KNOWLEDGE Rivers

# Recommended Methods for Monitoring Floodplains and Wetlands

MURRAY-DARLING BASIN COMMISSION

The Living Murray
One River. One Life. Our Future.

The Murray-Darling Freshwater Research Centre

**Recommended Methods for Monitoring Floodplains and Wetlands**
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# Recommended Methods for Monitoring Floodplains and Wetlands

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# Purpose

In 2002 the Murray-Darling Basin Ministerial Council established its *Living Murray Initiative* in response to substantial evidence that the River Murray system is degraded (http://www.thelivingmurray.mdbc.gov.au), and its concern that this degradation threatens the Basin's agricultural industries, communities, natural and cultural values, and national prosperity.

In November 2003 the Council took an historic first step decision to address the declining health of the River Murray system. The key elements of this decision were a focus on achieving specific ecological objectives and outcomes for six significant ecological assets across the River Murray system. An important component of many of these objectives is their link with floodplains and wetlands that are dependent upon the River Murray.

In order to understand the nature of this decline and how health might be restored, it is necessary to collect bio-physical information about the floodplain and wetlands in which we are interested.

**The purpose of this handbook is to detail the preferred methods for sampling environmental data used in monitoring floodplains and wetlands so that governments and the community are better able to determine the success of environmental management actions, and hence their investment in** *The Living Murray.*

It is through having an agreed set of methods to collect information and a consistent approach to evaluation and reporting on the changes to floodplain and wetlands that we can better understand the impact of our management actions.

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# List of Acronyms

| | |
|---|---|
| **ANZECC** | Australian and New Zealand Environment and Conservation Council |
| **APHA** | American Public Health Association |
| **ARMCANZ** | Agriculture and Resource Management Council of Australia and New Zealand |
| **AS/NZS** | Australian Standard/ New Zealand Standard |
| **ASTM** | American Society of Testing Materials |
| **BACI** | Before - After - Control - Impact |
| **BOD** | Biological Oxygen Demand |
| **CEAH** | Centre of Environmental Applied Hydrology |
| **DBH** | Diameter at Breast Height |
| **DIPNR** | Department of Infrastructure, Planning and Natural Resources |
| **DO** | Dissolved Oxygen |
| **DSE** | Department of Sustainability and Environment |
| **EDTA** | ethylene diamine tetra acetic acid |
| **EPA** | Environment Protection Agency |
| **EPBC Act** | Environmental Protection and Biodiversity Conservation Act 1999 |
| **EC** | Electrical Conductivity |
| **GIS** | Geographic Information System |
| **GPS** | Global Positioning System |
| **ISC** | Index of Stream Condition |
| **ISO** | International Standards Organisation |
| **LAI** | Leaf Area Index |
| **MCARI** | Modified Chlorophyll Absorption in Reflectance Index |
| **MDBC** | Murray-Darling Basin Commission |
| **NAAMP** | North American Amphibian Monitoring Program |
| **NAPP** | Net annual primary productivity |
| **NDVI** | Normalised difference Vegetation Index |
| **NSW IMEF** | New South Wales Integrated Monitoring of Environmental Flows |
| **NSW SWAC** | New South Wales State Wetland Advisory Committee |
| **NSW ASSMAC** | New South Wales Acid Sulfate Soil Management Advisory Committee |
| **NHMRC** | National Health and Medical Research Council |
| **PAR** | Photosynthetically active radiation |
| **QA/QC** | Quality Assurance/Quality Control |
| **QAPP** | Quality Assurance Project Plan |
| **RBA** | River Bioassessment |
| **RGR** | Relative Growth Rate |
| **SAAB** | South Australia Aquatic Biota (database) |
| **SAVI** | Soil Adjusted Vegetation Index |
| **SL** | Standard Length |
| **SVI** | Spectral Vegetation Indicies |
| **SWI** | Shannon-Wiener index |
| **TL** | Total Length |
| **US EPA** | United States Environment Protection Agency |

# Chapter 1
## Basic Considerations when Designing a Monitoring Program

The following chapter is not meant to be an exhaustive account of how to design a monitoring program but simply to identify key points that should be considered. The *Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC, 2000) gives a comprehensive overview of all the elements necessary for the successful implementation of a monitoring program and should be consulted. In addition, a number of excellent reviews of monitoring in floodplain and wetland environments exist. The frameworks for these reviews vary from state programs for monitoring wetlands (Suter and Atkins, 1994; Harding, 2003; Butcher, 2003) to projects aimed specifically at monitoring for environmental water allocations (e.g. Reid and Brooks, 2000; Chessman and Jones, 2001; Barmah-Millewa Forum, 2001; King *et al.*, 2003). There are also a number of very useful reports based on monitoring specific ecosystem components (e.g. Suter *et al.*, 1995; Harris and Gehrke, 1997; McKinnon, 1997; Whitton and Kelly, 1999; Roberts *et al.*, 2000; Halse *et al.*, 2000). There are a significant number of publications targeting students, landholders and community groups in monitoring wetlands (e.g. Brock, 1997; Brock and Casanova, 2000; Brock *et al.*, 2000; Lloyd and Alexander, 2002; Laegdsgaard, 2003) and others more useful for wetland managers, government bodies and researchers (e.g. Tucker, 2003). A list of some recent monitoring programs is presented in Appendix 1.

### 1.1 Monitoring and Evaluation in an Adaptive Management Framework

Adaptive management is "a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs" (Bennett and Lawrence, 2002). Monitoring and evaluation plays a key role in an adaptive management framework (Figure 1.1). Monitoring programs play a role both in describing the current condition of the environment of interest (i.e. gathering baseline data to determine whether or not management intervention is required) and in determining the impact or otherwise of the management intervention.

It is critical in designing an adaptive management framework that the monitoring objectives and questions are clearly articulated, and that the monitoring program is based on an agreed conceptual model of how the system works and how it should respond to the imposed management intervention.

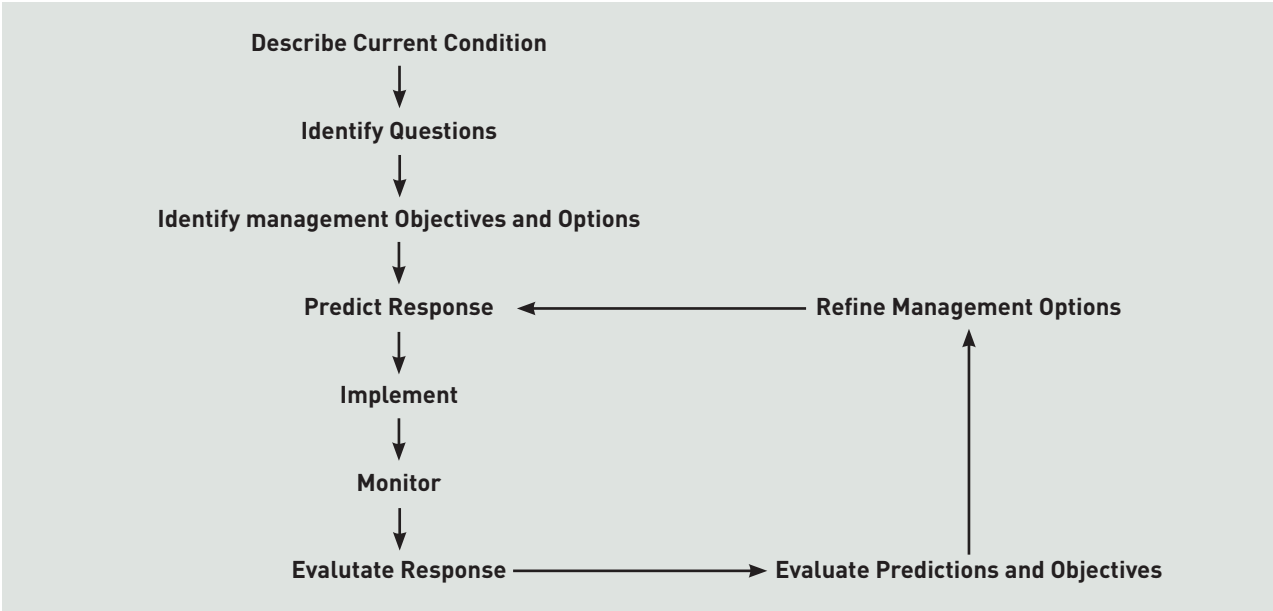


*Figure 1.1 – The adaptive management framework - Modified from Tucker (2003).*

## 1.2 Setting Monitoring Objectives and Questions

Monitoring is a process that provides information for management purposes (Finlayson and Mitchell, 1999). Essentially, it must provide the basis for management actions and judgements, most importantly, monitoring needs to be able to measure change in reference to a set of objectives.

Streever (1997) found that many wetland rehabilitation projects had not developed clear goals and objectives that could be used to determine project success. While many of these projects had monitoring programs in place, the ability of these programs to evaluate project goals and objectives was rated as "strong" in 21% of projects, "partial" in 60% and "weak" in 19%. This suggests that a significant number of monitoring programs do not produce quantitative and meaningful information that is useful to wetland managers.

Downes *et al.* (2002) categorise monitoring projects on the basis of their objectives.

- **State-of-environment reporting** aims to provide instantaneous reporting of current conditions;
- **compliance monitoring** is put in place to ensure legal requirements are satisfied;
- **Impact monitoring** is implemented to detect the direction and magnitude of human induced change; and
- **Long-term and reference site monitoring** is used to provide background data.

The *Australian Guidelines for Water Quality Monitoring and Reporting* has developed a checklist for determining information needs and monitoring program objectives (Table 1.1)

*Table 1.1* - Checklist for determining information needs and monitoring program objectives; from *Australian Guidelines for Water Quality Monitoring and Reporting*

1. Has the issue or question been defined?
2. Have the identities of all the information users been ascertained, so that information is obtained that will address all the stakeholders' needs?
3. Has all the available information relating to the issue or problem been collected, checked and put in a common form?
4. Have knowledge gaps been identified and the information obtained, or have the limitations and restrictions of not having that information been evaluated?
5. Has a shared conceptual process model been made explicit?
6. Have the assumptions underlying the model been made explicit?
7. Has an analysis been undertaken to identify the essential information required?
8. Are specific objectives:
    a. Clear and concisely defined?
    b. Sufficient to specify what is to be achieved?
    c. Specific enough to indicate when each stage is complete?

As noted in the checklist – the first task in designing a monitoring program is to define the question. An example might be "How will environmental flows affect native fish breeding in wetland and floodplain environments over the next 10 years?" Downes *et al.* (2002) recommend that the language of the question is clear and precise and that the environmental stressor(s) be explicitly named (e.g. How will stressor "A" change the density of species "X" in locations 1 and 2 over the next "N" years?) This facilitates the selection of appropriate monitoring variables.

Some generalised questions posed by monitoring groups in past studies are listed below:

#### 1.2.1 Inventory Questions

- What is the present condition of this wetland? Is the ecosystem healthy? What species are present now? What are the key characteristics of specific populations in this ecosystem? What are the similarities and differences between changes in the biological communities at sites of differing environmental conditions? (Suter *et al.*, 1995; Cole and Fenton, 1995; Downes *et al.*, 2002; Barmah-Millewa Forum, 2001; Moore, 2003).

#### 1.2.2 Assessment Questions

- What is the relationship between ecosystem components and ecosystem processes? (Chessman and Jones, 2001).
- What parameters can be used to measure the effects of altered environmental conditions? (Suter *et al.*, 1995).
- What are the threatening processes? Is this wetland at risk? (Cole and Fenton, 1995; Downes *et al.*, 2002; Moore, 2003).
- What responses will ecosystem components and processes have to the proposed management action? Do these responses signify damage? (Suter *et al.*, 1995; Chessman and Jones, 2001; Downes *et al.*, 2002).

#### 1.2.3 Monitoring Questions

- Does the difference between control and impact sites change between the before and after times? (BACI designs) (Downes *et al.*, 2002).
- Does water quality comply with statutory standards? Have regulatory standards been exceeded? (Downes *et al.*, 2002).
- Has restoration been successful? Is the created wetland area recovering to a state that is similar to naturally occurring wetlands nearby? (King *et al.*, 2003; Laegdsgaard, 2003).
- What short and long term changes occur in wetland ecosystems in response to management actions? (Reid and Brooks, 1998; Moore, 2003).

#### 1.2.4 Adaptive Management Questions

- Can the findings of this program be used to predict long-term effects and facilitate adaptive management? (Chessman and Jones, 2001).
- What management measures are required to protect and enhance this wetland? (Cole and Fenton, 1995; Moore, 2003).

In many monitoring and evaluation programs, particularly those based within an adaptive management framework, these generalised questions can be reframed in the form of a hypothesis, which are in turn based on a conceptual model (implicit or actual) of the system and how it will respond to change.

### 1.3 Defining the Conceptual Model

To successfully implement a monitoring and evaluation project in an adaptive management framework, it is critical that the program is based on a conceptual model of how the system works and how it will respond to a given management intervention. A representation of this model should be included in the documentation associated with the monitoring and evaluation program.

Having a conceptual model of how the system works not only helps identify which elements of the ecosystem will respond in the anticipated way – but also help identify changes that might be detrimental (and therefore also require monitoring). As an example, leaving water on a floodplain for extended periods for improving the condition of vegetation can lead to degradation in water quality (eg low dissolved oxygen and increased levels of potentially toxic tannins).

### 1.4 Choosing the Environmental Indicators

#### 1.4.1 Environmental Indicators

The selection of parameters for a monitoring program is a vital part of the program design. A number of authors have approached this issue and there are several comprehensive guides to the selection of indicators available (Cairns *et al.*, 1993; Downes *et al.*, 2002). Butcher (2003) has listed the advantages and disadvantages of various indicators for use specifically in wetland monitoring programs (see Appendix 2).

It is important to first define the objectives of the monitoring program and the level at which a change in the environment is either acceptable or unacceptable. In order to do this it is appropriate to construct a conceptual model that proposes a mechanism through which an event might cause a change in ecosystem components (Downes *et al.*, 2002). Response variables should be sensitive to the putative stressor or driver and should provide information relevant to the management goals (Reid and Brooks, 2000). A proven causal relationship between the stressor or driver and the response variable and knowledge of the significance of the magnitude of change are important

for interpreting the response data. Variables must signal changes that are "important" (Downes *et al.*, 2002).

The parameters that are measured in any monitoring program will depend on:

- Aims and budget of the project;
- The temporal and spatial framework proposed; and
- The level of sensitivity to change required.

Parameters that change slowly through time, or that exhibit high year to year variability, are more suited to long term monitoring with seasonal, annual, or biannual sampling (e.g. birds, trees). Variables that change rapidly through time are suited to short term monitoring with a high frequency of sampling (e.g. zooplankton - Reid and Brooks, 2000). Monitoring rapidly changing variables over the long term could prove prohibitively costly and it may be prudent to confine short and long term monitoring objectives to separate programs. For restoration projects the NSW State Wetland Advisory Committee (2002) recommends a monitoring period of 20 years, to ensure functional equivalence is achieved. Otherwise a site should be monitored until it is deemed self-sustaining.

Variables that provide a good signal to noise ratio and are low in labour or equipment will deliver maximum cost effectiveness (Downes *et al.*, 2002). Some variables may be required to be measured by law or may already be measured at the site as part of another project. A cost-effective strategy is to routinely measure a suite of easy variables and supplement these data with less frequent measurement of more difficult variables. Choosing variables because of convention, habit or social pressure should be avoided. There should be consideration of the physical and environmental constraints involved in collecting the data. A variable should be able to be quantified over the full range of probable values. Where quantifying a variable is difficult, surrogate variables should be considered (Downes *et al.*, 2002). These are variables that are highly correlated to the variable of interest but easier to measure. For example, satellite imagery may be used to measure plant vigour and density in place of ground surveys. Other indirect measurements include examination of tracks and scats, enumeration of nests and burrows, and enzyme assays.

Ideally, a wide range of both physico-chemical and biotic indicators should be monitored (Reid and Brooks, 1998). Physico-chemical indicators have been most commonly used to assess aquatic ecosystems on an historical basis. They generally are rapid, simple, cost-effective, easily quantified and have low variability. However, as many relationships between physico-chemical variables and biotic variables have not been thoroughly examined, biomonitoring is also an essential component of ecosystem monitoring. Physico-chemical parameters change rapidly over time but measurements are instantaneous. Biota express a continuous exposure to those conditions over time but their response is not indicative of pulse disturbances.

One of the most common forms of biomonitoring is the use of indicator species. Different species respond in different ways and to different stressors. Thus, the presence of multiple stressors necessitates the use of multiple indicator species. The response of the organism to a stressor can also differ between sites. This is because the organism's response is at least partially dependent on ambient conditions. This means that one species may not be a useful indicator at all sites. Further, while the presence of the indicator species may indicate the absence of the stressor, the absence of the species does not infer unequivocally the presence of the stressor or the lack of conditions suitable for its survival (Reid and Brooks, 1998).

Indicator species are most useful where attempts are being made to remediate a specific environmental problem, rather than for assessment of overall ecosystem condition. A species known for its sensitivity to a specific stressor would provide useful monitoring data. A variety of characteristics of the species would ideally be measured. Single species monitoring is also useful where attempts are being made to restore the numbers and/or condition of a specific population (Reid and Brooks, 1998).

A commonly used biotic indicator is community structure. This measures the response of the animal or plant assemblage at a site to environmental stressors. Measures of community structure include species richness, species diversity, relative abundance/dominance and biomass. Community measures of ecosystem function include primary and secondary production, decomposition rates and nutrient cycling (Reid and Brooks, 1998).

It is also helpful to aim for:

(1) Both physico-chemical and biological indicators;

(2) Indicators that represent both wetland structures and functions; and

(3) A range of ecosystem level indicators (habitat, species, community). (Reid and Brooks, 1998).

Spencer *et al.* (1998) used the following criteria for selecting variables for their "rapid appraisal wetland condition" index:

1. Low natural variability;
2. High responsiveness to condition change;
3. No ambiguity in interpretation;
4. Cost effective and simple to apply;
5. Regional applicability;
6. Biological relevance;
7. Simple or commonly measured parameter;
8. Non-destructive to the ecosystem; and
9. Able to have results summarised to be understood by non-experts.

In order to illustrate what might be included in a wetland and floodplain monitoring program to asses the effectiveness of management intervention, four hypothetical examples of changes to floodplain and wetland hydrology along with potential monitoring activities are presented in Appendix 3.

### 1.4.2 Taxonomic Resolution

The resolution required in the identification of wetland taxa will depend on the level of certainty that is required by the program. The greater the detail obtained in species identification, the more information is gained about the wetland. However, increased levels of information may ultimately be redundant in terms of the project objectives. Taxonomic resolution will also depend on the group of organisms being studied. For example while coarser levels of taxonomic resolution may apply to macroinvertebrates (see Chapter 7), plants, fish, frogs and birds are typically identified to species.

Practical constraints must also be considered when determining the taxonomic resolution required. Some groups of algae require specialised processing before species can be identified (Hötzel and Croome, 1999). Also, for some groups or life stages there may not be an adequate taxonomic key available (US EPA, 2002a). There may also be a shortage of experienced taxonomists capable of identifying samples to species level (Nielsen *et al*., 1998).

Nielsen *et al.* (1998) investigated the level of taxonomic resolution required to determine the impact of a disturbance (flooding) on microinvertebrate communities and found that a disturbance was detected at both family and genus levels. They found that increased taxonomic resolution correlated with increased dissimilarity between pre and post-flood groups. While they acknowledge that species resolution is ideal, they submit that lower resolution may be sufficient to detect a disturbance. Lower taxonomic resolution was also found to be suitable for biodiversity determinations, but only when experienced taxonomists identified the taxa. Identification to at least genus level is recommended if the data is to be used for management decisions (US EPA, 2002a).

Growns and Growns (1996) found that analysing whole aquatic communities to coarse taxonomic levels was a more reliable indicator of community species richness than species level identification of indicator groups. This is in part explained by the fact that low species diversity in one group may be offset by high species diversity in another. Growns and Growns (1996) suggest that important information regarding species endemicity, rarity, susceptibility to extinction and distribution are lost when lower taxonomic resolution is used. This is an important consideration, particularly if the monitoring program has a high emphasis on biodiversity or rare and threatened species.

It should be noted that different species within a genus and different genera within a family might have quite different sensitivities to environmental stressors (US EPA, 2002a). Hötzel and Croome (1999) state that "habitat requirements in algae are species specific rather than genus or family specific." The smaller the variation in sensitivity within specific taxa, the less information will be gained from identification to a lower taxonomic level. Sullivan *et al.* (1988) addressed this problem by identifying only the dominant species.

Care needs to be taken during sample identification as the diagnostic features differentiating species may not be initially obvious. For example, there may be a temptation to identify a medium sized decapod immediately as a yabby (*Cherax destructor*), but there are four genera that resemble yabbies, some species of which are rare (Tarmo Raadik, pers. comm.). It is possible to photograph specimens of dubious identity or to preserve a specimen for later identification. A record of diagnostic features (e.g. mouthparts or gonads) of particular genera may also be required and it is useful to be aware of the important features of the anatomy of invertebrates of interest before sampling (Tarmo Raadik, pers. comm.). A wide range of taxonomic keys is available to assist with identification. Hawking's (2000) "Key to Keys" is an excellent reference for locating an appropriate key to identify aquatic invertebrates.

## 1.5 Statistical Methods for the Design and Interpretation of Monitoring Programs

A detailed discussion on the statistical methods used in the design and interpretation of monitoring programs is beyond the scope of this handbook. A detailed discussion on appropriate statistical methods (including worked examples) is included in Chapter 6 and Appendix 5 of the *Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC, 2000). It is strongly recommended that professional statistical advice is sought during the design phase including:

- The appropriate monitoring framework (e.g. Before-After Control Impact);
- Determining the most appropriate sample frequency and intensity to account for temporal and spatial variability;
- Determining appropriate sample size required; and
- The most appropriate methods for interpreting the monitoring data.

## 1.6 Quality Assurance and Quality Control

Even the best-designed monitoring program will be of little value if there is no way of ensuring the quality of the data that is collected, stored and processed. Therefore, inherent in the good design and implementation of a monitoring and evaluation program is a well-documented

and practical quality assurance program. This section briefly describes the key elements of such a program. Further information on the design of a quality assurance program for monitoring wetlands can be found in the *Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC, 2000) and in the *Volunteers Monitor's Guide to Quality Assurance Project Plans* (US EPA, 1996).

**Definitions:**

**"Quality Assurance** (QA) is an integrated management system designed to ensure that a product or service meets defined standards of quality with a stated level of confidence. QA activities involve planning, quality control, quality assessment reporting and, quality improvement.

**Quality Assurance Project Plan** (QAPP) is a formal written document describing the detailed quality control procedures that will be used to achieve a specific project's data quality requirements.

**Quality Control** (QC) is the overall system of technical activities designed to measure quality and limit error in a product or service. A QC program manages quality so that data meets the needs of the user as expressed in a quality assurance project plan."

*Source: US EPA, (1996)*

### 1.6.1 Quality Assurance Project Plan

To be successful, any monitoring and evaluation project must have a documented Quality Assurance Project Plan (QAPP) or Quality manual. A QAPP is based around four elements (US EPA, 1996):

- Project Management;
- Measurement/Data Acquisition;
- Assessment and Oversight; and
- Data Validation and Usability.

#### *1.6.1.1 Project Management*

The project management component of a QAPP should include:

- A list of the key personnel involved in the project which includes their specific roles and responsibilities;
- A clear statement of the problems/questions being addressed in the monitoring program;
- A clear description of the project and the tasks to be undertaken;
- A statement on the data quality objectives for measurement data (including statements about the precision, accuracy, representativeness, completeness, comparability and measurement range of the data);
- Training and certification requirements for key personnel;
- A list of documentation required/generated in the project (including copies of all forms used in the project); and
- Identification of potential occupational, health, safety and environment hazards, risk assessment and risk minimisation plans.

