour.

6.8.2 Population structure data for target species

Additional data is required for target species:

- Total length (mm) OR fork length (mm) (certain species only e.g. bony herring).
- Mass (g) (large-bodied species only).

6.8.3 Community data

We will also be conducting Basin-scale analyses of community response to Commonwealth environmental water. For these analyses we require CPUE data at the level of the site (species by site matrices) corresponding to each sampling method:

1. Coarse-mesh fyke nets (large-bodied species; target + non-target);
2. Fine-mesh fyke nets (small-bodied species; target + non-target)

6.8.4 Data management

All data provided for this indicator must conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is: the site (wetland).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

It is strongly recommended that Monitoring and Evaluation Providers make themselves familiar with the data standard requirements for this standard method prior to detailed monitoring program design and implementation.

6.9 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the Monitoring and Evaluation Plan for all Selected Areas. QA/QC activities specific to this protocol include:

- It is the responsibility of the provider to have specific fisheries and ethics permits with them while sampling.

- Providers must also have experience with appropriate PIT implantation procedures.
- Fyke nets should be checked for holes in either wing- or cod-ends prior to every field trip. Any net with a hole should be repaired or replaced.

6.10 Health and safety

As with all programs that include field based methods, a Health Safety and Environment Plan (HSEP) must be developed. The HSEP must include an assessment of all identified potential risks and a plan on how these risks will be managed in the field.

Example: Large-mesh fyke data sheet WETLANDS

Date**:** _____ Selected Area: _____

Zone: _____ Site: _____

Fyke #	Time set	Time retrieve	Species	TL (mm)	SL (mm)	FL (mm)	Weight (g)	Recapture (0,1)	Tag #

Example: Fine-mesh fyke field data sheet WETLANDS

Date**:** _____ Selected Area: _____

_____

Zone: _____ Site: _____

Fyke 1 of ___ for this wetland

Time set: _____ Time retrieved: _____

Abundances:

Species	Sub-sample (proportion)	Count

Standard lengths of two target small-bodied species (refer to LTIM protocol)

Species Standard lengths (mm) of first (random) 20 individuals

Hypseleotris

Fyke 2 of ___ for this wetland

Time set: _____ Time retrieved: _____

Abundances:

Species	Sub-sample (proportion)	Count

Standard lengths of two target small-bodied species (refer to LTIM protocol)

Species Standard lengths (mm) of first (random) 20 individuals

Hypseleotris

7 Fish (Larvae)

7.1 Evaluation questions

Long-term (five-year) question:

- What did Commonwealth environmental water contribute to native fish populations?
- What did Commonwealth environmental water contribute to native fish species diversity?

Short-term (one-year) questions:

- What did Commonwealth environmental water contribute to native fish reproduction?
- What did Commonwealth environmental water contribute to native larval fish growth?
- What did Commonwealth environmental water contribute to native fish survival?

The process for evaluating these questions is illustrated in Figure 15, with components covered by this protocol highlighted in blue. Note that the boxes marked in red for otolith examination and daily age and growth are optional (category 2) monitoring associated with this method.

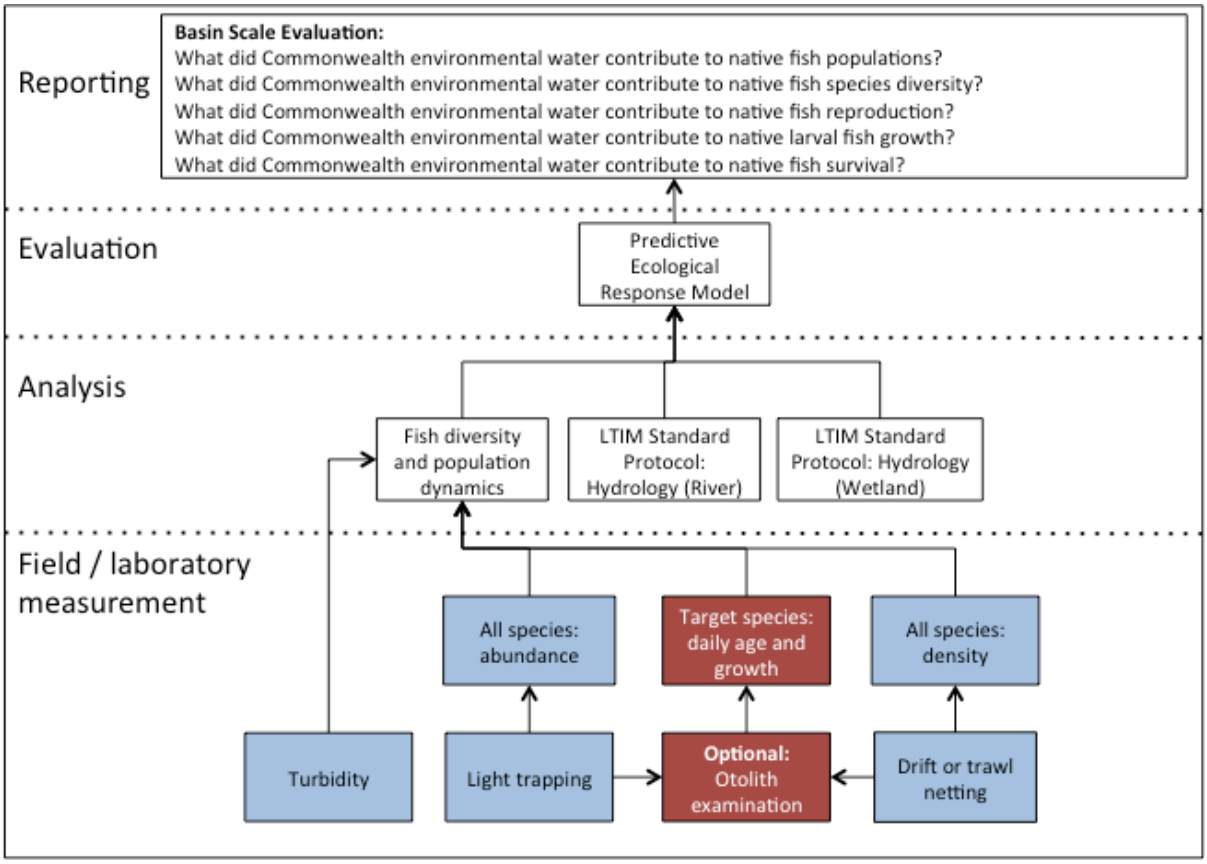

Figure 15: Schematic of key elements in LTIM Standard Protocol: Fish (Larvae).

7.2 Relevant ecosystem types

Rivers, wetlands.

7.3 Relevant flow types

These methods describe annual monitoring conducted during the period September to March of each year independent of specific watering events. The methods are therefore relevant to all flow types.

7.4 Overview and context

These standard methods describe monitoring required for the Basin Scale evaluation of fish breeding in response to Commonwealth environmental water. The methods describe the sampling design and protocol for fish larvae in rivers and wetlands for the LTIM project.

This protocol describes sampling fortnightly from September through to February each year to measure:

- Catch-per-unit-effort (CPUE) of each larval fish species in rivers and wetlands using:
    - Light traps
    - Fixed position drift nets in flowing sites or towed trawl nets in low/no current sites.
- Collection of water quality sample or *in situ* measurement of turbidity.

In addition, there is an optional (category 2) procedure for daily age of larvae (from otoliths), towards estimation of hatch date and growth rates. It should be noted that the standard methods as documented here is to inform Basin scale evaluation of fish. ***It is recognised that the requirements for sampling larval fish have loosened since the first draft of this document and that some Selected Areas are monitoring larval fish only in response to Commonwealth environmental water at a reduced sampling frequency (and intensity) than that documented here.***

7.5 Establishing assessment sites

7.5.1 Equipment

- GPS
- Map of floodplain wetlands in area or zone
- Possibly a boat, depending on access

7.5.2 Protocol

LTIM for Basin-scale evaluation has adopted a hierarchical approach to sample design (see Gawne et al. 2013). The spatial hierarchy for fish (river) monitoring is as follows:

- Selected Area
    - Zone
        - Site

Please refer to LTIM Standard Protocol: Fish (River) and LTIM Standard Protocol: Fish (Wetlands) for more detail on the nested hierarchical approach design adopted for LTIM fish sampling.

Site placement within zones

Larval fish monitoring for Basin-scale analysis will take place at a subset of the same sites specified for (a) monitoring of fishes in the channel (see LTIM Standard Protocol: Fish (River)); (b) monitoring of fishes in wetlands (see LTIM Standard Protocol: Fish (Wetlands)). The rationale underlying this is to seek as much synergy as possible among the three different monitoring components for fishes. Larval fish sampling will occur within a minimum of six sites:

- Three channel sites (also sampled for adult fish)

- Three wetland sites (also sampled for adult fish)

The subset of sites selected will be determined by Monitoring and Evaluation Providers and should be documented in the Monitoring and Evaluation Plan.

Sample placement within sites

Channel

Up to three different larval sampling gears will be used within the three channel sites of the zone targeted for Basin-scale analyses: Light traps, drift nets, and larval tows/trawls. For further detail on why these three methods have been selected, and gear specifications, refer to Section 7.6.

Ten **light traps** should be randomly allocated within each site. The same randomisation approach recommended in LTIM Standard Protocol: Fish (River) should be used, with the following caveat: light traps must be positioned within slackwater. Select the set of 10 random PS waypoints (see LTIM Standard Protocol: Fish (River)), then find the closest slackwater to that waypoint for positioning of light traps. If no slackwater is available within 20m either side of the waypoint select another random waypoint.

Light traps will be used for larval assemblage composition and potentially for relative abundance comparisons/contrasts among areas. Their efficacy is heavily dependent on turbidity, so any comparisons of relative abundance among areas will be dependent on the inter-area differences in turbidity levels.

Larval density is measured using stationary drift nets for higher current areas and towed nets for low current pools.

Three **Drift nets** per site (total of nine per zone, per sampling event) should be positioned in water with a moderate velocity, preferably where the discharge is concentrated through a narrow section of the river (a funnel effect). Ideally, drift nets should not be closer than 100 m to each other.

If a site does not contain suitable water for setting drift nets (too slow, wide, deep, etc.) then a boat should be used for taking **larval trawls**. Three replicate five-minute trawls at approximately ½ m per second should be allocated to each site (nine five-min trawls per area, per sampling event). To ensure samples are independent, the water column in any space must only trawled once (don't 'double-back', contrary to the advice of ZZ Top).

Wetlands

Two different larval sampling gears will be used within the three wetland sites of the zone targeted for Basin-scale analyses: Light traps and larval tows/trawls. For further detail on why these two methods have been selected, and gear specifications, refer to Section 7.6.

Ten **light traps** should be randomly allocated within each of the three wetland sites. The same randomisation approach recommended in LTIM Standard Protocol: Fish (Wetland) should be used; area providers are to devise a randomisation approach appropriate for the wetland.

A boat (or some other device to the same effect) should be used for taking up to three five-minute **larval trawls** at approximately ½ m per second per wetland. Some wetlands may not be large enough to permit three independent samples, so select wetlands that are likely large enough. To ensure samples are independent, any given space of water column must only be trawled once.

7.6 Sampling protocol

7.6.1 Equipment

- Ethics and fisheries permits from relevant institutions;
- Light traps;
- Larval drift nets;
- Boat;
- Data sheets

7.6.2 Protocol

Timing of sampling

At each site, **larval sampling will take place fortnightly from September through to February inclusive** (total of 6 (months) x 2 (weeks per month) = 12 sampling events). These are referred to as the 12 **'sampling events'** below.

Sampling

The sampling procedure is the same for wetlands and channels.

At each site on each sampling event, a water quality sample should be collected and transported to a NATA accredited laboratory for turbidity analysis. Alternatively *in situ* measurements via an appropriately calibrated meter can be recorded.

The same make of **light trap** should be used by all Monitoring and Evaluation Providers, to eliminate sampling bias among areas. Modified quatrefoil light traps should be used with the following dimensions: square top (220 x 220 mm) and height of 170 mm. Mesh should be fitted around the light traps to eliminate larger fish from entering the trap, and eating the sample (3 mm knot-to-knot). The ten light traps set within each of the three sites should be set in the afternoon and retrieved the following morning. Set and retrieval times should be recorded, so that relative abundance can be expressed as catch-per-unit-effort (CPUE). Each light trap should be 'baited' with a yellow Cyalume® 12 h light stick (or equivalent manufacturer, but yellow in colour).

If **drift nets** are appropriate for the site, they should be constructed of 500 µm mesh, have an opening diameter of 50 cm, tapering over 1.5 m to an opening of 9 cm, to which a reducing bottle should be fitted. Positioning of drift nets is explained earlier. Volume through the net should be estimated so that larval abundances in drift nets can be expressed as a density: number of individuals per m^3. Volume sampled by the net is estimated as $\pi r^2 \cdot v \cdot t$, where *r* is radius in metres, *v* is mean velocity in m s^{-1}, and *t* is time set in seconds.

If **larval trawls** are appropriate then larval tow nets should be similar dimensions to the stationary drift nets. Similarly, volume through the net must be estimated using a flow meter attached to the front of the net. Velocity of the boat should be no less than ½ m per second, to avoid fish swimming away from the net. Larval trawls should take place during the night, and abundances should be expressed as number of individuals per cubic metre.

Processing

Entire samples should be preserved individually in 90% ethanol and returned to the laboratory for larval identification and enumeration, as well as, if selected optional otolith removal and daily ageing (see below).

Optional (Category 2 procedure): Otolith removal and analysis

The procedures of otolith removal and examination are now so widely implemented they need little explanation here. We refer service providers to Secor et al. (1992) for a detailed description of principles and methods.

If this optional procedure is implemented, we request daily ageing of target species only (representative species from each of the three life-history guilds; refer to Section 7.6 of LTIM Standard Protocol: Fish (River)). If larvae of the target species for that area are captured during any of the 12 sampling events, the optional procedure is as follows:

- Within any given area, the six target species selected for detailed larval analysis should be the same species selected for detailed juvenile and adult population analysis (see Section 7.6 of LTIM Standard Protocol: Fish (River)).
- Obtain the total (round or square caudal fin; mm) or fork length (forked tail species; mm) of larvae, and ensure daily age estimates are coupled with a corresponding length.
- Within each sampling event provide daily ages of *up to* 30 larvae of *each* of the target species. During certain sampling events such a sample size will, of course, not be available. The same applies to the number of species spawning; larvae of all 6 target species will likely not be available for ageing within each sampling event. It follows that providers will have to estimate daily ages of *a maximum* of 6 (target species) x 30 (individuals per species) = 180 larvae per sampling event;
    - This is a lot of processing, and is likely going to be expensive. Service providers may like to prepare two budgets when preparing their proposals: one that encompasses all 6 target species, and one that encompasses only the 3 fixed target species (one from each guild; refer to Section 7.6 of LTIM Standard Methods – Fish (River)).
- If there are more than 30 individuals in total, across all three sites, for that sampling event, ensure one's sample of 30 is a random sample from the total. Again, we leave the sub-sampling protocol selected to the Monitoring and Evaluation Provider's discretion. The sample of 30 must be random with respect to the size-distribution of the larvae of the target species.
- With respect to the site-specific composition of the 30 individuals, the number of individuals coming from each of the three sites should be approximately proportionate to their abundance distribution across those sites. For example, if during the November sampling event, say, Sites 1, 2 and 3 yield 90, 70 and 20 golden perch respectively (180 in total), then aim for a random sample of 90/180 x 30 = 15 individuals from Site 1, 70/180 x 30 = 12 (approx.) individuals from Site 2, and 3 individuals from Site 3.

7.7 Data analysis and reporting

7.7.1 Turbidity

Turbidity measures should be recorded as mean turbidity per site per sampling event and matched to Light trap abundance data.

7.7.2 Relative abundance estimation

Light-trap abundances should be expressed as 'catch-per-unit-effort' (CPUE), where the units are number of individuals per trap per hour of deployment. Drift and trawl net abundances will be expressed as densities; number of individuals per cubic metre of water filtered (see Section 7.6).

7.7.3 Community data

We require CPUE data at the level of the site (species by site abundance matrices). Abundance data is reported for each species as the mean CPUE for the site. Data should be provided separately for each sampling method:

3. Light-trap channel;
4. Light-trap wetland;
5. Drift net OR larval trawl channel;
6. Drift net OR larval trawl wetland.

7.7.4 Daily age and growth data

Daily ages of larvae should be provided, tagged by their species identity, site of capture, date of capture, and total (round or square caudal fin) or fork (fork tailed) length (nearest mm).

7.7.5 Data management

All data provided for this indicator must conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is: the site (river section or wetland).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

It is strongly recommended that Monitoring and Evaluation Providers make themselves familiar with the data standard requirements for this standard method prior to detailed monitoring program design and implementation.

7.8 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the Monitoring and Evaluation Plan for all Selected Areas. QA/QC activities specific to this protocol include:

- It is the responsibility of the provider to have specific fisheries and ethics permits with them while sampling.

7.9 Health and safety

As with all programs that include field based methods, a Health Safety and Environment Plan (HSEP) must be developed. The HSEP must include an assessment of all identified potential risks and a plan on how these risks will be managed in the field.

7.10 References

Brooks S and Wealands S (2014) Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Data Standard. Report prepared for the Commonwealth Environmental Water Office by The Murray-Darling Freshwater Research Centre, MDFRC Publication 29.3/2013 Revised Jan 2014

Humphries, P., Serafini, L.G., and King, A.J. 2002. River regulation and fish larvae: variation through space and time. Freshw. Biol. 47(7): 1307-1331.

Secor, D.H., Dean, J.M., and Laban, E.H. 1992. Otolith removal and preparation for microstructural examination. *In* Otolith Microstructure Examination and Analysis. *Edited by* D.K. Stevensen and S.E. Campana. Canadian Special Publication in Fisheries and Aquatic Science. 117. pp. 19-57.

LTIM Monitoring – Larval fish light trap data sheet (Channel and Wetland)

Date**:** _____ Selected Area: _____

Zone: _____ Site: _____

Trap #	Time set	Time retrieve	Trap #	Time set	Time retrieve	Trap #	Time set	Time retrieve

LTIM Monitoring – Larval fish drift/trawl data sheet (Channel and Wetland)

Date**:** _____ Selected Area: _____

Zone: _____ Site: _____

Drift/trawl #	Time start/set	Time finish/retrieve	Mean velocity	Drift/trawl #	Time start/set	Time finish/retrieve	Mean velocity

8 Fish (Movement)

8.1 Evaluation questions

Long-term (five-year) question:

- What did Commonwealth environmental water contribute to native fish populations?

Short-term (one-year) questions:

- What did Commonwealth environmental water contribute to native fish dispersal?

The process for evaluating these questions is illustrated in Figure 16, with components covered by this protocol highlighted in blue.

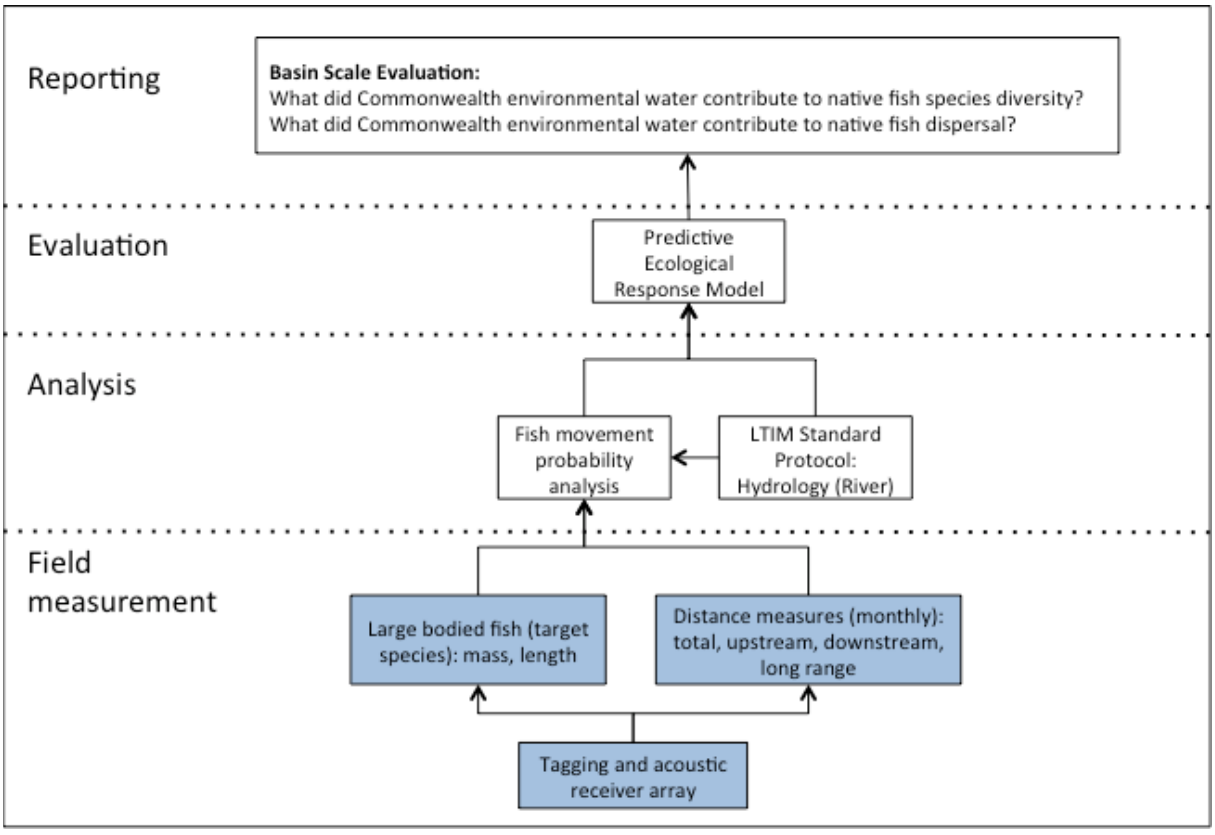

Figure 16: Schematic of key elements in LTIM Standard Protocol: Fish (Movement).

8.2 Relevant ecosystem types

Rivers and wetlands.

8.3 Relevant flow types

The methods are relevant to all flow types.

8.4 Overview and context

These standard methods describe monitoring required for the Basin Scale evaluation of the response of river fish to Commonwealth environmental water. The methods describe the sampling design and protocol for small- and large-bodied fishes in river channels for the LTIM project.

This protocol describes equipment specifications and implantation procedures to measure:

- Dispersal rates and directions of target equilibrium and periodic life-history fishes

8.5 Establishing sites

8.5.1 Equipment

- Boat
- GPS

8.5.2 Protocol

LTIM for Basin-scale evaluation has adopted a hierarchical approach to sample design. The spatial hierarchy for fish (movement) monitoring is as follows:

- Selected Area
    - Zone
        - Site

Zone placement within Selected Areas

A 'zone' is a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. For example, separate river systems, sub-catchments or large groups of wetlands.

For Basin-scale evaluation, M&E Advisors require selection of one or more zones for monitoring of fish in rivers channels as follows:

- Different zones within Selected Areas represent spatially-, geomorphologically- and/or hydrologically-distinct units;
- Zones must be likely to receive Commonwealth environmental water at least once in the next five years;
- Zones must have an expected outcome related to the indicator in question (in this instance fish);

The zone selected for monitoring fish movement response to flows should be the same one selected for monitoring fish population and community structure for Basin-scale modelling data (see LTIM Standard Protocol: Fish (River)). In this way we may achieve synergies amongst different forms of fish data collected.