#### *1.6.1.2 Measurement/Data Acquisition*

This section of a QAPP includes:

- An outline of the experimental design including sample types, sampling frequency, locations etc;
- A detailed description of the sampling methods to be used including instrumentation, sample size, preservatives, whether or not the samples are to be composted etc;
- Sample handling and chain of custody documentation (see Chapter 2);
- Analytical methods to be used;
- Quality control requirements including both field QC requirements (including the number and types of field blanks, number of replicate samples, number and type of sample spikes, the frequency of cross checks of field data entries etc) and laboratory QC requirements (recovery of known additions, calibration check standards, blanks, duplicate analyses, use of certified reference materials, performance audits, independent method comparisons, participation in inter-laboratory comparison programs, periodic sorting and identification checks of organisms, maintenance of voucher and reference collections and third party certification);
- A detailed instrument and equipment assurance plan including frequency of maintenance;
- Documented frequency and methods for the calibration of field and laboratory equipment; and
- A description of data acquisition and storage requirements.

#### *1.6.1.3 Auditing Processes*

To be successful, adherence to the QAPP needs to be routinely audited, and if necessary modified. The frequency of audits, what they involve and who carries them out needs to be documented in the QAPP. Furthermore, the QAPP should include the requirements for the formal reporting of QA/QC activities, including results of internal assessments, audits and corrective actions that have been undertaken.

#### *1.6.1.4 Data Validation and Usability*

Finally, once the data has been collected it needs to be stored. Errors, can be introduced in the process. There is a need to document:

- How the data collected is reviewed and whether or not it is accepted based on the Quality Control protocols that are in place (e.g. determining whether or not a sample may have become contaminated);
- How to verify that data entry is correct; and
- What the process is to determine whether or not the data collected meets the monitoring and evaluation program's objectives.

The written Quality Assurance Project Plan does not need to be elaborate or complex. Rather, it should be practical and, more importantly, be able to be implemented.

### 1.6.2 Data Storage and Handling

While the actual protocols used for the storage and handling of data will vary both between and within jurisdictions, all data storage and handling protocols should have the following features:

- Consistent/compatible with the *Australian and New Zealand Land Information Council National Standard;*
- Have agreed protocols to transfer field and laboratory data to electronic data-bases;
- Able to locate original data sheets, laboratory records, chain-of-custody documentation and/or QA/QC data associated with an entry, from the electronic data-base;
- Procedures for validation of data entered including accuracy of transcription and whether or not any of the data recorded is outside the range expected for that type of system (cross-checked against QA/QC data associated with a given entry);
- Documented procedures for determining who can enter or change data on the data-base and appropriate security measures to stop unauthorised access to the database;
- Flexible enough to accommodate a range of different data types;
- Relatively straightforward retrieval of data using a variety of fields (time, place, flow etc.);
- Be able to handle chemical data which is below the detection limit (see ANZECC, 2000);
- Agreed protocols for updating the data-base to account for improvements/changes in software and hardware; and
- Agreed ownership of the data-base and procedures to be followed during organisational restructuring.

As the data will most likely be collected within an adaptive management framework (See Section 1.1), protocols should be in place to determine at what stage(s) the data is reviewed against the monitoring objectives, and who is responsible for evaluating system responses and modifying predictions and management options.

## 1.7 Other Considerations

### 1.7.1 Permits and other Legislative and Statutory Requirements

The following list of legislative and statutory requirements that may apply to monitoring and evaluation programs is indicative only. It is the responsibility of the people designing each individual monitoring and evaluation program to ensure that they comply with all appropriate legislation and regulations and that they hold all appropriate permits. Sufficient lead-in time should be allowed before the start of a monitoring program to secure all required permits. Special permits may be required to collect some species (fish, frogs and birds) – but details will vary between jurisdictions.

Commonwealth and State government bodies generally require ethic approval on a project before issuing a permit. Government regulating bodies and institutions will generally have their own ethics committee. These committees review project proposals and provide authorisations supporting applications for permits or licenses.

#### *1.7.1.1 Commonwealth*

Research that takes place in Australia is subject to *the Environmental Protection and Biodiversity Conservation Act, 1999* (EPBC Act). This states that permits are required for virtually every kind of scientific research that takes place in a national park. State Parks and Forests also require permits but these are considered separately.

The EPBC Act states that permits are required for any activity occurring in or on Commonwealth land that may affect a listed threatened species or ecological community or a member of a listed migratory species. It is an offence to kill, injure, take, trade, keep or move such a species or community without a permit (http://www.deh.gov.au/epbc/permits/index.html, accessed Feb, 2004).

Australia is a signatory to the Ramsar Convention, 1971. This involves a commitment to establish the ecological character of each listed wetland so that changes in ecological character can be documented. The *EPBC Act* is used to ensure this character is retained (Butcher, 2003). Australia is also a signatory to treaties with China and Japan to protect and monitor migratory birds.

Applications for research in Commonwealth Parks and Reserves must be submitted in writing at least 28 days in advance (http://www.deh.gov.au/epbc/permits/parks/research.html). If specimens will be sent outside of Australia, an export permit will be required. A fee

(currently $100) is payable for permits relating to listed species or ecological communities. Fauna research is subject to continued approval of the project under the *Prevention of Cruelty to Animals Act* (1985) (SA).

An Australian National Parks and Wildlife Bird and Bat Banding permit is required for the live capture of birds and bats using mist nets, other netting devices and the use of bird and bat bands (http://www.unisa.edu.au/orc/ethics/permits.htm).

Permits may be required to:

- Conduct research that may have Aboriginal cultural issues;
- Conduct captive birth/hatching observations;
- Quarantine animals before release back into the wild;
- Collect seeds or propagules;
- Use wildlife for a commercial purpose;
- Collect an endangered or vulnerable plant species;
- Export specimens from Australia;
- Field Quarantine Frogs;
- Conduct general flora and fauna surveys;
- Conduct general invertebrates collecting;
- Conduct geological surveys;
- Conduct research in areas protected under the Heritage Act, 1993; and
- Collect plant specimens on any reserve, on any crown land, on any reserve dedicated to public purposes or on any forest reserve. (http://www.environment.sa.gov.au/biodiversity/research.html).

Sightings of threatened species listed on Schedules 1 and 2 of the *Threatened Species' Conservation Act, (1995)*, or any flora, fauna or other features which are rare or otherwise important, are to be reported immediately, if possible, but within 48 hours of sighting.

New South Wales Fisheries, The Natural Heritage Trust and Fisheries Action Program have commenced the *"NSW Threatened, Protected and Pest Species Sighting program"*. They ask that all sightings of these species, listed on the website, be reported to the Threatened Species Unit of NSW Fisheries. More information can be found on the website (www.fisheries.nsw.gov.au).

Comprehensive listings of species deemed extinct, extinct in the wild, critically endangered, vulnerable or conservation dependent can be found at http://www.deh.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=fauna.

#### *1.7.1.2 New South Wales*

The NSW *Threatened Species Conservation Act* (1995) and the NSW *Fisheries Management Act* (1994) also affect activities within NSW. For example, under the NSW TSC Act 1995, a licence is required to harm, pick or damage threatened species habitat, including critical habitat. Under the NSW FMA 1994, a person must not harm marine vegetation in a protected area, except under the authority of a permit.

The aquatic community in the natural drainage system of the lower Murray River catchment is listed under the *NSW Fisheries Management Act* (part 3 of schedule 4) as an "endangered aquatic community" (http://www.fisheries.nsw.gov.au/fsc/recommend/FR16-MR-EEC.pdf). A fisheries eight point test needs to be completed and approved prior to any assessment or manipulation of the environment.

State Forests of New South Wales issue research permits for a period of 12 months for *bona fide* research projects. There is no charge for the permit but renewal will depend on compliance with conditions. Research involving vertebrate animals must comply with the NSW *Animal Research Act No. 124* and the *Animal Research Regulation 1990, No. 403*. Where a permit authorises the collection of protected flora or fauna, the holder must carry a licence issued by the National Parks and Wildlife Service and must hold Animal Ethics Approval. (http://www.forest.nsw.gov.au/research/permits/default.asp).

Standard conditions apply to the issue of Special Purposes Permits for Research, and further special conditions may also be imposed where necessary.

Under the *Animal Research Act 1985 (NSW)*, all experiments with vertebrates need to be approved by an accredited Animal Care and Ethics Committee (ACEC) (Barker *et al.*, 2002). The NSW Fisheries ACEC will assess applications for research on fish from NSW Fisheries scientists, Australian Water Technologies and occasionally from other agencies. Animal Research Authorities are valid for a period of 12 months (Barker *et al.*, 2002).

#### *1.7.1.3 South Australia*

In South Australia, permits are regulated under the Scientific Permit System that is administered by the *Biological Survey and Monitoring Program*. A permit is required where a project involves "taking" a protected species from the wild, where research is carried out in a reserve or for plant specimen collecting. Any work with native animals requires a license for teaching, research or experimentation and animal ethics committee approval. Exceptions are where the study is purely observational or where animals involved in the study have died of natural causes. (http://www.environment.sa.gov.au/biodiversity/research.html). The *Prevention of Cruelty to Animals Act, 1985*, must be adhered to. An animal and plant control Commission Permit is required to house animals or to use plants that are declared pests. A Department of Environment permit is required to house native Australian animals and birds, collect carcasses, skeletons and other remains of native Australian animals and birds or collect selected native plant species (http://www.unisa.edu.au/orc/ethics/permits.htm).

In South Australia, researchers and teachers who are not members of licensed organizations will be required to gain approval from the animal ethics committee prior to the commencement of the project. (http://www.environment.sa.gov.au/biodiversity/research.html).

#### *1.7.1.4 Victoria*

A permit is required for all scientific research carried out in areas covered by the *National Parks Act 1975*. All projects and surveys in the biological, earth, physical and social sciences are included in this requirement, where the work involves sample collection or site manipulation, or location of equipment, or disturbance to the environment or to park visitors.

Research permits are issued to qualified people for a genuine scientific research project that will produce useful information for park management, or improve scientific knowledge. Additional permits may be required for projects involving taking of protected flora, handling native wildlife or activities covered by other legislation such as the *Fisheries Act* 1995, *Wildlife Act,* 1975 (Vic), *Flora and Fauna Guarantee Act*, 1988 (Vic) or *Forests Act*, 1958 (Vic) (http://www.dse.vic.gov.au/web/root/domino/cm_da/dsencor.nsf/frameset/DSE+Corporate?OpenDocument&[http://www.dse.vic.gov.au/search.html). In addition to the above permits, a forests research permit is required for any research in State Forests. Permit applications should be made to Department of Sustainability and Environment a minimum of four weeks prior to the commencement of the research (http://www.dse.vic.gov.au/web/root/domino/cm_da/dsencor.nsf/frameset/DSE+Corporate?OpenDocument&[http://www.dse.vic.gov.au/search.html).

#### *1.7.1.5 Queensland*

To explore, survey, examine or research an area for cultural heritage places as part of the environmental impact assessment process or academic research, you must apply for a permit. A permit is required if the research involves:

- The use of apparatus prescribed for commercial use only;
- Being in possession of undersize fish; and
- Exceeding a bag limit; (Licensing Section, Qld Fisheries Service - http://www.dpi.qld.gov.au/fishweb/3028.html).

Level of experience and qualifications, as well as the amount of consultation undertaken, play a major role in the assessment of permit applications. A permit is also required if excavation or collection of items is proposed.

There are two types of permits: one for research, survey, and examination; and another for excavation or collection. Permits are only issued with the landowner's permission and may be valid for up to 12 months. Permits must be applied for in writing to the Environmental Protection Agency (http://crimp.marine.csiro.au/nimpis/authorities.asp).

The generally accepted standard for ethical practice is the "*Australian code of practice for the care and use of animals for scientific purposes*", published by the National Health and Medical Research Council (2004).

#### *1.7.1.6 Australian Capital Territory*

Under the *Nature Conservation Act 1980 (ACT)*, a licence is required for the following activities in the ACT:

- Taking native animals;
- Killing native animals;
- Picking native plants;
- Keeping animals, whether a native animal or an exotic species;
- Importing into or exporting animals or protected native plants from the Territory; or
- Selling or trading in native animals or protected native plants.

Only bird and bat banders with a current licence issued under the *Nature Conservation Act 1980* can legally undertake banding activities in the ACT. The Australian Bird and Bat Banding Authority is a separate authority. Generally licences will only be issued for a maximum of 12 months to expire on 30 June each year. Further information on permits and licensing is available from the Environment ACT website: (http://www.environment.act.gov.au/nativeplantsandanimals/scienlicaps.html).

### 1.7.2 Costs

There is significant inconsistency in the way that the costs of techniques are calculated, reported and compared. Some comparisons include travel, accommodation and labour but exclude costs for capital items, sample preservation, training and certification (Faragher and Rodgers, 1997). Additional costs may include permits, licenses, inoculations and other health considerations and insurance. There are significant savings to be made in terms of travel, accommodation and labour when a variety of techniques are performed on the same field trip as these costs are divided amongst the number of techniques used. Further savings on calculated costs will be made if a group already owns the necessary capital items, where staff are already qualified, or where volunteers can fulfil some of the labour requirements.

Where we have indicated an estimate of costs in the following chapters they should be seen as indicative only and should not be relied upon solely when in developing a monitoring program.

# Chapter 2
# Monitoring Surface Water

## 2.1 Preliminary Considerations

Water quality is probably the most commonly measured component of monitoring programs for wetlands and floodplains (Hart, 2002). However, in some cases, the value of this data to monitoring and evaluation is compromised by poor or unknown quality assurance/ quality control. Therefore, the key element of a successful surface water-quality monitoring program is ensuring an adequate and well-documented quality assurance system is in place.

The two largest sources of error in any water-quality monitoring program are associated with sampling and analysis. Therefore, before discussing in detail the selection and application of techniques for a particular analyte, the first part of this section deals with general considerations for designing and implementing a surface-water quality sampling program and the structure of a general analytical laboratory Quality Assurance/Quality Control Program.

## 2.2 Sampling Program

### 2.2.1 Design of Sampling Program.

The initial design of a water quality sampling protocol will ultimately depend on the nature of the monitoring and evaluation task. However, the design of the monitoring program should be consistent with the *Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC, 2000) and conform to AS/NZS Standard 5667.1:1998.

Of particular importance when looking at floodplain responses to inundation is the question of flow responses. In particular, as noted in the *ANZECC Guidelines*, when designing a monitoring and evaluation program where flow is an important parameter, it is important to consider:

- "the importance of flow-based monitoring and, of capturing first flush and peak events;
- the need to measure and record flow data in conjunction with analyte concentration data obtained at the same time;
- the need to sample and obtain information at all flow regimes, including low flows, so that water quality can be described for all conditions of the water body".

*Source: Australian Guidelines for Water Quality Monitoring and Reporting*

Many monitoring programs will take a single sample from a water body under the assumption that the analyte of interest is uniformly distributed throughout the water column through time. It is well known that some analytes (e.g. dissolved oxygen, temperature and pH) can vary over a diurnal cycle (Stumm and Morgan, 1996), while even very shallow wetlands can stratify producing significant differences in the water chemistry in the between surface and bottom waters (e.g. Gribben *et al.*, 2003). Furthermore, dried floodplain/wetland soils and sediments can rapidly release nutrients, carbon and salt on re-wetting which can result in substantial changes to the overlying water chemistry (Baldwin and Mitchell, 2000). Reid and Brooks (1998) recommended that physical and chemical parameters should be measured in association with fixed transects with frequent sampling during the periods of fastest change, that is, flooding and draw-down (spring/summer). It is important to measure physical and chemical parameters of wetlands to establish seasonal patterns and the changes that occur with flooding and drying. Without strong base line data, it is difficult to detect long term changes and responses to management (Lloyd and Alexander, 2002).

### 2.2.2 Choice of Sample Containers and Preservatives

Sample containers and preservatives used in the monitoring and evaluation program should conform to AS/ NZS 5667.1:1998. A list of recommended containers and preservatives for analytes typically used in wetland and floodplain monitoring programs is presented in Table 2.1

## 2.3 Surface Water Sampling

### 2.3.1 Sampling Protocol

Sampling protocols used in the monitoring program should confirm to *AS/NZS 5667.4:1998 Water Quality Sampling Part 4: Guidance on Sampling from lakes, natural and man-made* and *AS/NZS5667.6:1998 Water Quality Sampling Part 6: guidance on sampling of rivers and streams.*

*Table 2.1 Recommended Sampling Containers and Preservatives Source: AS/NZS 5667.1:1998; APHA, 1998*

| Analyte | Type of Container | Preservative | Maximum Holding Time |
|---|---|---|---|
| Acidity | Plastic or glass | Refrigerate | 24 hours |
| Alkalinity | Plastic or glass | Refrigerate | 24 hours |
| Ammonia | Plastic | Filter in the field (0.45µm) and freeze | 1 month |
| Chlorophyll *a* | | | |
| Conductivity (EC) | Plastic or glass | Refrigerate | 1 month |
| Major Cations (Na, K, Ca, Mg) | Plastic | None Required. Acidification (pH < 2) allows determination of other metals from the same sample | 1 week (1 month if acidified) |
| Metals (Cd, Co, Cu, Fe, Mn, Pb, Zn) | Acid washed plastic | Adjust pH to < 2 | 6 months |
| Total and Dissolved Organic Carbon | Pre-fired borosilicate glass with Teflon™ cap liner | For dissolved organic carbon, filter in the field (0.45µm). Adjust pH to 2 with phosphoric acid then refrigerate | 7 days |
| Total Nitrogen | Plastic | Freeze | 1 month |
| Nitrate | Plastic | Filter in the field (0.45µm) and freeze | I month |
| Soluble Reactive Phosphorus | Plastic | Filter in the field (0.45µm) and freeze | 1 month |
| Total Phosphorus | Plastic | Freeze | 1 month |
| Reactive Silica | | Filter in the field and refrigerate (do not freeze) | |
| Sulfate | Plastic | Freeze | 1 month |
| Sulfide | Plastic | Add 2mL of 10% (m/v) Zn acetate to 500mL sample and refrigerate | 1 week |
| Turbidity | Plastic | Refrigerate | 24 hours |

#### 2.3.1.1 Quality Assurance/Quality Control

Contamination during sampling and transport, can be an important source of error in chemical monitoring programs. Therefore it is important to include appropriate blank samples in any sampling run. QA/QC check-samples should not be labelled in such away that the analysing laboratory can identify them as such.

*Field and Transport Blanks*

AS/NZS 5667.1:1998 recommends the use of field and transport blanks in all monitoring programs. To prepare these blanks take a quantity of water of known composition preferably with very low (if any) levels of the analyte of interest. One portion is retained in the laboratory, one portion (the field blank) is treated as far as practicable as a real sample including filtration (if required) and addition of preservatives, while the third portion (transport blank) is preserved and transported as a real sample. At least one field and transport blank should be included in any given sampling run.

*Container Blank*

A cleaned sample container is filled with water of a known quality, preserved appropriately and stored for the same period of time as the real samples and then analysed. Differences between observed and anticipated results give an indication of any potential contamination from the sample container. At least one container blank should be used per batch of containers (AS/NZS 5667.1:1998).

*Field Spikes/Spike Recovery*

Spike recovery samples are used to determine possible losses of an analyte during sampling and transport. A water sample is divided into two portions of known volume. A small volume (typically less than 1% of the sample volume) of a concentrated solution of the analyte of interest is added to the water sample. The concentration of the spike should be sufficient to approximately double the concentration of the analyte of interest in the sample. The spiked and unspiked water samples are then processed as normal, preserved and transported back to the laboratory for analysis. (AS/NZS 5667.1:1998).

*Duplicate samples*

Duplicate samples, separate samples taken at the same site and time, can be used to estimate the sampling error.

#### 2.3.1.2 Sample Chain of Custody Documentation

Chain of custody documentation (Table 2.2) is necessary to trace the providence of any given sample – which may be especially necessary if the samples are subject to litigation.

*Table 2.2 – Chain of Custody Documentation Source: ANZECC, 2000.*

| Processes Step | Quality Assurance Procedure |
|---|---|
| Field Sampling | Field register of sample number, site, type/technique, time date, technician, field data sheet |
| Sample Storage and Transport | Field register of transport container number and sample numbers, time and date |
| Laboratory Receipt of Samples | Laboratory register of transport container number and sample numbers, time and date |
| Laboratory Storage of Samples | Laboratory register of storage location, type, temperature, time, date |
| Sample Preparation | Analysis register of laboratory sample number, pre-treatment, date, technician |
| Sample Analysis | Analysis register of instrument, calibration, technician, standard method, date result |

Field records sheets should contain sufficient information to unambiguously describe:

- The time and place of sampling;
- Who took the sample;
- Results of any field measurements taken;
- A description of any unusual conditions;
- The number and type of samples taken, preservatives used and what analyses are required; and
- A list of quality control samples used.

A copy of a model field record sheet for surface waters can be found in Appendix 6 of *Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC, 2000).

#### 2.3.1.3 Field Instrument Logs

Log books should be kept for all field instruments. The log book should at least record

- Usage;
- Dates for scheduled calibration and diagnostic tests;
- The results of all diagnostic and calibration test (preferably on Quality Control Charts if applicable); and
- Records of any repairs or replacements.

## 2.4 Laboratory Quality Assurance/ Quality Control Program

Where possible all samples should be analysed by an analytical laboratory that has a third party accredited Quality Assurance/ Quality Control program in place and is certified to carry out the analysis in natural waters.

Where practicable, analyses must be associated with a diagnostic program. This program will involve the routine analysis of various quality control (check) samples. While the type of check-samples will vary for different test methods, the routine analysis of sample duplicates, blanks, spike recoveries, in-house quality control standards, and certified reference materials is desirable.

The types and frequencies of analysis of check samples is described in the individual operating procedures (see above). However, as a general rule the following protocols are suggested:

- At least one in twenty samples tested should be analysed in duplicate (i.e. two portions of the sample tested);
- At least one spike recovery sample be analysed per batch;
- At least one reagent blank should be analysed in each batch;
- At least two quality control standards of appropriate concentration be analysed in each batch;
- If the method relies on comparison against standards, at least one additional standard must be processed with every twenty samples; and
- An appropriate certified reference materials should be analysed on a routine basis - at least once every three months.

The results of check-sample analyses should be recorded on appropriate quality control charts (mean charts for blanks, quality control samples and percent recoveries and, range charts for duplicate analyses as outlined in APHA 1020 B (APHA, 1998). The control lines of these charts should be updated on a regular basis, preferably using a running average of the most recent data points (20 to 40 data points). Control chart analysis should indicate potential quality control problems. Protocols for corrective action are reported in APHA 1020B (APHA, 1998). Issued reports should indicate what quality control check-samples were used in the analysis reported and whether or not they met the prescribed Quality Control Criteria.

## 2.5 Specific Analytes

### 2.5.1 Electrical Conductivity

(Adapted from *Victorian Water Quality Monitoring Network and State Biological Monitoring Program*, (1998); Tucker, 2003; APHA 2510 B)

#### *2.5.1.1 Commonly asked questions*

High salinities in wetlands can be caused by seepage of saline ground waters into wetlands or by concentration of surface waters through evaporation (Tucker, 2003). Salt concentrations in excess of 1000 mg $L^{-1}$ can begin to affect species composition in Australian wetlands and increasing salinisation is considered a long-term threat to the health of many inland wetlands (Nielsen *et al.,* 2003). Commonly asked questions include:

- What is the baseline concentration of salt in a given floodplain water body?
- What are the long-term trends in salinity data in a given wetland or wetland complex?
- What is the effect of changing flow regime on the salt regime in a given floodplain water body?
- Is there a net export of salt from a floodplain and floodplain water bodies during flooding?
- Is the salinity concentration at a level likely to affect the wetland flora and fauna?

#### *2.5.1.2 Standard Technique*

The standard method for determining electrical conductivity is APHA 2510 B, which although a laboratory based technique, can be adapted for field measurements.

#### *2.5.1.3 Alternative Techniques*

Electrical conductivity is only a surrogate measure of salinity - with the ratio of total dissolved solids (in mg $L^{-1}$) to electrical conductivity (in µs $cm^{-1}$ at 25ºC or EC units) varying from 0.55 to 0.8 depending on the water body and salt composition (APHA 1030 E; McKay *et al.*, 1988). If a more accurate determination of total dissolved solids is required (for example to estimate loads of dissolved solids exported during floods) then it should be directly determined gravimetrically according to Australian Standard AS 3550.4 (filtration through GF/C filters and drying to constant weight at 105ºC).

#### *2.5.1.4 Recommended Method*

(To be read in conjunction with APHA 2510 B and state agencies standard operating procedure.)

*Equipment*

This method requires either a laboratory or field based conductivity meter with a range of at least 0 - 50000 µS $cm^{-1}$ at 25ºC, a resolution of 1 at 25ºC for conductivities less than 5000 µS $cm^{-1}$ and an accuracy of at least 1% or 1µS $cm^{-1}$, whichever is greater. If the conductivity meter is not equipped with a temperature sensor, then a calibrated thermometer is also required.

*Calibration*

The meter must be calibrated on use with a KCl standard similar to the range expected for the water body (Table 2.3) and across the full scale each year.

*Table 2.3 - Calibration Standards for conductivity determination.*

| Expected Conductivity (approximate ) µS $cm^{-1}$ at 25ºC | Calibration Standard | Conductivity of Standard µS $cm^{-1}$ at 25ºC |
|---|---|---|
| 0 – 500 | 0.001 M KCl | 146.9 |
| 500-5000 | 0.01 M KCl | 1412 |
| 5000-50000 | 0.1 M KCl | 12890 |

The thermometer or temperature sensor (if equipped) should be calibrated against a reference thermometer at two points (ice point and ambient) every three months.

*Operation*

The meter should be used according to the operating instructions. Sample or measuring containers (if used) should be rinsed at least three times with sample or standard solution before use.

*Special Considerations*

1. As distinct haloclines can exist in some wetlands, particularly where groundwater seepage is a problem, at least two conductivity measurements should be taken from the deepest point of the wetland, one near the surface (about 0 .1 - 0.5 metres deep) and one near the bottom of the water body (about 0.5 metres from the bottom).
2. Electrical conductivity measurements are temperature dependent; therefore care must be taken to ensure that it is clear whether the recorded conductivity has been standardised to 25ºC or if temperature correction is still required.
3. If high salinities are encountered in a given wetland (greater than about 2000 µS $cm^{-1}$), consideration should be given to determining if the wetland sediment is sulfidic – see Chapter 4.

*Costs*

Low, once equipment has been purchased.

### 2.5.2 pH

(Adapted from *Victorian Water Quality Monitoring Network and State Biological Monitoring Program*, (1998); Tucker, 2003; APHA 4500 – $H^+$ B).

#### *2.5.2.1 Commonly asked questions*

pH in natural waters usually falls within the range of about 6-9. Measured pH outside this range may indicate unusual processes. Decreases in pH may be caused by high organic loads ('blackwater' – Barmah Millewa Forum, 2001) bacterial process (e.g. nitrification or sulfate reduction or oxidation of sulfidic sediments) (e.g. McCarthy *et al.*, 2003). Increases in pH may be caused by some bacterial processes (e.g. denitrification) or accelerated algal growth (e.g. algal blooms - McKelvie, 2002); with the later showing potentially large diurnal changes.

Commonly asked questions include:

- What is the baseline pH range in a given floodplain water body?
- What are the long-term trends pH in a given wetland or wetland complex?
- What is the effect of changing flow regime on the pH in a given floodplain water?
- Is the pH at a level likely to affect the wetland flora and fauna?

#### *2.5.2.2 Standard Technique*

In general, short-term pH measurements can be made accurately and reproducibly in the field using a glass electrode and following standard methods (APHA 4500 – $H^+$ B). Australian Standard AS 2300.1.6 – 1989 is also relevant.

#### *2.5.2.3 Alternative Techniques*

A number of alternate methods are available to determine pH. Including

- pH test strip;
- Spectrophotometry using an indicator solution (Dickson, 1993, as cited in McKelvie, 2002);
- Flow injection system (Bellerby *et al.*, 1995, as cited in McKelvie, 2002); or
- Continuous-flow spectrophotometric system (Tapp *et al.*, 2000, as cited in McKelvie, 2002).

While none of these techniques offers any advantage over glass electrode for routine field sampling, the continuous flow methods may be applicable for long-term continuous monitoring of pH in wetlands as the glass electrodes tend to biofoul and become unreliable if immersed for extended periods of time.

#### *2.5.2.4 Recommended Method*

(To be read in conjunction with APHA 4500 .B and state agencies standard operating procedure.)

*Equipment*

A field portable pH meter with in-built temperature compensation and an accuracy of at least 0.1 pH units, attached either to both a glass and reference electrode or a combination electrode. Electrode filling solution and storage solutions (as per manufactures specifications), fresh, pre-prepared pH 4 and pH 7 buffers, and a wash bottle containing deionised water are also required.

*Calibration*

The meter must be calibrated on use with pH 4 and pH 7 buffer solutions. During calibration the slope response of the electrode should be recorded. The slope response is temperature dependent. At 20°C the theoretical slope response is 58.2 mV/pH unit. If the response is less than 55.2 or greater than 59.3mV at 20°C then the electrode should be replaced before a measurement is taken (AS 2300.1.6). The junction potential should also be checked routinely and the results recorded in the instruments field log-book. The junction potential is determined by measuring the pH of a pH 6.88 phosphate buffer solution (3.54 g dry $Na_2HPO_4$ and 3.39 g dry $KH_2PO_4$ diluted to 1 litre in deionised water) and comparing it with a 1:10 dilution of the same buffer. The pH of the diluted buffer should be 0.20 ± 0.05 pH units greater than the undiluted buffer (AS 2300.1.6).

*Operation*

Follow manufacturers instructions. The electrode(s) must be washed with distilled water and carefully patted dry (using soft paper or cloth) between each measurement to minimise cross-contamination. Special care should be taken in the handling and storage of electrodes.

*Special Considerations*

1. Glass electrodes are fragile and should be maintained according to manufactures instructions.
2. The pH in eutrophic wetlands can vary diurnally. Therefore, if only one measure is taken it should be at about the same time on each sampling period.
3. If very low pH values (< pH 4) are found, test for the presence of acid producing sediments – see Chapter 4.

*Costs*

Low, once equipment has been purchased.

### 2.5.3 Optical Properties - Turbidity, Suspended Solids, Water Clarity and Colour

(Adapted from *Victorian Water Quality Monitoring Network and State Biological Monitoring Program*, (1998); Tucker, 2003, APHA 2120, 2130-B, AS 3550.4 and 7).

#### *2.5.3.1 Commonly asked questions*

Light penetration (clarity) is one of the principal controls for determining primary productivity in wetlands.

The clarity of the water is dependent, in the most part on the amount of material (including clays, other inorganic matter, organic matter and algal and bacterial cells) that is either dissolved or suspended in the water column. Common questions include:

- What is the baseline clarity of a given floodplain water body?
- What are the long-term trends of clarity in a given wetland or wetland complex?
- How much suspended material is exported from a floodplain during flooding?

#### *2.5.3.2 Standard Technique*

There is a number of related (but not necessarily interchangeable) techniques for determining the optical properties of water – measuring the degree of light scatter (turbidity), measuring the absorbance of light at a particular wavelength (colour), gravimetrically determining the amount of material suspended in the water column (total suspended solids) or visual index of light penetration (secchi disk). There are Australian Standards for determining total suspended solids (AS 3550.4) and the construction and use of a secchi disk (AS 3550.7). American Public Health Association (1998) describes standard techniques for determining turbidity (APHA 2130 B) and a number of methods for determining colour (APHA 2120 B, C and D).

#### *2.5.3.3 Alternative Techniques/Methods*

There are a number of ways to determine turbidity and colour. Turbidity can be measured either using a nephelometer (turbidity meter) or turbidity tube - which relies on filling a graduated tube with water until a mark on the bottom of the tube is no longer visible. Given the subjective nature of this later method, it is not recommended for monitoring and evaluation programs where quantitative data is required.

Colour is a surrogate measure for the amount of organic material (and occasionally iron and manganese) dissolved in the water. Colour can be measured in a colour comparator against known standards (APHA 2120B), by measuring the adsorption of light at a fixed wavelength (eg "gilvin" at 440nm) using a spectrophotometer, or by determining the hue, brightness and saturation by measuring the light transmission characteristics of a filtered water sample (APHA 2120 C). Given the importance of dissolved organic carbon to the functioning of floodplains and wetlands, it is recommended that rather than using colour as a surrogate measurement, dissolved organic carbon is determined directly –see below.

#### *2.5.3.4 Recommended Methods*

**Suspended Solids** – refer to AS 3550.4

**Secchi Depth** – refer to AS 3550.7

**Turbidity -** (To be read in conjunction with APHA 2130 B and State agencies standard operating procedure.)

*Equipment*

A field portable turbidity meter with a range of 0-1000 NTU and reference standards.

*Calibration*

The meter must be calibrated on use with a turbidity standard of approximately the same turbidity as the water sample. The turbidity meter (and field standards if applicable) should be calibrated over their full range annually using formazin standards - see APHA 2130 B.

*Operation*

Follow Manufacturers instructions.

*Special Considerations*

Although it is preferable to measure turbidity in situ, samples can be stored for up to 24 hours before analysis in the laboratory (AS 5667.1). If samples are to be stored they must be well mixed before analysis.

*Costs*

Low, once equipment has been purchased.

### 2.5.4 Dissolved Oxygen

(Adapted from APH4500 O - G).

#### *2.5.4.1 Commonly asked questions*

The saturation concentration of oxygen in water is typically in the range of 7-10 mg $L^{-1}$ depending on the temperature, however the dissolved oxygen concentration in eutrophic waters or waters high in dissolved organic carbon (e.g. blackwater from receding floods) is often substantially lower. Considerable differences in DO also can exist between surface and bottom water as a consequence of temperature or salt induced stratification. Low oxygen levels can be detrimental to many higher organisms and, changes in oxygen concentration can affect the way nutrients cycle in a water body. Commonly asked questions include:

- What is the baseline level of dissolved oxygen in a floodplain water body?
- Is the wetland stratified?
- During floods, particularly of forested floodplain, what is the dissolved oxygen concentration of the return flood water?
- Is there sufficient dissolved oxygen to support aquatic organisms such as fish and invertebrates?

#### *2.5.4.2 Standard Technique*

Dissolved oxygen concentrations can be determined either chemically using a Winkler titration (APHA 4500-O B) or electrochemically using a membrane electrode and meter (APHA 4500-O G). Although the Winkler method is more accurate, for most field monitoring programs, the electrochemical method, if correctly applied, should give sufficient accuracy.

#### *2.5.4.3 Recommended Method*

To be read in conjunction with APHA 4500-O G and relevant state agency standard operating procedure.

*Equipment*

A field portable oxygen meter with a range of 0 - 20 mg $L^{-1}$. It is preferable to have an instrument that compensates for both temperature and salinity. Tables for oxygen solubility in water and atmospheric pressure correction-factor with elevation (if the atmospheric pressure is not known) are also required.

*Calibration*

Generally, the manufacturers instructions should be followed. Before an instrument is taken in the field it should be calibrated against moist air (or air-saturated water) and a zero dissolved oxygen solution (prepared by adding excess sodium sulfite to distilled water). Once in the field the probe should be calibrated against moist-air or air saturated-water at temperatures close to ambient. The calibration value will depend on the temperature as well as the atmospheric pressure. If the atmospheric pressure is not known it can be estimated from the site's height above sea-level using tables.

If a temperature probe is attached, it should be calibrated against a reference thermometer at two points (ice point and ambient) every three months.

*Operation*

It is preferable to measure the oxygen concentration *in situ* rather than taking a discrete sample and then measuring it. If a discrete sample has to be taken it should be taken with equipment that samples by displacing water rather than air – that is samples should be taken by syringe or pump rather than by immersing an empty container into the water body (AS 5667.1). When samples are taken at a pump outlet, a flexible inert tube which delivers liquid to the bottom of the container is recommended, to ensure that minimal aeration occurs (AS 5667.1). If a discrete sample is taken the dissolved oxygen concentration should be measured immediately.

Electrode response is dependent on salinity so it is important that electrical conductivity is measured and recorded at the same time as dissolved oxygen. It is also important to note whether the reported dissolved oxygen concentration has been corrected for salinity or not -

some instruments automatically compensate for salinity. The temperature of the sample should also be recorded.

*Special Considerations*

1. Before use, it is important to check the electrode membrane to ensure that the membrane is not cracked and that there are no air bubbles beneath the membrane.
2. Electrode membranes should be replaced regularly.
3. Dissolved oxygen can vary diurnally therefore, for ongoing monitoring, it is important to measure dissolved oxygen concentrations at approximately the same time – preferably early morning.
4. If the water body is stratified there will be a dissolved oxygen gradient between the surface and the sediment. Therefore, dissolved oxygen measurements should be taken from just below the surface and just above the sediments in the deepest part of the lake.

*Costs*

Low, once equipment has been purchased.

### 2.5.5 Nutrients (Total Phosphorus, Soluble Reactive Phosphorus, Total Nitrogen, Nitrate, Nitrite, Ammonia, Silicate and Sulfate)

#### *2.5.5.1 Commonly asked questions*

One of the key areas in understanding the interaction between a river and its floodplain is determining the extent of bilateral movement of materials between the river and the floodplain (including floodplain lakes) during floods. Commonly asked questions associated with monitoring and evaluation programs are:

- What are the stores of nutrients in floodplain lakes?
- How do nutrient levels in floodplain lakes change in response to changing water regime (including drying)?
- What is the net exchange of nutrients between rivers and floodplains during floods?
- Is the wetland eutrophic?

#### *2.5.5.2 Standard Technique*

The American Public Health Association describes standard techniques for measuring total and soluble phosphorus (APHA 4500- P), total nitrogen (APHA 4500-N), ammonia (APHA 4500-$NH_3$), nitrate (APHA 4500-$NO_3^-$), nitrite (APHA 4500-$NO_2^-$), silica (APHA $SiO_2$) and sulfate (APHA 4500-$SO_4^{2-}$). However, each of those chapters describes a number of different methods.

#### *2.5.5.3 Alternative Techniques*

Given appropriate quality control and quality assurance protocols, methods other than those described in APHA 'Standard Methods" can be used successfully. For example silica is routinely measured using inductively coupled plasma spectrometry rather than colourimetrically (as per APHA 4500-Si) but with similar results (Wruck *et al.*, 2003).

In general, it is preferable to analyse samples for nutrients in the laboratory (with filtering in the field where necessary). Field kits do exist for measuring nutrient concentrations in the field, but before results from these kits are used in monitoring and assessment programs it is necessary to show that the detection limit and reproducibility of data produced with these kits is comparable to laboratory methods (Ormaza-Gonzalez and Villalba-Flor, 1994).

#### *2.5.5.4 Recommended Method*

*Sampling*

Contamination of samples is potentially one of the most significant sources of error in nutrient studies. Therefore, it is important that QA/QC samples are included in the sampling program (see section 2.3 above). If filtration is required, samples should be filtered through a 0.45µM cellulose acetate filter (AS 5667.1), and a filtering blank included in the QA/QC sampling protocol. In general, nitrogen and phosphorus samples should be preserved by freezing rather than acid preservation. Freezing has been shown to be an effective preservative and it removes the possibility of sample contamination from the acid preservative, at the same time removing occupational health safety and environment issues associated with the transport and use of strong acids.

*Analysis*

There are no recommended methods for analysing nutrients. If appropriate quality assurance and quality control protocols are in place, results using different techniques should be comparable (Wruck *et al.*, 2003). It is strongly recommended that laboratories involved in analysing nutrients as part of the *Living Murray Initiative* should participate in the *National Low-Level Nutrient Collaborative Trials.*

*Special Considerations:*

1. If the water body is stratified there will probably be differences in nutrient concentrations between the surface and bottom waters. Therefore, the use of depth-integrated or composite sampling procedures (see AS 5667.4, APHA 1060B) is recommended.
2. If bottom waters are anoxic, significant changes in nutrient speciation can occur on reoxidation. For example, oxidation can cause the precipitation of previously dissolved iron, which in turn can lead to the loss of soluble P from solution.
3. If samples for dissolved organic carbon are to be taken at the same time, extra care needs to be taken to ensure that cross contamination from the phosphoric acid preservative does not occur.
4. Ammonia samples can be easily contaminated from ambient sources including cleaner residues and tobacco smoke; however, such source of contamination should be identifiable from appropriate QA/QC sampling protocols.

5. The ultra-violet spectrophotometric screening method (APHA-$NO_3^-$-B) for determining nitrate concentrations is not recommended for use in wetlands because of interference from other dissolved species that can adsorb UV light (e.g. some dissolved organic carbon species).

*Costs*

The cost of analyses varies between laboratories – with costs ranging from <$5 to >$20 per analyte per sample. Costs should be determined when designing the monitoring program.

### 2.5.6 Total and Dissolved Organic Carbon

#### *2.5.6.1 Commonly asked questions*

Carbon is one of the major drivers in lowland river systems. Changing flow patterns should change the way carbon is processed and moves in these systems. Of particular interest is the net export of C from the floodplain back to the river following inundation of the floodplain. Excessive levels of dissolved organic carbon can result in anoxia in the floodwater and ultimately lead to unacceptable downstream consequences such as fish kills (Baldwin *et al,* 2001). Therefore, during flooding experiments, it is important to monitor the flux of C from the floodplain. Commonly asked questions associated with monitoring and evaluation programs are:

- What are the stores of carbon in floodplain lakes?
- How do carbon levels in floodplain lakes change in response to changing water regime (including drying)?
- What is the net exchange of carbon between rivers and floodplains during floods?

#### *2.5.6.2 Standard Technique*

The American Public Health Association describes a standard technique for measuring total organic carbon (APHA 5310), which can be adapted for determining dissolved organic carbon.

#### *2.5.6.3 Alternative Techniques*

Measures of total carbon do not give any estimation on how bioavailable the carbon is. Estimates of bioavailability can be determined using classic five day BOD tests (APHA 5210; AS4351.5), loss of oxygen (e.g. AS 4351.3, 1996) or generation of $CO_2$ (e.g. AS 4351.4, 1996) or changes in UV adsorption over time (e.g. Baldwin, 1999).

#### *2.5.6.4 Recommended Method*

*Sampling*

It is important that QA/QC samples are included in the sampling program (see section 2.3 above). For dissolved organic carbon samples, the samples should be filtered through a 0.45μm cellulose acetate filter (AS 5667.1), and a filtering blank included in the QA/QC sampling protocol. It is recommended that samples are preserved with phosphoric acid (AS 5667.1). Samples for dissolved organic carbon should not be frozen.

*Analysis*

Refer to APHA 5310.

*Costs*

The cost of analyses varies between laboratories and should be determined when designing the monitoring program.

### 2.5.7 Major Cations (Na, K, Ca, Mg)

#### *2.5.7.1 Commonly asked questions*

The major cationic species ($Na^+$, $K^+$, $Mg^{2+}$, and $Ca^{2+}$) vary between locations in both abundance and concentration. Freshwater biota are influenced as much by the ionic composition and pH of water as by the total concentration of dissolved substances (Frey, 1993). The relative proportions of the main cations and anions modify the way biota respond to high salinities (Bayly, 1969; Bailey and James, 2000; Radke *et al.,* 2002). Bayly (1969) suggests that the ratio of $(Na^+ + K^+)/(Mg^{2+} + Ca^{2+})$ is important in determining toxicity and suggests that the monovalent ions are more toxic than divalent ions.

#### *2.5.7.2 Standard Technique*

There are Australian Standards for determining calcium by EDTA titration (AS2383, 1986), and calcium and magnesium by atomic adsorption spectroscopy (AS 3550.6, 1990 and AS2976, 1987 respectively). The American Public Health Association describes standard techniques for measuring sodium (3500- Na), potassium (3500-K), calcium (3500- Ca) and magnesium (3500 – Mg) using atomic adsorption spectroscopy (all cations), inductively coupled plasma (all cations), flame emission photometry (Na and K), titrimetrically (Ca and Mg) or gravimetrically (Mg).

#### *2.5.7.3 Alternative Techniques*

Given appropriate quality control and quality assurance protocols, methods other than those described in APHA "*Standard Methods*" can be used successfully.

#### *2.5.7.4 Recommended Method*

There are no recommended methods for analysing major cations. If appropriate quality assurance and quality control protocols are in place, results using different techniques should be comparable.

*Costs*

The cost of analyses varies between laboratories and should be determined when designing the monitoring program.

### 2.5.8 Reduced Species (Fe(II), Mn(II) and $S^{2-}$)

Reduced iron and sulphur compounds can be found in anoxic bottom waters and groundwaters; for further details on analyses see Chapter 3 – Monitoring Groundwater.

# Chapter 3
# Monitoring Groundwater

## 3.1 Preliminary Considerations

Characterization of groundwater levels, flows and quality is probably as important as that of surface water for floodplain ecosystems. Within the context of the Murray-Darling Basin, groundwater plays a key role in the transport and accumulation of salts in floodplain soils and wetlands, which can compromise ecosystem health (Jolly, 1996). In addition, the displacement of saline groundwater during flood cycles can lead to significant increases in the discharge of salts from floodplains to the main river channels (Jolly *et al.*, 1994).

Most of the QA/QC protocols and procedures that apply to surface water monitoring apply equally to groundwater monitoring programs and should be followed (see Chapter 2). However, there are a number of ancillary considerations that should be noted. Firstly, the chemical composition of groundwater can change during sampling. In particular, oxidation of anaerobic groundwater can result in changes to chemical speciation (particularly of iron, manganese and reduced sulphur species). Pressure differentials between the groundwater sampling depth and the surface can cause release of carbon dioxide and subsequent increase in pH, which in turn can affect metal speciation (Groundwater Working Group, undated). Secondly, sample contamination and representativeness can also be an issue. Samples can be contaminated by entrained sediment in the bore, or be cross-contaminated from residues in the pumps or sampling equipment. Surface water (either from rain or overland flow) entering into the bore or running down the bore casing, can also compromise the results. Stagnant water in the bore may be totally different from the surrounding groundwater and therefore requires the routine purging of the bore before sampling.

## 3.2 Sampling Program

### 3.2.1 Design of Sampling Program

Although there are a number of similarities in the design of surface and groundwater monitoring programs, studying groundwater movement and quality requires special expertise and therefore a specialist hydrogeologist should be consulted. The monitoring program, including the placement of bores, should be based on a conceptual hydrogeological model of the area of interest.

## 3.3 Groundwater Sampling

### 3.3.1 Bore Construction

Bores used in ground water sampling should only be constructed by operators who hold a National Water Well Drillers Licence of a class suitable to the aquifer being studied. The bore construction should conform to ARMCANZ (1997) *Minimum Construction Requirements for Bores in Australia*. The bore annulus in shallow bores should be sealed with bentonite or bentonite/cement slurry with a specific gravity > 1.45. Bentonite alone is generally not suitable where the groundwater is even slightly saline (greater than about 500 EC - Department of Environment, undated). Following construction, basic information with respect to the bore should be recorded in such a way as can be readily retrieved specifically:

- The geographical position of the site;
- The elevation of the site, as a reference for measurements of water levels;
- Drilling details of bores (method, depth, diameter, time);
- Construction details, particularly bore casing and screens and sealants;
- The condition of the bore and the purpose(s) of the groundwater extracted;
- Down-hole lithology and interpreted stratigraphy; and
- Information on the aquifer intervals or water cuts intersected down hole.

(Source: National Groundwater Committee Working Group on National Groundwater Data Standards (1999); see also ASTM D5254-92 *Minimum set of data elements to identify a groundwater site*).

### 3.3.2 Sampling Protocol

Although there is an Australian Standard for groundwater sampling (AS/NZS 5667.11:1998), where appropriate, all groundwater monitoring and evaluation programs will conform to *Murray-Darling Basin Groundwater Quality Sampling Guidelines* (Groundwater Working Group, undated – available directly from the Murray-Darling Basin Commission). A summary of the *Guidelines* is presented in Table 3.1. Sample containers, preservatives and QA/QC protocols for both the sampling and analysis should be the same as those recommended for surface waters

(see Chapter 2). Copies of model field record forms for purging, sampling and chain of custody/analysis requests respectively can be found in the *Murray-Darling Basin Groundwater Quality Sampling Guidelines*.

There are a number of different devices for sampling groundwater – each with their own inherent advantages and disadvantages. While no particular sampling method is specifically recommended or discouraged, where sample integrity depends on maintaining gas concentrations at ambient levels (e.g. redox sensitive elements such as dissolved Fe(II) and sulfide), equipment should be chosen which minimizes oxidation in particular samples by displacing water rather than air. (AS/NZS 5667.1, 1998).