Receiver design / placement within zones

We do not specify here how individual service providers setup their arrays, or design their specific telemetry studies. Many service providers already have hydro-acoustic arrays in place. Instead, we merely establish some general requirements for data that would improve our ability to model population dynamics across spatial scales:

- Receivers should span the length of channel defined by the ten sites established as part of the population/community monitoring; these are placed within a 100 km segment (see LTIM Standard Protocol: Fish (River));
- It would be useful to detect movements on scales from 1 km to 100 km. This may necessitate a moderate density of receivers as well as total distance spanned.
- GPS coordinates of receiver locations will need to be recorded.

8.6 Representative species from life-history guilds

8.6.1 Overview

Fishes belonging to different life history guilds may respond in different ways to managed and natural flows. Towards a more complete knowledge of fish population response to flows, monitoring will target representatives of the three primary life history guilds: equilibrium, periodic and opportunistic.

8.6.2 Protocol

Within each Selected Area we request providers identify **six target species, two from each guild**. Within each guild, one of the two species will be fixed, and common to all Selected Areas (as much as practicable), while the identity of the other species will be flexible across Selected Areas.

Across all Selected Areas the equilibrium life history species targeted for detailed data collection will be **Murray cod**. The second equilibrium species should be selected on the basis of how well it is represented within a Selected Area (is there a reasonable chance of obtaining quality data?), as well as conservation concern. Examples include freshwater catfish and river blackfish.

Across all Selected Areas the periodic life-history species targeted will be **golden perch**. The basis for selection of a second, Selected Area-specific periodic species is similar to that outlined above for equilibrium species. Examples include silver perch and bony herring.

Across all Selected Areas the opportunistic life-history species targeted will be **carp gudgeon**, *Hypseleotris* spp. Several options exist for selection of a second opportunistic species within Selected Areas: smelt, Murray rainbowfish, fly-specked hardyhead, and *Ambassis* spp., for example.

8.7 Sampling protocol

8.7.1 Equipment

- For reliability as well as consistency with current projects (Murrumbidgee, Gwydir, Edward-Wakool and Goulburn) we recommend use of Vemco (http://vemco.com/) VR2W acoustic monitoring receivers operating on 69 kHz;
- Vemco tags should also be used. Other 'compatible' tags are available on the market but cannot guarantee unique tag numbers. Duplicate tag numbers need to be avoided. The best way to standardise this is to use the same vendor;
- Tag size may vary with target species within a selected area whilst maintaining the 2% of body weight rule. M&E Providers should seek to maximise tag life while considering transmission delays to reduce code collision. Some points to note here:
    - Tag size is governed by battery size; larger tags = a larger battery = a longer tag life;
    - Tags with a 5 year life can be purchased but only implanted into large fish;

- Tags transmit on a random delay. The delay is determined at the time of purchase and influences two things:
    - The chances of code collision. More tags in a location at any given time requires a longer transmission delay to reduce the risk of tags transmitting at the same time and collision of transmission codes (i.e. 2 tags transmitting at the same time in the same location will usually result in no detections)
    - Tag life. Longer delays = longer tag life. BUT increase the chance a fish can swim past a receiver and not be detected as receivers are passive and only detect tags when tags transmit.
- Current Murrumbidgee and Edward-Wakool projects use Vemco model V9 tags (http://vemco.com/products/v7-to-v16-69khz/) on an average 90 delay (i.e. transmission occurs randomly between 50 and 130 seconds) for small fish (tag weight 3.6 g, battery life ~225 days) and V13 tags on an average 90 second delay for larger fish (tag weight 11g, battery life ~885 days)

8.7.2 Protocol

Which individuals to tag?

Species tagged for movement study should be the same as those targeted for detailed population data. A minimum of either golden perch or Murray cod should be targeted, preferably both. The modelling team cannot support tagging of other species instead of these two species, as one of the major objectives for CEWOs purposes is to obtain a better quantitative understanding of population dynamics of these two species. That is, other species can be tagged in addition to these two species, but not in place of these two species.

A minimum sample size of n=30 individuals per selected species is required, and we request adequate representation of size ranges within each species. As a very rough guide, 1/3 of the individuals tagged should be juvenile, with the remainder spread across a broad range of adult sizes.

Note: Size restrictions are typically limited by tag size with 2% of tag weight to body weight a rule of thumb. Realistically this could go as high 4% although consideration should be given to body cavity space and the fact that tag burden influences buoyancy. Large tags will therefore affect behaviour. With recommended tag sizes (*see* Telemetry equipment) to maximise operating life an approximate minimum size of 200 mm TL is achievable for periodic and equilibrium species. Smaller tags could be used but would result in a reduced battery life.

Implantation

- Transmitter implantation should be standardised among M&E providers.
- Telemetry tagging should be conducted between March and August to avoid high water temperatures and reproductive events. Fish with advanced gonad development have little room in the coelomic cavity to accommodate a tag. Tagging at this time increases the chance of suture rupture and tag loss.
- Fish should be immediately tagged on-site following recovery from capture.
- All transmitters will be surgically implanted into the coelomic cavity whilst fish are under anaesthesia. Dose rates of anaesthesia will comply animal ethics approval.
- Anaesthesia will be achieved using through submersion of fish in an induction bath of either benzocaine or Aqui-S (http://www.aqui-s.com/). **Note**: An issue with human consumption of fish

following anaesthesia in benzocaine. A withholding period is necessary. It may be necessary for all M&E Providers to use Aqui-S. M&E Providers must demonstrate that the type of anaesthesia and surgical techniques has animal ethics approval.

- Stage 4 anaesthesia, characterised by total loss of equilibrium and no reaction to handling, is typically the stage required for surgical procedures on fish (Summerfelt & Smith 1990).
- Relevant total length (TL: mm) and fork length (FL: mm) as well as mass (g) will be recorded
- Fish exhibiting visible signs of disease, injuries and deformities are to be excluded from tagging.
- Surgery will take place in a V-shaped cradle and fish are to have water continually pumped over the gills (containing a reduced concentration of anaesthetic where necessary).
- Mid-ventral incisions of 20–30 mm will be made through the body wall of the fish posterior to the pelvic girdle and anterior of the anal vent.
- Every possible effort should be made to sex the fish is to be determined by examining the gonads through the incision prior to transmitter insertion or by collecting a fin clip to retrospectively assign sex. It will be important for later interpretation of data and identifying possible reproductive behaviour during flow events.
- Use of antibiotics and disinfection of tags and surgical equipment should be a standard practice used by M&E Providers.
- Incisions are to be closed using 2–3 interrupted monofilament absorbable sutures (Ethicon PDS II sutures: http://www.ecatalog.ethicon.com/sutures-absorbable/view/pds-ii-suture) using multiple surgeons knots.
- A single surgeon should be used for each selected area where possible, or record kept if multiple surgeons.
- Fish are to be fitted with external, individually numbered dart tags in the dorsal musculature to aid angler identification and facilitate tag returns which is important to understand fate of the fish if it is detected in the future.
- Post-surgery fish should be recovered on-site and released within 24 hours of capture/surgery at the point of capture.

8.8 Data analysis and reporting

8.8.1 Receiver download schedule

- Acoustic receivers are to be downloaded quarterly to reduce the possible risk of lost/stolen receivers.
- Data should be filtered to remove single detections (Clements et al. 2005), false detections and orphan tags.
- M&E Providers are responsible for the appropriate storage and management of raw data files.

8.8.2 Data outputs

- We recommend use of the freeware V-Track (Campbell et al. 2012; http://www.uq.edu.au/eco-lab/v-track) add on for R to generate movement metrics.
- A receiver distance matrix can be generated separately to account for river sinuosity and added into R. An example is given here (leading row and column specify receiver number, while body of matrix specifies distance between receivers):

DM	1	2	3	4	5
1	0	2.3	3.8	6.2	9.1
2	2.3	0	1.5	3.9	6.8
3	3.8	1.5	0	2.4	5.3
4	6.2	3.9	2.4	0	2.9
5	9.1	6.8	5.3	2.9	0

- Temporal resolution of position collection should be weekly.

Individual fish metrics

With respect to population modelling, the following are requested:

- Total longitudinal distance (TD) moved, stratified by month:
    - This is the sum of all distances (upstream and downstream) covered by an individual, within a receiver array.
    - We request these monthly statistics for each individual, so that we can establish a TD probability distribution as a function of month, species and (approximate) age-class or stage-class.
- Total longitudinal distance (TDU) moved upstream, stratified by month:
    - This is the sum of all distances moved upstream made by an individual, within a receiver array.
    - We request these monthly statistics for each individual, so that we can establish a TDU probability distribution as a function of month, species and (approximate) age-class or stage-class.
- Total longitudinal distance (TDD) moved downstream, stratified by month:
    - This is the sum of all distances moved downstream made by an individual, within a receiver array.
    - We request these monthly statistics for each individual, so that we can establish a TDD probability distribution as a function of month, species and (approximate) age-class or stage-class.
- Net longitudinal displacement (NLD) downstream, stratified by month:
    - TDD – TDU (can be < 0).
    - We request these monthly statistics for each individual, so that we can establish an NLD probability distribution as a function of month, species and (approximate) age-class or stage-class.
- Longitudinal range (LR), stratified by month:
    - The farthest upstream location minus the farthest downstream location, within a receiver array.
    - We request these monthly statistics for each individual, so that we can establish an LR probability distribution as a function of month, species and (approximate) age-class or stage-class.

8.8.3 Data management

All data provided for this indicator must conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is: the site (river section).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

It is strongly recommended that Monitoring and Evaluation Providers make themselves familiar with the data standard requirements for this standard method prior to detailed monitoring program design and implementation.

8.9 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the Monitoring and Evaluation Plan for all Selected Areas. QA/QC activities specific to this protocol include:

- Electrofishers must be experienced operators of units. They should be supervised by Senior Operators on-site, and have obtained their electrofishing certificates through a reputable course.
- Monitoring and Evaluation Providers must have relevant boat licenses.
- It is the responsibility of the Monitoring and Evaluation Providers to have specific fisheries and ethics permits with them while sampling.
- Monitoring and Evaluation Providers must also have experience with appropriate PIT implantation procedures.
- Fyke nets should be checked for holes in either wing- or cod-ends prior to every field trip. Any net with a hole should be repaired or replaced.
- Minnow traps should have functional zips and not contain holes. Traps with zips that do not fully close or traps that contain holes should be repaired or replaced prior to the sampling of each site.

8.10 Health and safety

As with all programs that include field based methods, a Health Safety and Environment Plan (HSEP) must be developed. The HSEP must include an assessment of all identified potential risks and a plan on how these risks will be managed in the file

8.11 References

Brooks S and Wealands S (2014) Commonwealth Environmental Water Office Long Term Intervention Monitoring Project: Data Standard. Report prepared for the Commonwealth Environmental Water Office by The Murray-Darling Freshwater Research Centre, MDFRC Publication 29.3/2013 Revised Jan 2014.

Campbell, H. A., Watts, M. E., Dwyer, R. G., & Franklin, C. E. (2012). V-Track: software for analysing and visualising animal movement from acoustic telemetry detections. Marine and Freshwater Research, 63(9), 815-820.

Clements, S., Jepsen, D., Karnowski, M., & Schreck, C. B. (2005). Optimization of an acoustic telemetry array for detecting transmitter-implanted fish. North American Journal of Fisheries Management, 25(2), 429-436.

Summerfelt, R. C., & L. S. Smith. (1990). Anesthesia, surgery and related techniques. Pages 213–272 *In* C. B. Schreck and P. B. Moyle, (eds.) Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

9 Waterbird Breeding

9.1 Evaluation questions

This monitoring protocol addresses the following Basin-scale evaluation questions:

- **Long-term (five-year) question:**
  - What did Commonwealth environmental water contribute to waterbird populations?
- **Short-term (one-year) and long-term (five year) questions:**
  - What did Commonwealth environmental water contribute to waterbird breeding?
  - What did Commonwealth environmental water contribute to waterbird chick fledging?
  - What did Commonwealth environmental water contribute to waterbird survival?

The process for evaluating these questions is illustrated in Figure 17, with components covered by this protocol highlighted in blue.

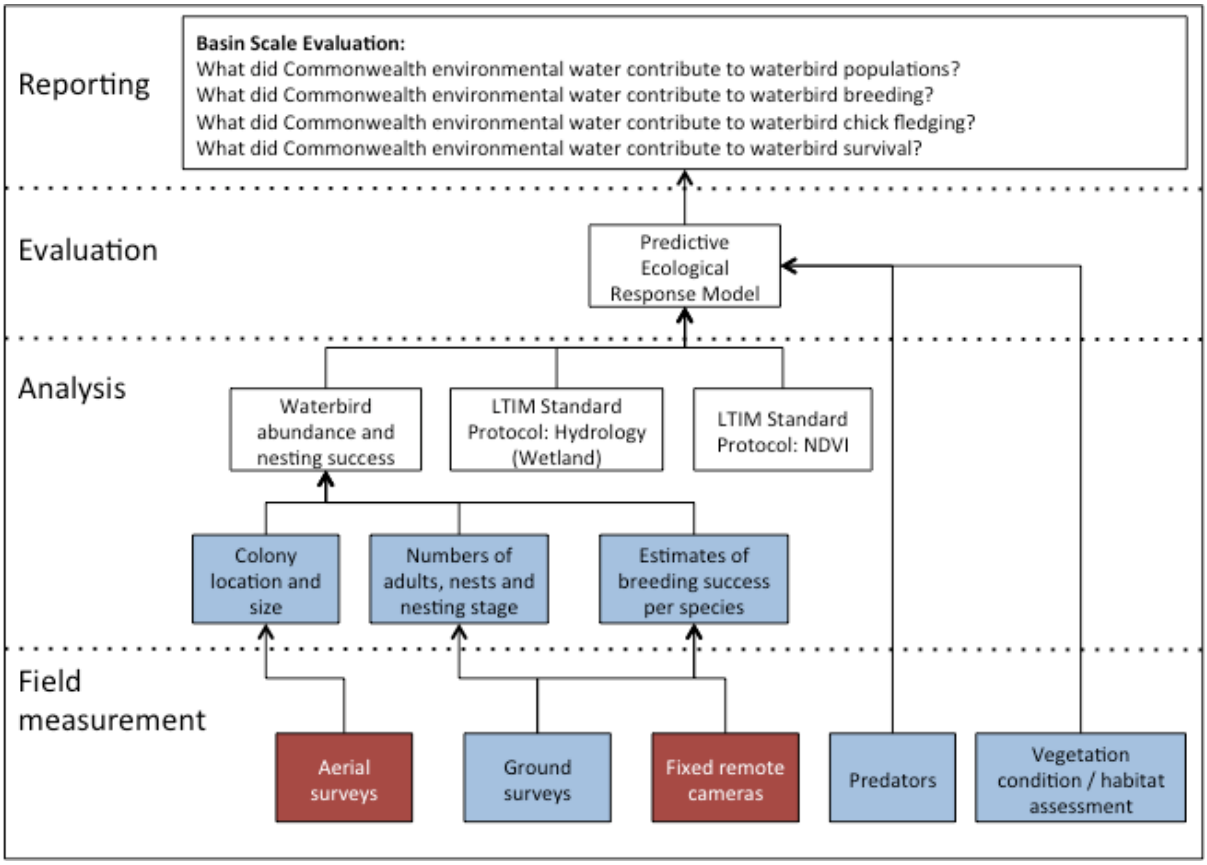

Figure 17: Schematic of key elements in LTIM Standard Protocol: Waterbird Breeding.

9.2 Relevant ecosystem types

Wetlands and floodplains.

9.3 Relevant flow types

Freshes, bankfull, overbank (infrastructure assisted)

9.4 Overview and context

This protocol describes event based monitoring to detect the effect of Commonwealth environmental water on breeding of colonial nesting waterbirds. In recognition of the wide variety of wetlands in the Basin, this is a flexible protocol that provides a range of options for monitoring, including: aerial surveys, ground surveys and fixed remote cameras. Site appropriate methods are to be developed for specific Selected Areas. However, to inform Basin scale evaluation they must meet the minimum requirements detailed below with respect to:

- Site establishment
- Frequency of ground surveys
- Field measures
- Reporting of results

The measurements for this protocol comprise:

1. Waterbird breeding measures (monthly over the duration of a breeding event):
    - Identity of species breeding
    - Number of adults
    - Number of nests
    - Number of nests in stages: eggs, early stage nestling (< 2 weeks old); later stage nestling (2 – 5 weeks old)
    - Fledgling estimate
2. Covariates
    - Vegetation type and condition
    - Number of nests in each vegetation / habitat type
    - Predators

Key references used in the development of this protocol include the Living Murray (TLM) program (e.g. MDFRC 2011); *Guidance on waterbird monitoring methodology: Field Protocol for waterbird counting* (Wetlands International 2010) and methods from the *National Waterbird Assessment* (Kingsford et al. 2012).

9.5 Complementary monitoring and data

The field measures required for the assessment of waterbird breeding are specific to this protocol. However, existing breeding information for each Selected Area should be used in the first instance to aid in identifying potential monitoring locations (sites).

In addition diversity data for non-breeding birds should be opportunistically collected during waterbird breeding surveys. See the LTIM Standard Protocol: Waterbird Diversity.

9.6 Sites, survey types and timing

9.6.1 Establishing sites

As this is an event based monitoring program, sampling locations and times are determined by the use or planned use of Commonwealth environmental water, and the likelihood of colonial nesting species establishing at a site that could receive Commonwealth environmental water. Species included in this protocol are:

- Ibis
- Egrets
- Herons
- Cormorants, Darter
- Pelicans
- Spoonbills
- Magpie geese

Potential monitoring sites can be identified through aerial reconnaissance flights, stakeholder consultation or visual observations.

Sites may be a single large wetland or a complex of wetlands and given the variability in wetlands targeted for watering, it is not possible to be prescriptive about the selection of sites. Site selection is therefore at the discretion of Monitoring and Evaluation Providers. Consideration may be given to choosing sites with known bathymetry (or DEM) and water level recording infrastructure (otherwise a bathymetric survey, DEM and installation of water level recorders will be required, see LTIM Standard Protocol: Hydrology (Wetland)).

For Basin-scale evaluation, data is reported on an assessment unit defined by a colony of nesting waterbirds. Colonies are defined as a single location supporting breeding birds located close enough in distance to interact socially; i.e. a clear aggregation of nesting waterbirds in the landscape. Therefore a site may comprise multiple assessment units (colonies) within a single wetland or wetland complex.

9.6.2 Survey type and timing

There are three methods for surveying waterbird breeding:

1. Aerial surveys via a fixed wing aeroplane, helicopter or drone - optional
2. Ground surveys – required
3. Fixed cameras – optional, but highly desirable

The choice of survey selected is based on the size of the site, access and potential for disturbance. Surveys commence once a site has been identified and a trigger such as water level, bird breeding or local knowledge indicate that colonial breeding is likely to commence. At large sites aerial surveys may be required to identify breeding sites, delineate colony boundaries and provide estimates of colony sizes. Ground surveys are repeated at four week intervals until most young have fledged (or nests have failed), with a shorter interval between surveys at the final stages of nesting. Where possible, fixed camera stations should be considered to capture estimates of fledged chicks from a sample of nests, as this technique should minimise disturbance of birds. Details of the sample design and survey type(s) for each Selected Area must be documented in Monitoring and Evaluation Plans.

9.7 Aerial surveys (reconnaissance, delineating colony boundaries)

9.7.1 Reconnaissance flights

Aerial surveys can be undertaken to assist in identification of breeding occurrences and breeding success during watering or flooding events. In the first instance, these will be reconnaissance surveys and rely heavily on information compiled regarding nesting locations within the Selected Area prior to the first flight, under the premise that colonial nesting waterbirds are generally faithful to previously

used sites. If reconnaissance flights capture early breeding stages, consideration should be given to a second aerial survey 4 – 6 weeks later to identify potential additional colonies.

9.7.2 Aerial counting techniques

Prior to deploying to the field, flight paths must be established. These should be designed to most effectively capture all major breeding colonies (> 150 nests) within a site. There are a variety of techniques, dependent on the size and shape of the site and the distribution of colonies (Figure 18).

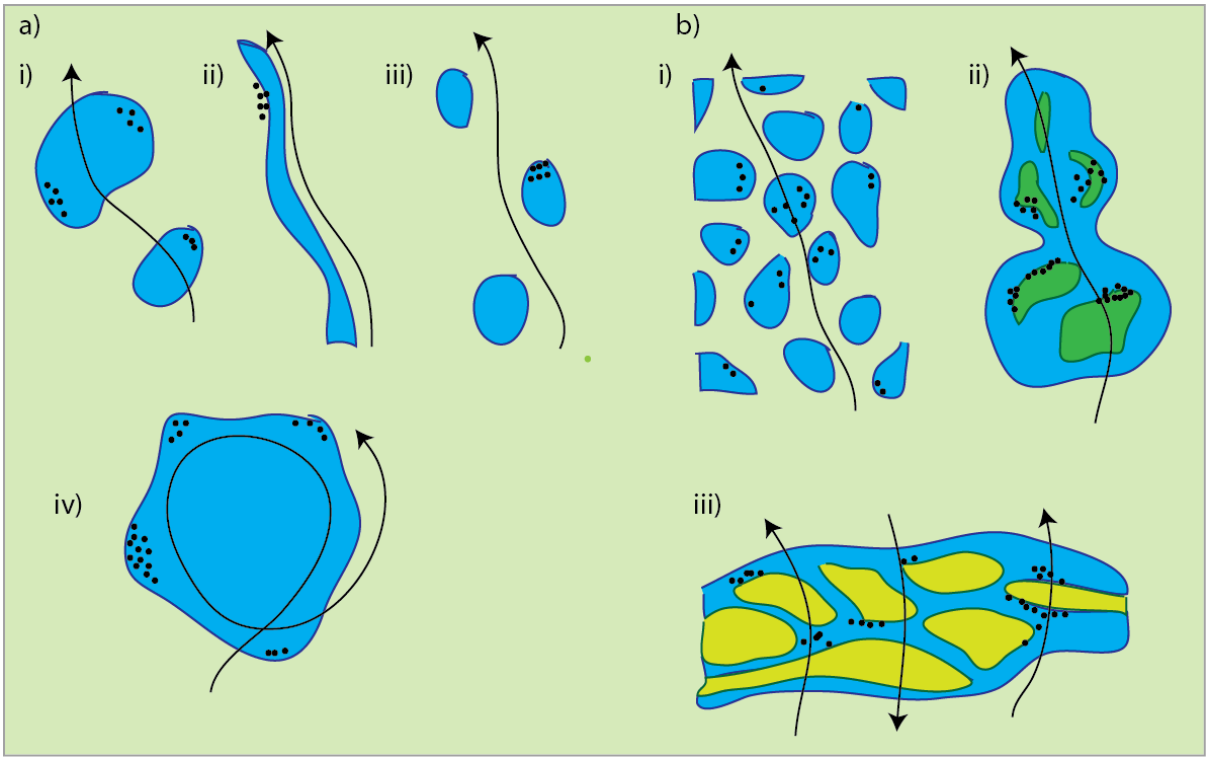

Figure 18: Illustration of aerial counting options for assessing nesting colonies (modified from Braithwaite et al. 1986). a) total counts where an assessment is obtained for the total nesting colonies (indicated by the dots) on, for example i) discrete waterbodies of less than about 50 ha; ii) a river channel; iii) small impoundment; iv) large lake or impoundment with nesting predominantly along shorelines. b). Transect counts with counting limited to nests within a band at ground level of 100m either side of the aircraft; i) on a landscape dotted with wetlands, each usually of less than 1 ha of surface water; ii) a floodplain with inter-dispersed water and land; iii) a braided river channel.