### 3.3.3 Reporting

An *Australian National Groundwater Data Transfer Standard* is currently being developed (National Groundwater Committee Working Group on National Groundwater Data Standards, 1999). All groundwater data, including basic data about the bore (location, elevation etc) water level, and water quality should be produced in a form consistent with the proposed standard.

## 3.4 Specific Analytes

Many of the analytes commonly measured in groundwater studies have been discussed in the chapter on surface water monitoring (Chapter 2) and, with the exception of electrical conductivity, will not be dealt with here.

### 3.4.1 Groundwater Level

#### *3.4.1.1 Commonly asked questions*

Knowledge of the groundwater level is one of the basic parameters required for any groundwater monitoring program as it will determine for example, whether or not the groundwater will intersect with surface water features (e.g. wetlands or channels) or whether or not it will impact (favourably or unfavourably) with floodplain vegetation. Questions include:

- What is the depth of the groundwater at a given time?
- How does the depth of the groundwater change over time?
- How does the depth of the groundwater change in response to a given flow event?
- How does the depth of the groundwater change in response to a change in flow regime in an adjacent surface waterbody (eg weir drawdown)?

*Standard Technique*

Currently there isn't an Australian Standard for determining groundwater levels. The American Society for testing and materials has a standard *Test Method for determining subsurface liquid levels in a borehole or monitoring well (observation well)* (ASTM D4750-87) based on pressure measurements.

*Table 3.1 – Elements of a groundwater monitoring program. Source : Murray Darling Basin Groundwater Quality Sampling Guidelines,*

| Step | Goal | Recommendation |
|---|---|---|
| **Preparation** | To integrate sampling and analysis functions. | Confer with laboratory personnel about the objectives of the program and the choice of best techniques for collection, preservation and testing. |
| **Set-up** | To prevent ground contamination and have everything ready for the sampling process. | Prepare field record sheets and record data in logbooks. Place plastic sheeting around well area to prevent direct contact with ground and lay out equipment. Calibrate probes, preferably everyday or when accuracy is in doubt during the sampling program. |
| **Decontamination** | To clean sampling equipment and prevent cross contamination. | Use bleach or detergent solution. Clean system internally and externally Consider disposal of decontamination solution. |
| **Hydrologic Measurements** | Establish non-pumping water level. | Measure depth to water, total depth of well and height of casing to +1mm. |
| **Bore Purging** | To remove stagnant water, pump a minimum of 3 bore volumes until pH, temperature, and EC have stabilised. | Record volume, rate, duration and time of purge. |
| **Pumping /Bailing to Obtain Sample** | To collect samples with minimal disturbance of sample chemistry. | Collect samples using appropriate pump device/bailer. Use low pump rate for gas sensitive parameters. Higher rates can be used for inorganic parameters. |
| **Field Measurements** | To avoid bias in determination of parameters/ constituents which do not store well, e.g. gases, pH, alkalinity. | Analysis for determinations of gases, alkalinity, temperature, pH, EC, and DO, should be carried out in the field. The best system is a flow-through chamber fitted with probes. Record results. |
| **Sample Collection** | To collect samples with minimal disturbance of sample chemistry. | Use containers as recommended in Table 2.1 Ideally run a plastic hose from the bore head outlet to the bottom of the sampling bottle (Do not use plastic with organics). |
| **Filtration** | To determine 'soluble' constituents and preserve sample. To be carried out in the field as soon as possible after collection. | Standard filter is 0.45µm. Use with vacuum or pressure pump. Filter trace metals, inorganics, anions/cations, alkalinity. Do not filter for microbiology, some stable isotopes and organic compounds. |
| **Rinse and Fill** | To collect samples with minimal disturbance of sample chemistry. | Rinse the sample container and cap 3 to 4 times taking care of disposing the water away from the sampling site. If sample requires filtering then use filtered water for rinsing. Fill to overflow and expel completely any air trapped in the sample bottle. If sample is to be frozen, leave air space for expansion. If container has pre-prepared preserving material in it do not rinse and allow to overflow. Cap container as soon as possible. |
| **Sample Preservation/ Storage and Transport** | To minimise chemical alteration of samples prior to analysis by temperature control and/or addition of preservative. | Follow preservation method and maximum sample holding period as recommended in Table 2.1 above. Document preservation method and holding time and make sure bottles are properly labeled. Store securely and at appropriate temperature for transport. |
| **QA/QC** | To ensure analytical results accurately represent water in the field and to permit any correction of analytical result for changes which may occur after sample collection. | Collect blank, duplicate and spiked samples. There should be a minimum of 5% samples submitted as blind duplicates to a laboratory. |
| **Chain of Custody Documentation** | To be able to follow the sample history of each sample. | Ensure that each sample procedure is properly documented on the appropriate form and that there are sufficient copies for filing. |

#### *3.4.1.2 Alternative Techniques*

There are various other methods for determining water depth including, weighted tape measure, electrical contacts, acoustic techniques (e.g. 'fox whistles') and automated pressure sensors. No one method is recommended. However, care must be taken to ensure that the water in the well is in equilibrium with the surrounding groundwater level. If the purpose of the study is to determine changes in water levels over time or after a particular event, it is recommended that the same technique is used over the course of the monitoring program. If techniques are changed, comparability between techniques must be shown.

#### *3.4.1.3 Other Considerations*

Groundwater levels should be quoted against Australian Height Datum; therefore all well sites should be surveyed.

### 3.4.2 Electrical Conductivity

#### *3.4.2.1 Commonly asked questions*

Salt derived from groundwater sources is potentially a major threat to floodplain and wetland health. Therefore it is important to know whether or not the water in an aquifer is saline or not and how the saline groundwater responds to management interventions such as flooding or changes to flow regimes in adjacent waterbodies (eg weir draw-down). Commonly asked questions include:

- What is the baseline concentration of salt in an aquifer?
- What are the long-term trends in salinity data in a given aquifer?
- What is the effect of changing flow regime on the salt regime in a given floodplain water body?
- Is there a net export of salt from an aquifer during flooding?
- Does flooding introduce a freshwater lens into the aquifer?

#### *3.4.2.2 Standard Technique*

The standard method for determining electrical conductivity is APHA 2510 B, which although a laboratory based technique, can be adapted for field measurements.

#### *3.4.2.3 Alternate Methods*

Other methods are available to determine salt concentration in water (see Chapter 2), but electrical conductivity is by far the simplest method. The use of automated in-situ probes is not recommended because of their tendency to be fouled by biofilms and corrode in saline groundwaters.

#### *3.4.2.4 Recommended Methods*

See Chapter 2

### 3.4.3 Reduced Iron and Manganese

#### *3.4.3.1 Commonly asked questions*

Reduced iron ($Fe^{2+}$) and manganese ($Mn^{2+}$) are produced by metal-reducing bacteria, which use iron and manganese minerals as electron acceptors in anaerobic respiration. The metals (particularly iron) are rapidly oxidized under aerobic conditions, which often results in their precipitation from solution. Reoxidation of the metals can lead to:

- Fouling of pipes and bores;
- Loss of phosphorus from solution - dissolved phosphorus is rapidly adsorbed to freshly precipitated iron minerals; and
- In extreme cases a lowering of solution pH as the oxidation reaction produces acid.

Therefore, as part of a baseline monitoring program it may be appropriate to determine whether or not groundwater contains high levels of dissolved iron and manganese and whether or not the concentrations of these elements change in response to flooding or changes to flow patterns.

#### *3.4.3.2 Standard Technique*

There are no Australian Standards for determining reduced iron or manganese in water. American Public Health Association describe a colourimetric technique for determining reduced iron (APHA 3500-E).

#### *3.4.3.3 Alternative Techniques*

A number of colourimetric techniques are available for the routine determination of reduced iron (e.g. using ferrozine – Sorenson, 1982) and manganese (tetra(*p*-carboxyphenyl) porphyrin method - Ishii *et al.*,1982), at levels commonly found in both groundwater and surface water. At circum-neutral pH, measurements of total filterable iron and manganese would give a good estimate of the concentration of reduced species (most dissolved Fe and Mn in water samples are in the reduced state). However, care must be taken to prevent oxidation during sampling and filtering of the sample – reduced iron has a half-life of less than 10 minutes at neutral pH in an aerated solution.

#### *3.4.3.4 Recommended Method*

There are no recommended methods for analysing reduced iron and manganese. If appropriate quality assurance and quality control protocols are in place, results using different techniques should be comparable.

### 3.4.4 Sulfate and Sulfide

#### *3.4.4.1 Commonly asked questions*

Unlike marine systems, it is generally thought that sulfur species do not significantly influence water quality in freshwater environments. However, within the context of the Murray-Darling Basin, the sulfur cycle could be

important. Sulfate can account for up to 20% of dissolved anions in surface and groundwaters in the Murray-Darling Basin (Herczeg *et al.*, 2001). Highly saline waters will therefore contain appreciable levels of these species. However, unlike $Cl^-$, $SO_4^{2-}$ is reactive in the environment. Notably, $SO_4^{2-}$ can be reduced to sulfides ($HS^-$, $H_2S$) by anaerobic respiration in sediments. The significance of sulfate reduction to water quality includes the production of noxious smells (by $H_2S$), the toxicity of sulfides to many plants and animals, the release of $PO_4^{3-}$ from sediments and the generation of sulfidic materials (see Chapter 4). Oxidation of sulfidic materials can release pulses of acid. For example, in 2002, oxidation of sulfidic wetland sediments at BottleBend Lagoon on the Murray near Mildura resulted in pH in the water falling to below 3 (McCarthy *et al.*, 2003).

Therefore, commonly asked questions could include:

- What is the baseline concentration of sulfate and sulfide in ground water?
- Do the concentrations change in response to floods?

#### *3.4.4.2 Standard Technique*

Australian Standard AS 3550.1-1988 describes a colourimetric technique for the determination of dissolved sulfide in water. American Public Health Association describe a variety of techniques for the determination of sulfate (APHA 4500 $SO_4^{2-}$) and sulfide (APHA 4500-$S^{2-}$).

#### *3.4.4.3 Recommended Method*

There are no recommended methods for analysing sulfate. If appropriate quality assurance and quality control protocols are in place, results using different techniques should be comparable. As sulfide is slowly oxidized back to sulfate it is necessary to preserve samples with zinc acetate at the time of sampling. The methylene blue method (APHA 4500$S^{2-}$ - D) has been shown to be suitable for determining sulfide at levels commonly found in wetland sediment pore-waters (Mitchell, 2002).

# Chapter 4
# Monitoring Soil and Sediment

## 4.1 Preliminary Considerations

Floodplain soils and wetland sediments will change in response to changing flow regimes and flooding. Indeed, changes to soil properties (eg leaching of salt from topsoil) may be an anticipated outcome of an environmental flow. This chapter describes techniques commonly used in monitoring soils and sediments in response to changing flow patterns.

## 4.2 Sampling Techniques

Sediment sampling protocols should conform to AS/NZS 5667.12:1999 *Water Quality – Sampling Part 12: Guidance on sampling of bottom sediments.* The choice of sampling device used will depend on the particular study design but, in general a hand sediment corer is recommended for sampling shallow (<2m) wetlands as it tends to disturb the surface floc less than other methods. In deeper wetlands, deployment of hand corers may be impractical in which case either gravity corers or grab samplers may be used. However, grabs only sample the top layer of sediment, and fine material may be lost as the sample is raised to the surface. Freeze corers should not be used for sediment sampling for most chemical analysis as freezing of the sediment can lead to changes in chemical speciation.

Floodplain soil-sampling protocols should conform to AS 1289.1.3.1:1999 *Methods for testing soils for engineering purposes: Sampling and preparation of soils – undisturbed samples – Standard method.* Soil samplers range from simple scoops and shovels, through to truck mounted augers. The choice of sampling device used will depend on the particular study design and the soil type. However, once chosen, the sampling method should not be changed during the course of the monitoring program without first verifying that both the new and old techniques are comparable.

## 4.3 Quality Assurance /Quality Control

### 4.3.1 Sampling Blanks and Check-Samples

Quality control check-samples for sediment samples are more problematical to use in practise than for water samples (Chapter 2). Finding a sediment reference that is sufficiently well characterised, stable and with similar properties to the sediment of interest, for use as a field blank, transport blank or container blank is difficult. Similarly, the problem of ensuring that an added spike (either as solid or liquid) is sufficiently well mixed through the sediment sample matrix reduces the usefulness of field spiking and spike recovery. Nevertheless, the errors arising from field sampling are much larger than any other source of error (Crepin and Johnson, 1993) and need to be addressed. It is recommended that any sediment sampling program include:

- Replicate samples – two or more samples taken in close proximity to each other to determine sampling errors;
- Split samples – a field sample that is divided in two (or more) equal parts at time of sampling but prior to any sample processing. Split samples can help identify errors associated with post-sampling processing, transport and analysis (van Ee *et al.*,1990); and
- Rinsate samples – After sediment sampling and preparation apparatus are cleaned, and prior to the next sample being taken or processed, the equipment is washed in high purity water, which is preserved and analysed. Rinsate check-samples should be used where contamination from the sampling or processing equipment posses a problem (van Ee *et al.*, 1990).

About 5% of sediment samples should be QA/QC check samples.

### 4.3.2 Sampling Containers

Sediment and soil samples can be stored in appropriate glass or plastic bottles (preferably wide-mouthed) similar to those recommended for water samples (AS/NZS 5667.12.1999; US EPA, 1994) or conversely use sealable plastic bags (e.g. Snaplock™ bags - US EPA, 1994). Chemical preservation of solids is not recommended. It is best to store the samples at 4°C for the recommended holding time for the analysis (US EPA, 1994), – usually less than 72 hours for common analytes (Resource Inventory Committee, 1997).

In general, sediments in wetlands are anoxic and therefore, exposure to air will alter the distribution of analytes within the sediment matrix. Therefore, if anything other than total concentration of a given element is to be analysed, then care must be taken to exclude exposure to the atmosphere. One approach has been to store the sediment in sealable plastic bags, exclude air and place the bag in a larger container of anoxic mud (Baldwin, 1996 and references therein). The oxygen demand of the outer layer of mud prevents oxygen reaching the inner sample.

## 4.4 Soil

### 4.4.1 Soil Moisture Content

#### *4.4.1.1 Commonly asked Questions*

The moisture content of the soil determines the availability of water to floodplain macrophytes particularly shallow rooted plants that can not utilise groundwater. Soil moisture content also determines the impact of increased soil salinity and other dissolved stressors on plant health. It is the soil water concentration of dissolved stressors (eg salt) rather than the total soil concentration that plants encounter. For example, if the total salt load in a soil is 1mg salt $g^{-1}$ of soil, and the soil moisture content is 1g $g^{-1}$ of soil, the salt concentration that a plant's root would encounter would be one part per thousand; if the salt load is the same (1mg $g^{-1}$) but the soil is drier with a soil moisture content of only 0.1g $g^{-1}$ soil, the concentration of salt that a plant's root would encounter would be 10 times higher – 10 parts per thousand. Therefore, when considering soil properties, it is important to consider the actual soil water concentration.

#### *4.4.1.2 Standard Method*

Australian Standard AS 1289.2.1.1-1992 describes the standard gravimetric test for determining soil moisture content by drying in an oven at 105°C. *Australian Standards* AS 1289.2.1-6 describe alternative drying methods other than oven drying for determining moisture content. AS 1289.5.8.1:1995 describes the use of neutron scattering techniques for determining field moisture content as well as field density.

*Other Methods*

Zazueta and Xin (1994) describe a number of other techniques that can be used for determining soil - moisture content including:

- Gamma attenuation;
- Nuclear magnetic resonance;
- Resistive sensors;
- Capacitive Sensors;
- Time Domain Reflectometer;
- Hygrometric Techniques;
- Remote Sensing techniques; and
- Near infra-red spectroscopy.

The response of some of these parameters (neutron scattering, nuclear magnetic resonance, resistivity and capacitance sensors) depend in part on the soil salinity and therefore aren't applicable to floodplains where soil salinity is variable. While time-domain reflectometry is independent of salt concentration, the technique is expensive. Remote sensing techniques can determine relative surface soil water content over broad ranges but are not sensitive enough to be used in estimating osmotic potential/salt stress from direct soil measurements – see later.

#### *4.4.1.3 Recommended Method*

Gravimetric determination following oven drying at 105°C following the protocol outlined in AS1289.2.1.1-1992 is the preferred method for determining soil moisture content for estimating soil solution concentrations.

*Other Considerations*

- Samples need to be kept cool to minimize evaporation of soil water during transport. The use of a check-sample (a soil of predetermined moisture content that is taken out into the field, returned to the laboratory and reanalysed) will indicate if evaporation during transportation is an issue; and
- Other techniques can be used but they should be cross-checked against the preferred method.

### 4.4.2 Soil Electrical Conductivity (Salinity)

#### *4.4.2.1 Commonly Asked Questions*

Salt can build up in floodplain soils as a consequence of evaporation or the influence of shallow saline groundwater. One potential outcome of flooding floodplains is the mobilisation of this salt from the soil into the river channel. While this may be beneficial for floodplain soil health it may have detrimental effects downstream. Therefore an estimate of the soil salt-store before and after flooding can be used to judge the extent of nett salt export. Electrical conductivity of soil solution is commonly used as a surrogate for salinity (see Chapter 2)

#### *4.4.2.2 Standard Method*

Although there is no Australian Standard for determining soil electrical conductivity, measurement of the electrical conductivity of 1:5 soil:water extract is widely used for soils throughout Australia (Rayment and Higginson, 1992).

#### *4.4.2.3 Alternate methods*

Electromagnetic induction surveys (either hand held or aircraft mounted) offer a qualitative method for determining soil salt concentrations (Jolly *et al.*, 2002). As the response is dependent on a number of other soil parameters (structure, texture etc), site-specific quantitation requires careful calibration using the preferred method. Nevertheless electromagnetic induction may be useful for initial site characterisation (Jolly *et al.*, 2002).

#### *4.4.2.4 Recommended Method*

The electrical conductivity of the 1:5 air-dried soil to water extract is the preferred measurement, using a modification of the technique used to determine electrical conductivity in waters (Chapter 2). In addition to reporting the 1:5 soil extract conductivity (and clearly marked as such), the results should also include a calculated value of the soil solution conductivity, based on soil water content – above.

*Special Considerations*

Electrical conductivity of a soil extract is only an approximate measure of soil salinity. If the purpose of the monitoring program is to understand the osmotic potential of the soil, $Cl^-$ concentrations should be determined (Jolly *et al.*, 2002).

### 4.4.3 Soil Water Potential (Matric and Osmotic Potentials)

#### *4.4.3.1 Commonly asked Questions*

Water potential is important in understanding water status and the energetics of water movement in the soil-plant atmospheric continuum (Livingston, 1993). In its simplest terms, the water potential is a measure of the amount of work necessary to remove water from the soil matrix. The water potential is made up of four components – gravitational potential, pressure potential, matric potential and osmotic potential (Livingston, 1993). The gravitational potential is simply related to the depth of the sample relative to a reference point (water moves under the force of gravity). The pressure potential relates to the distance between the point of interest and the free water surface above it - water will move from high pressure environments (e.g. ponded water) to low pressure environments. Matric potential is a measure of how strongly the soil matrix actually binds water. The osmotic potential is determined by the total amount of salts dissolved in the soil solution and in part reflects the increasing difficulty of water to cross the plant-root boundary as salt concentrations increase. Soil water potentials will change in response to changes in both surface and ground water levels. As soil water potential impacts on a plant's ability to access water from the soil, changes to the potential should be determined as part of long term floodplain monitoring programs – particularly where the condition of floodplain vegetation is being considered.

#### *4.4.3.2 Standard Methods*

Australian Standard AS 1289.2.2.1 – 1998 describes a thermocouple psychometer test for determining total soil suction (matric potential) for soils for construction purposes.

#### *4.4.3.3 Alternate Methods*

In practice, only soil matric potentials and osmotic potentials are determined through analyses. Gravimetric and pressure potentials are simply related to relative depth and position relative to free water level. There are a variety of techniques for determining water potential and or matric potential including:

- Resistance blocks;
- Tensiometers; or
- Thermocouple Psychometers.

Livingston (1993) discusses the various advantages and disadvantages of each technique. An alternative method for determining matric potential is a simple filter paper technique, where filter papers are equilibrated with soil samples either *in situ* or in the laboratory (Graecen *et al.*,1987). Osmotic potential can be estimated from the electrical conductivity of the soil solution (assuming a constant conversion factor between conductivity and salt concentration, or calculated from the chloride concentration (assuming most of all of the dissolved solutes are sodium chloride).

#### *4.4.3.4 Recommended Method - Matric Potential*

The preferred method for determining matric potential is the filter paper method described by Graecen *et al.* (1987) as reported by Jolly *et al.* (2002). Essentially a wide-mouthed jar is filled to approximately ¼ of its depth with soil. The soil is tamped down to produce a flat surface and a 55mm diameter Whatman #42 filter paper carefully placed on the soil surface. Another ¼ of the soil is added, tamped down and a second filter paper added, the processes repeated a third time, and finally finishing off with a layer of soil. The jar is sealed and equilibrated for at least six days at constant temperature (25°C). After equilibration the filter papers are removed, carefully brushed to remove loosely bound soil, weighed, dried at 105°C to constant weight, and reweighed. The water content of the filter paper is determined by subtracting the wet weight from the dry weight and dividing the result by the dry weight. Matric potential is estimated from filter paper water content by referring to water release curves which are specific for the type of filter paper used (see Jolly *et al.*, 2002 for details).

#### *4.4.3.5 Preferred Method – Osmotic Potential (modified from Jolly et al., 2002)*

The preferred method for determining osmotic potential is to measure the amount of chloride ion extracted using a 1:5 soil:water extraction (see above), estimating the chloride ion concentration in soil solution (see above), and converting chloride concentration to osmotic potential (assuming that all the salt is present as NaCl) using the equation:

$$-\psi_o = 0.127 \times [Cl^-]_{soil\ soln}\ (mgL^{-1})/1000$$

where $\psi_o$ is the osmotic potential and $[Cl^-]$ is the concentration of chloride ions in the soil solution – not the soil water extract – in mg $L^{-1}$. Chloride ions can be measured either potentiometrically, colourimetrically or by ion-exchange chromatography (see APHA 4500 $Cl^-$ D-F) in the laboratory.

*Other Considerations*

- Soil water potentials should be estimated throughout the soil profile;
- For chloride analysis, standard laboratory quality assurance/quality control protocols should be used (see Chapter 2); and
- If electrical conductivity is also to be determined on the 1:5 soil:water extract and, chloride concentration is to be determined using ion-selective electrodes, the conductivity should be measured first because of the possibility of cross contamination from the reference electrode used in the potentiometric determination of $Cl^-$.

### 4.4.4 Soil Carbon

#### *4.4.4.1 Commonly Asked Questions*

The rate of carbon metabolism is faster in inundated soils than dry soils (J. McGregor pers. comm.). Therefore, repeated flooding, particularly for an extended period of time, has the potential to remove labile carbon from the soil profile. In a natural flood, this pool of carbon may be replenished from C associated with deposited silt. However, if the flood is managed by impounding a small volume of water behind an artificial levee, replenishment would be significantly reduced. Losses of labile carbon will in turn impact on a variety of processes mediated by micro-organisms, including nutrient cycling. Therefore, important question would be:

- How has the store of labile carbon changed as a consequence of a flooding event?
- What are the long-term trends in labile carbon pools in floodplain soils?

#### *4.4.4.2 Standard Methods*

There are no Australian Standards for determining labile carbon in soils but the series of standards AS 4351.1-8 -1996, relating to the biodegradability of organic compounds in aqueous solution are relevant.

#### *4.4.4.3 Alternate Methods*

A large number of chemical and spectrophotometric methods exist for determining C in soils. Almost all the chemical techniques involve both some form of oxidation of carbon and either measurement of the oxidation product (e.g. $CO_2$ in respirometric studies), or depletion of the oxidant (eg loss of $KMnO_4$ in the permanganate oxidation technique); or alternately measuring the amount of C extracted using a particular extractant (eg water). Spectroscopic methods for determining C include $^{13}C$-nuclear magnetic resonance spectroscopy and 3-dimensional fluorescence spectroscopy.

#### *4.4.4.4 Recommended Method*

No one method is ideal to determine labile C. The $KMnO_4$ oxidation method of Blair *et al.* (1995) - but using 33mM $KMnO_4$ (e.g. see Mendham *et al*, 2002) has the advantage that it has been used widely by soil scientists, and it is relatively easily performed with limited equipment. Respirometric tests for labile C (see AS 4351.3 and 4-1996) have the advantage of using naturally occurring micro-organisms as the consumers of carbon – the same organisms that would be using the carbon in floodplain soils.

*Other considerations*

- As no two methods are directly comparable, once a method has been chosen, only that method should be used for the length of the monitoring program; and
- As labile C is generally only a small fraction of the total carbon in soil, measuring changes in total C is not recommended.

## 4.5 Sediments

Many of the techniques used for soils (see above) can be directly applied to sediments and will not be dealt with further.

### 4.5.1 Presence of Sulfidic and/or Acid Producing Sediments

Sulfidic environments or materials are soils and sediments enriched in sulfide minerals such as monosulfides (FeS) and pyrite ($FeS_2$). It has only been recently recognised that such materials can be found in inland environments, including the Murray-Darling Basin (McCarthy *et al.*, 2003, Sullivan and Bush, 2003; Lamontagne *et al.*, 2004a,b). Sulfidic materials tend to accumulate when elevated $SO_4^{2-}$ concentrations (common in saline environments) and anaerobic conditions promote elevated rates of sulfate reduction. Sulfidic materials are stable in the environment as long as they are not exposed to oxygen. However, a number of environmental issues are of concern when sulfidic materials are oxidised through drying or re-suspension in the water column, including:

- Generation of noxious (and potentially toxic) smells;
- Deoxygenation of the water column; and
- Acidification.

There is documented evidence for at least one Lower Murray wetland having acidified during a draw-down event where the exposure of sulfidic materials was implicated (McCarthy *et al.*, 2003).

When present, sulfidic materials could impose some restriction on how water levels can be managed in wetlands. It should also be noted that the discharge of metal-rich, anoxic groundwater to wetlands during water level manipulations could have similar environmental impacts as sulfidic materials.

#### 4.5.1.1 Commonly asked questions

- Are sulfidic sediments present in wetland sediments?
- How much is there?
- Do changes in hydrology or hydrogeology affect the production of sulfidic materials?
- Do changes in hydrology or hydrogeology affect the oxidation of sulfidic materials?
- Do the sediments in a given wetland have the potential to produce acid?

#### 4.5.1.2 Methods

Most of the techniques that are applicable for sediments are adaptations of methods originally developed for coastal acid sulfide soils. Both New South Wales (Talau, 2000) and Queensland (Ahern *et al.*, 1998) have guidelines for sampling and analysis of acid sulfate soils including field tests.

#### 4.5.1.3 Recommended Methods:

Field Methods: (modified from Ahern *et al.,* 1998; Talua, 2000): A qualitative field test approach for determining the extent of acid producing sediments/soils in wetlands and floodplains is recommended in the first instance. For detailed methodology refer to Ahern *et al.* (1998) and Talau (2000). The qualitative field test consists of four steps

- Initial visualisation of sediment profile;
- Measuring the actual sediment/soil pH;
- Measuring the pH after the sediment/soil has been oxidised; and
- Determining the presence of sulfate and pH in surface water.

Visual examination alone can often indicate if sulfidic sediments pose a substantial risk. Highly affected wetlands often have oxidised iron deposits (rust) covering the sediments and any submerged surfaces such as snags – see Figure 4.1

*Figure 4.1 Oxidised iron deposits typically seen in wetlands that have large deposits of sulfidic sediments. (Photo courtesy of K. Hall and A. Richardson)*

In the first instance a pit 300 – 600mm deep is dug at the water's edge using a shovel. The profile is visually examined for evidence of an oxidised surface layer (red-orange in colour) overlying a black layer (see Figure 4.2). Samples for field analysis are then taken either using a corer (for inundated sediments) or hand auger (for dry sediments/soils) and samples taken for testing approximately every 10 - 25cm. The sediment pH is measured in a similar manner to that for water (see Chapter 2) except using a spear point pH electrode which is immersed directly into the core; dried sediments are made into a paste using a minimum quantity of distilled water. The reactivity and pH of the sediment after being treated with 30% hydrogen peroxide (adjusted to pH 4.5-5.5) is also determined - see Ahern *et al.* (1998) for details. The pH and sulfate concentration of overlying water is determined according to the methods outlined in Chapter 2.

- If the pH of the sediment or overlying water column is less than about four it indicates that acid sediments may be present and that they have recently been oxidised.
- Sulfate concentrations of greater than about 30mg S $L^{-1}$ may indicate the presence of sulfur rich groundwaters and/or sediments.
- If the sediment reacts vigorously with peroxide it means that either sulfidic materials are present or, alternatively the sediment is rich in organic matter.
- If the pH of the sediment is less than about 3 after the addition of peroxide, then it is probable that the sediments contain acid producing sulfides and further testing is required.
- If the pH of the sediment after the addition of peroxide is less than about 4 or is lower than the sediment pH without added peroxide by about 1 pH unit acid producing sediments may be present and further testing is required.
- If the pH of the sediments without peroxide is relatively high (above about pH 8), the sediment reacts violently with the addition of peroxide, but the pH of the sediment after the addition of peroxide doesn't change – it may indicate that the sediment is well buffered and further testing is required.

(modified from Ahern *et al.*,1998; Talau, 2000)

*Other Considerations*

- The field tests are only qualitative and need to be verified by laboratories specifically accredited for determining acid sulfate soils.
- Recommended techniques for sampling and transport of samples for laboratory analysis can be found in Ahern *et al.* (1998) and NSW ASSMAC (1998). In particular, protection of the samples from oxidation is required.

*Figure 4.2 Sediment profile at Boeill Creek showing red oxidised surface layer overlying black sulfidic sediment. Oxidation of sulfidic acids produces acid.*

(Photo courtesy of K. Hall and A. Richardson.)

# Chapter 5
# Phytoplankton

## 5.1 Introduction

Phytoplankton are an important element in the ecology of wetlands and floodplain lakes and because they are fast-growing, they respond rapidly to changes to environmental conditions (Hötzel and Croome, 1999), and therefore, are often included in monitoring programs.

Measurement of chlorophyll-*a* concentration has been used as a surrogate measure of algal biomass. It has the advantage of being faster, simpler and less expensive than identification and enumeration procedures, and it gives an estimate of the potential photosynthetic activity of the algae. However, it can't be used to determine shifts in community structure and as the concentration of chlorophyll-*a* per cell can vary in relation to environmental conditions (e.g. light), it should only be considered a semi-quantitative gauge of algal biomass. Extraction difficulties may also occur with some types of algae, in particular blue-green algae.

The objectives of monitoring programs will differ depending on the question/hypothesis to be addressed. Phytoplankton have been used (Hötzel and Croome, 1999):

- As indicators of water quality (particularly for changes in nutrients and metals);
- For assessing environmental health; and
- For assessing changes in management practices, including changes to flow patterns.

## 5.2 Commonly Asked Questions

- What is the baseline community structure (noting of course that this will vary seasonally)?
- What is the relationship between wetland and floodplain flooding regimes and the diversity and abundance of phytoplankton?
- What is the response of phytoplankton communities to either flooding or drying events?

## 5.3 Recommended Methods

There is no Australian standard specifically for sampling and enumeration of phytoplankton. However, in an attempt to standardise methods for monitoring phytoplankton in Australian freshwater ecosystems, LWRRDC (later Land and Water Australia) commissioned a methods manual specifically for monitoring phytoplankton in Australia – Hötzel and Croome (1999) available at www.lwa.gov.au/downloads/PR990300.pdf.

### 5.3.1 Algal Community Structure

The preferred method for sampling, preservation, sub-sampling and identification of phytoplankton in wetlands are described in *A Phytoplankton Methods Manual for Australian Waters* (Hötzel and Croome, 1999).

- For shallow water bodies, a grab sample should be taken from 0.5m below the water surface - in deeper waters a depth integrated sample should be taken.
- Samples for identification and enumeration should be preserved in Lugol's solution.
- Samples should be concentrated through sedimentation.
- The use of a counting chamber is recommended.
- Taxonomic resolution will depend on the question being asked. In general, the higher the taxonomic resolution required, then the greater the level of expertise required (with increased cost).

### 5.3.2 Chlorophyll-*a*

There is no Australian standard for determining chlorophyll-*a* concentrations in freshwaters but there is an international standard - ISO10260: 1992(E) *Water quality – measurements of biochemical parameters – spectrophotometric determination of the chlorophyll a concentration.*

The spectrophotometric determination of chlorophyll-*a* extracted in ethanol and measured at 665nm (after correcting for turbidity at 750nm) as outlined in ISO 10260:1992(E) is the preferred method. Briefly:

- A water sample (typically between about 100mL – 2L depending on algal concentration) is filtered through a small glass fibre filter and the filter placed directly into the container used for extraction;
- Filtration ideally should occur at the time of sampling, but at maximum within eight hours;
- Extraction with hot ethanol (see ISO 10260 for details) should occur as soon as possible after filtration; and
- If samples are to be stored before analysis, it is preferable to store the ethanol extract rather than the un-extracted filter paper.

## 5.4 Quality Assurance/Quality Control

Quality Assurance and Quality Control is an issue in phytoplankton identification and enumeration. Hötzel and Croome (1999) outline a QA/QC protocol that should be followed and the results documented. QA/QC procedures for chlorophyll-*a* should follow protocols outlined in Chapter 2 for other water quality parameters.

## 5.5 Costs

There are no published costs of phytoplankton identification and enumeration – with the cost depending in part on the degree of taxonomic resolution and the counting precision required. As a guide, one person can count between about 4 and 8 samples in a day. The cost of chlorophyll-*a* analyses will vary with the laboratory and needs to be determined as part of the monitoring planning.

# Chapter 6
# Floodplain and Wetland Vegetation

## 6.1 Introduction

Vegetation is one of the most obvious features of wetland ecosystems. Vegetation in this context includes floating, submerged and emergent macrophytes growing within the water body and along its edges, and plants within the floodplain. Wetland and floodplain vegetation performs a variety of ecosystem functions including:

- Primary production;
- Source of food/detritus for secondary production;
- Habitat for both terrestrial and aquatic fauna;
- Bank/sediment stabilisation; and
- Nutrient and water cycling.

Assessment of vegetation can provide a good indication of disturbance at a site. Community changes have been observed in response to hydrologic alterations (Gosselink and Turner, 1978; van der Valk, 1981; Spence, 1982; Squires and van der Valk, 1992; Wilcox, 1995), nutrient enrichment (Pip, 1984; Kadlec and Bevis, 1990; Templer *et al.*, 1998; Craft and Richardson, 1998), sediment loading and turbidity (van der Valk, 1981; 1986; Sager *et al.*, 1998; Wardrop and Brooks, 1998) and metals and other pollutants.

Advantages of including plants in a monitoring program are that:

- They are an intrinsically valuable component of aquatic ecosystems;
- They occur in some form in nearly all wetlands;
- Low-tech, rapid methods of assessment are available enabling staff with limited technical expertise to measure responses;
- Generally plants are easily visible;
- Identification of communities into broad categories is generally possible by staff with limited training;
- Plants are stationary, and so are definite indicators of conditions at a particular site; and
- There is a range of long and short-lived species suitable for different monitoring purposes.

Considerations when using vegetation in monitoring programs include:

- Seasonal growth patterns (especially for annual plants);
- Problems arise when assessing submerged species;
- A lag may occur between a stressor/management intervention and the plant community's response, especially in long-lived species; and
- Plant identification to species level can be time-consuming and often requires expert knowledge.

### 6.1.1 Sampling Methods

Unlike many of the other biotic groups, there are a range of sampling methods that can be applied when monitoring floodplain and wetland vegetation. The choice of technique(s) used will depend in part on the parameter(s) being assessed and the spatial and temporal scales that they are being assessed at. There are three broad categories of sampling methods:

- Point Methods;
- Quadrats; and
- Transects.

#### *6.1.1.1 Point Methods*

Point methods are a group of methods where the operator stands at a point either randomly selected within an area of interest, or as part of a series along a transect (see Section 6.3.3). Types of point measurements include:

- True point (non-directional). Sampling or data acquisition takes place at a single point in three-dimensional space (e.g. GPS mapping);
- Horizontal plane. Measurement is performed at a single point but data is obtained from a horizontal plane (at a specified height) surrounding the measurement point. The plane may encompass the entire area surrounding the measurement point (360º plane) or a fraction thereof (e.g. 180º plane at water's edge). Bitterlich sampling utilises horizontal plane sampling around a measurement point; and
- Vertical plane. Measurement is performed at a single point but data is obtained from a vertical plane intersecting that point (e.g. photo-points, line-intercept techniques). The orientation of the plane must be specified (e.g. photo taken at X, Y co-ordinates while facing west).

*GPS Mapping*

Specific instructions for the use of particular models of differential GPS should be obtained from the manufacturer. Often, systems allow the entry of additional data lines associated with the co-ordinates acquired, which can be used to enter data such as vegetation type. Co-ordinates are acquired at points of interest (e.g. to mark photo-point locations), along the edges of macrophyte beds or boundaries between different vegetation types, or in an ordered grid for topographical mapping. Generally, elevation data obtained from GPS are not of sufficient resolution to enable accurate contour mapping. Clinometers, dumpy levels or laser surveyors should be used to obtain topographical elevations where these are required. Analysis of GPS data requires GIS software.

*Bitterlich sampling*

Bitterlich sampling is a rapid assessment technique used to calculate the proportion of ground area occupied by plants (usually trees) within a pre-determined arc (Bitterlich, 1984; Eriedel and Chewings, 1988), an established practice used by forestry staff and ecologists. A sighting device with a crosspiece at one end is held horizontally with the crosspiece at the far end. The viewer slowly rotates to the required degree, counting (and identifying if necessary) each tree whose trunk exceeds the width of the crosspiece. The radius of the arc and size of trees included are determined by the length of the sighting stick and width of the crosspiece. Arc size selection will depend on vegetation density, with smaller quadrats (10m radius) used in dense vegetation and larger quadrats (30m radius) used in sparsely vegetated regions.

*Photo points:*

Photo points are panoramic or smaller-scale photographs taken over regular intervals from an established location and provide a simple and inexpensive technique for monitoring large-scale changes to vegetation type, extent and condition over time. When choosing a location for your photo points the following should be considered (modified from Tucker, 2003):

- If possible choose a high vantage point so that photographs can be taken even if vegetation expands, gets taller or water levels change;
- Include the skyline and/or fixed objects to give perspective;
- Erect a pole at a set distance and include in photographs to give relative height;
- Encompass the variability of your study site with numerous photo-points;
- Ensure that the photo-point is able to be located at subsequent sampling occasions (e.g. record location co-ordinates with GPS); and
- Ensure that the photograph is taken in the same direction each time.

#### *6.1.1.2 Quadrats*

Quadrat sampling involves assessment of a particular parameter (e.g. number of species) within a specified area whose boundaries may be marked off using a specially-constructed frame (wood, plastic, metal), corner posts, lines drawn on a map or GPS co-ordinates. Quadrat placement is dependent upon the parameter being assessed, vegetation type and scale of work. Common variations are:

- Random. Locating quadrats in a completely random manner;
- Stratified random. Selecting a community or stand subjectively and then locating quadrats randomly within the selected area; or
- Ordered or systematic. Locating quadrats according to a grid or linear pattern across the landscape.

The size and shape of quadrats used will vary depending on the aim of the survey, spatial scale, vegetation type and size and density of plants. Landscape-scale vegetation classification schemes may use digital quadrats of tens to hundreds of metres, while in woodlands quadrats of 10m x 10m to 30m x 30m are commonly used (Richardson and Vymazal, 2001; US EPA, 2002b). Depending on plant size and density, quadrats for macrophytes, grasses, herbs and forbs can range from 0.02 – 1.0$m^2$.

While rectangular quadrats are often used to encompass variability along a gradient or for ease of construction and/or application, their large perimeter to area ratio reduces the accuracy of counts due to edge effects. Round quadrats are considered to be the most accurate because of their small perimeter to area ratio (Richardson and Vymazal, 2001; US EPA, 2002b). Square quadrats are a good compromise between accuracy and variability.

The number of quadrats used depends on the size of the plot, level of variability and available resources (including time). Three to ten replicates would generally be acceptable for monitoring macrophytes, grasses, herbs, forbs and shrubs in programs of this type. Within forested areas it is normal to set a percentage sampling – a percentage sampling effort of less than 1% is not acceptable unless the vegetation type is a monoculture.

#### *6.1.1.3 Transects*

Transects are useful for determining changes in vegetation parameters along an environmental gradient. Transect sampling is conducted by assessing parameters along a sampling line (transect) across the landscape. The length and number of transects used, and frequency of sampling along them, are dependent on the size of

the study area and objectives of the monitoring program. There are several variations in the use of transects for sampling vegetation (Richardson and Vymazal, 2001; US EPA, 2002b), and as with quadrats, transect location can be determined in several ways:

- Randomly;
- Located using a stratified random design; or
- Systematically (e.g. located at fixed intervals)

Transect lines may be delineated by pegging out a long, flexible line (e.g. rope, flagging tape, cable, measuring tape), marking only the start and end points (either with stakes or GPS co-ordinates) or with lines on a map. Data collection along transects can utilise:

- the line-intercept technique (a vertical plane running the length of the transect line);
- a continuous horizontal band of a specified width along the length of the transect line; or
- quadrat or point techniques at various locations along the transect (either at regular intervals or with varying frequency depending on the parameter being assessed and degree of environmental variability).

## 6.2 Commonly Asked Questions

The vegetation parameters to be monitored will depend on the objective of the monitoring program. Some examples of questions addressed by monitoring programs are listed below. Questions may relate to all vegetation associated with a wetland, specific community types (e.g. macrophytes), or key species such as River Red Gums.

- Do changes to hydrology affect key plant species abundance and distribution?
- Does periodic flooding affect the age class structure (demography) of key plant species?
- Does vegetation condition change with changes to surface and/or groundwater?
- Has the introduction of a drying phase altered vegetation community structure?

## 6.3 Recommended Methods

There are no Australian Standards for monitoring wetland and floodplain vegetation. Two broad approaches can be used when monitoring vegetation on floodplains and in wetlands – either determining changes in

- Community Structure and/or
- Vegetation condition.

Within each of these approaches a number of parameters can be assessed; the choice of parameter(s) will depend on the specific ecological outcome anticipated. Furthermore, the actual technique used to assess each vegetation parameter will depend on the spatial scale of the monitoring program. Broadly speaking, vegetation on floodplains and in wetlands can be monitored at three spatial scales, each requiring different approaches:

- Wetland or Floodplain Zone – Monitoring sites within a wetland or floodplain – usually at scales less than 500m;
- Wetland - Monitoring an entire wetland or wetlands – less than about 10km each; or
- Landscape – Monitoring a wetland or wetlands plus the surrounding floodplain or catchment - usually greater than 10km.

### 6.3.1 Vegetation Community Structure

The vegetation community structure at a site can be characterised by determining species composition, abundance and distribution. This allows comparison to vegetation communities at other sites or the monitoring of changes over time due to management interventions.

#### *6.3.1.1 Distribution Mapping*

Understanding how the extent and distribution of vegetation changes over time is a useful general indicator of plant response to management interventions, natural variability in environmental conditions or anthropogenic stressors. It can also provide information on vegetation width, overhang and fragmentation, which are important aspects of habitat provision by wetland vegetation.

Vegetation distribution mapping at all spatial scales commences with obtaining topographic maps and/or digital terrain data (e.g. digital elevation models) of the study site. Regardless of the spatial scale of the study or techniques used, vegetation distribution data should be recorded as overlays of the terrain maps (either digital or as hard-copy), showing vegetation patch locations and extent. The total area of, or number of grid squares occupied by, each vegetation type assessed should be reported on data sheets. Photo-points should be established and cross-sectional sketches developed. Depending on plant expansion rates, distributions may change within weeks to years and sampling intervals should be selected accordingly. Techniques for measurement of this parameter at different spatial scales are described below.

*Landscape Scale*

On the assumption that the vegetation types of interest at this scale will be either upper canopy riparian species or emergent macrophytes, mapping using remotely-sensed imagery is recommended. Ground-truthing is required to validate data obtained from remote sensing. Photo-points which capture the general characteristics of each wetland should be established. Three to five cross-sectional sketches for each wetland should be generated.

*Wetland Scale*

Depending on the size of the wetland/s in question, remote sensing or on-ground mapping using a GPS are recommended for mapping vegetation distributions. A differential GPS with a tracking or line function is recommended. Photo-points at important sites in each wetland should be established. Five to ten cross-sectional sketches should be generated for each wetland.

*Wetland Zone Scale*

Vegetation mapping using a GPS is the preferred technique; for very small reaches or areas of vegetation, measuring wheels or tapes are acceptable. Photo-points which cover the entire zone should be established. Ten cross-sectional sketches should be generated for the wetland zone.

### *6.3.1.2 Species Composition*

Assessment of the species present at a site provides information on the vegetation's diversity and weediness, and can be used to determine structural complexity. Vegetation diversity is generally interpreted as an indicator of the community's stability and capacity to respond to disturbance. Determination of species composition involves plant identification within the vegetation area of interest. Identification of all species at a site can be highly labour-intensive and time-consuming, and requires a high degree of taxonomic expertise. For these reasons identification is often limited to common species (those which each contribute at least 15% of cover at each canopy layer), or a subset based on vegetation type (e.g. large or woody species) or sampling effort.

For all but the largest spatial scales and/or upper canopy layers, on-ground assessment, involving plant collection and identification, is required to determine species composition. Depending on the monitoring objective, all species, woody plants or common species only may be assessed. Where all species are to be assessed but resources are limited, it is recommended that a sampling effort limit is applied. Species differentiation requires some taxonomic skill, and is facilitated by assessment during the early summer growth flush. Assessment of species composition in autumn or winter should be avoided as seasonal growth patterns of many annual plants result in a scarcity of above-ground material during these seasons, making identification difficult or causing underestimation in species counts.

*Plant Collection*

Species lists are constructed from visual surveying of the vegetation in quadrats. A representative specimen of each species should be collected for confirmation of identification and development of a reference collection. All specimens found for the first time are to be collected. On subsequent surveys any new plants should be collected. The specimen should be a good representative of those found at your location and bear intact leaves attached to the stem/branch, and preferably, flowers, fruit and bark (for trees). The sample should be large enough to cover at A3 sized sheet – for smaller species whole plants should be collected including basal area and roots. Collected plants should be placed immediately into plastic bags and labelled with a voucher number, the date and collector's name, and placed in an insulated container (Esky) to minimise desiccation. A brief description of the plant's habit, location, etc. should be noted on a data sheet upon collection. Plants are best pressed before leaving each site, however, as a minimum they should be pressed by the end of each day's field work. A voucher tag should be attached to each specimen when it is placed in the plant press. Ensure adequate paper is used between specimens to absorb moisture and change this as necessary.

*Plant Identification*

Plants should be identified to species level using appropriate taxonomic keys, and the source provided with the species name (e.g. Flora of NSW). It is important to collect voucher specimens of the plant species which should then be lodged at a herbarium. A specimen of each species referred to in the data sheets is collected and provided with a voucher number. A trained plant taxonomist should verify all identifications.

*Landscape Scale*

While plant identification is usually conducted in the field, high-resolution digital aerial photography or satellite imagery can be used to determine the species composition of the uppermost canopy over very large spatial scales. Validation of remotely sensed data using field surveys is required.

*Wetland and Wetland Zone Scales:* Can only be assessed in the field.

### *6.3.1.3 Vegetation Abundance*

On-ground assessment of this parameter is required. Abundance should be measured at a minimum of three locations for every macrophyte bed or floodplain patch up to 500m$^2$ in area, for each species being assessed (stratified random sampling design). Average abundance values should be calculated for each macrophyte bed or floodplain patch assessed and recorded as part of the distribution mapping. Overall average abundances for each species assessed should be reported on data sheets.

Abundance data can be obtained from several on-ground techniques, including stem density counts and Bitterlich sampling. Stem density usually refers to counts of plant stems/trunks within relatively small quadrats for smaller plants. The number of stems counted is scaled for reporting per square metre. When used for assessing abundance, stem counts from Bitterlich sampling are divided by the area of the arc used, in order to report density on an aerial basis.