This protocol requires a minimum of two observers (in addition to the pilot) in the plane. The observers on each side of the plane estimate numbers of waterbirds on their side of the aircraft, recording the information on small tape recorders for later transcription (Kingsford et al. 2012). Care must be taken to ensure that nesting birds are not distressed leading to abandonment of nests.

The location (as a point or a polygon) of each colony must be recorded together with:

- Species composition
- Estimates of the number of active nests
- Breeding stage – i.e. eggs/chicks/ runners present?
- Colony boundary

- Nesting vegetation type

Observers (two for each flight) should independently identify and record species abundances and numbers of nests and broods. Where no birds, nests or broods are observed, a zero count is to be recorded (Kingsford et al. 2012).

Where the species of waterbird cannot be determined with confidence, record as categories: spoonbills, egrets, cormorants ('pied', or 'black'), ibis, and 'white birds' (egrets and spoonbills), and be as specific as possible, e.g. 'unidentified breeding egrets (40 nests), seemed large' (which implies they were probably Eastern Great Egret).

9.8 On-ground surveys

9.8.1 Equipment: Identification guides

A good field guide must be taken on all field trips. Most waterbirds are quite conspicuous and, with notable exceptions, straightforward to identify in good conditions if care is taken. The most frequently encountered problem is identifying birds at long range in the extensive and flat terrain preferred by most congregatory waterbirds. This is when the additional power of a telescope is needed, but at some sites, a certain proportion of the birds will often remain unidentified because they are too distant to see properly (Wetlands International 2010), and because some colonial nesting species tend to 'hide' their nests in screening foliage, e.g. Nankeen Night Heron and Glossy Ibis.

The recommended field guides are: Simpson and Day (2010 - 8th edition), Slater et al. (2009), Morecombe (2003)and Pizzey and Knight (2007).

9.8.2 Equipment: Field survey

- Compass
- Camera (35 mm format camera -SLR or dSLR - with 50–150 mm zoom lens, automatic exposure, auto wind-on, or digital equivalent)
- Watch
- Maps of Selected Area including assessment site information
- 2B pencils, sharpener and eraser
- Hand held tally counter
- Appropriate field identification guide (see above)
- Binoculars or Telescope (for on-ground surveys/validation – see below)
- Field note book or datasheets and/or field computer
- Appropriate field clothing/safety gear – first aid kit, hat, sunblock etc

9.8.3 Breeding surveys

Once breeding colonies have been identified (see above), monitoring will occur every four weeks to obtain a measure of overall breeding success. These may be entirely on-ground (by boat or foot), or in the case of large / inaccessible colonies, aerial surveys with on-ground validation. Ground surveys will continue until fledglings leave the nest.

For small colonies and wetlands a census (i.e. complete count) should be undertaken by foot or boat. For larger sites, a sampling approach may be adopted where a proportion of the site is surveyed on ground and estimates made for the entire site.

At each colony the following is recorded:

- Position of the colony (as a polygon)
- Number of nests of each colonial nesting waterbird species in each vegetation species in the following categories:
    - River red gum
    - Black box
    - Coolibah
    - River cooba
    - Paperbark
    - Other tree
    - Lignum
    - Other shrub
    - Saltmarsh
    - Tall emergent aquatic (reeds, phragmities, typha, etc.)
    - Aquatic sedge/grass/forb
    - Dead trees.
- Number of nests in breeding stage categories:
    - Eggs
    - Early stage nestling (< two weeks old)
    - Late stage nestling (2 – 5 weeks old, whether in nests or crèched outside)

  Number of adults present in a colony
- Dominant vegetation type and condition score (at the commencement of breeding - first survey only - see 1.8.5 below)
- Observations of predators

Consideration must be given to minimising disturbance of nesting birds. Surveys should be conducted for < 2 hours at a colony site and preference given to early morning. Measures taken to minimise disturbance should be documented in Monitoring and Evaluation Plans.

9.8.4 Fixed camera (optional)

In order to minimise disturbance of birds and gain greater confidence in data, the use of fixed cameras to monitor a sample of nests within a colony is highly recommended (see Brandis et al. in press). The procedure is flexible with respect to the type of camera and frequency of image capture but must meet the following minimum requirements:

- Minimum of ten cameras within a colony
- Cameras positioned to capture multiple nests
- Placement of cameras at the egg stage
- Replicate photos at a minimum of hourly for daylight hours
- Resulting photos visually assessed to determine:
    - Number of nests in breeding stage categories:
        - Eggs
        - Early stage nestling (< two weeks old)
        - Late stage nestling (2 – 5 weeks old)
    - Number of nests successfully fledged

Note that data collected from cameras must be scaled up to the colony for entry into the data management system (see section 9.10).

9.8.5 Covariates

Vegetation type and condition

The dominant vegetation type of the colony to be identified using the interim ANAE typology developed for the MDB (see (Brooks et al. 2013), and includes the following:

- Open water (no vegetation)
- River red gum forest
- River red gum woodland
- Black box forest
- Black box woodland
- Coolibah
- Standing dead trees
- River cooba
- Paperbark
- Lignum
- Other shrub
- Saltmarsh
- Tall emergent aquatic (reeds, phragmities, Typha, cumbungi etc)
- Aquatic sedge/grass/forb
- Freshwater grasses
- Freshwater forb

Each breeding colony must have the corresponding dominant vegetation class and condition score recorded during the first nesting survey. This is a qualitative ranking and is summarised in Table 6

Table 6: Vegetation condition ranks for colonial nesting locations. Use only for live vegetation, not for species which prefer to nest in dead trees.

Rank	Description
Good	Vegetation structure in dominant layer healthy, good cover (>70%) with virtually no weeds evident. No obvious indication of altered processes which may affect vegetation condition.
Moderate	50-70% cover in dominant vegetation layer, some areas of dead branches present, or limited evidence of disease (i.e. die back), shrub layer more sparse, less connected and somewhat patchy. Some evidence of weeds and or indication of altered processes
Poor	Significant loss, <30%, of cover in dominant vegetation type, considerable amount of weeds, large number of dead branches, crown highly patchy. Stands of vegetation patchy and disconnected, considerable or obvious evidence of altered processes (i.e. drowned stumps).

Predators and Reasons for Nest Desertion/Failure

Known predators at colonies are humans, dingos (wild dogs), foxes, cats, Australian raven, swamp harrier and wedge-tailed eagle. Any evidence or observation of nest contents or adult bird predation by these or other species should be recorded. Also, mass nest desertion can occur if water levels drop

suddenly around the nests or if the ground below the nest dries out (or if islands become connected to the main shore, for ground-nesting species), and these events and the likely triggers for desertion/nesting abandonment should be recorded.

9.9 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the Monitoring and Evaluation Plan for all Selected Areas. QA/QC requirements specific to this protocol, which should be captured in the Quality plan are described briefly below.

All Waterbird Breeding assessments within a Selected Area, where possible, should be undertaken by the same experienced observers to maintain consistency over time. All observers must undergo training prior to undertaking monitoring surveys, including calibration against experienced observers to ensure standardisation of measurements. Training and calibration procedures must be documented in the MEP and relevant records maintained.

Identification of difficult to see species will often differ between observers. To minimise the variance associated with different observers, a minimum of two staff are assigned to Waterbird Breeding assessments, particularly when aerial methods are used. Where there are significant differences in original observer scores, observers will discuss their rationale and where appropriate adjust scores to mutually agreed values. For aerial surveys this should be done immediately after flights to get agreement on species identifications.

9.10 Data analysis and reporting

9.10.1 Waterbird breeding data

The variables required to be reported for each colony for each survey are:

- Location (polygon of the colony)
- ANAE Wetlandid
- Size of wetland surrounding colony (ha)
- Number of nests of each species per vegetation type / structural habitat
- Number of nests in each nesting stage for each species
- Estimate of number of nests successfully fledged for each species (i.e. one or more chicks fledged per nest) since last survey
- Estimate of the mean number of chicks thought to have fledged per successful nest for each species, where possible (for nests fledged since last survey)
- Number of adults of each species
- Vegetation type, condition scores
- Observations of colony level disturbance (e.g. predators, other disturbance agents, or probable causes of colony desertion)

9.10.2 Data management

All data provided for this indicator must conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is: the colony.

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

It is strongly recommended that Monitoring and Evaluation Providers make themselves familiar with the data standard requirements for this standard method prior to detailed monitoring program design and implementation.

9.11 Health and safety

As with all programs that include field based methods, a Health Safety and Environment Plan (HSEP) must be developed. The HSEP must include an assessment of all identified potential risks and a plan on how these risks will be managed in the field.

9.11.1 References

Braithwaite, L.W., Maher, M., Briggs, S.V., and Parker, B.S. 1986. An Aerial Survey of Three Game Species of Waterfowl (Family Anatidae) Populations in Eastern Australia. Australian Wildlife Research **13**: 213–223.

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Simpson, K., and Day, N. 2010. Field guide to the birds of Australia. *In* 8th ed. Penguin, Camberwell, Vic.

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9.12 Waterbird species and codes

Census of Australian Vertebrate Species (CVAS) codes sourced from
http://www.environment.gov.au/biodiversity/abrs/online-resources/fauna/afd/search/biocode

Term	Definition
Colonial breeding waterbirds (based on Jaensch 2002)	***Target species*** CAVS: 0106: Australian pelican *Pelecanus conspicillatus* CAVS: 0179: Australian white ibis *Threskiornis molucca* CAVS: 0203: Black swan *Cygnus atratus* CAVS: 0977: Cattle Egret *Ardea ibis* CAVS 8731: Darter *Anhinga novaehollandiae** CAVS 8712: Eastern Great Egret *Ardea modesta* CAVS 0187: Glossy ibis *Plegadis falcinellus* CAVS 0096: Great cormorant *Phalacrocorax carbo* CAVS 0186: Intermediate Egret *Ardea intermedia* CAVS 0097: Little Black Cormorant *Phalacrocorax sulcirostris* CAVS 0185: Little Egret *Egretta garzetta* CAVS 0100: Little Pied Cormorant *Microcarbo melanoleucos* CAVS 0192: Nankeen Night Heron *Nycticorax caledonicus* CAVS 0099: Pied cormorant *Phalacrocorax varius* CAVS 0181: Royal spoonbill *Platalea regia* CAVS 0180: Straw-necked ibis *Threskiornis spinicollis* CAVS 0069: White-necked heron *Ardea pacifica** CAVS 0182: Yellow-billed spoonbill *Platalea flavipes** [* NB these species often nest 'singly' away from colonies] ***Other non-target colonial species*** CAVS 0060: Great crested grebe *Podiceps cristatus* CAVS 0062: Hoary-headed grebe *Poliocephalus poliocephalus* CAVS 0059: Eurasian coot *Fulica atra* CAVS 0146: Black-winged stilt *Himantopus himantopus* CAVS 0147: Banded stilt *Cladorhynchus leucocephalus* CAVS 0148: Red-necked avocet *Recurvirostra novaehollandiae* CAVS 0125: Silver gull *Chroicocephalus novaehollandiae* CAVS 0111: Gull-billed term *Gelochelidon nilotica* CAVS 0112: Caspian tern *Hydroprogne caspia* CAVS 0110: Whiskered tern *Chlidonias hybrida*
Waterbirds (from DSE 2009)	Anatidae (swans, geese, ducks) Podicipedidae (grebes) Anhingidae (darters) Phalacrocoracidae (cormorants) Pelecanidae (pelicans) Ardeidae (herons, egrets, night herons, bitterns) Threskiornithidae (ibises, spoonbills) Accipitridae (hawks, harriers) not included in aerial surveys Rallidae (crakes, rails, gallinules) Scolopacidae (snipe, godwits, curlews, sandpipers, stints, phalaropes) Recurvirostridae (stilts, avocets) Charadriidae (plovers, dotterels, lapwings) Laridae (gulls, terns) Alcedinidae (azure kingfisher), and Slyviidae (old world warblers)

Example waterbird breeding field sheet

WATERBIRD BREEDING FIELD SHEET: Page ---------- of ----------					
Site name			**Total site wetland area (ha)**		
Date:			**Name of Recorder:**		
Survey start time:			**Survey end time:**		
WetlandID:		**WetlandID:**		**WetlandID:**	
WetlandID:		**WetlandID:**		**WetlandID:**	
WetlandID:		**WetlandID:**		**WetlandID:**	
Stream ID:		**Stream ID:**		**Stream ID:**	
Observer 1:			**Observer 2:**		
Approach type:	**A.** Aerial observer **B.** On-ground observer			**% of wetland of site/wetland wet……..%**	
Count method:	1. Total count 2. Proportion			**Proportion surveyed**:…….%	
GPS co-ordinates and/or tracks for site/sub-sampled area boundaries and survey route/location Attach a mud map as required:					
Survey area (ha):					
Notes: e.g. number of colonies, mixed species colonies, etc					

WATERBIRD BREEDING FIELD SHEET: Page ---------- of ----------			
Site name		**Total site wetland area (ha)**	
Date:		**Name of Recorder:**	

Key: Vegetation codes (dominant vegetation used in nesting):

River red gum forest = RRGf; River red gum woodland = RRGw; Black box forest = BBf; Black box woodland = BBw; Coolibah = Cool; River cooba = RCb; Paperbark = Pb; Lignum = Lig; Other shrub = OS; Saltmarsh = SM; Tall emergent aquatic (reeds, phragmities, Typha, cumbungi etc) = TEA; Aquatic sedge/grass/forb = AqSGF; Freshwater grasses = FGr; Freshwater forb = FFb

Dominant vegetation code and area of colony (% and ha):

Vegetation condition (first nesting survey only):

Assign ranking of Good, Moderate or Poor to each dominant vegetation type in which colonial nesting is occurring.

Comments:

Species	Number of nests	Number of adults	Number of live young per successful nest	Number of fledging per nest	Vegetation condition rank

WATERBIRD BREEDING FIELD SHEET: Page ---------- of ----------					
Site name			**Total site wetland area (ha)**		
Date:			**Name of Recorder:**		

10 Waterbird Diversity

10.1 Evaluation questions

This monitoring protocol addresses the following Basin-scale evaluation questions:

- **Long-term (five-year) question:**
  - What did Commonwealth environmental water contribute to waterbird populations?
  - What did Commonwealth environmental water contribute to waterbird species diversity?
- **Short-term (one-year) and long-term (five year) questions:**
  - What did Commonwealth environmental water contribute to waterbird survival?

The process for evaluating these questions is illustrated in Figure 19, with components covered by this protocol highlighted in blue.

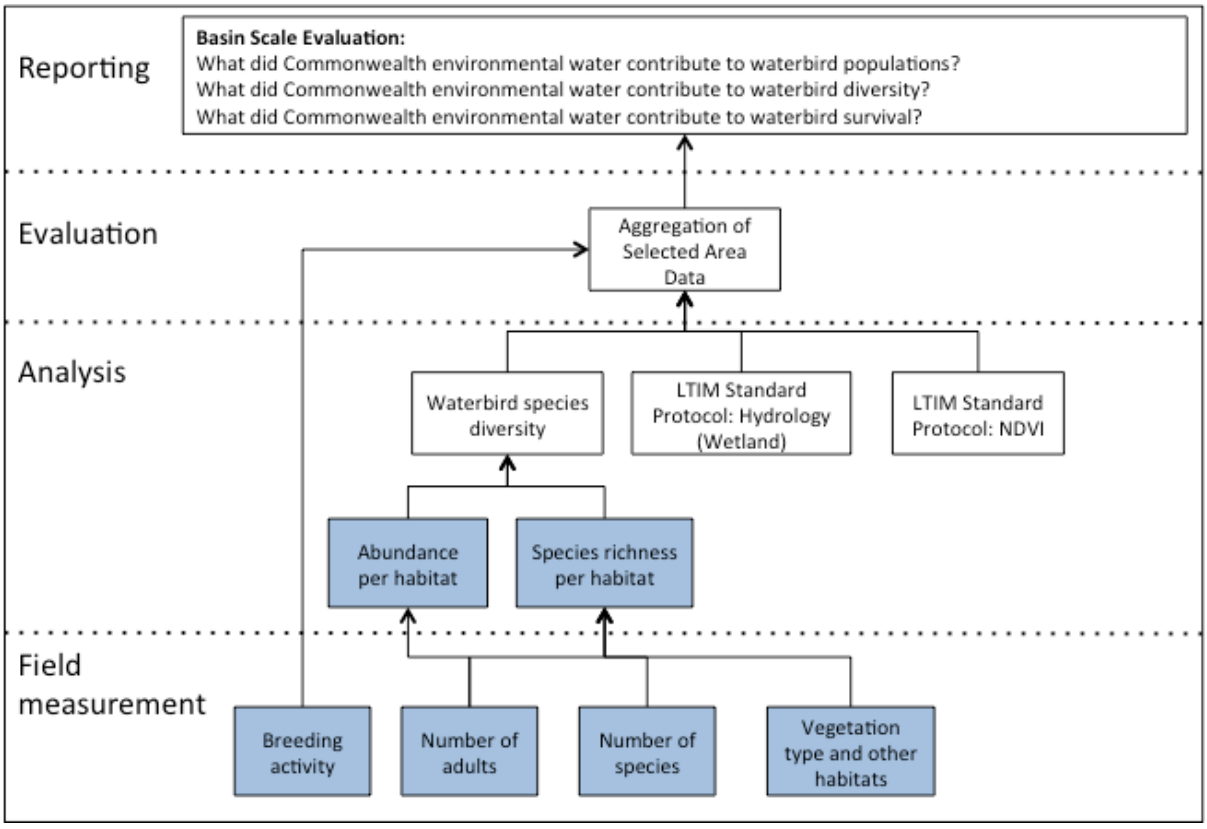

Figure 19: Schematic of key elements in LTIM Standard Protocol: Waterbird Breeding.

10.2 Relevant ecosystem types

Wetlands and floodplains.

10.3 Relevant flow types

Freshes, bankfull, overbank (infrastructure assisted).

10.4 Overview and context

This protocol describes monitoring to detect the effect of Commonwealth environmental water on diversity and abundance of waterbirds. In recognition of the wide variety of wetlands in the Basin, this is a flexible protocol that provides a range of options for monitoring, including both aerial and ground surveys. Site appropriate methods are to be developed for specific Selected Areas. However, to inform Basin scale evaluation they must meet the minimum requirements detailed below with respect to:

- Site establishment
- Frequency of surveys
- Field measures
- Reporting of results

The measurements for this protocol comprise:

3. Waterbird diversity and abundance (at a minimum to occur twice per year at permanent wetland sites):
    - Number of individuals of each species
    - Evidence of breeding
4. Covariates
    - Vegetation type
    - Other habitats

Key references used in the development of this protocol include the Living Murray (TLM) program (e.g. MDFRC 2011); Guidance on waterbird monitoring methodology: Field Protocol for waterbird counting (Wetlands International 2010) and methods from the National Waterbird Assessment (Kingsford et al. 2012).

10.5 Complementary monitoring and data

Data from additional sources and monitoring programs may be used to contribute in whole or part to this monitoring protocol. For example, the Eastern Aerial Waterbird Survey (EAWS) may pass over assessment sites and be used to augment ground surveys. There may also be local aerial or ground surveys undertaken under other monitoring programs that should be considered as supplementary data.

In addition diversity data for non-breeding birds should be opportunistically collected during waterbird breeding surveys and can contribute to the monitoring outcomes for this protocol, as the wetlands in which colonies are sited may also be selected for this component. See the LTIM Standard Protocol: Waterbird Breeding.

10.6 Establishing sites

LTIM for Basin-scale evaluation has adopted a hierarchical approach to sample design (see (Gawne et al. 2013). Briefly, the spatial hierarchy for waterbird monitoring is as follows:

- Selected Area
    - Zone
        - Site
            - Habitat (vegetation type, unvegetated habitats)

Selection of zone(s)

A ‘zone’ is a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. For example, separate river or distributary systems, sub-catchments or large groups of wetlands.

For Basin-scale evaluation, we require selection of a single zone for monitoring of waterbird diversity as follows:

- The zone must be likely to receive Commonwealth environmental water at least once in the next five years;
- The zone must have an expected outcome related to the indicator in question (in this instance waterbirds).

The zone selected is to be included in monitoring throughout the five year LTIM program. Monitoring and Evaluation Providers may wish to include wetlands from other zones in their area-specific monitoring and analysis, and the number of zones selected will be determined by area-specific constraints and requirements, as well as fiscal constraints.

Selection of sites

Monitoring of waterbird diversity should be undertaken at fixed wetland sites established in year one of the program. Sites may be a single large wetland or a complex of wetlands within a zone, with a preference for multiple fixed sites. It is not possible to be prescriptive about the selection of sites within zones. Wetlands targeted for watering and monitoring will vary immensely in surface area, volume and shape as well as landscape position, connectivity and permanence. Site selection within a zone is therefore at the discretion of Monitoring and Evaluation Providers. However, sites should have the following characteristics:

- Each site should be accessible and representative of the zone—one’s site should not be an obvious ecological aberration for that zone.
- Sites should adequately represent a range of habitats used by waterbirds characteristic of the Selected Area and zone, and so ought to be sufficiently large to encompass several habitats, e.g. separately, treed and grassy/reedy margins, extensive areas of shallow littoral waters and deeper parts, containing islands and/or peninsulas with basking/loafing sites and areas of emergent dead trees (these desirable characteristics are simply a guide).
- Sites should be spatially distinct/circumscribable, e.g. a mapped entity or adjacent entities (lake and adjacent swamp) on a 1:250,000 mapsheet, with size generally in the order of one to two hundred ha (vegetated swamps and marshes) to tens of square kilometres (open lake with smaller adjacent swamps), but not so large that a complete count or representative samples of ground and/or boat based counts cannot be completed in one day.
- The site must be highly likely to receive Commonwealth environmental water at least once in the next five years.
- The site should be known habitat for waterbirds and likely to contain water for at least one of the ground surveys annually (however, bias towards permanent wetlands is discouraged).
- Preference should be given to sites with known bathymetry (or DEM) and water level recording infrastructure (otherwise a bathymetric survey, DEM and installation of water level recorders will be required, see LTIM Standard Protocol: Hydrology (Wetland)).

Surveying habitat types

Ground and aerial surveys should aim to capture a representative number of habitat types within an assessment unit. In terms of LTIM Basin-scale evaluation, the interim ANAE vegetation types have been

used to categorise vegetated habitats based on dominant vegetation with additional non-vegetated habitats important for waterbirds included:

- Open water (no vegetation)
- River red gum forest
- River red gum woodland
- Black box forest
- Black box woodland
- Coolibah
- Standing dead trees
- River cooba
- Paperbark
- Lignum
- Other shrub
- Saltmarsh
- Tall emergent aquatic (reeds, phragmities, Typha, cumbungi etc)
- Aquatic sedge/grass/forb
- Freshwater grasses
- Freshwater forb
- Open (unvegetated) shorelines

10.7 Survey type

There are two survey types:

1. Annual aerial surveys (optional; but matched to at least one ground survey)
2. Bi-annual on-ground diversity surveys (flexible time)

Waterbird diversity data are collected twice per year by ground survey, with the option for an annual aerial survey.