*Landscape Scale*

Bitterlich sampling is recommended for measuring abundance of trees/shrubs (arc radius of up to 60m), whereas stem density counts in quadrats up to $1m^2$ should be used for measuring macrophyte abundance.

*Wetland Scale*

Bitterlich sampling is recommended for measuring abundance of trees/shrubs (arc radius of up to 40m), whereas stem density counts in quadrats up to $1m^2$ should be used for measuring macrophyte abundance.

*Wetland Zone Scale*

For small zones stem density measurements can be used to measure abundance for all vegetation types, using large quadrats for trees/shrubs and small quadrats for macrophytes. For large zones, Bitterlich sampling is recommended for measuring abundance of trees/shrubs (arc radius of up to 20m) and measurement of stem density in quadrats up to $1m^2$ is recommended for macrophytes.

### 6.3.2 Vegetation Condition

#### *6.3.2.1 Vegetation Cover*

Vegetation cover refers to the a real proportion of a horizontal plane at a given height (e.g. in the upper canopy or on the forest floor) which is occupied by vegetative biomass. While being a coarse-scale indicator of the amount of vegetation occupying different canopy layers, it is also a measure of the quantity of canopy available to absorb sunlight, and hence relates to vegetation condition. Comparisons of canopy cover per unit abundance relate to the productivity of a particular site or the health of its vegetation.

*Landscape Scale*

Vegetation cover can be estimated for the upper canopy from remotely-sensed images. Percentage cover is estimated in quadrats overlaid on the image in comparison to reference coverage charts (e.g. Heard and Channon, 1997).

*Wetland And Wetland Zone Scales*

On-ground measurement may utilise point (180º photos), quadrat or transect (line-intercept) techniques.

Fish-eye lenses or similar can be used to obtain 180º photographs of canopy at a given point, with vegetation cover estimated from the image obtained. Photographs may be taken looking up at overhead canopies or looking down at shrubs, emergent and floating macrophytes and groundcovers. Processing utilises image analysis software on digital images or visual estimation in comparison to reference charts. It can be difficult to differentiate different canopy layers using this technique, however the image obtained is a permanent data source available for later analysis if required.

Vegetation cover can also be assessed using quadrats. Using this technique, the percentage of the quadrat area that is occupied by vegetative biomass is estimated visually by comparison with coverage charts. The quadrat may be located at any height, from on the ground to within the upper canopy. Quadrat markers up to $1m^2$ in size are useful for estimates of ground cover, herbs and low shrubs and also floating macrophytes where the quadrats are buoyant. When assessing overhead canopies, quadrats are delineated by holding a small frame (e.g. cardboard cylinder, slide-mounting frame) close to the eye and looking directly up at the canopy through it. Canopy layers occurring between waist-height and head-height can be difficult to measure using quadrat techniques, although lying on the ground to perform measurements can be helpful. This method is suitable for assessments of submerged macrophytes (using viewing buckets, mask and snorkel or grab samplers and rakes).

With the line-intercept technique, the transect is thought of as a vertical plane perpendicular to the ground. The length of this plane which is intersected by each canopy type is measured. The total decimal fraction of the line's length covered by each species is multiplied by 100 to give percentage cover. This technique is useful for all canopy layers and is not subjective, however it can be quite time-consuming. This technique is suitable for assessments of submerged macrophytes, but may be difficult to apply to emergent species.

#### *6.3.2.2 Canopy Condition*

The physiological condition of vegetation affects its survivorship, growth, reproduction, habitat quality and ability to perform ecosystem functions. Assessment of the condition of a plant's canopy provides information about the physiological condition of that individual. It indicates how well individuals in the population are dealing with current environmental conditions. Plants that are stressed by adverse environmental conditions have increased mortality rates and decreased capacity to perform ecosystem functions.

Spectral vegetation indices (SVIs) such as the Normalised Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI) and Modified Chlorophyll Absorption in Reflectance Index (MCARI) are commonly used indicators of vegetation condition, and are regularly applied to large-scale assessments of condition in a range of vegetation communities. Each index provides information on different aspects of the physiological status of the plant community (such as light absorption, water-use, photosynthetic efficiency and leaf area index - LAI) and so a combination of indices, selected to complement each other, is most useful for assessing vegetation vigour and comparing different plant communities.

The ability of these indices to detect responses associated with sublethal stress effects provides a short-term predictive capacity as to vegetation condition and persistence. Measurement of these indices is based on comparisons of different colour bands reflected by vegetation in multi-spectral digital imagery obtained through remote sensing (only the uppermost canopy can be assessed). This is a rapid method of assessment providing important data on vegetation condition, which are directly comparable across sites and to a large range of vegetation communities worldwide. However, high levels of technical expertise are required. Because SVI analysis requires familiarity with imaging software, data may be most easily obtained during image processing by the photogrammetry supplier.

Canopy condition has also been assessed using visual ratings systems based on canopy characteristics such as discolouration, proportion of epicormic growth, canopy size, colour and general appearance. Although visual assessments incorporate a certain degree of subjectivity, they have proved useful in several monitoring programs (e.g. Tucker, 2003) and so have been included here in modified form. It is recommended that assessment of canopy condition be based on visual survey of four components for trees (with only the last two of these assessed for macrophytes):

- % of branches which are dead;
- % of canopy represented as epicormic growth;
- % of canopy which is discoloured; and
- canopy density (% cover) for that individual.

*Landscape Scale*

Assessment of the SVIs using remotely-sensed imagery is recommended. NDVI, SAVI and MCARI should be calculated for entire patches for each species. Average values for each index for selected vegetation type/s should be reported.

*Wetland Scale*

Depending on monitoring objective and size/number of wetlands, assessment could involve analysis of SVIs using remotely-sensed imagery or application of the visual ratings system. Where remote sensing is used, NDVI, SAVI and MCARI should be calculated for entire patches for each species. On-ground measurement involves applying the visual ratings system to 10 randomly selected individual plants for each species under study, with averages reported.

*Wetland Zone Scale*

Use the visual ratings system applied to 10 randomly selected individual plants of each species under study. Report averages for each of the four components.

### *6.3.2.3 Plant Growth*

This parameter is measured on live plants only. It is recommended that assessment involve the non-destructive measurement of changes to plant girth and height over time. At least ten individuals should be measured on each sampling occasion. Sampling interval will depend on the species and growth stage, ranging from days to weeks for macrophytes, weeks to months for young trees and shrubs, or months to years for older trees. Mean girth and height increments per time period should be reported.

*Landscape Scale*

Because growth increments are often quite small, remote sensing techniques lack the necessary resolution to accurately assess this parameter and so on-ground assessment must be conducted.

*Wetland and Wetland Zone Scales*

Girth increment should be assessed at breast height (1.3m) for trees. A measuring tape is passed around the tree's trunk at 1.3m above ground level and the girth recorded. For trees less than 1.3m high and non-clumping macrophytes (*Phragmites*, *Typha*, etc.), stem diameter measurement should be performed at a standard distance above ground level (e.g. 15cm) on the main stem of the plant using callipers, and girth calculated based on the shape of the stem in cross-section (e.g. circular stem girth (perimeter) is calculated using $\pi$ X diameter). For clumping macrophytes (*Juncus*, *Eleocharis*, etc.) clump girth is measured at a standard distance above ground level (15cm).

Plant height can be assessed on-site using a range of equipment depending on the size of the plant in question. For tall trees, clinometers or survey equipment provide an easy and rapid means of assessment. Both techniques require some training and practice to ensure proficiency. Smaller plants (e.g. macrophytes, small trees and shrubs) can be measured using the above techniques or an extendable measuring staff available from surveying equipment suppliers.

### *6.3.2.4 Vegetation Demography*

Vegetation demography refers to the proportions of different life-stages of a species present at a site at a given point in time. On ground assessment of this parameter is required for all spatial scales. Measurement involves on-site assessment of abundance of different life-stages of plants. The abundance of dominant vegetation is partitioned into a range of different life-stage classes (including standing and fallen dead). The dominant species may be operationally defined as those species that each contribute greater than 30% of cover. Definitions of life-stage categories for different plant types are listed in Table 6.1. At least five replicates should be assessed and the average values for each life-stage reported.

Techniques for different spatial scales are the same as those used to assess Vegetation Abundance.

### *6.3.2.5 Reproductive Allocation*

The reproductive allocation of plants provides information about its health, gives an indication of expected size of the next cohort, and is also of significance in relation to food availability for many terrestrial animals.

This parameter must be measured on-site. Previous studies have assessed reproductive allocation using visual classification into reproductive categories or giving a rating based on the presence of regeneration of indigenous species. It is recommended that this parameter be assessed as the percentage of the population of interest (single species, all vegetation, certain guilds, etc.) bearing reproductive structures. It is important to consider the seasonality of reproduction of target species when interpreting data on this parameter.

Techniques for assessing this parameter at different spatial scales are the same as for Vegetation Abundance. The average of at least three replicates should be calculated.

*6.3.2.6 Standing Litter*

Abundance and composition of standing litter is a good indicator of anthropogenic impacts and has been shown to be a major discriminant of site condition when used in a rapid appraisal method for assessing ecological condition of riparian areas (Jansen and Robertson, 2001).

Measurement of this parameter involves on-site assessment. Measurement of the dry weight of litter collected from replicate $1m^2$ quadrats is the preferred technique for all spatial scales. At least five replicates of standing litter dry weight should be assessed and average values reported. Litter should be collected into labeled paper bags and dried to a constant weight at $60^oC$. Upon removal from the oven, samples should be cooled in a desiccator before weighing (in their bags). Average dried bag weight should be determined for each batch of bags by weighing five empty, dried and labeled bags. This value should be subtracted from each sample weight.

## 6.4 Quality Assurance and Quality Control

When the sampling program design is confirmed, field sampling protocol documents should be written and distributed to all staff involved. It is necessary to establish quality control measures to ensure consistency of sampling, data recording, data processing and reporting. Possible sources of error and strategies to address these are shown in Table 6.2.

*Table 6.1: Definitions of age-class categories for different plant types. Rushes, sedges and grasses should be classified according to the categories used for macrophytes.*

| Category | Name | Description |
|---|---|---|
| TREES | | |
| A | live seedling | live plant less than 1m high |
| B | live sapling | live plant less than 10cm DBH |
| C | live mature | live plant, DBH > 10cm |
| D | senescing | live plant but with signs of senescence |
| E | dead fallen sapling | dead, lying prostrate or semi-prostrate, 5 – 10cm mean diameter |
| F | dead fallen mature | dead, lying prostrate or semi-prostrate, mean diameter > 10cm |
| G | dead standing sapling | standing dead with DBH < 10cm |
| H | dead standing mature | standing dead with DBH > 10cm |
| SHRUBS | | |
| A | live seedling | live plant with main stem < 2cm thick |
| B | live juvenile | live plant less than 10cm high |
| C | live mature | live plant with main stem > 2cm thick |
| D | senescing | live plant but with signs of senescence |
| E | dead fallen seedling | dead, lying prostrate or semi-prostrate, main stem < 2cm thick |
| F | dead fallen mature | dead, lying prostrate or semi-prostrate, main stem > 2cm thick |
| G | dead standing seedling | standing dead, main stem < 2cm thick |
| H | dead standing mature | standing dead, main stem > 2cm thick |
| MACROPHYTES | | |
| A | Dead Partial Shoot | shoot is visibly chlorotic over 50% of its above-ground biomass and has obviously lost at least 50% of its above-ground biomass (probably a dead shoot from the previous growth season) |
| B | Dead Intact Shoot | shoot is visibly chlorotic over 50% of its above-ground biomass but is relatively intact (probably a dead shoot from the current growing season) |
| C | Senescing Shoot | shoot is visibly chlorotic over 1/3 to 1/2 of its above-ground biomass |
| D | Emerging Shoot Tip | unexpanded shoot tip emerging from the sediment |
| E | Live Vegetative Shoot | if any chlorotic tissue is present, it comprises less than 50% of the above-ground biomass; no reproductive structures present |

*Table 6.1: Definitions of age-class categories for different plant types. Rushes, sedges and grasses should be classified according to the categories used for macrophytes. (continued)*

| Category | Name | Description |
|---|---|---|
| MACROPHYTES Cont'd | | |
| F | Live Reproductive – Flowering | live shoot with flower/s present |
| G | Live Reproductive – Fruiting | live shoot with fruit/s present |
| H | Live Reproductive – Dehiscent | live shoot showing evidence that fruiting has occurred however floral/fruiting bodies are no longer present |

US EPA (2002b) and Heard and Channon (1997) provide a useful guide to the collection of vouchers and QA/QC for plant identification. In summary:

- Anyone performing plant identification should attend a vegetation identification course;
- All identifications should be verified by a trained or herbarium-recognised plant taxonomist;
- Voucher specimens are to be collected and lodged at a herbarium;
- As plants are identified their correct scientific name should be entered on the voucher sheet along with the name of the person who did the identification; and
- A voucher data sheet should be kept with the plant press.

*Table 6.2: Possible sources of error encountered in monitoring wetland vegetation and strategies to reduce their occurrence [adapted from Tucker (2003)]*

| Possible sources of error | Strategies to address these problems |
|---|---|
| Inaccurate measurement (e.g. Poor instrument calibration) | Ensure monitoring equipment is in good condition |
| Inaccurate observer skills | Train staff thoroughly |
| Operator bias in assessing subjective parameters | Compare measurements of subjective parameters obtained from different operators |
| Staff turnover leading to inconsistent technique application | Ensure an overlap when staff are replaced |
| Technique change over time | If changing techniques, ensure comparisons between the old and new technique are performed |
| Inaccurate data recording | Use pencils on standard field data sheets |
| Inaccurate instruction/interpretation of methods and techniques | Have a proportion of monitoring surveys (e.g. 5%) repeated by an independent team |
| Prior sampling affects parameters to be measured | Take care not to damage the vegetation being assessed or otherwise unduly impact on the study site |
| Not sampling at the same location each time | Carefully identify sites (map, GPS) to ensure successive sampling is at the same place and sample at about the same time of the day/year |
| Temporal/spatial variability | Ensure initial pilot sampling is conducted to assess variability and account for it in the sampling program design |

## 6.5 Costs

Assessing riparian and aquatic macrophytes using standard field techniques is moderately expensive, requiring at least two people in the field. As a guide submerged macrophytes in 2-3 wetlands can be assessed in a day (depending on size of the wetland and travel time between wetlands). Vegetation monitoring using remote sensing techniques can be relatively expensive; multiple wetlands may require multiple flights and post-processing of data is required.

# Chapter 7
# Macroinvertebrates

## 7.1 Introduction

There has been increasing interest in monitoring macroinvertebrates in aquatic environments, particularly in rivers, which has resulted in the development of rapid bioassessment techniques (e.g. National River Health Program – Davies, 1994).

There are advantages and disadvantages in using invertebrates to monitor wetlands, however the most important advantage is that they are common, widely distributed, complete their life cycle within wetlands, comprise an important component of food webs and are known to respond to range of physical and chemical stressors (Batzer *et al.*, 2001; US EPA, 2002a).

Standardised methods are well established for the collection of macroinvertebrates (e.g. Davies, 1994). These methods ensure that high numbers of taxa and individuals permits the use of statistical techniques that might be more difficult with groups with low numbers of taxa and low abundance (e.g. fish). The taxonomy of macroinvertebrates is well known and regularly revised. Workshops revising the taxonomy are held by organizations such as the Murray-Darling Freshwater Research Centre. They provide training and enable practitioners to keep up to date with revisions.

The disadvantages of macroinvertebrates are that there is high spatial variability between even closely adjacent wetlands which makes detecting changes difficult. Although metrics have been well developed for river monitoring programs these statistical methods have not been well developed for lakes and wetlands. Wetlands also pose sampling problems in that samples will contain more organic material than those collected from rivers. This will make counts and identification more time consuming.

### 7.1.1 Sampling

After surveying researchers in USA on their preferences for sampling techniques, Batzer *et al.* (2001) also concluded that sweep nets should be the method of choice for most monitoring programs using wetland macroinvertebrates. Furthermore sweep netting has been the preferred method in wetland monitoring programs (e.g. A biological and physico-chemical monitoring study of wetlands from the River Murray floodplain in South Australia - Suter *et al.*, 1995 and the NSW IMEF program - Chessman *et al.*, 2001), and is the preferred method in riverine monitoring programs (e.g. Davies, 1994). Other techniques used for sampling macroinvertebrates in wetlands include benthic samplers (e.g. corers and grab samplers) and passive samplers such as artificial substrates (Batzer *et al.*, 2001 - Table 7.1). However, comparisons between sweep nets and benthic samplers such as corers and grab samplers have generally found that sweep nets collect more taxa, including chironomids, than either corers or artificial substrate samplers (US EPA, 2002a). Benthic samplers have been found to be least suitable for describing invertebrate communities in wetlands as they caught fewer taxa and failed to capture mobile planktonic taxa (Davis and Christidis, 1997). Benthic samplers, however, do give a quantitative sample and are suitable for studies targeting specific groups (e.g. mussels - Figure 7.1).

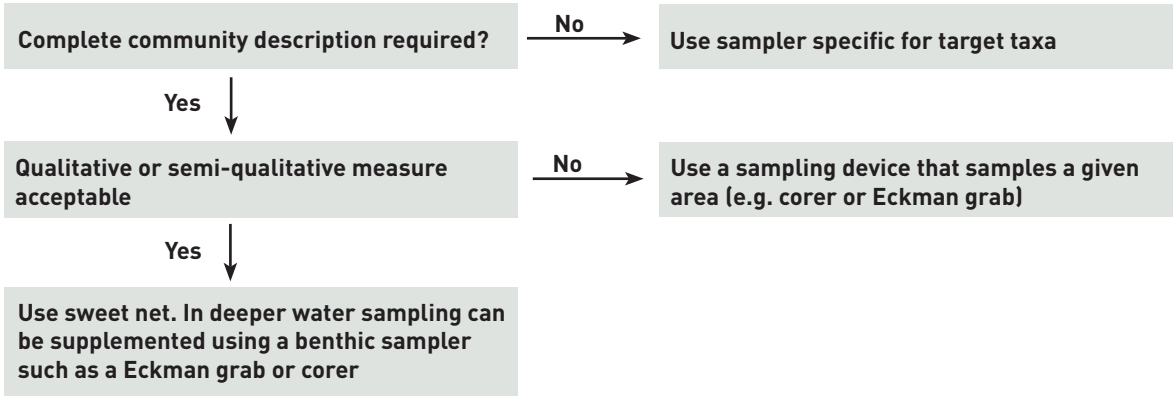


*Figure 7.1. Flow chart for selection of samplers for wetland monitoring programs (modified from Batzer et al., 2001)*

*Table 7.1. Advantages and disadvantages of common techniques use for sampling invertebrates in wetlands (Batzer et al., 2001; US EPA, 2002a).*

| Corer | **Advantages** | **Disadvantages** |
|---|---|---|
| | • Standardised, quantitative sample<br>• Small and large invertebrates collected<br>• Benthic and planktonic animals collected<br>• Can be used by inexperienced operators<br>• Inexpensive<br>• Portable | • Time consuming to sort samples<br>• Effectiveness can be inhibited by vegetation and woody debris<br>• Mobile animals can escape<br>• Sampling is destructive<br>• Difficult to remove core loose sediment<br>• Large corers cumbersome to use |
| Sweep nets | • Can collect all invertebrates present<br>• Samples are relatively clean<br>• Inexpensive<br>• Easy to use<br>• Protocols have been developed to stratify sampling across a range of habitats within a wetland | • Semi-quantitative data<br>• Small invertebrates can pass through the net and be missed<br>• Nets may clog<br>• Effectiveness can be inhibited by vegetation<br>• Highly mobile invertebrates can evade capture |
| Emergence traps | • Quantitative data of insect emergence<br>• Low processing time<br>• Taxonomy of adult insects better known that immature stages | • Traps only collect flying insects<br>• Predators living inside traps can consume emerged insects<br>• Can be damaged<br>• Requires at least two visits for each sampling occasion |
| Activity traps | • Sample area very clean<br>• Efficiency not impaired by vegetation<br>• Not destructive to habitat | • Sampling biased towards active swimmers<br>• Qualitative data<br>• Requires at least two visits for each sampling occasion<br>• Motile predators may consume other invertebrates caught<br>• Non target taxa (i.e. fish) may be caught |
| Grab samplers | • Quantitative data collected<br>• Can be used in deep water<br>• Collects surface sediment where most benthic invertebrates occur in wetlands | • Effectiveness can be inhibited by vegetation and woody debris<br>• Time consuming to process due to large amounts of sediment<br>• Mobile animals can escape<br>• Loose sediment may be lost |
| Artificial substrate | • Standardized sample is collected that relates to colonisable substrate surface<br>• Samples can be processed rapidly | • Biased due to artificial nature of substrate<br>• Need to allow time for colonization<br>• Requires at least two visits for each sampling occasion |

## 7.2 Commonly Asked Questions

Most monitoring programs are interested in shifts in macroinvertebrate community structure *per se* (i.e. changes in measures of diversity and abundance), rather than changes in biomass within specific groups that may be used as food resources by iconic species (particularly birds and fish). Therefore, the four most common questions associated with monitoring and evaluation programs looking at changes in flow regimes in wetlands floodplains are:

- What is the baseline community structure?
- What is the relationship between wetland and floodplain flooding regimes and the diversity and abundance of macroinvertebrates (Chessman *et al.*, 2001)?
- What is the impact on macroinvertebrate communities of changing the hydrological regime (Suter *et al.*, 1995)?
- What is the response of macroinvertebrate communities to flood events (Suter *et al.*, 1995)?

## 7.3 Recommended Method

As at 2004, there are no Australian Standards for sampling macroinvertebrates in floodplains and wetlands. Wetland and floodplain monitoring handbooks for Victorian (Anon., 1999), New South Wales (Chessman *et al.*, 2001) and SA (Tucker, 2003) state agencies all recommend sweep netting to sample macroinvertebrates. The following recommended method has been adapted from Davies, 1994; Tiller and Metzeling, 1998; Anon., 1999; Chessman *et al.*, 2001; US EPA, 2002a; Tucker, 2003).

### 7.3.1 Sampling

Sweep nets should conform to international specifications as defined by the International Standards Organisation standard ISO 7828. Mesh size can vary but it is recommended that a mesh of 250µm is used.

Sweep net samples can be collected from a single habitat or from multiple habitats. When different habitats are sampled they should be kept separate and processed individually.

Samples need be collected in a consistent, standardized method over a 10 metre distance (Davies, 1994; Anon., 1999; US EPA, 2002a; Tiller and Metzeling, 1998; Chessman *et al.,* 2001; Tucker, 2003). By using a consistent, standardized sampling regime the data may be treated as semi-quantitative (US EPA, 2002a).

The net should be moved in sequential short movements in a 1 metre wide path, alternatively lifting the net above the substratum and up to the surface and the dropping it vertically down to the substratum. Sweeping should be done in a vigorous action to dislodge invertebrates attached to any substrates present (Chessman *et al.*, 2001).

### 7.3.2 Field Data Sheets

Standardised field data sheets should be developed and used to ensure that methods and site conditions are thoroughly recorded and procedures documented (US EPA, 2002a). For an example of a field data sheet see Tucker (2003).

### 7.3.3 Processing and Sorting Samples

Sorting of macroinvertebrates will be based on the rapid bioassessment method (Davies, 1994), the main objective of which is to sample the widest diversity of macroinvertebrates possible within a set time. The RBA method is semi-quantitative in which macroinvertebrates are collected from the sample for 30 minutes or 200 invertebrates are collected – which ever occurs first. If samples are very turbid or contain lots of organic material the sorting time can be extended up to 60 minutes. The decision to extend the time is determined by whether or not any new taxa have been collected.

Samples can be either live-picked or preserved and sorted in the laboratory, however there are advantages and disadvantages to either method (Table 7.2).