Annual aerial surveys should be coordinated with those of TLM and the Annual Eastern Australia Waterbird Survey (EAWS) or other existing aerial survey, where possible. Co-ordination between waterbird diversity and any waterbird breeding surveys at the Selected Areas should be undertaken when possible/relevant.

On-ground surveys are done at flexible times in response to inundation / season specific to the Selected Area and site. If a Commonwealth environmental watering event occurs, then at least one and probably both of the ground surveys should be linked to the event. Replicate counts within a survey period are at the discretion of Monitoring and Evaluation Providers and should be justified and documented in Monitoring and Evaluation Plans, but it is recommended that comprehensive counts are undertaken once at each wetland per survey so as to maximise spatial replication for a limited survey budget. In the same vein, it is recommended that surveys be undertaken twice per year, rather than quarterly, so as to increase the number of sites that can be surveyed in a given zone.

Aerial count data and on-ground count data will be used to calculate measures of abundance and species richness. Counts are to include all waterbird species which in terms of this protocol is defined as the following groups:

- Anatidae (swans, geese, ducks)

- Podicipedidae (grebes)
- Anhingidae (darters)
- Phalacrocoracidae (cormorants)
- Pelecanidae (pelicans)
- Ardeidae (herons, egrets, night herons, bitterns)
- Threskiornithidae (ibises, spoonbills)
- Accipitridae (hawks, harriers) not included in aerial surveys
- Rallidae (crakes, rails, gallinules)
- Scolopacidae (snipe, godwits, curlews, sandpipers, stints, phalaropes)
- Recurvirostridae (stilts, avocets)
- Charadriidae (plovers, dotterels, lapwings)
- Laridae (gulls, terns)
- Alcedinidae (azure kingfisher), and
- Slyviidae (old world warblers).

10.8 Aerial surveys

10.8.1 Aerial counting techniques

Prior to deploying to the field, flight paths must be established. These should be designed to most effectively capture all waterbird habitats and the majority of individuals within a site. Counting techniques for aerial surveys are to a large extent determined by the aquatic ecosystem type and size. Three main choices are available: proportional counts, total counts and transect counts (see Figure 20). This protocol requires a minimum of two observers (in addition to the pilot) in the plane. The observers on each side of the plane estimate numbers of waterbirds on their side of the aircraft, recording the information on small tape recorders for later transcription (Kingsford et al. 2012).

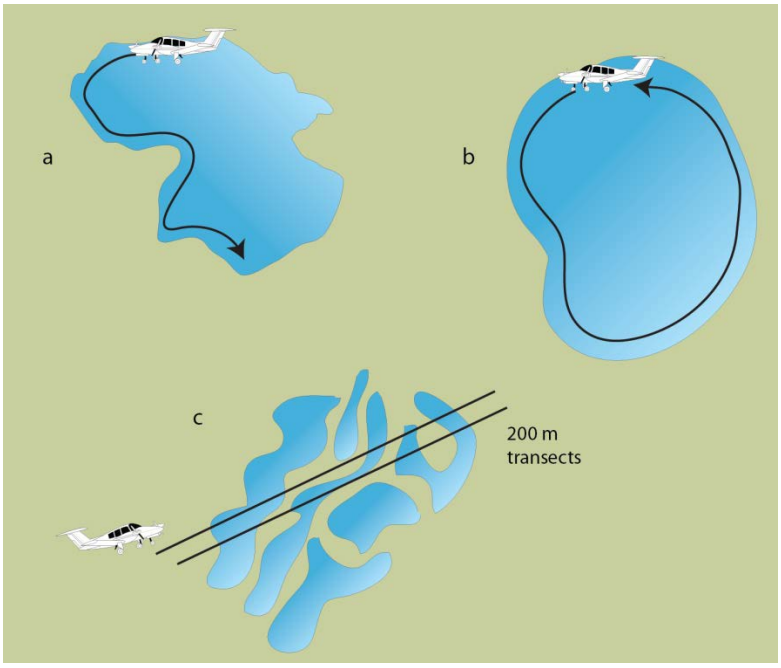

Figure 20: Three counting techniques used in Annual aerial surveys of waterbirds: proportion counts a), total counts b) and transect counts c) (after Braithwaite et al. 1985 modified from Kingsford et al. 2012).

Where possible all birds should be identified to species with the exception of a number of the smaller species which are harder to identify from aerial surveys (Kingsford et al. 2012) These may include but are not limited to: small grebes, some egrets, terns, gulls, small and large migratory wading birds.

Waterbirds should be counted singly and in groups, with group sizes estimated by counting birds in small parcels of an estimated 5, 10 or 50 individuals. For larger groups of birds, counting parcels can be increased to 100, 200, 500, 1000 and sometimes 2000 individuals (although note that large parcels are typically only used for birds in flight).

Observers (two for each flight) should independently identify and record species abundances and numbers of species. Where no birds, nests or broods are observed, a zero count is to be recorded (Kingsford et al. 2012). Waterbirds that cannot be identified to species should be counted in unidentified waterbird groups (e.g. duck sp., spoonbill sp.).

10.9 On-ground surveys

10.9.1 Equipment:

- Field guide (e.g. Simpson and Day (2010 - 8th edition), Slater et al. (2009), Morecombe (2003) or Pizzey and Knight (2007)
- GPS
- Camera
- Watch
- Maps of Selected Area including assessment site information
- 2B pencils, sharpener and eraser
- Hand held tally counter
- Appropriate field identification guide (see above)
- Binoculars or Telescope and tripod (for on-ground surveys/validation – see below)
- Field note book or datasheets and/or field computer
- Appropriate field clothing/safety gear – first aid kit, hat, sunblock etc

10.9.2 Waterbird measures

Waterbird surveys can be conducted throughout the day and into early evening, but should ordinarily not be conducted in heavy rain or strong winds. Preference is for a 'Complete Count' of the wetland in question either by foot, boat, or a combination of the two. As the name implies, the aim of a complete count is to identify and enumerate all obvious waterbirds within the prescribed wetland, bearing in mind that for some cryptic groups (rails, crakes, bitterns and warblers), a complete census is generally not possible using standard survey techniques and non-experts.

In the event that logistics dictate that the entire wetland cannot be surveyed, a sub-sampling technique may be implemented. However, Monitoring and Evaluation Plans must demonstrate that the sample design will adequately capture the waterbird diversity and abundance of a site.

Regardless of the survey type, the following waterbird measures are recorded:

- Start and end time of the survey
- Area of the wetland surveyed
- Abundance of each species

- Evidence of breeding. Breeding includes any evidence of attempted breeding ranging from nest construction through to successful fledging (Arthur et al. 2012). Species are considered to be breeding if (BirdLife Australia 2012):
    - A nest with contents (eggs, young or brooding bird) is found
    - A bird carrying food is seen to make repeated visits to a nest or hollow. Birds seen carrying nest-material and courtship rituals are insufficient evidence for a record of breeding.
    - Newly-fledged young are seen with a parent. Young must be fledglings or very young juveniles, and it must be obvious they are near the nest. Non-flying dependent young of waterbirds (ducklings or 'runners') are also evidence of breeding.

Complete Count 1, Foot Survey: The surveyors quietly work their way round the perimeter of the wetland, assuming it is dominated by open water, stopping briefly at various vantage points to use binoculars/scopes to identify and count/estimate the abundance of all birds, keeping in mind birds that have been encountered previously (no double counting). Generally at the start, surveyors approach the shore at one end of the wetland covertly and quickly scan the visible open water to obtain estimates of all species and abundances (many birds, ducks in particular, will fly off when initially disturbed). Once these details are recorded, the shores and emergent vegetation are scanned for additional birds. The surveyors then proceed along one shore to the other end of the wetland, counting additional birds as they come into view and are encountered. If the conditions and size of the wetland permit, the surveyors can walk around the entire shore, and search for less obvious species in fringing vegetation, backwaters and swamps along the way, or complete the census at the far end of one shore, and add additional species/individuals to the count if they retrace their steps. For larger wetlands with a trafficable route around the perimeter, it can be more efficient to drive around the outside margins of the wetlands, stopping at *ca* 500-m intervals, to scan and record all waterbirds, with brief foot searches as required to investigate dense fringing vegetation patches. Start and end times of the entire survey period (minus any comfort/rest breaks) are recorded. Counts should be completed in one day, and should generally take from two to four hours to complete (depending on wetland size, complexity and accessibility of the shore.) Very large lakes (30+ km^2, with complex shorelines, peninsulas and embayments) might take all day to get a complete count.

Complete Count 2, Boat Survey: This technique applies to large lakes and similar extensive open-water wetlands, where the shores are far apart and the extent of open water (with possible obstructions, e.g. islands) makes counts from the shore inadequate (based on the expert opinion and knowledge of the monitoring team). A licensed boat operator is required, and at least two observers (one of whom can be the operator). The boat traverses the inner circumference of the wetland/lake, i.e. staying close to the shore so that the shore can be scanned for waterbirds by one surveyor and the pelagic zone by the other surveyor/boat handler; the boat is stopped as frequently as required to use binoculars to identify all species and obtain accurate counts/estimates of abundance. If the waterbody is so large or complex that the middle portions cannot be surveyed adequately from near the shore, a separate pass through the central portions of the wetland is undertaken to count additional birds, after the shore circumscription is completed. Brief stops of the boat and disembarkation in densely vegetated margins of the wetland are made to search for and count cryptic waterbirds. If there are parts of the wetland inaccessible by boat and which are accessible by vehicle/foot, brief ground surveys of these parts of the wetland should be performed, with the counts added to the totals, after disallowing any birds which are thought to have been already counted. As this last point implies, it may be most efficient to combine count types 1 and 2, using both foot and boat surveys in a single wetland.

With either 'Complete Count' type the aim is to obtain a comprehensive, not necessarily complete, count of all waterbirds on the wetland. If there are very large numbers of waterbirds present, estimates of abundance will need to be taken, while for the range of cryptic species previously mentioned (plus some cryptic shorebirds), the aim is to obtain a record of the species present and perhaps an approximate idea of their relative abundance (as in order of magnitude: one or two; 10-20; 100; 100s). Careful attention must be paid to avoiding counting the same birds twice (or more times), and experience is needed to make these judgements, when large flocks of waterbirds (usually ducks) have flown off one part of the wetland and probably alighted at a distant part which will be surveyed subsequently; this takes experience and judgement, decisions cannot be made with certainty. Both of the 'Complete Count' types are similar in essence to the 'Point Counts' method described below, but the emphasis here is on aiming to get to/observe across every part of the defined wetland, as the objective of the survey is a complete count of the wetland. Evidence of breeding, including certain and possible evidence, should also be recorded, and the number of nests, nesting pairs or broods where relevant.

Sub-sample by foot or boat: Only as a last resort should subsampling approaches to wetlands be undertaken, and then the surveyors should strive to apply an equal area-equal time quadrat sampling approach to the exercise, e.g. 300m of shore by 300m of adjacent water/marsh, i.e. 9-ha quadrats, aiming for at least 10% coverage of the entire wetland area.

10.9.3 Covariates

Vegetation type

Vegetation types to be identified based the interim ANAE typology developed for the MDB (see (Brooks et al. 2013), which are based on dominant type and comprise:

- Open water (no vegetation)
- River red gum forest
- River red gum woodland
- Black box forest
- Black box woodland
- Coolibah
- River cooba
- Paperbark
- Lignum
- Other shrub
- Saltmarsh
- Tall emergent aquatic (reeds, phragmities, Typha, cumbungi etc)
- Aquatic sedge/grass/forb
- Freshwater grasses
- Freshwater forb
- Standing dead trees

Estimate the area (hectares) of each vegetation type (including open water) within the entire assessment unit (wetland); and the approximate depth of water for each. The estimation of vegetation area may be undertaken from existing good quality vegetation mapping, aerial photography or from ground surveys.

Other habitats

Shoreline complexity: applied at the wetland scale and selected from one of the following categories:

- **Plain**: completely round or square shore, with no peninsulas or embayments;
- **Low**: modest/limited shoreline complexity, with some unevenness but no obvious peninsulas or deeply eccentric bays;
- **Moderate**: more complex shoreline with evidence of small peninsulas and some level embayment development, so that much of the shoreline is obscured from any vantage point;
- **High**: highly complex shaped wetland perimeter, such that only small parts of the wetland are visible from most points on the shore.

Shoreline type proportions: estimate the proportions of the wetland's shoreline to the following categories:

- Vegetated (with emergent vegetation within 2 metres of the waterline);
- Unvegetated muddy – no vegetation within 2 metres of the waterline and a soft / muddy substrate
- Unvegetated sandy – no vegetation within 2 metres of the waterline and a hard / sandy substrate

Islands/Islets: Recorded the number and total area of islands and islets.

10.10 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the Monitoring and Evaluation Plan for all Selected Areas. QA/QC requirements specific to this protocol, which should be captured in the Quality plan are described briefly below.

All Waterbird Diversity assessments within a Selected Area, where possible, should be undertaken by the same experienced observers during the LTIM project to maintain consistency over time. All observers must undergo training prior to undertaking monitoring surveys, including calibration against experienced observers to ensure standardisation of measurements. Training and calibration procedures must be documented in the MEP and relevant records maintained.

Identification of difficult species will often differ between observers. To minimise the variance associated with different observers, a minimum of two staff are assigned to Waterbird Breeding assessments, particularly when aerial methods are used. Where there are significant differences in original observer scores, observers will discuss their rationale and where appropriate adjust scores to mutually agreed values. For aerial surveys this should be done immediately after flights to get agreement on species identifications.

10.11 Data analysis and reporting

For aerial surveys counts for each species are totalled for each observer to give either a total count for a wetland or a proportional count for the wetland. Counts on proportions of wetlands are extrapolated to give an index of total waterbird numbers for the whole wetland (Kingsford and Porter 2012).

For aerial surveys which use transects, all birds are counted within the survey transects and estimates of total numbers determined using variable transect lengths (Caughley 1977 cited in Kingsford and Porter 2012).

For ground surveys, the total abundance of each species per wetland and per hectare should be calculated and reported.

For Basin scale evaluation, waterbirds will be classified in terms of the following ten function groups:

- Piscivores (including grebes, cormorants, egrets, bitterns, terns and kingfisher);
- Diving ducks, aquatic gallinules and swans;
- Dabbling and filter-feeding ducks;
- Grazing ducks and geese;
- Rails and shoreline gallinules;
- Storks, cranes, ibis and spoonbills (large wading birds);
- Australian-breeding Charadriiform shorebirds;
- Migratory Charadriiform shorebirds;
- Reed-inhabiting passerines;
- Raptors;
-

10.11.1 Data management

All data provided for this indicator must conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is: the wetland.

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

It is strongly recommended that Monitoring and Evaluation Providers make themselves familiar with the data standard requirements for this standard method prior to detailed monitoring program design and implementation.

10.12 Health and safety

As with all programs that include field based methods, a Health Safety and Environment Plan (HSEP) must be developed. The HSEP must include an assessment of all identified potential risks and a plan on how these risks will be managed in the field.

10.13 References

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Example waterbird diversity field sheet

WATERBIRD DIVERSITY FIELD SHEET: Page ---------- of ----------					
Site name			**Total site wetland area (ha)**		
Date:			**Name of Recorder:**		
Survey start time:			**Survey end time:**		
WetlandID:		**WetlandID:**		**WetlandID:**	
WetlandID:		**WetlandID:**		**WetlandID:**	
WetlandID:		**WetlandID:**		**WetlandID:**	
Stream ID:		**Stream ID:**		**Stream ID:**	
Observer 1:			**Observer 2:**		
Approach type:	**C.** Aerial observer **D.** On-ground observer			**% of wetland of site/wetland wet……..%**	
Count method:	3. Total count 4. Proportion			**Proportion surveyed**:…….%	
GPS co-ordinates and/or tracks for site/sub-sampled area boundaries and survey route/location Attach a mud map as required:					
Survey area (ha):					
Notes:					
Dominant vegetation areas (% and ha):					
Shoreline complexity (circle 1): Plain; Low; Moderate; High					
Shoreline type (% of each): **Vegetated** **Unvegetated (muddy):** **Unvegetated (sandy):**					

WATERBIRD DIVERSITY FIELD SHEET: Page ---------- of ----------			
Site name		**Total site wetland area (ha)**	
Date:		**Name of Recorder:**	

Islands (Number and total area):

Census of Australian Vertebrate Species (CVAS) codes sourced from

http://www.environment.gov.au/biodiversity/abrs/online-resources/fauna/afd/search/biocode

Species name	Code	Number of adults	Number of young	Evidence of breeding	Vegetation habitat type

11 Macroinvertebrates

11.1 Evaluation questions

This monitoring protocol addresses the following Basin scale evaluation questions:

- ***Short-term (one-year) and long-term (five year) question:***
  - What did Commonwealth environmental water contribute to macroinvertebrate diversity?

The process for evaluating these questions is illustrated in Figure 21, with components covered by this protocol highlighted in blue.

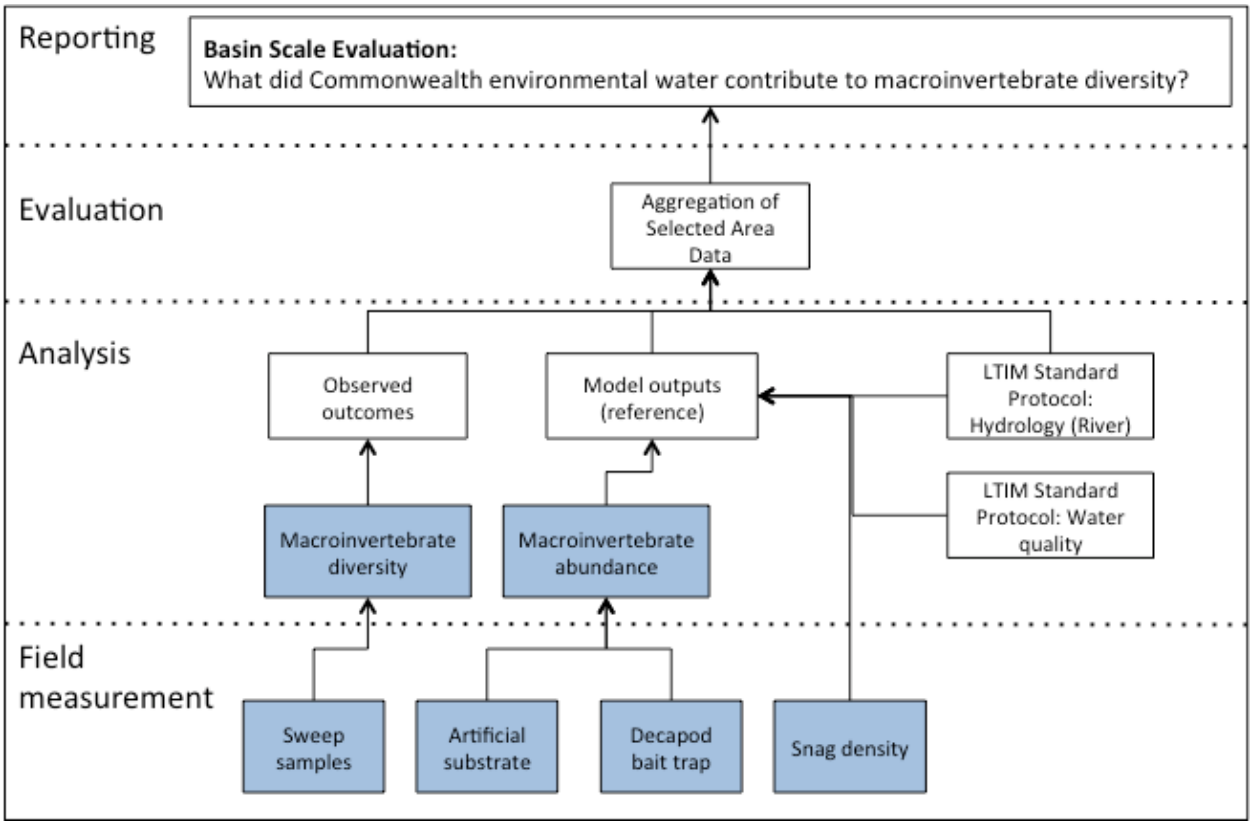


Figure 21: Schematic of key elements of the LTIM Standard Protocol: Macroinvertebrates.

11.2 Relevant ecosystem types

River

11.3 Relevant flow types

This method is event based and relevant to: fresh, bankfull, overbank

11.4 Overview and context

These methods are used in gathering macroinvertebrate data required for the Basin Scale evaluation of macroinvertebrate diversity for the LTIM project. The document here covers establishing sample sites, collection of samples in the field using three methods, estimation of habitat density (snags), and laboratory processing of samples. This macroinvertebrate protocol is event based monitoring with the collection of data both before and during / after a Commonwealth environmental watering event.

Once sites are established, at each trip it is recommended that work flow occur in the following order:

- Hydrological and water quality measurements (see LTIM Standard Protocol: Hydrology (River) and LTIM Standard Protocol: Water Quality).
- Estimation of total in channel snag surface area
- Deployment of bait traps
- Deployment of artificial substrates
- Replicated sweep edge samples
- Retrieval of bait traps (after ~3 hours)
- Retrieval of artificial substrates (4-6 weeks later)

Deployment and retrieval of the bait traps should occur at approximately the same time of day at each sampling event at a site.

11.5 Complementary monitoring and data

Hydrological measures such as flow and stream discharge are used to inform the calculation and interpretation of macroinvertebrate data. The existing stream gauging network may provide relevant information and should be assessed with respect to potential site locations.

11.6 Establishing sites

11.6.1 Overview

LTIM for Basin-scale evaluation has adopted a hierarchical approach to sample design (see (Gawne et al. 2013). Briefly, the spatial hierarchy for stream metabolism is as follows:

- Selected Area
    - Zone
        - Site
            - Sample location

Zone placement within Selected Areas

A ‘zone’ is a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. For example, separate river systems, sub-catchments or large groups of wetlands. It is a mechanism for stratifying sample design, with monitoring occurring in one or more zones, as identified by Monitoring and Evaluation Providers and detailed in the Monitoring and Evaluation Plan. The number of zones required is at the discretion of Monitoring and Evaluation Providers and will be influenced by the expected outcomes of Commonwealth environmental watering and resource availability.

A zone should have the following characteristics:

- The zone should be situated on a single river within a Selected Area, and the zone should contain channel habitat that is generally representative of the Selected Area as a whole;
- Within the channel of this zone there should ideally be a flow gauging station measuring height and discharge (otherwise a manual gaging station must be established (see LTIM Standard Protocol: Hydrology (River);
- This zone must be among the zones of an Selected Area most likely to receive Commonwealth environmental water;
- The zone must contain channel habitat that can be readily accessed—either by boat or car—for sampling using the full suite of active and passive gears detailed below;

Site placement within zones

A site is nested within a zone and in this instance will be a section of river. Sites should have the following characteristics:

- A site is defined as two 100 m segments of channel within a zone separated by at least 1 km.
- A site should be accessible and be representative of the zone.
- Ideally, each site will coincide with a pre-existing discharge and river height gauging station. In the event a site does not contain a gauging station, new gauging stations (and associated rating curves etc.) will have to be established.
- Each site should not be within 1 km of a significant tributary and/or distributary.
- A site must be scheduled to receive Commonwealth environmental water, with at least six weeks advance notice (to allow time for collecting pre-flow samples). As an event based program, the location of sites is likely to change annually.

Sample placement within sites

Sample locations consist of a 100m stretch of river, with the two locations to be on the same river, no less than 1 km apart. However, the sample locations should be close enough to permit ease of travel between the two. Sample locations should be defined by a single point location (GDA 94) and once established, these should be marked permanently following the procedure outlined below and repeat surveys undertaken at these exact locations.

The first sample location (furthest upstream) is to be sampled in order to gather species diversity data using the Standard Edge Sweep Sample described below. The second location is sampled in order to gain abundance data and will use artificial substrates and bait traps.

11.6.2 Timing

Sampling events are to take place prior to and after environmental water releases. To ensure pre-flow sampling initial (pre e-flow) deployment of artificial substrates should be undertaken at least 6 weeks prior to flow releases and retrieved before flows are released (noting that in non-permanent rivers that are dry prior to Commonwealth environmental water, there will be no “before” sample). Subsequent (during e-flow) deployment should occur while flows releases are occurring and should be retrieved 4-6 weeks later, even if the flow has ceased. Due to the fluctuating nature of flow releases it will be important to carefully consider placement of artificial substrates so that they are not likely to be stranded during the deployment period or become too inundated to retrieve.

11.6.3 Equipment

- GPS and spare batteries

- Compass
- Maps of Selected Area including assessment site information
- 100 m surveyor's measuring tape or range finder
- Wooden stakes
- Hammer
- Permanent marker pens
- Camera
- Datasheets and/or field computer

11.6.4 Protocol for site establishment

1. Find the assessment site using the point location established in the Monitoring and Evaluation Plan.
2. Mark the point location by hammering a wooden stake on either side of the river above the bank full water level. These stakes indicate the middle of the sampling site. On each stake write the word "Mid 50 m".
3. Using the 100 m surveyor's measuring tape or range finder, measure 50 m upstream and downstream from the mid marker. At the upstream extent, on both sides of the river, hammer in a wooden stake above the bank full water level and mark as "Top 100 m". At the downstream extent, on both sides of the river, hammer in a wooden stake above the bank full water level and mark as "Bot 0 m"
4. At each wooden stake take a photo that can be used to locate the position of the stake in the event that the stake is dislodged. Include in the photo:
5. The stake
6. Any obvious permanent landmark near the stake
7. Indicate the site reach on a map of the Selected Area.
8. Draw a mud map of the reach indicating the position of stakes relative to obvious permanent landmarks.
9. If the hydrology of the site cannot be adequately captured by the existing stream gauge network, set up a hydrological gauging station as per the LTIM Standard Protocol: Hydrology (River)

11.7 In Channel Snag Estimations

11.7.1 Equipment

- Maps of Selected Area including assessment site information
- Rope with 1 m interval markers
- Measuring tape
- Rope with weight for measuring depth of river
- Waders/wet suit booties/field clothing (per person)
- Life jackets
- Datasheets and/or field computer
- Copy of this protocol
- Boat or Canoe if working in a large river

11.7.2 Protocol for sampling

The following protocols follow the methods outlined in Wallace and Benke (1984) and O'conner (1992). The method is to be performed during the pre-environmental flow period only. Initial measurements are carried out on snags that are submerged, emergent or stranded. Subsequent estimations are then

established for the wetted area of the snags only (i.e. those actively contributing to in-stream fauna habitat). Therefore, estimations should change over time as river levels fluctuate.

Twenty transects are to be taken throughout the 100 m reach of the downstream site (where bait trapping and SASS are to be conducted). Transects are placed at 5 m intervals across the river extending from the bank-full channel height of one bank to the other. Measurements of diameter are to be taken from all woody structures that cross a transect and that are ≥1 cm in diameter. Measurements are to be taken 50 cm below the water level, 50 cm above the water level and then every meter from there upwards until either the end of the snag is reached or the bank-full height is reached.

Initial Measurements

1. Record hydrological information as per the LTIM Hydrology (River) Standard Method
2. At a transect line suspend the rope with the 1 m interval markers from one bank to the next approximately 1 m above water level. If the bank is higher than 1 m above the water level, lie the rope on the ground in a straight line until bank-full height is met.
3. Start at one side of the rope and work towards the other.
4. At every 2 m mark, measure the depth of the river (record 0 for non-wetted areas).
5. Within each meter tabulate the snags ≥1 cm in diameter that intersect the transect at the following heights.
   - 0-50 cm below water level
   - 50 cm above water level
   - And then every meter upwards until either no more snags intersect the transect or the snag lies above the bank-full mark.

Subsequent Estimations

1. Undertake hydrology measurements as per the LTIM Hydrology (River) Standard Method
2. Tabulate all snags that would be inundated by current flows (as estimated by the river height and previous characterisation of transects).

11.8 Decapod Bait Trap

11.8.1 Equipment

- Maps of Selected Area including assessment site information
- 10 X rectangular foldable bait traps (Figure 22)
- Nylon stocking/mesh
- 700 g dry Cat food (50 g per trap plus extra)
- Buckets (2 per person)
- A 250 µm mesh sieve (1 per person)
- 10 X 500 ml sample jars (plus spares)
- 10 X tent pegs
- Sample record sheet

11.8.2 Protocol for sampling

1. Find the assessment site using the point location established in the Monitoring and Evaluation Plan.
2. Bait traps are to be placed within 5 meters of the water's edge at regular intervals along the reach (approximately 1 every 20 meters).

3. Place 50 g of the dried cat food into a piece of stocking or mesh and tie so as to create a small package. Place the package into the centre of the bait holder of the trap.
4. If possible tie the bait trap to some structure along the water's edge or peg down.
5. Throw the trap to within 5 m of the water's edge
6. Record on the sampling sheet the trap replicate number and any habitat information.
7. Assess the surrounding 5 m from where the bait trap is placed and record an approximate percentage of each of the four habitat types on the record sheet (i.e. Snags, bare ground, leaf packs, and macrophytes). The total should add up to 100%.
8. Leave for 3 hours.
9. Retrieve the bait trap and empty the contents, away from the waters edge, through the 250 µm mesh sieve. Return any fish collected back to the water.
10. Collect any decapods into a 500 ml sampling jar and fill with ethanol
11. Be sure to collect any decapods that may have jumped from the sieve.
12. Place a label inside the jar and label the outside being sure to record the replicate number (i.e. 1-10)

Figure 22: Bait trap

11.9 Snag Artificial Substrate Sampler (SASS)

The method described here for the Snag Artificial Substrate Sampler (SASS) is adapted from that developed as part of CRC project investigating successional processes in lowland river slackwaters (Gawne et. al 2005). The method described here differs in that it employs a single log per sampler as opposed to eight logs.

11.9.1 Equipment

- Maps of Selected Area including assessment site information
- 10 X SASS – each SASS consists of:
    - One log 30 mm average circumference, 40cm length (log should be of the dominant riparian tree species at the site (e.g. river red gum, coolibah) and have been weathered (preferably from some period of inundation)
    - One besser-style brick
    - Cable ties
- Perspex collecting tube with 250 µm mesh cap
- Toothbrush/scrubbing brush

- Camera
- Wooden stakes
- Rope
- Buckets
- 250 µm mesh sieve
- 500 ml sample jars
- External labels – laser printed onto adhesive labels
- Internal labels – laser printed or photocopied onto water proof paper
- Permanent marker pens, scissors, pencils, alcohol proof pens
- Wash bottles of ethanol
- 10 Lt jerry can of ethanol
- Spare external and internal labels
- Waders/wet suit booties/field clothing (per person)
- Datasheets and/or field computer
- Copy of this protocol
- Boat or Canoe if working in a large river

11.9.2 Design of the SASS and Perspex collecting tube

Each SASS is composed of a log attached to a besser-style block by cable ties (Figure 23). Each log has an average circumference of 30 cm and a length of 40 cm. The circumference of the log must not exceed 40 cm and must be relatively straight in order to fit within the collecting tube. Log volumes should be recorded for each SASS (volumes can be calculated using a water displacement method). Ideally the log should be of the same species that is dominant in the adjacent riparian zone, and be weathered (by inundation) for a period of time.

The log is placed on top of the besser block in such a way that it protrudes forward from the block with at least 20 cm exposed. The log is held in place by fastening two cable ties through the centre of the besser block and over the log (if needed, holes can be drilled through the besser block near to where the log is positioned and the cable ties passed through these in order to gain a tighter clasp).

The collecting tube is a ~14 cm diameter 50 cm length of Perspex tube with a cap on one end. The cap is made from 250 µm mesh held in place by a Perspex ring (see Figure 24).

11.9.3 Protocol for sampling

SASS are to be deployed and left in situ for 4-6 weeks. Retrieval should be undertaken by two operators. One operator mans the collecting tube while the other operator cuts the cable ties; detaching the log from the brick.

Deployment

1. 10 SASS are to be deployed at each site with the expectation of retrieving a maximum of five and at least three.
2. SASS locations need to be well hidden to prevent vandalism or investigation by other people.
3. SASS are to be placed on the river bed at depths less than 1 m to enable periphyton growth on the samplers.
   Note: Placement depth needs to be adjusted according to the turbidity of the water such that the SASS is still in the zone of light penetration.

4. Each SASS is tied to secure logs, vegetation or roots on the river bank. Where there are limited tie off spots, SASS may be tied to stakes placed along the bank.
5. Take 2 location images for each SASS; one as a locator showing the anchor point and some river; one showing the point where the string is tied. One operator should be in both images pointing to the SASS or the tie off point. Record the location images and location details on the data sheet.
6. On the data sheet, draw a detailed map of the site indicating the location of each SASS with details of where it was tied off.
7. Immersion time is four to six weeks. In the intervening time, river/wetland heights should be checked at regular intervals and recorded on the field data sheets.

Retrieval

1. Retrieval is best accomplished by two personnel.
2. Determine the location of each SASS using the images and description from field data sheets.
3. Locate the tide off rope and follow it to the SASS without disturbing the SASS.
4. One operator slides the Perspex collecting tube over the log while the second operator cuts the cable ties. The log should smoothly enter the Perspex tube.
5. Lift the tube open side up out of the water and allow to drain.
6. Tip the SASS into a labelled bucket filled 1/3 with clean river water.
7. Wash the contents of the Perspex tube into the bucket using clean (net strained) water making sure to dislodge any animals clinging to the net or the sides of the sampler.
8. Using a toothbrush or scrubbing brush, rub the log in the bucket of water to remove any animals attached to it.
9. Remove the log and pour the contents of the bucket through a 250 µm sieve.
10. Using ethanol, rinse the contents of the sieve into a 500ml sample jar. Add an internal label and close the lid tightly
11. Label the outside of the sample jar.
12. At least 3 SASS need to be retrieved and a maximum of 5 should be aimed for.
13. Any SASS that cannot be retrieved correctly or are deemed lost must be recorded on the data sheet.

Figure 23: SASS

Figure 24: Collecting tube

11.10 Replicated Edge Sweep Sample (RESS)

This semi-quantitative replicated sweep method using a hand net to sample edge habitats was formulated for the Murray Irrigation Limited Aquatic Ecosystem Monitoring Program initiated in 2005 (Gigney et al. 2007a). The protocols handbook for that monitoring program (Gigney et al. 2007b) have been peer reviewed by scientists experienced in the collection and study of aquatic macroinvertebrates. The concept stemmed from the AUSRIVAS protocol of sampling every edge habitat that is present in the sampling reach (EPA 2003). This modified method is a replicated procedure where each replicate represents a similar sweep length and contains the same percentage of edge habitat type. For this method, four habitat types are recognised: bare edge, macrophyte beds, snags, and leaf packs.

The RESS method can be carried out by one person. However, if on-site reduction of the sample is required, then the sampling is more readily completed by two people.

11.10.1 Equipment

- Maps of Selected Area including assessment site information
- Life Jacket (1 per person)
- Hand sweep net 250 µm mesh, D-opening of 300mm X 300mm with a depth of 500mm.
- Buckets (2 per person)
- Set of 2 Seives – 10 mm, 250 µm mesh (1 per person)
- 500 ml sample jars (3 per replicate)
- External labels – laser printed onto adhesive labels
- Internal labels – laser printed or photocopied onto water proof paper
- Nylex tubes for sample jars
- Permanent marker pens, scissors, pencils, alcohol proof pens
- Wash bottles of ethanol
- 10 Lt jerry can of ethanol
- Spare external and internal labels
- Waders/wet suit booties/field clothing (per person)
- Datasheets and/or field computer
- Copy of this protocol
- Boat or Canoe if working in a large river

11.10.2 Protocol for sampling

1. Find the assessment site using the point location established in the Monitoring and Evaluation Plan.
2. Identify the mid-stream, up-stream, and down-stream markers to determine reach length.
    - If markers need re-marking, do so.
3. When entering the water ensure to take safety precautions. It is recommended that a life jacket be worn.
4. Take water quality measurements as outlined in the document LTIM Standard Protocol: Water Quality
5. Identify the major habitat types within the reach (bare ground, snags, macrophyte beds, leaf litter deposits) and estimate their relative percent cover within the reach (this estimate will determine how much of each habitat type is sampled from).
6. Always begin sampling at the downstream extent of the sampling reach and gradually move upstream.

7. Take an edge sweep sample as follows:
    a. Each completed sweep sample will have sampled a 3 m long section of habitat, but the 3 m section does not need to be continuous. Each sample will consist of 10 sweeps. Each sweep will cover an area of habitat 300 mm^2 (the width of the opening on a standard sweep net).
    b. Each sample will include all available habitat types in a way that represents each habitat's relative percent cover i.e. a habitat type with greater percent cover will contribute to a greater portion of the sample. The contribution of a single habitat must be a minimum of 1 sweep (300 mm^2). For instance, in a reach with 50% bare edge, 30% macrophyte and 20% snags, five sweeps will be taken in bare edge habitat, three sweeps in macrophyte beds, and two sweeps over a snag to total 10 sweeps for the complete sample.
    c. In large rivers, take 50% of each sample from one bank before moving to the other bank to sample the remaining 50% of each sweep sample (this may require the use of a boat or canoe).
    d. Collect samples only from water that is waist deep or shallower.
    e. To collect each sweep conduct vigorous sweeping motions in a 300 mm section using the following standardised method.
        i. 2 sweeps in an upstream direction
        ii. 2 sweeps toward the bank, at right angle to first sweeps
        iii. 1 final sweep in an upstream direction
    f. In the river, rinse the netted sample to reduce the fine sediment content.
    g. Inspect and rub off any attached animals in to the net and discard coarse leaves and twigs.
    h. Empty the net contents into a bucket half full with sieved water. Make sure to wash off any animals attached to the net.
    i. Pass the contents of the bucket through a 10 mm and a 250 µm sieve in sequence (Figure 25) to reduce the size of the sample.
    j. Wash the sample in the sieves and sluice sediment at least 3 times to remove fine sediment.
    k. Transfer collected sample to sample jar and preserve in ethanol. Ensure sample preservation by filling no more than half the container with sample before the ethanol is added. If required, use extra sample jars.
    l. Insert alcohol proof label inside the sample jar(s)
    m. Label the outside of the sample jar(s)
    n. Record the number of sample jars used per sample.
8. Record sweep information on the macroinvertebrate field data sheet. Include the:

    - Percentage composition of habitats (bare edge, macrophyte beds, snags, and leaf packs) within the sampling reach (the area that extends from downstream to upstream extents and from the water's edge into the river until a distance where the water level is about waist height).
    - Composition of sweeps in each sample according to the percentage composition of habitats in the sampling reach.

9. Each sample is to be replicated 3-5 times contingent on the extent of the habitat with the lowest percent cover. If a habitat cannot be swept at least 3 times (without sweeping over habitat that has already been collected from) this habitat should be noted on the record sheet as composing of <10% habitat and NOT swept. The total sample (10 sweeps) should be made up of the remaining habitat types. Therefore, each sample should contain the same percentage composition of habitat types.

11.10.3 Sources of error

Error can be introduced through:

1. Inconsistent and incorrect estimation of the percentage presence of the different edge habitats so that each habitat is not swept in proportion to its presence in the reach, thus resulting in a misrepresentation of the taxa present.
2. Poor approach to the edge section so that macroinvertebrates are disturbed and lost prior to the sampling process.
3. Insufficient sweeping effort of the edge section so that maximum macroinvertebrates are not collected during the sweeping process.
4. Inconsistent sweeping effort so that the variability in the number of macroinvertebrates collected is increased by operator error rather than natural variation.

Figure 25: 10 mm and 250 µm sieves in sequence

11.11 Laboratory processing of sample

The processing of samples is divided into two sections: Sorting and Identifying. These methods align with the "Sample processing in the laboratory" method detailed in **ISO 16665** *Water Quality – Guidelines for quantitative sampling and sample processing of marine soft-bottom macrofauna* (in the absence of any freshwater ISO laboratory processing standards). The preservative is altered in principle from 80% ethanol with 10-20% glycerol to 70% ethanol as indicated in Eaton et al. (2005) and as is commonly accepted for use in Australian freshwater laboratories.

This method requires the use of a 100 cell sub-sampler similar to that developed by Marchant (1989).

Macroinvertebrates are washed and sorted from fine organic and inorganic material using a standardised sorting effort of greater than 300 macroinvertebrates from a known sub-sample (random and standardised) of the field collected sample; generally a minimum of 10%. Macroinvertebrates are separated into ten vials and preserved ready for identification; nine vials each contain a distinct taxonomic group (usually order level) and the remaining vial contains 'others'. Sorting data is recorded on the Species Level Identification Sheet in the appropriate section (under "Sorting" at the top of the data sheet).

Specimens are identified to lowest possible taxonomic level. Identification data is recorded on the Species Level Identification Sheet in the appropriate section (under “Identifications” in the bottom half of the sheet)

11.11.1 Equipment

- 250 µm sieve
- 100-cell sub-sampler (“Marchant sub-sampler”)
- 69% ethanol
- Wash bottles of ethanol
- 5 ml vials
- 150 ml screw cap jar
- channel sorting tray
- Steriomicroscope, 1.0 – 8.0X zoom, 1X objective, 10X eyepieces
- mag-light (optional)
- 500ml sample jars
- Species Level Identification Sheet
- Relevant macroinvertebrate identification keys
- Waste ethanol collection container
- Forceps
- Tally counters
- Several small petri dishes
- Post-it notes
- Ethanol proof pens

11.11.2 Laboratory sorting of macroinvertebrate samples procedure for SASS and RES samples

1. Tip the entire contents of the sample jar (or jars) into a 250 µm sieve held over a large plastic beaker to catch all the ethanol.
2. Rinse the sample in the 250 µm sieve with tap water, removing larger pieces of debris by hand.

    - Note: Debris must be rubbed and rinsed under running tap water before being discarded; in particular check aquatic leaves for lepidopteran cases and sticks for trichopteran cases.
    - If there is a concern that macroinvertebrates may still be attached to any larger pieces of debris, place the debris into a large petri dish and view the contents under a mag-light or a microscope at low resolution. Any macroinvertebrates collected at this stage must be placed back into the main sample BEFORE sub-sampling.

3. When no more fine particulate matter flows from the sieve and no more large pieces of debris remain, transfer the sample to the 100-cell sub-sampler (“Marchant sub-sampler”).

    - Note: If the sample is too small to spread across the 100-cell sampler then use a quarter tray (similar to the 100-cell sub-sampler but with only four cells). DO NOT try to sort 100% without some form of sub-sampling as this may result in the sorting taking extended time and an excessive number of animals being sorted.

4. Fill the 100-cell sub-sampler with tap water to just below the cell walls so that when shaken the contents of the sampler can be evenly distributed.

5. Shake vigorously with a sideways-and-around motion to ensure that the sample is evenly distributed across all 100 cells.
6. Using a random numbers table, select and transfer the contents of 5 cells back into the 250 µm sieve. This gives a sub-sample of 5%.
7. Transfer the sub-sample from the sieve into a 150 ml screw cap jar and cover with 69% ethanol.
8. Transfer the sample details from sample jar label to a Species Level Identification Sheet
9. Transfer some of the sub-sample from the screw cap jar to a channel sorting tray, spread evenly in the channels, add 69% ethanol, if required, to cover the macroinvertebrates.

    - Note: Do not overfill the channels, you must be able to readily see through the layers of material in the tray to be able to pick out macroinvertebrates.

10. Focus the microscope so that the field of view covers the internal width on the channel.
11. Sort into Major Group/Order level groups, placing macroinvertebrates into 5 ml vials part filled with 69% ethanol.
12. Start sorting at one end of the continuous channel, plan to methodically scan, pick and move, along the entire length of the channel.
13. Scan the field of view for macroinvertebrates, sometimes you will need to zoom in to be sure of smaller specimens.
14. Remove any macroinvertebrates found and place them in the appropriate 5 ml vial.

    - Keep a tally of each macroinvertebrate placed into a vial, either on a labelled counter or as a mark in the tally column of the Species Level Identification Sheet

15. When all the macroinvertebrates have been removed from the field of view, move the tray along to view the adjacent section of the channel and repeat from 12.
16. Every tray must be scanned twice at minimum. If an animal is removed from the tray in the second scan then a third scan must be done. Repeat until no animals are removed during a whole scan (from start of channel to finish).

    - Note: Subsequent scans should be faster, if not then there is too much sample debris in the sorting tray.

17. When all the macroinvertebrates have been removed from the sorting tray, the residue must be retained in a 500ml sample jar for Quality Control audit and labelled with

    - All sample details
    - % sub-sample sorted
    - RESIDUE

18. Repeat from 9.
19. When all the macroinvertebrates from the sub-sample have been sorted into vials, calculate the total number of macroinvertebrates sorted. If greater than 300 macroinvertebrates have been collected then sorting is complete. If less than 300 macroinvertebrates have been collected then sorting continues.
20. To continue, use the random numbers table to select and transfer the contents of another 5 cells. This now gives a total sub-sample of 10%. If using the quarter tray, take the next quarter to give a sub-sample of 50%.
21. Sort all of the extra 5% and repeat the process until greater than 300 macroinvertebrates are recorded.

22. When >300 macroinvertebrates have been sorted into vials, calculate and record the number of macroinvertebrates in each Major Group/Order and the total number of macroinvertebrates sorted, on the data sheet (under the column "# in %" for the relevant taxa).
23. Record the final % sub-sample sorted.
24. Return the unsorted portion in the 100-cell sub-sampler to a 500ml sample jar and ensure it is clearly labelled with

    - All sample details
    - Remaining % sub-sample
    - UNSORTED

25. Fill each vial with 69% ethanol for preservation until identification. No vial shall have more than half of its capacity taken up by macroinvertebrates (too much invertebrate material will prevent adequate preservation). If more than 1 vial is required for 1 group, ensure all sample details are copied to the extra labels and the extra vials.

11.11.3 Laboratory sorting of decapod samples

1. Tip the entire contents of the sample jar (or jars) into a 250 µm sieve held over a large plastic beaker to catch all the ethanol.
2. All decapods need to be identified to lowest possible taxonomic level.
3. Larval specimens are counted but only identified to Decapoda.
4. To preserve specimens while processing, place the specimens into petri dishes with ethanol (multiple specimens can be placed in each petri dish).
5. Identify each decapod using a microscope and record on data sheet.
6. Identified specimens are to be placed back into the 500 ml container with a label stating that the container has been processed.