Samples should be processed using the methods set out in Davies (1994) Chessman *et al.* (2001) and Anon. (2003):

- Fill buckets with tap water or water filtered through a net finer than 250µm;
- Empty sample into a white butchers' or photographic tray and check that no invertebrates have been left behind;
- If live sorting, sort through the sample in small portions adding enough filtered water to allow invertebrates to survive but not actively swim;
- Rinse and remove any large vegetation and woody debris;
- If the sample is large sort only a portion at a time, but allocate a comparative proportion of time to sort. The whole sample needs to be sorted in the allotted time;
- Collect invertebrates for 30 minutes or until 200 animals have been collected – which ever comes first. If sample has low abundance collect for a further 10 minutes;
- Care must be taken not to spend too much time picking out large numbers of abundant taxa as this will result in less common taxa being under represented. For example if a sample contains 1000 or more corixids only 30 need to be counted and the rest ignored, similarly it is not necessary to pick out every individual of the large and conspicuous but less abundant animals;
- Collected invertebrates are placed into jars and preserved in a minimum of 70% ethanol; and
- If sorting live in the field return remaining sample back into the wetland.

*Table 7.2 Advantages and Disadvantages of picking macroinvertebrates in the live field or preserved in the laboratory (US EPA, 2002a)*

| Live Field Pick | Laboratory Pick |
|---|---|
| Reduces time for sample picking in lab. Less material needs to be preserved and returned to laboratory | Samples processed under consistent conditions with light source and microscope. Sub-sampling more controlled. |
| Conditions of weather and light may make for inconsistency in quality of picking. Lack of magnification slows down the field work and may reduce taxonomic resolution | Takes time depending on how much debris is in the sample |

#### 7.3.4 Identification

For broad scale monitoring programs it is recommended that specimens should be identified to the taxonomic resolution of Family. Hawking (2000) provides a comprehensive listing of available keys and guides for use in identification of samples.

Currently there is no national taxonomic coding systems for invertebrates in Australia however one has been developed by the Victorian EPA (John Dean *pers comm.*). This coding system is used by the Queensland Department of Natural Resources, Mines and Energy and is used in the AusRivAS program. Although this coding system has not been published its use is recommended.

## 7.4 Quality Assurance/ Quality Control

#### 7.4.1 Labeling

All samples should be labeled with:

- Wetland identifier (name or unique code);
- Habitat type;
- Date; and
- Samplers name.

Labels should be placed on the outside of the jar (not on lid) and in the sample using alcohol resistant pen or pencil on waterproof paper. These details should also be included on the field data sheet.

#### 7.4.2 Other aspects

- All staff must be trained in the appropriate sampling techniques. The technique of staff should be reviewed on a regular basis;
- Training in the identification of specimens is to be provided;
- Quality control of identification to be undertaken by using "standard" macroinvertebrate samples previously enumerated and identified by experienced staff (Davies, 1994);
- 5% of all samples selected at random should be re-identified by an independent specialist (Anon., 1999; Chessman *et al.*, 2001);
- Representative specimens should be sent to relevant experts for verification;
- Reference collections should be maintained for each type of animal identified; and
- Results of QA/QC samples to be included in database.

## 7.5 Costs

Monitoring macrovertebrates is moderately expensive, requiring two people in the field. As a guide 2- 3 wetlands can be sampled in a day (depending on the size of the wetland and travel time between wetlands). Costs increase if samples are processed in the laboratory and/or to a higher taxonomic resolution. Currently an ISO standard net costs approximately $200.

# Chapter 8
# Fish

## 8.1 Introduction

Fish are an important and integral component of many wetland systems, possessing many physiological and behavioural adaptations that allow them to either persist or move to adjacent, more favourable habitats as conditions deteriorate (Snowgrass and Burger, 2001). Fish can be useful tools for assessing aquatic environments. They cover a broad trophic range and can be used over wide spatial scales. The taxonomy of most groups of fish is well established and, in comparison to some other biotic groups they are relatively inexpensive to sample (Harris, 1995). Importantly they have great appeal to the general public and are therefore often included in monitoring programs purely on this basis.

The disadvantage of using fish as a wetland monitoring tool is their mobility. Due to their mobility they can move between habitats. Their presence or absence from a particular habitat does not necessarily mean that the habitat is in poor condition.

Most monitoring programs are interested in changes to the composition and abundance of fish community structure *per se* (i.e. changes in measures of diversity, abundance and biomass). The Sustainable Rivers Audit recommends 13 indicators that can be used as indicators of fish community health including richness and abundance (MDBC, 2004c). The Sustainable Rivers Audit also suggests reproduction, migration and size structure of the community could be used as additional indicators.

## 8.2 Commonly Asked Questions.

Modification of flow regimes is important to fish that use floodplains. These changes include the timing, duration, magnitude of inundation and the rate of water change at the beginning and end of flood events (Snowgrass and Burger, 2001). Consequently the most common questions associated with fish monitoring and evaluation programs are:

- What is the relationship between wetland and floodplain flooding regimes and the diversity and abundance of fish (Growns and Gehrke, 2001)?
- What species comprise the fish community and in what abundances do they occur (Tucker, 2003)?
- Are any threatened fish present (Tucker, 2003)?

## 8.3 Recommended Methods

There is no Australian or International Standard specifically for sampling fish. There are a range of both passive and active techniques that have been used to survey fish; for a comprehensive listing of techniques and their uses see Murphy and Willis (1996). However not all are suitable for monitoring. A combination of active and passive methods are required to adequately sample wetlands. Electrofishing is an active sampling method and should be the primary method of sampling (Harris and Gehrke, 1997; MDBC, 2004a). Either boat or backpack electrofishing can be used depending on the size and depth of the wetlands to be sampled. However, because electrofishing may underestimate rare and small species a combination of passive techniques should be used in combination with electrofishing (MDBC, 2004a). The recommended passive techniques are bait trapping, seine netting and fyke netting.

### 8.3.1 Electrofishing

Comparisons between electrofishing and other methods suggest that while some rare fish and some small fish are missed the overall community representation is not compromised (MDBC, 2004a).

Electrofishing is to be carried out in accordance with the *Australian Code of Electrofishing Practice* (Anon, 1997). All electrofishing operations must be carried out under the supervision and control of a Senior Operator who has been awarded a Certificate of Competency in Electrofishing Procedures and Safety for the particular type of equipment being used (i.e. backpack, shore-based, or boat-mounted - Anon, 1997).

#### *8.3.1.1 Boat electrofishing*

- Should be used in large, deep wetlands; with
- Minimum of 8 electrofishing shots (12 shots whenever possible) of 90 seconds power on time per site with a 2 minute gap between shots.

#### *8.3.1.2 Backpack electrofishing*

- Used in small shallow wetlands where it is not practical to use a boat; with
- Minimum of 8 electrofishing shots of 150 second power on time per site with a 2 minute gap between shots.

### 8.3.2 Bait traps

- Commercial collapsible bait traps;
- Minimum ten bait traps per wetland;
- Baits such as cyalume sticks, cat and dog food and soap can be used to improve capture efficiency;
- Maximum depth 1m;
- Set in a range of habitats; and
- Set between dusk and dawn.

### 8.3.3 Seine Nets

The top of the net has a float line and the bottom is weighed down with a lead line. Operators at either end of the net hold the float- and lead-lines taut and drag the net through the water keeping the lead-line at or close to the bottom throughout.

#### *8.3.3.1 Length 3 metres*

- Mesh size 3mm;
- Net should be dragged through the water for a set distance at a set speed to ensure consistency between replicate hauls (e.g. a 10m distance at 1m/sec is effective in wetlands). Wherever possible, in the final few seconds one operator should curve around into shore or around towards the other operator to encircle any fish fleeing in front of the net, before both operators simultaneously scoop and lift the entire net out of the water (one operator counting out seconds helps to coordinate this);
- Maximum depth 1m (deeper than this will not be able to maintain standard speed);
- Sample in a range of habitats and depths representative of the site (potentially ranging from open water, to littoral edges, to backwaters, as well as incorporating a range of habitat complexities from densely vegetated habitat patches to bare banks); with
- Minimum ten hauls per wetland.

#### *8.3.3.2 Length 20 metres*

Similar in principle to the 3m seine but is used to encircle a much larger area of habitat, rather like a purse-seine.

- Mesh size 13mm;
- Each haul covers approximately 25m, but at around 15m one end of the net is moved faster through the water and towards the other end of the net to start closing the circle. At 25m a purse seine is formed and then all four rope ends (two leadline, two floatline) are pulled together and the net carefully closed by feeding the leadlines together and up, trapping the fish in the main body of the net; with
- Minimum three hauls per wetland.

### 8.3.4 Fyke nets

Fyke nets work best in channelised areas of wetlands where fish movement is constrained rather than in open water areas.

- Mesh size 3mm and/or 25mm;
- Single wing;
- Set between dusk and dawn;
- Minimum of four nets per wetland;
- Set perpendicular to the wetland edge with the wing to the edge of the wetland;
- The end of the net is to be suspended above the water to allow bi-catch such as water birds, turtles and water rats to obtain air if they are trapped; and
- If the wetland is connected to feeder channels, set nets in pairs to assess what fish are moving into the wetland and what fish are moving out.

## 8.4 Quality Assurance/Quality Control

### 8.4.1 Field Data Sheets

Standardized field data sheets should be used to ensure that methods and site conditions are thoroughly recorded and procedures documented. An example of fish monitoring data sheet can be found in Tucker (2003).

The following information should be recorded:

*For electrofishing:*

- Number of shots;
- Duration of shots;
- Electrofishing settings;
- Elapsed time;
- Power-time on;
- Mean depth;
- Proportion of each habitat sampled; and
- Distance travelled.

*For bait traps and Fyke nets:*

- Number of traps or nets set;
- Depth of trap or net;
- Time set and time retrieved; and
- Habitat.

*For Seine Nets*

- Time of day;
- Number of trawls;
- Distance trawled;

- Mean depth trawled; and
- Habitat trawled.

### 8.4.2 Labeling

All samples should be labeled with:

- Wetland identifier (name or unique code);
- Habitat type;
- Date;
- Samplers name;
- Sampling method; and
- Sample number.

Labels should be placed on the outside of the jar (not on lid) and in with the sample using alcohol resistant pen or pencil on water proof paper. These details should also be included on the field data sheet.

### 8.4.3 Identification

Fish should be identified using appropriate keys (Appendix 4). In some cases identifications may be difficult and it may be appropriate to preserve some individuals for verification of identifications. A sub-sample of these collections should also be logged in an appropriate collection (e.g. museum or state government department).

### 8.4.4 Data handling

Basic data collected should at the minimum include:

- Identification of each individual to species;
- Sufficient measures of total length (TL - tip of nose to tip of tail to the nearest mm) and of standard length (SL- tip of nose to base of tail) should be taken to establish a TL-SL relation to be used whenever the caudal fin of a specimen is damaged;
- Measurement of live weight to the nearest gram on a field electronic balance;
- Assessment of breeding condition (by running finger and thumb along the fish's abdomen to test for release of gonadal products);
- Assessment of external disease condition (looking for red bacterial lesions, fungal mats or parasites such as anchor worm);
- For each sample, summary statistics of species richness and abundance should also be calculated;
- Consideration should also be given to tagging some individuals; and
- Fish should be released close to the site where they were captured.

The Sustainable Rivers Audit (MDBC, 2004c) recommends that there are 13 indicators that can be used as indicators of fish community health:

- Observed to expected ratio;
- Observed to predicted ratio;
- Total species richness;
- Proportion of native biomass;
- Proportion native abundance;
- Proportion native species;
- Pelagic species richness;
- Benthic species richness;
- Proportion macro carnivores;
- Proportion mega carnivores;
- Total abundance;
- Fish with abnormalities; and
- Intolerant species richness.

Further information can be obtained from MDBC, 2004a.

## 8.5 Cost

Costs associated with monitoring fish depend in part on the method(s) chosen. Boat electrofishing requires a minimum of 3 operators while back pack electrofishing requires 2 operators. Two-three wetlands can be sampled in a day and there is minimal post-sampling processing required. Passive techniques require 2 field staff - usually only one wetland per night can be sampled.

# Chapter 9
# Frogs

## 9.1 Introduction

Floodplain wetlands represent critical habitat for the breeding and larval development of many Australian frog species. As frogs are known to be sensitive indicators of environmental change (including water quality, habitat fragmentation and changes to hydrologic regime - US EPA 2002c) monitoring frog community structure and dynamics can give useful insights into changes in wetland condition. However, care must be exercised when using frogs in monitoring programs. Because many frog populations are in decline, it is preferable to use non-invasive (and definitely non-destructive) monitoring techniques. Specific care must be taken when handling frogs to minimise the spread of the chrytid fungus.

Frogs are relatively easily studied:

- Tadpoles are readily captured in funnel traps or dip nets (US EPA 2002c);
- Adult males are often vocal during the breeding season with well documented, species-specific calls. Recording male breeding-calls offers the advantage of non-invasive monitoring; and
- Because they are highly susceptible to contaminants, deformities in frogs can give an early warning of pollution (US EPA 2002c).

### 9.1.1 Sampling

A variety of methods have been used to monitor frogs including:

- Funnel trapping for tadpoles and some adults (US EPA 2000c);
- Visual encounter surveys along fixed transects or quadrats either during the day, the night or both;
- Random dip netting for juveniles (Ward 2004);
- Drift fences and pit traps;
- Male breeding call surveys (US EPA 2000c, NAAMP, 2001; Tucker 2003; Ward 2004).

Although no one method is ideal, the US EPA recommends use of funnel traps in the bioassessment of wetlands using frogs (US EPA 2000c). Funnel traps are inexpensive to construct and deploy, and don't rely on the expertise of the individual (e.g. in visual surveys). To be successful it is important to be able to identify tadpoles to species. While this has been made easier by the recent publication of keys (in particular Anstis, 2002), identification is not always straightforward. The other disadvantage of funnel traps is that they are an invasive technique and, require handling of the frogs. Dip nets and pit traps also require the capturing and handling. Furthermore, both funnel traps and pit traps have the requirement that the traps are left overnight, which means two trips to the wetland. Frog mortality can also occur if the traps are misused.

Male breeding call surveys are an alternative method for sampling frogs. The technique suffers the disadvantages of:

- Requiring multiple visits to the wetland over breeding seasons (as not all species breed simultaneously);
- Requiring some expertise in identifying frog species by their call; although this is made easier by readily available examples of known frog calls (e.g. audio tape by Littlejohn 1987 and web based recordings for Victorian and South Australian frogs found at http://frogs.org.au/frogs/; and www.epa.sa.gov.au/frogcensus/sa_frogs.html respectively; written descriptions of frog calls can be found in Hero *et al.*1991 and Robinson 2000);
- Requiring recording equipment (for QA/QC); and
- Only sampling calling males and therefore not sampling females, juveniles or non-breeding males, so the technique doesn't necessarily give an adequate description of community population structure.

However, these disadvantages are outweighed by the fact that breeding call monitoring is non-invasive and therefore poses a reduced risk to the frog community. Furthermore, because frogs and tadpoles aren't being handled, the likelihood of chrytid fungus spread is diminished.

## 9.2 Commonly Asked Questions

Commonly asked questions include:

- What is the baseline community structure?
- What is the relationship between wetland and floodplain flooding regimes and the diversity and abundance of frogs?

## 9.3 Recommended Method

There is no Australian or International Standards for monitoring frog populations. Despite its limitations, male breeding call surveying is the preferred technique for monitoring frogs, principally because it is less invasive than other techniques (Modified from NAAMP, 2001; Tucker 2003).

### 9.3.1 Equipment

All frog call surveys should be recorded either on tape or digitally using a good quality recorder.

### 9.3.2 Sampling:

Different frog species call at different times of the year (e.g. see Hero *et al.* 1991 for timing of frog calls for Victorian species). Therefore, a wetland should be sampled a number of times throughout the year to get a better census of the frog community. Tucker (2003) recommends at least 6 sampling times per year:

- At least monthly in spring (September, October and November; in South Australia the September sampling should preferably done in the second week of September to coincide with the EPA's frog census);
- Early summer;
- Late summer and;
- End of autumn.

The number of recording sites per wetland will depend on the size of the wetland – at least one site every 200 M along the wetland (Tucker, 2003). The same site should be used on every sampling occasion. Recordings should be made in the early evening, starting at least 30 minutes after sunset (NAAMP, 2001). A fifteen-minute recording at each location should be taken, with the time, location, and weather conditions clearly traceable back to each recording. Calling activity, especially of rare species can sometimes be promoted by the use of tape-playback of calls (i.e., playing amplified recordings of frog calls- Ward, 1994).

Male breeding call surveys can be augmented with active spot light searches; physically locating calling frogs can be made easier employing a triangulation survey technique (see Ward, 1992).

## 9.4 Quality Assurance/ Quality Control

Where possible at least 10% of recordings should be checked by a second qualified person and the two results compared.

## 9.5 Costs

In addition to actual analysis of the recordings, frog monitoring requires at least 4 field trips per year to each site, and the trips occur outside normal working hours and often in adverse weather or field conditions. Special hygiene protocols are also required between separate wetlands to minimise pathogen spread (particularly chitrid fungus), and hence also adds to the cost of survey time. Specific reporting requirements are also a condition of permits, and hence can also add to the time and costs of monitoring.

# Chapter 10
# Birds

## 10.1 Introduction

Bird breeding (including recruitment) is often used as a surrogate for environmental health and can be used to identify long-term trends. Overall waterbird abundance and community composition can be used to assess environmental or habitat condition or can be a 'target' for intervention/disturbance by natural resource managers. Accurate information on the success of breeding events is possible at the smaller scale (e.g. a colony), but at the larger scale (e.g. region or state) can only partly be determined from distribution and abundance surveys.

Due to the mobility of birds, their presence or absence from a particular habitat does not necessarily mean that the habitat is in poor condition. On a large regional scale the broad distribution of birds can give an indication of long term trends in bird abundances. However at a smaller scale the presence of a particular species may indicate the presence of a particular environmental condition (i.e. the presence of water in a wetland). The non-occurrence of the same species does not necessarily indicate the lack of the particular environmental condition (i.e. the bird might be on a nearby wetland that also has water). Nor does the artificial flooding of wetlands, or the presence of water at a particular time guarantee successful bird breeding. Although the presence of sufficient water may be a cue for breeding, other cues (for example, local flooding or changing food resources) may act as primary cues. Therefore, rather than asses the presence or absence of birds in a particular wetland or floodplain ecosystem, it may be preferable to asses the extent of favourable habitat required for a specific species. As an example Glen Scholz has prepared a list of habitat preferences for aquatic birds commonly found in South Australia – see Appendix 5

Waterbird community structure and abundances may indicate whether enough variability (e.g. water levels) is present in the system and potentially can be linked to environmental/ecological condition. It is known that long term measurements of waterbird breeding effort correlate well with water regimes at a range of scales but changes in the abundances of any given species may be due to conditions outside the survey area.

Birds are easily and cheaply surveyed being readily identified and counted – there is no need to collect and analyse laboratory samples or to use complex taxonomic keys (US EPA, 2002d). Some useful taxonomic keys and references are presented in Appendix 5.

Monitoring of bird species may provide some information on the presence of other organisms from knowledge of their diets.

## 10.2 Commonly Asked Questions

- What are the community composition, species richness and abundance of birds using the floodplain and wetland?
- What species use the floodplain and wetland for breeding?
- What are the habitat preferences of the various species within the floodplain and wetland?
- Has there been an increase in birds using the floodplain and wetland in response to management changes?
- Has there been an increase in the size of colonies in the wetland or floodplain?
- Has there been an increase in the breeding success of colonial wetland birds?

## 10.3 Recommended Methods

There is no Australian or International Standard specifically for sampling birds. There are ranges of both passive and active techniques that have been used to survey birds. A combination of aerial and ground surveys is the preferred method of monitoring birds. Aerial surveys can be utilised to determine the widespread distribution of birds, collect course abundance data and locate colonies. Ground surveys can more accurately determine smaller scale abundances, species composition and the timing and extent of breeding events.

Specific points to be considered:

- Wetlands need to be visited periodically (weekly or monthly) as water levels change and changes in bird communities occur;
- Surveys should be carried out at the same time of day each time; and
- Surveys should be standardized, systematic and repeatable.

### 10.3.1 Aerial Surveys

- Quick and inexpensive compared to ground surveys;
- Aerial surveys can be used to collect information on most (+50) species of aquatic birds (Kingsford, 1999);
- Birds can be counted in a given region on three consecutive days to give an indication of variability;
- Counts can be used in conjunction with video and photography; also
- Aerial counts need to be calibrated with a sample of accurate ground counts in matching wetlands.

### 10.3.2 Area Searches

#### *10.3.2.1 Wetlands*

Area searches are appropriate for wetlands (or parts of) where visibility is unobstructed. Species are counted based on visual and/or auditory identification (US EPA, 2002d).

- The area is visually searched using binoculars from one or more fixed points. The field of vision from each point should not overlap;
- Birds are identified and counted until all individuals have been included;
- The time taken to complete the counts and the area searched is recorded. These can be used as covariates in analysis; and
- Area surveys can be used on wetlands of any size providing vision is unobstructed.

#### *10.3.2.2 Floodplain Forests*

An unmarked 3ha area (200 x 150m) is walked slowly for 20 minutes. The numbers of birds seen and heard are counted (Loyn, 1986; Hewish and Loyn, 1989). This can be modified to a 2ha, 10 minute walk and count (Loyn, 1998).

### 10.3.3 Nest Surveys

For each species present estimates are made of:

- The number of nests per colony for each species;
- Numbers of eggs laid;
- Hatching success (% of eggs that hatch out of the total number of eggs laid); and
- Fledge success (% of birds that fledge out of the number of birds that have hatched).

Nest surveys should be undertaken by experienced personnel and care needs to be taken to keep disturbance of nests to a minimum to avoid/minimize nest failure and predation.

## 10.4 Quality Assurance and Quality Control

All bird observers for any method need to be experienced. In general, an experienced bird observer has more than 5 years experience. When observers need to be replaced, calibration against an experienced observer should be undertaken.

Standardized field data sheets should be developed and used to ensure that methods and site conditions are thoroughly recorded and procedures documented. An example of a field data sheet can be found in Tucker (2003).

## 10.5 Cost

Ground surveys can be completed by one field operator, the number of samples being conducted will depend in part on the distance between sites. Kingsford (1999) estimated that aerial surveys were significantly cheaper per wetland than ground surveys, but this will depend in part on the number of wetlands to be surveyed and the cost and availability of suitable planes and experienced pilots.