11.11.4 Laboratory identification of macroinvertebrate samples procedure for SASS and RES samples

1. The detail of this procedure assumes that the operator has experience in the identification of macroinvertebrates.
2. Check that the sample details on the data sheet match the sample details on the vial labels.
3. Identification of all specimens shall be conducted using relevant up-to-date macroinvertebrate keys.
4. When an identification is attained, record the full details of the taxon name and the number of individuals of that taxon present on the Species Level Data Sheet under the Identifications section.
5. Calculate the number of individuals identified for the Major Group/Order, then compare it to the number of individuals sorted for that Major Group/Order. If these numbers vary then an explanatory note should be made on the data sheet (e.g. many terrestrials were sorted; macroinvertebrates sorted into incorrect Major Group/Order).
   Note: DO NOT correct or obscure the record of the original number sorted.
6. When all the identifications for a Major Group/Order are completed, insert your initials in the "IDs" column next to the applicable taxonomic Major Group/Order to indicate that the identifications for this taxa are complete.
7. Make a dot on the lid of each vial when identification of all the specimens within it are completed.
8. Identification staff are to check, but not individually identify any further or count, representatives of the following taxa;
    - Oligochaeta

- Nematoda
- Bryozoa
- Cnidaria: Clavidae
- Cnidaria: Olindidae

9. Transfer numbers for Oligochaeta and Nematoda, also presence of Bryozoa, Clavidae and Olindidae to the identifications list. This will show that the specimens have been checked and ensure that the data is entered into the database.
10. When all the identifications for all Major Groups/Orders are completed, the completed data sheet must be signed and dated.

General notes

- Coleoptera adult and larvae of the same taxon should be enumerated and recorded separately. Note: ALWAYS record if the coleopteran in 'adult' or 'larva'.
- Diptera: Chironomidae larvae may be sub-sampled before identification and enumeration, as this family usually occurs in large numbers. A minimum of 60 individuals, randomly chosen, are to be identified.
  Note: The subsample must be kept separate and appropriately labelled, ready for quality control checking.
- Depending upon the project and the taxonomic resolution required, Diptera: Chironomidae larvae may need to be slide mounted, either temporary or permanent. Temporary mounts are made using water under a coverslip on a microscope slide.
- Pupae should be recorded at Order level (e.g. Trichoptera pupa) except for Diptera: Chironomidae pupae.
  Note: These are not included in the calculation of the total number of animals for the sample.
- Exuviae and empty shells should be disregarded as they are not representative of the aquatic macroinvertebrates present at the time of sampling.
- If there are immature or damaged specimens present, DO NOT ASSUME that they are the same as any mature or undamaged specimens present.

Indeterminates

- Taxonomic keys are usually designed for complete final instar larvae/nymphs and mature adult specimens. Immature and/or damaged specimens may give rise to incorrect identifications.
- If the taxonomic level cannot be achieved due to immaturity or damage then note this on the lab data sheet. This will appear in the data as 'Higherlevelname indeterminate' e.g. Baetidae indeterminate.
- In the case of broken specimens, generally only heads should be counted; however, if a body portion can be identified unequivocally as a separate individual, then it should also be counted BUT do not count a head and a body of the same taxon as 2 individuals.
- If the animal is so young that the required key feature has not yet developed, then identification should cease and the animal should be recorded at the higher taxonomic level;
  e.g. if sclerotization of the metanotum is not present for genus level identification of Ecnomidae specimens, then record as Ecnomidae indeterminate.
- If the animal being identified is less than half the stated total length of a final instar specimen, then identification should cease and the animal is recorded at the higher taxonomic level.
- The development of wing pads can be an indication of specimen maturity e.g. some Ephemeroptera, some Odonata, some Hemiptera.

- Identification of damaged specimens that no longer have the required key feature should not continue unless the alternative can be ruled out by distribution and/or a second feature; e.g. the identification of Odonata often requires the presence of gills; however, if the gills are missing the alternatives can sometimes be ruled out by distribution or by premental features. Note: Inexperienced staff MUST consult more experienced staff. Record on the data sheet that these assumptions have been made.
- Note: Pupae and indeterminates are NOT counted as distinct taxa in bioassessment.

Terrestrial specimens

- Terrestrial specimens are not to be counted but can be kept as examples for reference, BUT not retained in the Major Group/Order vial.
- The sorting operator should be made aware of the reasons that the specimen should be recognised as a terrestrial.

Calculations

1. # macroinvertebrates identified

- This calculation is used as part of the ongoing quality control of the sorting and identification processes. Carefully add the number of macroinvertebrates identified for each taxon to give the number for each Major Group/Order. Then add the number for each Major Group/Order to give the total number of macroinvertebrates identified. **Note:** If the number identified does not agree with number sorted then an explanatory note should be made on the data sheet (e.g. many terrestrials were sorted; macroinvertebrates sorted into incorrect Major Group/Order).

11.11.5 Sources of Error

Error can be introduced through:

- Incorrect application of an identification key so that a specimen is wrongly identified resulting in the misrepresentation of community composition.
- Over confident assumption of identification when a specimen is damaged or immature so that a specimen is wrongly identified or the numbers of a taxon are over estimated resulting in the misrepresentation of community composition and/or community structure.

11.12 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the Monitoring and Evaluation Plan for all Selected Areas

11.13 Data analysis and reporting

11.13.1 Snag density estimation

The following data are to be provided:

- Site
- Date
- Total snag surface area
    - Calculated as: $X_{sa} = (\frac{\pi^2}{2L})\Sigma d_i^2$

- Where *L* is the length of a transect and d_i is the diameters of all logs

- Volume of wood per site
  - Calculated as: $X_v = \left(\frac{\pi^2}{8L}\right) \Sigma d_i^2$
  - Where *L* is the length of a transect and d_i is the diameters of all logs

11.13.2 Macroinvertebrate abundance

Multivariate and descriptive statistics are to be provided designed to answer the following questions:

- What was the influence of flow on macroinvertebrate abundance during single sampling events
- What was the cumulative influence of flow on macroinvertebrate abundance over the sampling period

As well as statistical analyses the following data are to be provided:

- Site
- Sample date
- Sample type (Bait Trap, SASS, RESS)
- Snag density estimate for site
- Replicate number
- Taxa
- Number of individuals per taxa

11.13.3 Macroinvertebrate diversity

A comparison between expected taxa and taxa collected is to be formulated. An assessment of the flow habitat requirements for each taxon is to be made based on literature and expert opinion. This data will be used to assess (1) any increase in the occurrence of expected taxa at a site as a result of increased flows, and (2) any increase in the number of flow dependent taxa.

1. For each selected area a list of species expected to occur in the area is to be compiled. This reference list could be based on condition monitoring information, historical information or expert opinion.
2. Using relevant literature and expert opinion infer flow habitat requirements for all species (including those which were not expected at the site but were collected during the project). Flow habitat requirements should fall into one of six categories
3. Critically dependent (specialist taxa requiring flow throughout their life cycle)
4. Significantly dependent (taxa requiring flow for at least part of their life cycle)
5. Dependent (taxa for which flow is not directly needed at any life stage but increases individual fitness and species abundance)
6. Tolerant (taxa for which flow does not directly affect any life stage but for which abundance is decreased)
7. Minimally disturbed (taxa for which flow will impact on at least one life stage)
8. Disturbed (taxa that cannot tolerate flow)
9. Descriptive statistics are to be employed to investigate any increases in: (1) the number of taxa present at sites, and (2) the percentage of taxa with specific flow habitat requirements, following environmental flows each year and accumulatively.

10. Data must include:

- Site
- Sample date
- Sample type (Bait Trap, SASS)
- Replicate number
- Taxa
- Number of individuals per taxa

11.13.4 Data management

All data provided for this indicator must conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is: the site (two 100m sections of river separated by > 1 km).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

It is strongly recommended that Monitoring and Evaluation Providers make themselves familiar with the data standard requirements for this standard method prior to detailed monitoring program design and implementation.

11.14 Health and safety

As with all programs that include field based methods, a Health Safety and Environment Plan (HSEP) must be developed. The HSEP must include an assessment of all identified potential risks and a plan on how these risks will be managed in the field.

11.15 References

EPA Victoria (2003) Guideline for Environmental Management: Rapid bioassessment methodology for rivers and streams. Publication 604.1, October 2003, 87 pp. PDF.

Gawne, B., Cook, R., Gigney, H., Hawking, J., Mitchell, A., Nielsen, D., and Watson, G. (2005). Quantifying flow habitat biota relationships in riverine ecosystems: successional processes in lowland river slackwaters. CRC Freshwater Ecology Project A240. Final Report, July 2005.

Gigney, H., Hawking, J., **Smith, L**., Gawne, B. (2007a.) *Murray Irrigation Region Aquatic Ecosystem Monitoring Program Development: 2005 Pilot Study Report*. A report for Murray Irrigation Limited. 60pp PDF.

Gigney, H., Hawking, J., **Smith, L.** and Gawne, B. (2007b). Murray Irrigation Region Aquatic Ecosystem Monitoring Program: Protocols Handbook. Report prepared for Murray Irrigation Limited, April, 71pp. (this is a working document that is revised as required).

ISO 16665 (2005) *Water Quality – Guidelines for quantitative sampling and sample processing of marine soft-bottom macrofauna.* International Organization for Standardization, Switzerland PDF.

Marchant (1989) A subsampler for samples of benthic macroinvertebrates. *Bul. Aust. Soc. Limnol.* **12**: 49-52 PDF.

Wallace, J.B. and Benke, A.C. (1984) Quantification of wood habitat in subtropical coastal plain streams. Canadian Journal of Fisheries and Aquatic Sciences. **41(11)**: 1643-1652.

Snag Characterisation Sheet

Site: Transect:

Date: Samplers Sheet … of …

Meterage (1,2,3 etc)	Height (below, 50, 100, 200 etc)	River depth	Snag diameters												
			1	2	3	4	5	6	7	8	9	10	11	12	13

Bait trap record sheet

Project:		
River:	**Site:**	**Number:**
Date: **Time:**	**Samplers:**	**Sheet checked by:**

		Habitat as a % of surrounding 5 m				
		Snags	Bare ground	Leaf Packs	Macrophytes	Retrieved yes/no
Replicate	1					
Replicate	2					
Replicate	3					
Replicate	4					
Replicate	5					
Replicate	6					
Replicate	7					
Replicate	8					
Replicate	9					
Replicate	10					

Snag Artificial Substrate Sampler

Project:	
Site name:	**Site number:**
Sheet completed by:	**Sheet checked by:**
Deployment Date:	**Retrieval Date:**
River/Wetland Height Deployment:	**River/Wetland Height Retrieval:**

	Image numbers	Locator Notes	Retrieval Notes
SASS 1			
SASS 2			
SASS 3			
SASS 4			
SASS 5			
SASS 6			
SASS 7			
SASS 8			
SASS 9			
SASS 10			

Mud Map

Replicated edge sweep sample data sheet

Project:		
River:	**Site:**	**Number:**
Date: **Time:**	**Samplers:**	**Sheet checked by:**

Edge habitat composition in reach

Habitat	**% present**	**meters per sweep sample**
macrophyte		
litter		
bare		

% habitat within reach	0%	25%	50%	75%	100%
# 1 metre sweeps required	0	1	2	3	4

Edge habitat composition in samples

Sweep Composition	**Bank**	**Description**
1 metre	near [ ] far [ ]	
2 metre	near [ ] far [ ]	
3 metre	near [ ] far [ ]	
4 metre	near [ ] far [ ]	

Sweep No.	**No. of jars**
1	
2	
3	

Comments

Note: near bank = bank where boat is launched far bank = bank opposite where boat is launched

Species Level Identification Sheet

	Date identifications complete:			**Signed:**			**Date data entry complete**			**Signed:**		
	Sorting						*pupae should be counted but are NOT part of the >300 total					
Site		IDs	Tally	# in %		IDs	Tally	# in %		IDs	Tally	# in %
Sample	Acarina				Hemiptera							
Date	Bivalva				Lepidoptera							
Sorter	Coleoptera				Nematoda							
Date sorted	Collembola				Odonata							
% sample sorted	Decapoda				Oligochaeta				Bryozoa	Circle if present		
# animals sorted	Diptera (non-Chironomidae				Plecoptera				Cnidaria: Clavidae	Circle if present		
	Ephemeroptera				Temnocephalidea				Cnidaria: Olindiidae	Circle if present		
	Gastropoda				Trichoptera				Other Pupae	Circle if present		
	Chironomidae				Tricladia				Chironomidae pupae	Circle if present		

Identifications			*Coleoptera must be noted as adult or larva		
Higher taxa	**Family**	**Genus**	**Species**	**# in %**	**Comments**

Higher taxa	**Family**	**Genus**	**Species**	**# in %**	**Comments**

12 Stream metabolism

12.1 Evaluation questions

This monitoring protocol addresses the following Basin scale evaluation questions:

Short-term (one-year) and long-term (five year) questions:

- What did Commonwealth environmental water contribute to patterns and rates of decomposition?
- What did Commonwealth environmental water contribute to patterns and rates of primary productivity?

The process for evaluating these questions is illustrated in Figure 26, with components covered by this protocol highlighted in blue.

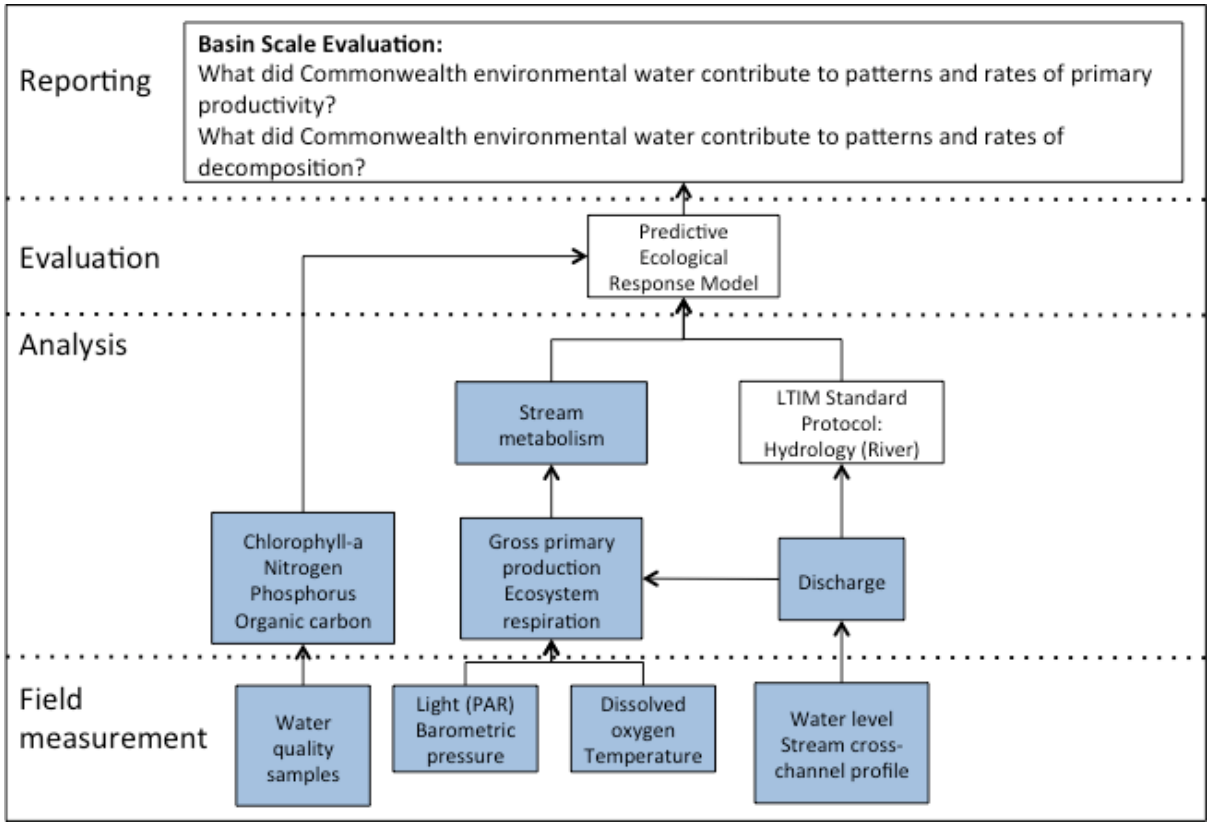


Figure 26: Schematic of key elements of the LTIM Standard Protocol: Stream metabolism.

12.2 Relevant ecosystem types

River

12.3 Relevant flow types

Fresh, bankfull, overbank

12.4 Overview and context

Under the LTIM program, stream metabolism is measured for two purposes:

5. To inform the Basin-scale quantitative evaluation of fish responses to Commonwealth environmental water (see LTIM Standard Protocol: Fish (River)); and
6. To detect changes in primary productivity and decomposition in river in response to Commonwealth environmental water.

This protocol uses the replicate single station open water method and comprises:

- Water level and stream characteristics (which may be available from an established gauging station)
- Discrete water quality samples (chlorophyll-a, total nitrogen, NOx, NH_4, total phosphorus, PO_4, dissolved organic carbon)
- *In situ* logging within the water column (dissolved oxygen, temperature) at every stream metabolism site
- Logging of photosynthetically active radiation (PAR) and barometric pressure in a nearby terrestrial location, with the potential for a single PAR / barometric pressure station to capture all stream metabolism sites within 100 km.

This protocol is based on the single station open water stream metabolism method as detailed in Grace, M. and Imberger, S. (2006) Stream Metabolism: Performing and Interpreting Measurements, Monash University (available to read online at: http://www.yumpu.com/en/document/view/5585275/stream-metabolism-faculty-of-science-monash-university).

12.5 Complementary monitoring and data

Hydrological measures of stream discharge are used to inform the interpretation of stream metabolism. The existing stream gauging network may provide relevant information and should be assessed with respect to potential site locations. A rationale for use of an existing stream gauging station should be provided in M&E Plans.

12.6 Establishing sites

12.6.1 Overview

LTIM for Basin-scale evaluation has adopted a hierarchical approach to sample design (see (Gawne et al. 2013). Briefly, the spatial hierarchy for stream metabolism is as follows:

- Selected Area
    - Zone
        - Site

A 'zone' is a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. For example, separate river systems, sub-catchments or large groups of wetlands.

A site is the unit of assessment nested within a zone and in this instance will be a section of river.

12.6.2 Sites to inform fish evaluation

Stream metabolism is required to inform the Basin-scale quantitative evaluation of fish responses to Commonwealth environmental water (see LTIM Standard Protocol: Fish (River)). The sample design for the fish protocol involves a minimum of a single zone with ten sites within a zone distributed over < 100 km of single channel. Depending on the placement of fish sites, it may be possible to adequately capture stream metabolism with a single open water station. However, this will be highly dependent on the characteristics of the river channel that contains the fish sites. M&E Providers

must develop a sample design to adequately capture stream metabolism at fish sites within river channels.

12.6.3 Sites to assess the influence of Commonwealth environmental water on stream metabolism

Stream metabolism measurements are mandated at river sites for fish monitoring, and this may also provide adequate data to assess changes in stream metabolism as a result of Commonwealth environmental water. However, at some Selected Areas, there may be a requirement to measure stream metabolism in isolation from fish sites. In this instance the nested hierarchical sampling design of: Selected Area, zone, site should be adopted, with the number of replicate stations justified in M&E Plans.

12.6.4 Placement of stations

Stations for stream metabolism measures from the water column should be located within a site as follows:

- Open water, mid stream, with sufficient depth that the sensors will not be exposed, nor touch the sediment
- Well mixed (non-stratified) water column to ensure sample is representative of reach
- Constant flow (small streams with rocky / riffle or waterfall areas are not appropriate)
- No interference from tributaries, drains or significant groundwater inflows. As a guide, there should be no major tributary for at least 2-5 km upstream of the logger location (see Section 1.14).
- Safe to access
- Protection from vandalism (sampling locations on private property, with landholders permission are preferable)
- Probes should not be located within a macrophyte bed.

Measures of light (PAR) and barometric pressure are to be collected from a nearby terrestrial location (e.g. a fence post within an adjacent property). These measures are to capture the ambient conditions of the surrounding landscape and so should be located in an open area, not impacted by tree canopy or shading. A single station for the measurement of light and barometric pressure may be sufficient to cover the requirements for multiple stream metabolism (water column) sites within a 100 km radius, providing there are no significant differences in ambient conditions (e.g. vastly different altitudes).

One important consideration is ‘how far upstream is integrated by a probe in a day?’. A reasonable estimate is provided by 3 v/K, where v is the mean water velocity in m/Day and K is the reaeration coefficient in /Day. As an example, a mean water velocity of 5 cm/s (0.05 m/s) equates to 4.3 km/Day. A typical value for K in a slow flowing river might be 5 /Day. Hence the distance upstream integrated by the probe will be 3 x 4.3/5 = 2.6 km. Both mean water velocity and K are dependent upon discharge, so the upstream distance integrated will change in a non-linear fashion with discharge.

12.6.5 Timing

It is recommended that stream metabolism measures only be undertaken during spring and summer in the southern Basin, due to temperature limiting processes during winter months. Timing in the northern Basin may be more flexible, if it is considered that temperature limitation is not relevant.

It is essential that monitoring be timed to capture the effect of the first in channel flow "pulse" of the season or the period of time during which the floodplain or wetlands are connected, to increase the likelihood of detecting a response to Commonwealth environmental water (Figure 27).

The length of deployment (and the number of days over which stream metabolism is measured and reported) will be dependent on a number of factors such as expected variability in metabolism over time, delivery of Commonwealth environmental water and the purpose of the monitoring. The frequency of sample collection must be justified and documented in Monitoring and Evaluation Plans. At a minimum stream metabolism must be measured for the period that Commonwealth environmental water influences the river, with deployment some time before environmental water delivery to capture "before" conditions.

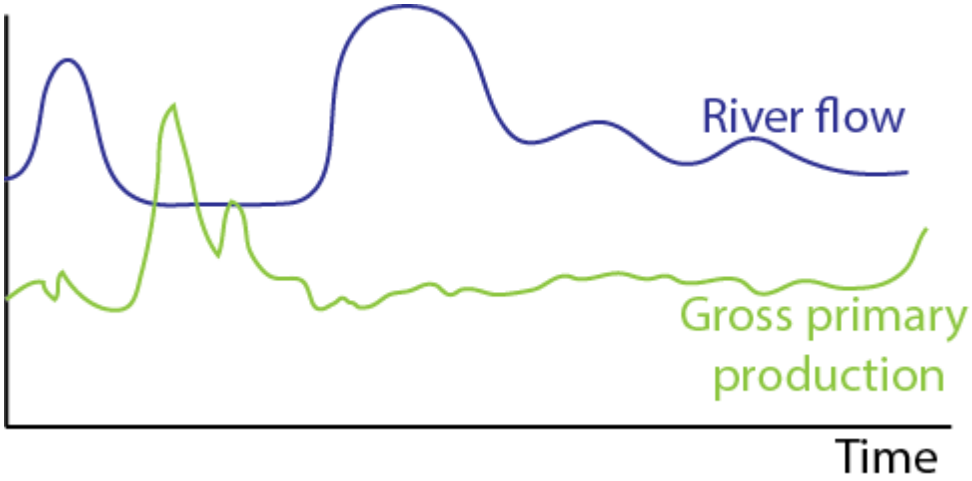


Figure 27: Stylised graphic illustrating the potential response of primary production to river flow and the importance of capturing the ecosystem response to the first pulse.

12.7 Flow and stream characteristics

River discharge (ML/day) and mean velocity (m/s) are required to interpret the stream metabolism measures and inform Basin scale evaluation. In the event that monitoring locations are located such that a permanent stream gauging station adequately captures discharge, this data can be accessed and used to inform the modelling.

Mean velocity is calculated as discharge / cross sectional-area). In some circumstances, this may be able to be derived from the nearest gauge (supplemented with some site measures of cross sectional area and water level)

However, if an existing stream gauge does not adequately capture discharge and / or velocity, then a cross-section survey and water level logger will need to be installed (see LTIM Standard Method: Hydrology (River)).

12.8 Water quality samples

Water quality variables are important for interpreting the stream metabolism results and are an input to the ecological response model for Basin scale evaluation. Water samples are collected for: chlorophyll-a, total nitrogen (TN), total phosphorus (TP), nitrate-nitrite (NOx), ammonium (NH_4), filterable reactive phosphorus (FRP) and dissolved organic carbon (DOC). In-situ spot measurements are taken for pH, turbidity and electrical conductivity (EC). As a minimum, these water quality samples and measures are collected when sensors are deployed and at 4 – 6 week intervals for the period of deployment. Further samples can be collected during site visits for other purposes.

The following is an outline of the sampling requirements, but details such as sample containers, type of filters, preservation and holding times should be detailed in Monitoring and Evaluation Plans in conjunction with the selected NATA accredited laboratory.

12.8.1 Equipment

- Sample containers and appropriate preservatives (sourced from laboratory)
- 0.2 μm filters and suitable filtering device (e.g. syringe filter) for dissolved nutrients and carbon
- 47 mm glass fibre (GFC) filters and suitable filtering device for chlorophyll-a
- Water quality meter(s) with pH, turbidity and electrical conductivity probes
- Deionised water for sample blanks
- Eskies and ice for sample preservation and storage
- Datasheets and/or field computer
- Chain of custody sheets
- Copy of this protocol

12.8.2 Protocol

7. Samples and measurements are collected mid stream and mid depth.
8. Ensure that sampler stands downstream of sample collection point.
9. Avoid surface films, but if present, a description should be entered onto the field sheet.
10. Filtering for dissolved nutrients (NOx, NH_4, FRP, DOC) and chlorophyll-a must take place on site as samples are collected.
11. Samples must be stored on ice for transport to laboratories.

12.9 *In-situ* logging

Stream metabolism measures for temperature, dissolved oxygen, light (PAR) and barometric pressure are logged at ten-minute intervals. Loggers must be deployed prior to an expected environmental water delivery and remain in place for the period that Commonwealth environmental water influences the river reach. Preference is for continuous logging over this period. Consideration must be given to maintenance, cleaning and battery life and details of the length of deployment provided in Monitoring and Evaluation Plans.

12.9.1 Equipment

- Dissolved oxygen logger:
  - Multi-parameter water quality probe with integrated logger that includes at a minimum: optical (fluorescence) dissolved oxygen probe as well as capacity to measure temperature. Noting that a separate temperature probe can be used if necessary.
- PAR sensor and logger. If the sensor does not read directly in μmol photons/m^2/s (μEs/m^2/s), then a calibration of the logger needs to be performed to enable logger units to be converted to standard PAR units. The purpose of the PAR logging is to allow for variable cloud cover. It is *not* intended to account for variation in shading by riparian vegetation.
- Barometric pressure sensor and logger.
- Tool kit and spare parts for the multi-parameter probe; including spare batteries
- Metal star pickets and star picket driver or mallet
- Means to attach probe to star picket or permanent structure
- GPS
- Probe calibration log
- Field sheets
- Laptop and data cables for connecting to probes / logger

- Air bubbler with battery (e.g. one suitable for a large fish tank) and a large bucket (e.g. 20 L), for probe calibration.

12.9.2 Protocol

Preparation

12. Prior to deployment in the field, the probe(s) must be calibrated according to manufacturers instructions and results of calibration entered into a calibration log.
13. Before leaving the office / laboratory the following should be checked for all electronic equipment (probes, loggers, GPS):

    - Batteries are charged and properly inserted
    - Previous data downloaded and memory cleared
    - Check cable and cable connections
    - Check for any obvious/minor faults on sensors including growth or dirt on the probes or tubing
    - Check contents and condition of probe toolkit
    - All equipment listed above is present and in functional order

Field method – PAR, barometric pressure

14. Establish a suitable location, above the area likely to be inundated and in a clear open (unshaded) area. This could be a nearby paddock. Note that on private property locations a fence post near gate access may be suitable.
15. Secure PAR logger to existing structure or if necessary, a newly placed star picket.
16. Set loggers to calibrate at 10 minute intervals.

Field method – water column measures

17. Record the following on the field sheet:
    - River name and ANAE Streamid
    - Date and time
    - GPS coordinates (latitude and longitude; GDA94)
    - Name(s) of survey team
18. Record site characteristics:
    - Substrate type
    - Width of channel
    - Presence of any geomorphic features
    - Percent canopy cover
    - Land use immediate adjacent to site
19. Collect water quality samples and spot measures according to instructions in 1.8 above.
20. Calibrate dissolved oxygen sensor on site:
    - Calibrate according to manufacturer's instructions for both oxygen free water (e.g. 1% sodium sulfite Na_2SO_3 solution) and 100% saturation (air saturated water). The easiest way to obtain a reliable on-site calibration of 100% saturation is to place the probe in a bucket of stream water which itself is sitting in the stream to ensure thermal control. Air is bubbled through the water in the bucket for at least 45-60 minutes. This should result in a stable reading from the probe. It is important that the probe is not in the direct line of air bubbles.
21. Set the dissolved oxygen, temperature, PAR and barometric pressure loggers to record at ten minute intervals. Synchronise loggers so as to obtain corresponding readings.
22. Select appropriate place for deployment of sensors and loggers noting:
    - Dissolved oxygen and temperature sensors must be placed in open water, mid stream and at a depth that will not expose sensors for entire deployment period. Sensors should not be placed in eddies, backwaters or where flow is influenced by structures.

- PAR sensor should be deployed above the water surface (and remain so for entire deployment) as described above.
- Sensors can be deployed on suitable existing structures or on star pickets securing embedded mid-stream.

23. Deploy loggers.
24. Leave loggers deployed for between four and six weeks.
25. Perform servicing, cleaning and calibration of loggers at each repeat visit.
26. Repeat water quality samples and spot measures at each repeat visit.
27. Repeat 100% saturation value check (water saturated air) and note the value of any drift.
28. Record any relevant information, such as changes in site characteristics since deployment.
29. Upload data onto laptop following manufacturer's instructions.
30. Calibrate all sensors and loggers and perform routine maintenance / cleaning as necessary.

12.10 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the MEP for all Selected Areas. In terms of this method, the Quality Plan must address:

- Requirements for NATA accreditation for water quality sampling
- Field duplicate and blank samples
- Holding times for water quality samples
- Preservation and transport of water quality samples
- Calibration and maintenance of sensors and loggers

12.11 Data analysis and reporting

This method adopts the approach of determining gross primary production (GPP), ecosystem respiration (ER) and reaeration rate (K_{O2}) from the diel dissolved oxygen curves. A program to evaluate these parameters for the diel dissolved oxygen curve has been developed by Mike Grace, Darren Giling and Ralph MacNally at Monash University and will be made available for the LTIM project via the Govdex website.

The model requires data for dissolved oxygen in mg O_2/L, temperature, PAR and barometric pressure (in atmospheres) at 10 minute intervals. The salinity also needs to be entered. This can be very reasonably approximated as 0 unless the electrical conductivity is above 500 µS/cm in which case salinity = 6 x 10^{-4} x EC (Based on conversion factor of 1 µS/cm = 0.6 mg/L TDS). The program provides estimates of GPP and ER in mg O_2 /L/Day with uncertainties for each and goodness of fit parameters. If desired, these parameters can be converted to areal measurements by multiplying by the average reach depth if known.

12.12 Data management

All data provided for this indicator must conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is: the site (river reach).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

It is strongly recommended that Monitoring and Evaluation Providers make themselves familiar with the data standard requirements for this standard method prior to detailed monitoring program design and implementation.

12.13 Health and safety

As with all programs that include field based methods, a Health Safety and Environment Plan (HSEP) must be developed. The HSEP must include an assessment of all identified potential risks and a plan on how these risks will be managed in the field.

12.14 References

Grace, M. and Imberger, S. (2006) Stream Metabolism: Performing and Interpreting Measurements, Monash University.

Example: stream metabolism data collection sheet

Streamid:		River name:		Date:	
Observers:			Deployment / retrieval		
Stream characteristics:					
Stream width (m):					
Substrate type:					
Geomorphic features:					
Canopy cover (%)					
Adjacent land use:					
Notes:					

Water quality samples (check if collected)

Chlorophyll-a		Total P		FRP	
Total N		NOx		NH_4	
DOC					

In-situ logging

DO calibration (% saturation):			
Oxygen free water		100% saturation	
Logging commence / finish time:			
DO / Temperature sensor depth:			
Notes:			

13 Water quality

13.1 Evaluation questions

This monitoring protocol addresses the following Basin scale evaluation questions:

Short-term (one-year) and long-term (five year) questions:

- What did Commonwealth environmental water contribute to temperature regimes?
- What did Commonwealth environmental water contribute to pH levels?
- What did Commonwealth environmental water contribute to turbidity regimes?
- What did Commonwealth environmental water contribute to salinity regimes?
- What did Commonwealth environmental water contribute to dissolved oxygen levels?

The process for evaluating these questions is illustrated in Figure 28, with components covered by this protocol highlighted in blue.

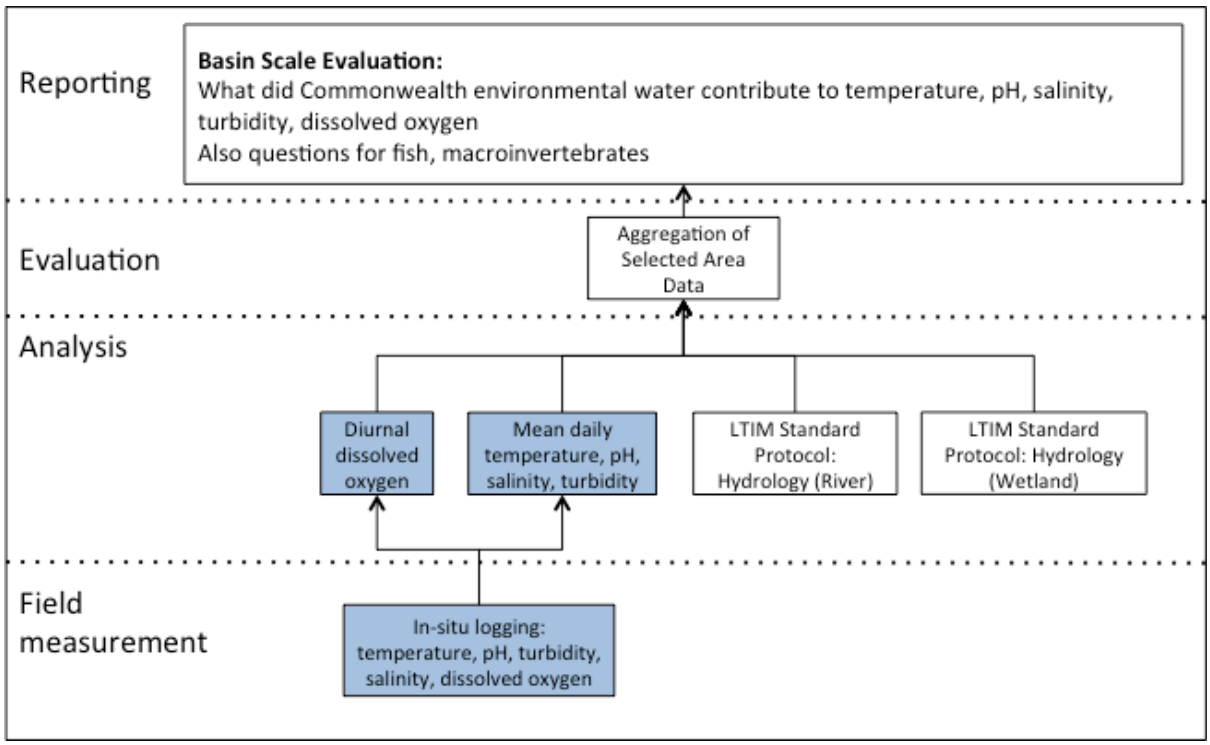


Figure 28: Schematic of key elements of the LTIM Standard Protocol: Water quality.

13.2 Relevant ecosystem types

River, wetland, floodplain

13.3 Relevant flow types

Fresh, bankfull, overbank

13.4 Overview and context

This monitoring protocol is for the in-situ continuous measurement of water quality parameters in rivers and wetlands. This is a flexible protocol that can be adapted to the needs of specific Selected Areas. M&E Providers may choose to measure one or more of the parameters listed below, with the

only requirement that the protocol comprise *in-situ* logging rather than spot samples. Parameters covered by this protocol are:

- Temperature
- pH
- Turbidity
- Salinity; and / or
- Dissolved oxygen

13.5 Complementary monitoring and data

The existing surface water monitoring networks measure a range of water quality parameters at a large number of sites across the Basin (see http://realtimedata.water.nsw.gov.au/water.stm; http://data.water.vic.gov.au/monitoring.htm; https://www.waterconnect.sa.gov.au/Systems/RTWD/SitePages/Home.aspx). There are also a number of existing monitoring programs undertaken by State Agencies, Water Suppliers, NGOs and educational institutions. Information from these sources may be suitable to address some of the information needs for Basin Scale evaluation.

LTIM Standard Protocol: Stream Metabolism involves the collection of dissolved oxygen and temperature from stream sites. It is possible that coordination between that monitoring program and this water quality monitoring could decrease duplication of measurements.

13.6 Establishing sites

13.6.1 Overview

LTIM for Basin-scale evaluation has adopted a hierarchical approach to sample design (see (Gawne et al. 2013). Briefly, the spatial hierarchy for stream metabolism is as follows:

- Selected Area
    - Zone
        - Site

A 'zone' is a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. For example, separate river systems, sub-catchments or large groups of wetlands.

A site is the unit of assessment nested within a zone and in this instance will be a section of river, wetland or complex of wetlands.

13.6.2 Placement of stations

Stations for water quality should be located within a site as follows:

- Open water with sufficient depth that the sensors will not be exposed, nor touch the sediment
- Well mixed (non-stratified) water column to ensure sample is representative of the waterbody; OR if the water column is known to be stratified consideration given to deploying sensors within each strata.
- Safe to access
- Protection from vandalism (sampling locations on private property, with landholders permission are preferable).

13.7 Field measurements

Water quality measures for temperature, pH, salinity, turbidity and dissolved oxygen are logged at 5 – 15 minute intervals. Loggers are deployed at a minimum for the period that the water regime at a zone (site) is influenced by Commonwealth environmental water. Consideration must be given to maintenance, cleaning and battery life; details of which are to be provided in Monitoring and Evaluation Plans.

13.7.1 Equipment

- Water quality sensors and loggers. Preferably as a multi-parameter probe, but separate probes for each parameter are acceptable. Note that dissolved oxygen probe must have an :optical (fluorescence) sensor.
- Tool kit and spare parts for the multi-parameter probe; including spare batteries
- Metal star pickets and star picket driver or mallet
- Means to attach probe to star picket or permanent structure
- GPS
- Probe calibration log
- Field sheets
- Laptop and data cables for connecting to probes / logger

13.7.2 Protocol

<u>Preparation</u>

1. Prior to deployment in the field, the probe(s) must be calibrated according to manufacturers instructions and results of calibration entered into a calibration log.
2. Before leaving the office / laboratory the following should be checked for all electronic equipment (probes, loggers, GPS):

    - Batteries are charged and properly inserted
    - Previous data downloaded and memory cleared
    - Check cable and cable connections
    - Check for any obvious/minor faults on sensors including growth or dirt on the probes or tubing
    - Check contents and condition of probe toolkit
    - All equipment listed above is present and in functional order

<u>Field method</u>

1. Record the following on the field sheet:
    - River name and ANAE Streamid or Wetlandid
    - Date and time
    - GPS coordinates (latitude and longitude; GDA94)
    - Name(s) of survey team
2. Record site characteristics:
    - Substrate type
    - Width of channel
    - Presence of any geomorphic features
    - Percent canopy cover
    - Land use immediate adjacent to site
3. Select appropriate place for deployment of sensors and loggers noting:
    - Water quality sensors must be placed in open water and at a depth that will not expose sensors for entire deployment period. Sensors should not be placed in eddies, backwaters or where flow is influenced by structures.

- Sensors can be deployed on suitable existing structures or on star pickets securely embedded in the stream or wetland bed.

4. Deploy loggers.
5. Leave loggers deployed for a period of time sufficient to capture the temporal extent of the influence of Commonwealth environmental water.
6. Retrieve loggers and record date and time on field sheet.
7. Record any relevant information, such as changes in site characteristics since deployment.
8. Upload data onto laptop following manufacturers instructions.
9. If loggers are to be immediately re-deployed, calibrate all sensors and loggers and perform routine maintenance / cleaning as necessary.

13.8 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the Monitoring and Evaluation Plan for all Selected Areas. In terms of this method, the Quality Plan must address:

- Calibration and maintenance of sensors and loggers; and
- Data correction procedures to account for sensor drift or fouling.

13.9 Data analysis and reporting

Data from loggers should be checked for sensor drift by comparing results from calibration on deployment with calibration readings on retrieval. Appropriate methods for linear corrections to account for any sensor drift, or for correcting for sensor fouling must be detailed in the Monitoring and Evaluation Plan.

Data requirements for Basin-scale evaluation are as follows and should be calculated from the corrected logged data:

- Daily mean temperature, pH, salinity and turbidity
- Hourly mean dissolved oxygen.

13.9.1 Data management

All data provided for this indicator must conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an ‘assessment unit’. The assessment unit for this indicator is: the site (river section or wetland).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

It is strongly recommended that Monitoring and Evaluation Providers make themselves familiar with the data standard requirements for this standard method prior to detailed monitoring program design and implementation.

13.10 Health and safety

As with all programs that include field based methods, a Health Safety and Environment Plan (HSEP) must be developed. The HSEP must include an assessment of all identified potential risks and a plan on how these risks will be managed in the field.

Example Water quality Data Collection Sheet

Wetlandid / Streamid:		Wetland / river name:	
Observers:			
Water quality logger location (s) (latitude and longitude; GDA94):			
Logging start time:			
Logging stop time:			
Notes:			

14 Hydrology (river)

14.1 Evaluation questions

This protocol does not directly address specific evaluation questions but is important for informing the analysis and evaluation of monitoring outcomes for hydrological connectivity, waterbirds and native fish. It indirectly addresses the following Basin scale evaluation questions:

Long-term (five year) questions:

- What did Commonwealth environmental water contribute to hydrological connectivity?
- What did Commonwealth environmental water contribute to native fish species diversity?
- What did Commonwealth environmental water contribute to fish community resilience?

Short-term (one year) questions:

- What did Commonwealth environmental water contribute to native fish reproduction?
- What did Commonwealth environmental water contribute to native larval fish growth and survival?

Short-term (one-year) and long-term (five year) questions:

- What did Commonwealth environmental water contribute to patterns and rates of decomposition?
- What did Commonwealth environmental contribute to patterns and rates of primary productivity?
- What did Commonwealth environmental water contribute to temperature regimes?
- What did Commonwealth environmental water contribute to pH levels?
- What did Commonwealth environmental water contribute to turbidity regimes?
- What did Commonwealth environmental water contribute to salinity regimes?
- What did Commonwealth environmental water contribute to dissolved oxygen levels?

The process for evaluating these questions is illustrated in Figure 29, with components covered by this protocol highlighted in blue.

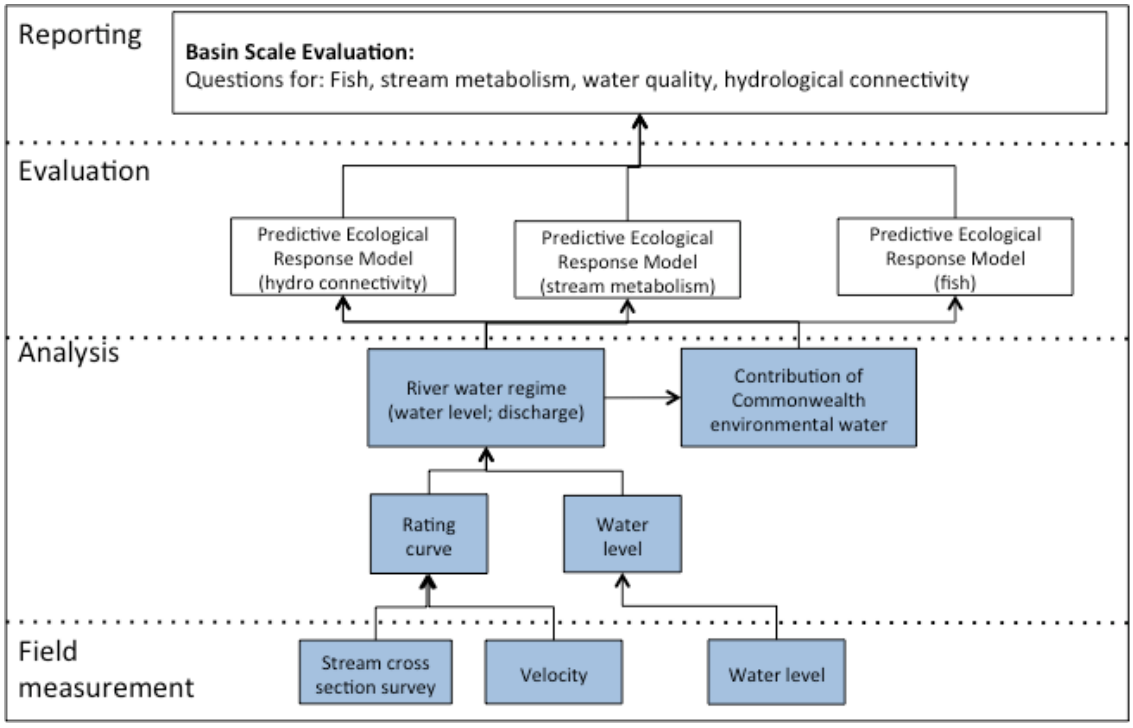


Figure 29: Schematic of key elements of the LTIM Standard Protocol: Hydrology (river).

In addition, if other monitoring (e.g. vegetation diversity, macroinvertebrates) is undertaken in river systems, consideration should be given to implementing this river hydrology protocol to provide paired hydrology and response data for evaluation.

14.2 Relevant ecosystem types

Rivers

14.3 Relevant flow types

Baseflow, freshes, and bankfull

14.4 Overview and context

Hydrology (river) is an event based monitoring protocol designed to capture aspects of a rivers water regime that influence behaviour and condition of native fish, stream metabolism, and water quality. In particular, this protocol aims to quantify the effect of Commonwealth Environmental Water on aspects of river hydrology that are most important for native fish, stream metabolism, and water quality. This protocol is based on a combination of field measures and hydrological modelling and comprises:

- Cross sectional survey
- Velocity measurements and development of a rating curve
- Daily Mean 'Stage' Height

14.5 Complementary monitoring and data

In many cases river hydrology may be available from local gauging stations or other LTIM projects. Such records should only be used if they are near the selected site (i.e. just upstream or within the zone) and if no tributaries exist between the site and the gauging station. Justification for the use of existing gauge sites should be provided in Monitoring and Evaluation Plans.

14.6 Establishing sites

14.6.1 Zones and sites

LTIM for Basin-scale evaluation has adopted a hierarchical approach to sample design (see (Gawne et al. 2013). Briefly, the spatial hierarchy for stream metabolism is as follows:

- Selected Area
    - Zone
        - Site

A 'zone' is a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. For example, separate river systems, sub-catchments or large groups of wetlands.

A site is the unit of assessment nested within a zone and in this instance will be a section of river. The sample design for the fish protocol involves a minimum of a single zone with 10 sites located within a 100 km stretch of river within the zone. Depending on the placement of fish sites, it may be possible to adequately capture river hydrology with a single gauging station. However, this will be highly dependent on the characteristics of the river channel that contains the fish sites. Monitoring and Evaluation Providers must develop a sample design to adequately capture river hydrology at fish, stream metabolism and water quality sites within river channels.

14.6.2 Placement of stations

In the event that a suitable existing gauge is not available, manual gauging stations are to be established at two positions within each site. These positions should be as far apart as possible while being within a straight, uniform reach where the slope is constant. The following should be taken into account when selecting positions for the gauging stations:

- The course of the stream is straight for approximately 100 meters upstream and downstream of the gauge.
- The flow is confined to only one channel at all stages and no flow bypasses the site.
- There are no tributaries between the two gauging stations.
- The flow is relatively uniform.
- The streambed is not affected by scouring, infilling, or excessive aquatic growth.
- Banks are permanent.
- The gauge is far enough upstream of a confluence or downstream control as to avoid variable backwater.

14.6.3 Timing

This protocol is event based and aims to capture the influence of Commonwealth Environmental Water (CEW). Therefore, monitoring must commence prior to the arrival of CEW and continue for the period over which CEW influences the hydrology of the river. Initial setup should be conducted during a period, before monitoring begins, when river flows are stable.

14.7 Gauge station setup and measurement recording

River hydrology is to be measured through the establishment of manual gauging stations. There are a number of accepted / standard methods for establishing and maintaining a river gauge site. At a minimum the method selected must involve:

- Cross section surveys at two or more locations at the beginning of the program, and at regular intervals (depending on reach stability) to account for geomorphological charges
- Measurement of cross section velocity at a number of river heights to establish a rating curve
- Development of a rating curve for the reach
- Continuous water level logging
- Calculation of daily mean discharge

A method is described below (adapted from the United States Geological Survey Measurement and Computation of Streamflow standard http://pubs.usgs.gov/wsp/wsp2175/pdf/WSP2175_vol1a.pdf). Other suitable, accepted standard methods may be used and the exact method is to be documented in Monitoring and Evaluation Plans.

14.7.1 Equipment

- Differential GPS and total station survey equipment
- Acoustic Doppler Current Profiler (ADCP)
- Depth sounder, or sounding weight
- Flow meter
- Tape measure or range-finder
- Camera
- Boat (for wide or deep streams)
- Life Jackets

- Data sheets
- A copy of this protocol

14.7.2 Gauge station setup

1. Find the assessment site using the point location established in the Monitoring and Evaluation Plan.
2. An ADCP is to be deployed within each end of the appropriate reach (as defined above). The height in meters above sea level (to 2 decimal places) of both gauges must be recorded. The height of the lowest gauge is considered the zero point for the datum of River 'stage' Height for subsequent measures at both gauges. Therefore, the height above this zero point must also be measured for the higher of the two gauges.
3. Establish the location of a 'control' down-stream of the most-down-stream gauging station. A 'control' is a feature that impacts on the discharge of the upstream section, such as the narrowing of the channel, the presence of a riffle, or a weir. Measure its height above sea level, distance to nearest gauge, and the height from the zero point.
4. A series of photos of the whole channel including the banks and extending between the two gauge stations are to be taken. These photos are to characterise the roughness of the channel surface.
5. A cross-section of river depth is to be surveyed at each gauge position. These surveys are to be conducted once at initial set-up and then again at a number of river 'stage' heights in order to establish a discharge rating curve.

    - The cross-section of the stream is to be divided into sub-sections of varying width depending on the velocities present. Each sub-section should have no more than 10% of the total discharge and should aim to be around 5%; therefore, areas with greater depth and discharge should have sub-sections with vertical boundaries that are closer together. Establishing the correct layout may require surveying the reach a number of times before an appropriate cross-section is established.
    - Place the tape-measure, or some means to measure distance from each bank, across the cross-section from bank to bank.
    - Starting at one bank and working towards the other, at intervals mark the rope and measure the distance from the bank. The mark on the rope indicates the vertical border of a sub-section. The initial sub-section will be bordered by the bank and the first mark on the rope and subsequent sub-sections will be bordered by two marks. Take depth measurements at both the boundaries and the middle of the sub-section. The depth measurements as well as the horizontal measurement of the sub section will give an approximate area for the sub-section.
    - Measure the velocity at two positions along the mid vertical of each sub-section at 0.2 and 0.8 of the depth. In sub-sections shallower than 1 m, a single measurement at 0.6 depth should be taken. Each velocity measurement should be taken as an average over 40 seconds.
    - All measurements are to be recorded on the appropriate record sheet.

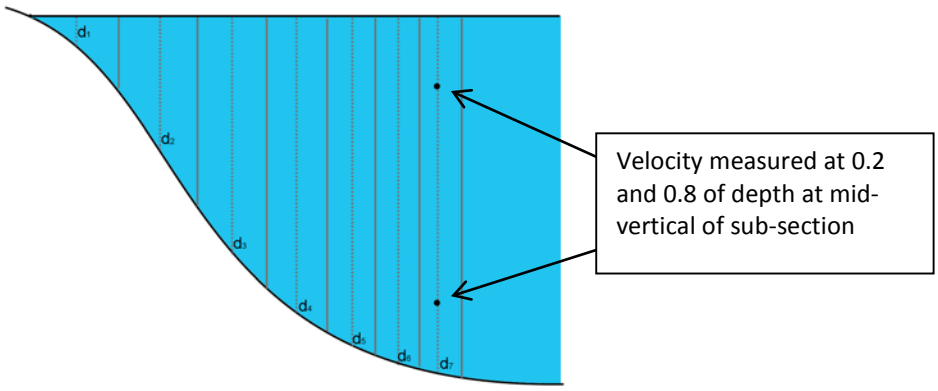


Figure 30: Cross-section of river indicating division of sub-sections (solid grey lines) and mid verticals of those sub-sections (dotted grey lines). Sub-sections in the mid reach have widths less than those closer to the bank in order to account for greater discharge per unit are in the mid-sections of the river.

6. Banks in the un-wetted area are to be surveyed for future estimates of flow volume.
    - The maximum height of each bank is to be determined and recorded as meters above sea level.
    - Starting from the bank take measurements at 1 m increments along a horizontal plane b) towards the water's edge. Additional measurement points can be established, at the service provider's discretion, where necessary to fully describe the cross-section of the channel. For instance, it may be necessary to establish further points beyond the river bank edge if the river bank is not well defined.
    - At each interval, measure the distance of the vertical (a) from the horizontal plane to the channel bed. The remaining axis (h) can be either measured or estimated as:

$$h = \sqrt{a^2} + b^2$$

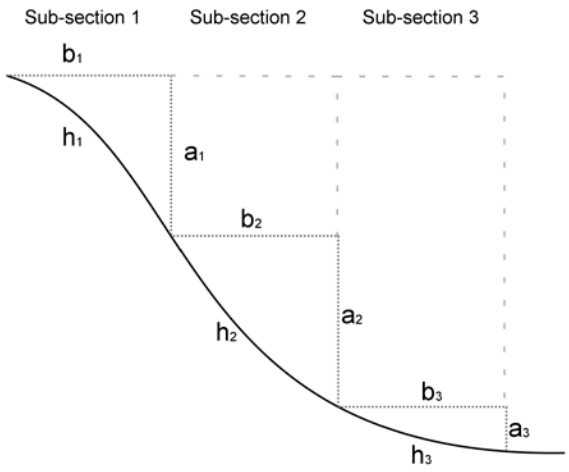
    - Calculate the area of the first sub-section as:

$$\frac{1}{2}a * b$$

    - For subsequent sub-sections measure from the base of the vertical of the previous sub-section out 1 m (if possible). Measure the vertical distance to the channel bed. The area is calculated as:

$$\left(\frac{1}{2}a * b\right) + h * \Sigma(\mathrm{a})$$

      Where $\Sigma(a_{1-i})$ is the sum of the verticals from the preceding sub-sections.



In Figure 31 the area of sub-section 3 would be calculated as:

$$= \left(\frac{1}{2}a_3 * b_3\right) + b_3(a_2 + a_1)$$

Figure 31: Cross-section of dried portion of river channel indicating the various measurements to be taken

7. The survey of the cross-section is used to calculate future discharge rates through measurements of stage height.

14.8 Daily Mean 'Stage' Water Height

The daily mean 'stage' water height is measured daily from the ADCP and recorded as meters above zero (to 2 decimal places), where zero is the point at which the lower of the two gauges sits in relation to sea level.

- Record Daily Mean 'Stage' Water Height from the ADCP.

14.9 Daily Mean Discharge

The Daily Mean Discharge is calculated from a rating curve and the 'stage' water height. To establish a rating curve, surveys of the discharge under various 'stage' water heights are to be conducted as per the method above. The number of surveys undertaken is at the discretion of the service provider but will provide a reasonable estimate of discharge within 10% error. Surveys can be taken at any time throughout the monitoring effort and Daily Mean Discharge values ascribed after a reliable rating curve is established. At each survey event the height of the 'control' must be measured in order to gain measurements of Point Zero Flow (PZF).

An applicable software package may be used to develop a ratings curve and to calculate the Daily Mean Discharge. A free downloadable tool is available at: http://www.dartmouth.edu/~renshaw/hydrotoolbox/.

14.10 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the Monitoring and Evaluation Plan for all Selected Areas.

In terms of this method, the Quality Plan must address:

- Precision and accuracy of stream cross sectional surveys
- Calibration and maintenance of sensors and loggers

14.11 Data analysis and reporting

Monitoring and Evaluation Providers are required to select a suitable hydrological modelling package to use water level data to calculate the following river water regime parameters:

- Daily mean river 'stage' water height (cm)
- Daily mean river discharge (ML/day)

14.11.1 Data management

All data provided for this indicator must conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is: the site (river section).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

It is strongly recommended that Monitoring and Evaluation Providers make themselves familiar with the data standard requirements for this standard method prior to detailed monitoring program design and implementation.

14.12 Health and safety

As with all programs that include field based methods, a Health Safety and Environment Plan (HSEP) must be developed. The HSEP must include an assessment of all identified potential risks and a plan on how these risks will be managed in the field.

Example Hydrology (River) Stage Height Data Collection Sheet

River name:		StreamId	
Observers:			
Water level logger location (s) (latitude and longitude; GDA94):			
Logging start time:			
Logging stop time:			
Notes:			

Example Hydrology (River) Discharge Data Collection Sheet

River Name:
StreamID:
Date:
Recorder(s):
Cross section number:
Gauge number:
Water level as per gauge station:

Distance from bank	**Time**	**Velocity 0.2**	**Velocity 0.8**	**Velocity 0.6**

15 Hydrology (wetland)

15.1 Evaluation questions

This protocol does not directly address specific evaluation questions but is important for informing the analysis and evaluation of monitoring outcomes for hydrological connectivity, waterbirds and native fish. It indirectly addresses the following Basin scale evaluation questions:

Long-term (five year) questions:

- What did Commonwealth environmental water contribute to hydrological connectivity?
- What did Commonwealth environmental water contribute to waterbird populations?
- What did Commonwealth environmental water contribute to native fish species diversity?
- What did Commonwealth environmental water contribute to fish community resilience?

Short-term (one year) questions:

- What did Commonwealth environmental water contribute to waterbird breeding?
- What did Commonwealth environmental water contribute to waterbird chick fledging?
- What did Commonwealth environmental water contribute to waterbird survival?
- What did Commonwealth environmental water contribute to native fish reproduction?
- What did Commonwealth environmental water contribute to native larval fish growth and survival?

The process for evaluating these questions is illustrated in Figure 32, with components covered by this protocol highlighted in blue.

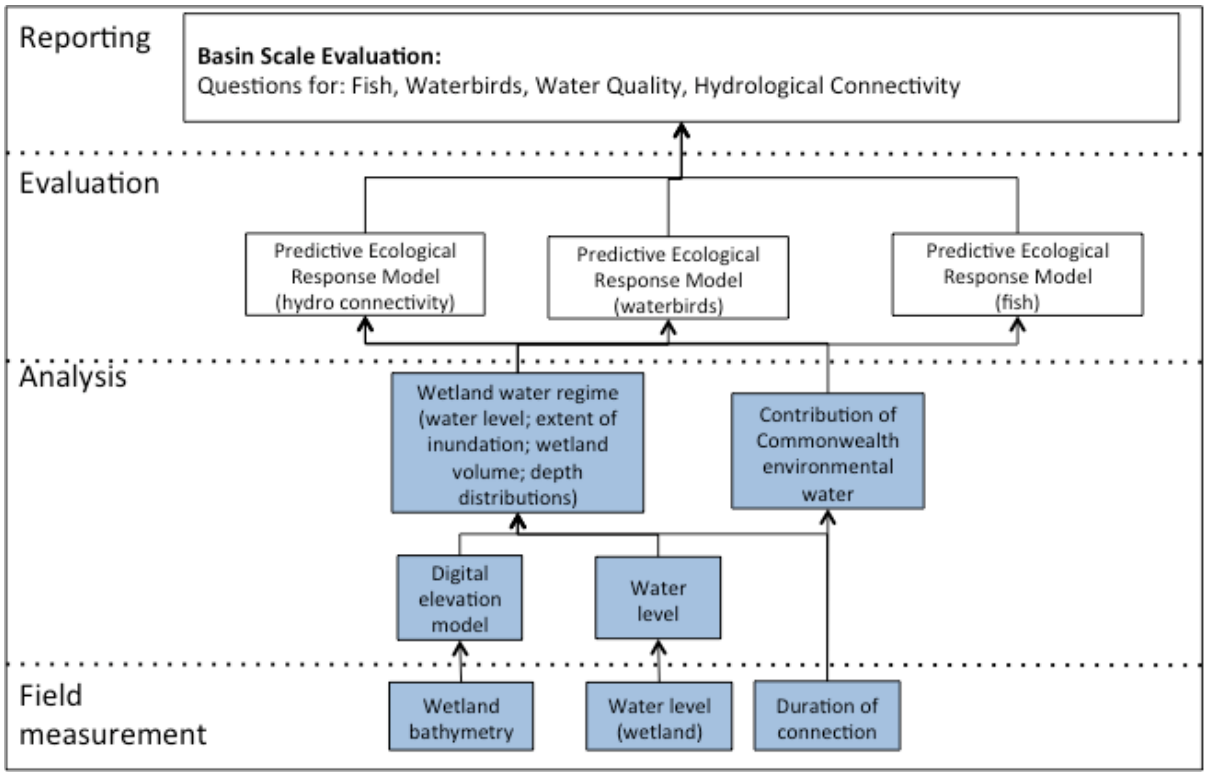


Figure 32: Schematic of key elements of the LTIM Standard Protocol: Hydrology (wetland).

In addition, if other monitoring (e.g. vegetation diversity) is undertaken in wetland ecosystems, consideration should be given to implementing this wetland hydrology protocol to provide paired hydrology and response data for evaluation.

15.2 Relevant ecosystem types

Wetlands

15.3 Relevant flow types

Bankfull, overbank (infrastructure assisted)

15.4 Overview and context

Hydrology (wetland) is an event based monitoring protocol designed to capture aspects of a wetland's water regime that influence behaviour and condition of waterbirds and native fish. In particular, this protocol aims to quantify the effect of Commonwealth Environmental Water on aspects of wetland hydrology that are most important for waterbirds and native fish. This protocol is based on a combination of field measures and hydrological modelling and comprises:

- Wetland bathymetry (digital elevation model)
- *In situ* water level loggers
- River inflows and outflows

15.5 Complementary monitoring and data

In many cases water level recorders and / or wetland bathymetry will be available from other studies or monitoring projects. Wherever possible existing data and information should be used to avoid duplication of effort.

15.6 Establishing sites

15.6.1 Overview

LTIM for Basin-scale evaluation has adopted a hierarchical approach to sample design (see (Gawne et al. 2013). Briefly, the spatial hierarchy for stream metabolism is as follows:

- Selected Area
    - Zone
        - Site

A 'zone' is a subset of a Selected Area that represents a spatially, geomorphological and/or hydrological distinct unit at a broad landscape scale. For example, separate river systems, sub-catchments or large groups of wetlands.

A site is the unit of assessment nested within a zone and in this instance will be a section of river, wetland or complex of wetlands. Wetland hydrology is required to inform the Basin-scale quantitative evaluation of fish and waterbird responses to Commonwealth environmental water (see LTIM Standard Protocol: Fish (Wetland); LTIM Standard Protocol: Waterbird breeding and LTIM Standard Protocol: Waterbird diversity). The sample design for the fish (wetland) protocol involves a minimum of a single zone with three wetland sites; protocols for waterbirds are more flexible. Wetland hydrology must be undertaken at all sites at which fish and / or waterbirds are monitored.

15.6.2 Timing

This protocol aims to capture the wetland hydrology of sites that are monitored for biotic responses as part of the LTIM program. Monitoring must therefore commence at the time the biological monitoring commences, or the time that Commonwealth environmental water is delivered to the site, whichever is the earlier. Monitoring of wetland hydrology must continue for the duration of

biological monitoring or the influence of Commonwealth environmental water on the site, whichever is the later.

15.7 Wetland bathymetry

Wetland bathymetry is required to develop a digital elevation model (DEM) of sufficient resolution to calculate measures such as extent and duration of inundation and water depth distributions. In some instances, a DEM may already be available for target wetlands; or measures of bathymetry available (e.g. from LIDAR) to enable the development of a DEM. In the absence of existing data, wetlands will require survey (by ground, boat or air) to collect bathymetric information.

The exact methods used to collect bathymetric information and derive a DEM are at the discretion of Monitoring Service Providers and are required to be detailed in the Monitoring Evaluation Plans. However, the following specifications must be met:

- Elevation and grid size must be sufficiently accurate for derivation of rate of rise and fall to within 0.2 m (noting that in some shallow systems a greater degree of accuracy may be more approriate)
- DEM should be referenced to m AHD
- Wetland maximum extent to be defined by the boundary between the wetland and the surrounding terrestrial land (i.e. the level or sill where further inundation would result in water spilling out of the wetland onto the surrounding land)
- The lowest point(s) of the wetland should be determined using a transect function in a suitable software package (e.g. Global Mapper™)

15.8 *In-situ* logging

Water level loggers are deployed in the deepest part of the wetland and set to record water level at least daily. Loggers are deployed for the entire period that Commonwealth environmental water is influencing the wetland water regime. If the wetland has a complex bathymetry that results in isolated wetland cells at lower water levels, more than one logger may be required to adequately capture wetland water regime. Consideration must be given to maintenance, cleaning and battery life; details of which are to be provided in Monitoring and Evaluation Plans.

15.8.1 Equipment

- Water level logger with an accuracy of no less than 1 cm.
- Tool kit and spare parts for the water level sensor; including spare batteries
- Metal star pickets and star picket driver or mallet
- Means to attach probe to star picket or permanent structure
- GPS
- Probe calibration log
- Field sheets
- Laptop and data cables for connecting to probes / logger

15.8.2 Protocol

Preparation

1. Prior to deployment in the field, the probe must be calibrated according to manufacturers instructions and results of calibration entered into a calibration log.
2. Before leaving the office / laboratory the following should be checked for all electronic equipment (sensors, loggers, GPS):

    - Batteries are charged and properly inserted

- Previous data downloaded and memory cleared
- Check cable and cable connections
- Check for any obvious/minor faults on sensors including growth or dirt on the probes
- Check contents and condition of probe toolkit
- All equipment listed above is present and in functional order

Field method

1. Record the following on the field sheet:
   - Wetland name and ANAE Wetlandid
   - Date and time
   - GPS coordinates (latitude and longitude; GDA94)
   - Name(s) of survey team
2. Select appropriate place for deployment of water quality logger noting:
   - Water level logger should be deployed in a position where it can capture the full range of water depths (i.e. at the deepest section of the wetland)
   - If the wetland has a complex bathymetry that results in isolated wetland cells at lower water levels, more than one logger may be required.
   - Sensors can be deployed on suitable existing structures such as water level gauging posts or on star pickets securely embedded in the wetland substrate.
3. Deploy loggers according to manufacturers instructions.
4. Leave loggers deployed for a period of time sufficient to capture the temporal extent of the influence of CEW.
5. Retrieve loggers and record date and time on field sheet.
6. Record any relevant information, such as changes in site characteristics since deployment.
7. Upload data onto laptop following manufacturers instructions.
8. If loggers are to be immediately re-deployed perform routine maintenance / cleaning as necessary.

15.9 Duration of connection

The duration for which wetland(s) are connected to adjoining river systems must be recorded at each site and for each adjoin river. This should be reported in terms of days, including start and finish dates.

15.10 Quality Assurance/Quality Control

Quality control and quality assurance protocols are documented in the Quality Plan developed as part of the MEP for all Selected Areas (insert reference to QA/QC requirements).

In terms of this method, the Quality Plan must address:

- Precision and accuracy of bathymetric measures and derived DEM
- Calibration and maintenance of sensors and loggers

15.11 Data analysis and reporting

Monitoring Service Providers are required to use water level data and the DEM to calculate the following wetland water regime parameters:

- Duration of connection (days)
- Daily water level (cm)
- Daily extent of inundation (m^2)
- Daily wetland volume (m^3)

- Wetland depth distributions (calculated a percentage of total wetland area) in the following categories:
    - Dry
    - 1-20 cm
    - 20-40 cm
    - 40-60 cm
    - 60-80 cm
    - 80-100 cm
    - > 100 cm

The exact methods used to analyse the data are at the discretion of Monitoring and Evaluation Providers and are required to be detailed in the Monitoring and Evaluation Plan.

15.11.1 Data management

All data provided for this indicator must conform to the data structure defined in the LTIM Data Standard (Brooks and Wealands 2014). The data standard provides a means of collating consistent data that can be managed within the LTIM Monitoring Data Management System (MDMS).

The spatial unit for which data is reported for this indicator is known as an 'assessment unit'. The assessment unit for this indicator is: the site (wetland).

Each row of data provided for this indicator will identify the assessment unit, the temporal extent of the data and a number of additional variables (as guided by this standard method). The exact data structure for this indicator is maintained and communicated in the LTIM Data Standard and will be enforced by the MDMS when data is submitted.

It is strongly recommended that Monitoring and Evaluation Providers make themselves familiar with the data standard requirements for this standard method prior to detailed monitoring program design and implementation.

15.12 Health and safety

As with all programs that include field based methods, a Health Safety and Environment Plan (HSEP) must be developed. The HSEP must include an assessment of all identified potential risks and a plan on how these risks will be managed in the field.

Example Hydrology (wetland) Data Collection Sheet

Wetlandid:		Wetland name:	
Observers:			
Water level logger location (s) (latitude and longitude; GDA94):			
Logging start time:			
Logging stop time:			
Notes:			