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# Appendix 1
## Monitoring Programs

| Program | Scope | State | References |
|---|---|---|---|
| 1. Your Wetland: Monitoring Manual | Wetland scale monitoring by community groups | SA | Tucker , 2003 |
| 2. Integrated Monitoring of Environmental Flows (IMEF) | Wetland scale monitoring by waterway management staff | NSW | Chessman and Jones, 2003 |
| 3. Pressure-Biota-Habitat (PBH) | Wetland scale (in streams) monitoring by waterway management staff | NSW | |
| 4. WaterWatch Victoria | Reach scale (in streams) monitoring by community groups | VIC | Waterwatch Victoria, 1998 |
| 5. Index of Stream Condition (ISC) ID&A and CEAH, 1997 | Landscape and wetland scale (in streams) monitoring by waterway management staff | VIC | CEAH and ID&A, 1997 |
| 6. Conservation Value and Status of Victorian Rivers (CVS) | Wetland scale (in streams) survey of conservation value of Victorian streams | VIC | MacMillan and Kunert, 1990 Macmillan, 1990 |
| 7. Water Victoria Handbooks | Wetland scale (in streams) assessment of stream condition for all Victorian river basins. | VIC | Department of Water Resources, Victoria, 1989a; 1989b |
| 8. The Environmental Condition of Victorian Streams | | VIC | Mitchell, 1990 |
| 9. State of the Environment Report , Victoria (SOEV) | Landscape and wetland scale (streams & wetlands) overall assessment of condition | VIC | Office of the Commissioner for the Environment, 1988 |
| 10. Border Rivers Flow Management | | QLD | |
| 11. State of the Rivers Project | Wetland and Reach scale (in streams) monitoring by community groups | QLD | Anderson, 1993 |
| 12. Sustainable Rivers Audit (SRA) | Landscape scale (in streams) monitoring by waterway management staff | MDB | MDBC, 2004c |
| 13. River Condition Surveys (RCS) | Wetland and reach scale (in streams) monitoring and classification systems for use by landholders | WA | Waterways Commission, 1994 |
| 14. Native Vegetation Survey Guidelines | Terrestrial landscape scale baseline inventory conducted by councils and consultants. | SA | Heard & Channon, 1997 |
| 15. AUSRIVAS | Landscape and Wetland scale (in streams) monitoring by waterway management staff | National | Davies *et al.*, 2000 |
| 16. Rapid bio-assessment protocols | Wetland and reach scale (in streams) monitoring by waterway management staff and community groups. | US | Plafkin *et al.*, 1989 |
| 17. A Riparian, Channel and Environmental Inventory (RCE) | Reach scale (in streams) monitoring | | Petersen, 1992 |

# Appendix 2

## Advantages and Disadvantages of Various Taxa as Tools for Monitoring Wetland Condition

*From Butcher (2003) - reproduced with permission.*

### Microbial Communities

ADVANTAGES

- Tight linkage to fundamental processes (eg, decomposition, denitrification,respiration)
- Samples easily collected, transported, and analysed
- Some taxa linked to animal welfare (eg, streptococci)
- Immediate response to contamination
- Measurable in wetlands which lack surface water
- Sensitive to presence of some contaminants (eg, Ames test, Microtox test)
- "Indicator taxa" relatively well-known (especially protozoans)
- Some culture bioassay data are available

DISADVANTAGES

- Response is often not identifiably stressor-specific
- Laborious and slow (plate culture) identification; process measurements difficult to interpret with regard to ecological significance
- General absence of existing regional field databases
- Rapid turnover requires frequent sampling; do not integrate conditions over time very well
- Naturally great micro-spatial variation, especially in tidal wetlands
- Drifting cells in riverine wetlands complicate interpretation
- Low social recognition of their importance
- Bioaccumulation is irrelevant and impractical to detect

### Algae

ADVANTAGES

- Tight linkage to fundamental processes (eg, photosynthesis, respiration)
- Pivotal relationships in food webs
- Simple biomass indicators
- Measurable in some wetlands which lack surface water
- Tolerances and indicator value are relatively well-known, particularly to nutrients, and most are very sensitive to herbicides, respond well to water quality variables such as nutrients, pH, alkalinity, metals and temperature
- Simple collection procedures with minimal wetland impact
- Identification rapid to division and family level
- Response to stressors is usually immediate
- Historic and prehistoric record in sediment diatoms
- Generally immobile and thus reflective of site conditions, useful for in situ exposure assessments and whole-effluent bioassays

DISADVANTAGES

- Response is often not identifiably stressor-specific
- Laborious identification requires taxonomic expertise
- Lack regional field databases
- Rapid turnover requires frequent sampling; strong temporal variability, do not integrate (except sediment diatoms)
- Low social recognition of their importance – not necessarily true in Australia
- Bioaccumulation is unmeasurable
- Quantitative inference of water quality requires large calibration data set
- Drifting cells of unattached species complicate interpretation
- Most relatively insensitive to heavy metals and pesticides (Hellawell 1986)

ALTERNATIVES

- Water quality measures for nutrients (N, P)
- Alkalinity, pH measurement
- Metal analysis
- BOD, COD
- ATP

## Mosses, Liverworts, Ferns

ADVANTAGES

- A few taxa are reputed indicator species for physicochemical contaminants
- Perhaps the most sensitive indicator of hydric regimes
- Integrator of the long-term geologic record (ie, peat core analyses for metals accumulation, land cover change, ground water flow reversals)
- Immobile and thus reflective of site conditions,
- Useful for in situ exposure assessments

DISADVANTAGES

- Response is often not identifiably stressor-specific
- Laborious sampling and identification
- Low social recognition of their importance
- Lack regional field databases exist
- Not previously used in Australia

## Submerged Aquatic Vascular Plants

ADVANTAGES

- Extremely sensitive to turbidity, eutrophication, hydroperiod, herbicides, metals
- Sensitivities of several indicator species are well known
- Relatively important in food webs (eg, waterfowl)
- Immobile and thus reflective of site conditions, useful for in situ exposure assessments
- Structural component; littoral habitat for fauna
- Sampling is relatively easy; simple abundance metric
- Integrators of environmental conditions
- patterns interpretable using remote sensing

DISADVANTAGES

- Some difficult to sample systematically throughout a wetland
- Absent from wetlands that lack standing water (eg, bogs)
- Tolerant of intermittent pollution
- Laborious identification
- Low social recognition of their importance
- Few if any regional field databases exist

ALTERNATIVES

- TSI
- Secchi
- Nutrient analysis
- Metal analysis
- Herbicide analysis

## Non-rooted Aquatic Vascular Plants

ADVANTAGES

- Extremely sensitive to nutrient additions
- Sensitivities of some indicator species (eg, Lemna) are well known
- Important in food webs (eg, waterfowl)
- Mostly immobile and thus reflective of site conditions, useful for in situ exposure
- Assessments
- Patterns sometimes interpretable using remote sensing

DISADVANTAGES

- Difficult to sample systematically throughout a wetland
- Limited bioaccumulation due to short lifespan
- Absent from wetlands that lack standing water (eg, bogs)
- Laborious identification
- Low social recognition of their importance
- Few if any regional field databases exist

## Emergent (Herbaceous) Vascular Plants

ADVANTAGES

- Occur in virtually all wetlands
- Sensitivities of some indicator species (eg, Typha, Phragmites, Phalaris) to nutrients/sediment are well known
- Immobile and thus reflective of site conditions, useful for in situ exposure assessments
- Bioaccumulate to a moderate degree
- Patterns interpretable using remote sensing
- Moderately sensitive to nutrients and hydroperiod alteration
- Some regional field databases may exist

DISADVANTAGES

- Not highly sensitive to contaminants and sedimentation
- Lagged response to stressors (episodic contamination may not be reflected)
- Low social recognition of importance
- Sampling and identification is laborious
- Dispersal, herbivory, soil type and other factors often overshadow contaminant effects

### Forested/Shrub (Woody) Vascular Plants

ADVANTAGES

- Occur widely
- Sensitivities of many species to hydroperiod change are relatively well known
- Immobile and thus reflective of site conditions
- Bioaccumulate to a moderate degree
- Patterns interpretable using remote sensing
- Sampling techniques and community metrics well-developed
- Trends can be inferred (with care) using tree ring analyses
- Signs of stress (eg, die-offs) are socially recognised
- Sampling and identification are fairly easy
- Community can be characterised even in the dormant season

DISADVANTAGES

- Not highly reflective of contaminants and sedimentation
- Long lagged response to stressors (episodic contamination may not be reflected); in situ experimentation is impractical
- Response difficult to interpret where past management (eg, silviculture) has been practiced

### Aquatic Insects (eg, dragonflies, midges)

ADVANTAGES

- Occur in all wetland types, even those lacking surface water
- Community metrics/indices well-developed (eg, Index of Biotic Integrity, RBA methods) but need adaptation for wetlands
- Intermediate life spans reflect episodic events without requiring extremely frequent sampling
- Bioaccumulate to a moderate degree
- Can be caged for whole-effluent bioassays or in situ assessments
- Relatively important in food webs
- Community can usually be sampled year-round
- Some regional field databases exist, though few for wetlands
- Show characteristic response to all major wetland stressors (hydroperiod, sediment, nutrients, contaminants)
- Some taxa linked to human welfare (eg, mosquitoes)
- Sampling protocols not fully developed for wetlands
- Contaminants may induce identifiable deformities

DISADVANTAGES

- Occurrence in isolated wetlands may be strongly tied to sources of colonisers and their dispersal mechanisms
- Sampling difficult and true densities very difficult to determine in wetlands with herbaceous vegetation
- Laborious identification
- Low social recognition of their importance
- Naturally great micro-spatial variation
- Community composition potentially affected by selective predation (eg, by fish, waterfowl)

### Benthic/Epiphytic Macro-crustaceans (eg, amphipods, crayfish, oligochaetes, isopods)

ADVANTAGES

- Less subject to dispersal than aquatic insects (and thus more reflective of conditions in a particular wetland)
- May be more sensitive than aquatic insects to contaminants
- Fairly simple sampling and identification
- Social recognition of some species (eg, crayfish)
- Other advantages --- similar to Aquatic Insects, above

DISADVANTAGES

- Naturally great micro-spatial variation
- Community composition potentially affected by selective predation (eg, by fish, waterfowl)

### Mollusca

ADVANTAGES

- Highly immobile and thus most reflective of site conditions, useful for in situ exposure assessments
- Highly bioaccumulative (eg, clams, mussels)
- Bioassay data fairly extensive (for Australian species)
- Contaminants may induce identifiable deformities
- Can be sampled year-round
- Historic recreation of growth is possible (with care)
- Presumptive indicator of hydroperiod (complete, sustained wetland drawdown)
- High social importance of coastal species (shellfish)

DISADVANTAGES

- Very localised occurrence, related largely to dissolved solids rather than contaminants
- Laborious sampling and (in freshwater) identification

## Macroinvertebrates in General

### ADVANTAGES

- Respond to : DO, sediment metals, other toxins, organic enrichment, fish
- Integrators of environmental conditions
- Low mobility
- Moderate temporal variability
- Tropic link to fish and birds

### DISADVANTAGES

- High spatial variability due to habitat dependence
- Littoral habitat sampling may be difficult
- Metrics are not well developed and tested in lakes and wetlands
- Laboratory identification and count can be time consuming requires expertise

### ALTERNATIVES

- DO
- Sediment TOC
- Toxicity bioassays
- Fish community structure

## Zooplankton

### ADVANTAGES

- Respond to fish, phytoplankton, thermal loading, acidity, and pesticides
- Field sampling and counting relatively easy but does require taxon expertise
- Trophic link to fish
- Sedimentary record for some groups

### DISADVANTAGES

- Response to human stressors and impacts not well documented
- Interpretation difficult: respond to both higher and lower trophic levels
- Do not integrate well – high temporal variability

### ALTERNATIVES

- Fish community structure
- Trophic state – secchi depth, chlorophyll, phosphorus
- Algae

## Fish

### ADVANTAGES

- Community metrics well-developed (Index of Biotic Integrity), though not for wetlands; many reputed indicators (eg, carp)
- Respond to: DO, pesticides, metals, organic enrichment, eutrophication, acidification, thermal loading
- Most comprehensive set of bioassay data, tolerance to stress known
- Can be caged for whole effluent bioassay and in situ studies, or avoidance measured using radiotelemetry
- Moderately bioaccumulative
- Integrators of environmental conditions
- Fairly simple identification (except larval stages)
- Universal endpoint
- Population characteristics, growth fairly easy to discern
- Contaminants may induce identifiable deformities
- Can be sampled year-round
- Presumptive indicator of hydroperiod (absent from isolated wetlands with complete, sustained drawdown)
- Integrate broad, longer-term, landscape-level impacts because of their mobility, high trophic position, and longer life span
- High social importance of most species; existing water quality standards for aquatic life focus on fish

### DISADVANTAGES

- Mobility makes it difficult to locate specific contaminant sources
- Absent (or present for only brief periods) in most wetlands
- Laborious sampling, field sampling is time consuming and expensive, with high spatial variance and gear problems
- Intensively managed; stocking, angling impact
- Early life stages and non-game species may be difficult to identify
- The only index which has bee developed and tested regionally

### ALTERNATIVES

- DO
- Trophic state
- Toxicity bioassays

- Contaminant analysis
- Alkalinity, pH measurement

## Amphibians and Reptiles

ADVANTAGES

- Small home range relative to larger vertebrates
- Highly (eg, tortoise) to moderately bioaccumulative; can be caged for in situ assessments
- Some social recognition
- Fairly simple identification
- Fairly well-established sampling protocols
- Sensitive to hydroperiod alteration
- Present in most inland wetland types

DISADVANTAGES

- Sampling limited to certain seasons in some regions
- Mostly absent from tidal wetlands
- Sampling can be laborious
- Presence can be strongly influenced by natural dispersal conditions

## Birds

ADVANTAGES

- High social recognition, particularly waterfowl
- Have the only relatively extensive databases on trends, habitat needs, distribution
- Moderately extensive bioassay data
- Some species (eg, wading birds, harrier) are highly bioaccumulative
- Avoidance is measurable using radiotelemetry, and in situ assessments are possible (caged or clipped individuals)
- Simple sampling and identification
- Present in all wetland types
- Established sampling protocols are available
- The only suitable indicator of degradation occurring at the landscape scale

DISADVANTAGES

- in general, community structure is highly controlled by physical habitat, and perhaps hunting mortality, rather than contaminants
- mobility makes it difficult to locate specific causes of mortality sources (could be thousands of miles away)
- essentially absent from some wetlands in winter

## Mammals

ADVANTAGES

- Many are highly bioaccumulative – in Australia??
- High social recognition and value (eg, platypus)
- Fairly simple sampling and identification
- Present in most wetland types
- Established sampling protocols are available

DISADVANTAGES

- Great temporal and spatial variation (many species are cyclic) makes data interpretation difficult
- In general, community structure is highly controlled by physical habitat, and perhaps trapping mortality, rather than contaminants
- Mobility (and frequent use of non-wetland habitat) makes it difficult to locate specific causes of mortality sources

## Biological Processes (Functions)

Definition: Whole-wetland measurement of photosynthesis, primary productivity, respiration, denitrification, nitrogen fixation, decomposition, leaching, and/or similar processes

ADVANTAGES

- most important indicators of wetland sustainability and life support function

DISADVANTAGES

- not as sensitive to contamination as is community structure or tissue analysis (Schindler 1987)
- measurement is laborious, time-consuming (eg, isotopes)
- social recognition of importance is weak
- extreme spatial and temporal variation
- measured values may reflect natural successional stage rather than human-induced stress

# Appendix 3

## Hypothetical Examples of Floodplain and Wetland Monitoring Programs for Specific Interventions

When designing a monitoring program, the parameters used must meet the following criteria:

- **Relevance** Does the measurement parameter reflect directly on the management action?
- **Validity** Does the measurement parameter respond to changes in the environment and can be quantified?
- **Diagnostic value** The measurement parameter must be able to detect changes and trends in conditions for the specified period. Can the amount of change be assessed quantitatively or qualitatively?
- **Responsiveness** Will the measurement parameter reflect changes due to manipulation by the management action?
- **Reliability** The measurement parameter should be measurable in a reliable, reproducible and cost effective way.
- **Appropriateness** Is the measurement parameter appropriate for the time and spatial scales of the study?

The following hypothetical scenarios are examples of what might be monitored based on a given intervention. Note that these examples are illustrative only and ultimately choice of parameters will vary on a case by case basis.

### Scenario 1: Re-introduction of a drying phase in a permanently inundated wetland

#### Intervention objective

- Introduction of periodic drying phases into a permanently inundated wetland with timing and frequency as specified in proposed operating plan.

#### Ecological objectives

Through the introduction of periodic drying in permanently inundated wetlands:

- Increase the diversity of wetland habitats in a region;
- Increase the diversity, distribution and abundance of emergent macrophytes and herbaceous mudflat plant species in selected wetlands;
- Remove introduced fish species;
- Provide greater habitat diversity for invertebrates and frogs; and
- Remobilise sediment bound carbon and nutrients on re-wetting of the dried sediments which will improve the overall productivity of the wetland.

#### Other Potential Outcomes

- Drying may kill native fish and other aquatic vertebrates that can't disperse to another wetland (eg some species of turtles);
- Loss of water from the wetland (particularly for extended periods) may affect the condition of riparian macrophytes reliant on the wetland for water;
- If sufficient build up of organic matter has occurred in the wetland during the drying phase, on rewetting the pulse of carbon (and to a lesser extent nutrients) may increase the level of microbial activity to the point where the water goes anoxic. (This is more likely to occur if re-inundation occurs in summer);
- If sulfidic sediments are present in the wetland, oxidation of the sediments during draw-down will produce a pulse of acid;
- If the drying is achieved through evaporation, the water in the wetland will become increasingly saline during drawdown. Subsequent re-wetting and drying without flushing will overtime result in increased concentration of salts in the sediment which will be mobilised on each re-wetting. This may eventually result concentrations exceeding threshold levels for many biota;
- Removal of surface water may allow the influx of (potentially saline) groundwater into the wetland.

#### Suggested monitoring activities (against intervention and ecological objectives)

Collate all existing data and collect baseline data.

*Intervention monitoring*

- Measure surface and sub-surface water levels to determine the extent of water level drawdown. Assess the success of the intervention against the operational plan for adaptive management.

*Increase the diversity of wetland habitats in a region*

- Measure the distribution and abundance of aquatic and semi-terrestrial macrophytes in and around multiple wetlands at different times through their wetting and drying cycle.

- Increase the diversity, distribution and abundance of emergent; macrophytes and herbaceous mudflat plant species in selected wetlands.
- Measure the distribution and abundance of aquatic and semi-terrestrial macrophytes in and around a wetland at different times through their wetting and drying cycle.

*Remove introduced fish species*

- If a wetland has not completely dried, assess the status of the fish population in residual pools.

*Provide greater habitat diversity for invertebrates and frogs*

- Measure habitat diversity by assessing the diversity of habitat provided by aquatic and semi-terrestrial macrophytes in and around the wetland; and
- Assess the diversity of macro-invertebrates and frogs.

*Increased productivity on re-wetting following drying event*

- Asses increases in algal abundance and/or Chlorophyll *a* concentrations.

**It is also necessary to monitor for potentially negative effects of the intervention.**

- Are sulfidic sediments present?
- Does drawdown and/or refilling result in acidification (pH), anoxia (dissolved oxygen) or salinisation of the wetland?
- Does draw down affect the condition of riparian vegetation?
- Does drawdown affect groundwater levels?

## Scenario 2: Re-inundation of a floodplain lake

### Intervention objective

- To artificially inundate a large floodplain lake that has been allowed to remain dry for an extended period of time as a consequence of current water management practices.

### Ecological objectives

Artificially re-flooding of the lake will result in:

- Re-introduction of aquatic habitat to the dry lake.
- Increase the diversity, distribution and abundance of submerged and emergent macrophytes in the lake.
- Greater habitat diversity for invertebrates, frogs, native fish and birds.
- Improved condition of riparian vegetation.

### Other Potential Outcomes

- If sufficient build up of organic matter has occurred in the lake bed during the drying phase, on rewetting the pulse of carbon (and to a lesser extent nutrients) may increase the level of microbial activity to the point where the water goes anoxic. (This is more likely to occur if re-inundation occurs in summer).
- Any salt accumulated in the lake bed prior to flooding may be mobilised during flooding.
- Establishment of toxic algal blooms on the lake.

### Suggested monitoring activities (against intervention and ecological objectives)

- Collate all existing data and collect baseline data.

*Intervention monitoring*

- Measure water surface levels to determine the extent of inundation. Assess the success of the intervention against the operational plan for adaptive management.

*Reintroduction of aquatic habitat*

- Measure water surface levels to determine the extent of inundation.
- Measure the distribution and abundance of aquatic and semi-terrestrial macrophytes in and around multiple wetlands at different times through hydrological cycle.

*Increase the diversity, distribution and abundance of submerged and emergent; macrophytes*

- Measure the distribution and abundance of aquatic and semi-terrestrial macrophytes in and around the lake at different times through the filling cycle.

*Provide greater habitat diversity for invertebrates, native fish, frogs and birds*

- Measure habitat diversity by assessing the diversity of habitat provided by aquatic and semi-terrestrial macrophytes in and around the wetland.
- Assess changes in abundance and diversity of macro-invertebrates, fish, frogs and birds over time.

*Improved condition of riparian condition*

- Assess changes to Riparian condition.

**It is also necessary to monitor for potentially negative effects of the intervention.**

- Does inundation result in anoxia (dissolved oxygen) or salinisation (electrical conductivity) of the lake?
- Does inundation of the lake create an algal bloom?

## Scenario 3: Inundation of flood runner or ephemeral floodplain creek.

### Intervention objectives

- Periodically restore in-channel flows to ephemeral flood runners and floodplain creeks and create temporary standing-water habitat in deeper pools in the channels.

### Ecological objectives

- Improvement in condition of riparian vegetation (watering).
- Export of accumulated carbon and nutrients to the main stem of the river.
- Formation of temporary standing water in deeper pools in the channel which becomes habitat for macro-invertebrates, frogs and small native fish.
- Increase in diversity of submerged and emergent vegetation in and around the temporary waterbodies.

### Other Potential Outcomes

- If sufficient build up of organic matter has occurred in the channel since the last flooding, the water quality of the leading edge of the flood may be poor (low in dissolved oxygen and high in organic carbon).
- If remnant pools exist in the channel prior to flooding, the water quality in the pools may be poor (low in dissolved oxygen and high in potentially toxic compounds such as sulfides); which on flooding may produce a slug of water of poor quality.
- If the remnant pools are maintained by saline groundwater the sediments may contain sulfidic sediments which can produce acid upon oxidation.
- Any salt accumulated in the channel sediments and remnant pools prior to flooding may be mobilised during flooding.

### Suggested monitoring activities (against intervention and ecological objectives)

Collate all existing data and collect baseline data.

*Intervention monitoring*

- Measure the in-channel flow distribution to determine the extent of inundation – including if water returns to the main stem of the river.
- Measure the distribution and depth of remnant pools following the flow event.
- Assess the success of the intervention against the operational plan for adaptive management.

*Improvement of Condition of Riparian Vegetation*

- Asses changes to riparian condition before and after the flow event.

*Export of Carbon and Nutrients from the Flood runner to the Main Stem of the River*

- Measure dissolved organic carbon and total and dissolved nutrients in the water as it flows along the runner.
- Determine whether flood water returns to main stem of the river.

*Formation of temporary standing water in deeper pools in the channel which becomes habitat for macro-invertebrates, frogs and small native fish*

- Measure the distribution and depth of remnant pools following the flow event.
- Assess changes in abundance and diversity of macro-invertebrates, fish and frogs over time.
- Measure habitat diversity by assessing the diversity of habitat provided by aquatic and semi-terrestrial macrophytes in and around the remnant pools.

*Increase in diversity of submerged and emergent vegetation in and around the temporary waterbodies*

- Measure habitat diversity by assessing the diversity of habitat provided by aquatic and semi-terrestrial macrophytes in and around the remnant pools.

**It is also necessary to monitor for potentially negative effects of the intervention.**

- Do remnant pools exist prior to imposing the flow?
- If so, what is the water quality like in the pools? Are they anoxic, saline or contain dissolved sulfides?
- Is the water quality in the flood water likely to harm organisms on return to the main river channel? Is the floodwater high in organic carbon, sulfides and/or salt? What is the dissolved oxygen level?

## Scenario 4: Significant over-bank flow

### Intervention objective

- To create a significant overbank flood in order to re-establish connectivity between the river and its floodplain and to inundate wetlands and floodplain lakes; with timing and frequency as specified in proposed operating plan.

### Ecological Objectives

The ecological objectives of the engineered flood are to:

- Facilitate the movement of carbon and nutrients from floodplain to the river channel to enhance riverine productivity.
- Allow for watering of floodplain vegetation resulting in a change in vegetation condition.
- Recharge ground-water table (decreasing salinity, and providing a freshwater lens in the plant root zone).

- Improve prospects for successful bird breeding if the flood is of sufficient duration.
- Improve prospects for successful recruitment of fish.
- Access to floodplain resources by channel species, particularly native fish.
- Deliver water to ephemeral floodplain waterbodies, increasing habitat for fish, macroinvertebrates, frogs and birds and increasing diversity of aquatic vegetation.

Other Potential Outcomes

- Export of blackwater (high in organic carbon, particularly tannins, and low in dissolved oxygen) which can result in fish kills downstream.
- Export of salt from the floodplain to the river.

**Suggested monitoring activities (against intervention and ecological objectives):**

Collate all existing data and collect baseline data.

*Intervention monitoring*

- Measure the distribution of water across the floodplain to determine the extent of inundation.
- Measure the distribution and depth of floodplain wetlands and lakes after the flood.
- Assess the success of the intervention against the operational plan for adaptive management.

*Facilitate the movement of carbon and nutrients from floodplain to the river channel to enhance riverine productivity*

- Measure changes in dissolved and particulate carbon and nutrients in the floodwater.
- Asses changes in floodplain soil carbon content.

*Allow for watering of floodplain vegetation*

- Determine changes in the distribution and abundance of aquatic and terrestrial macrophytes.
- Asses changes in vegetation condition over time.

*Recharge ground-water table (decreasing salinity, and providing a freshwater lens in the plant root zone)*

- Measure changes in groundwater levels over time.
- Monitor changes in groundwater salinity levels at a number of depths.

*Improve prospects for successful bird breeding if the flood is of sufficient duration*

- Monitor the extent of bird breeding during the flood.

*Improve prospects for successful recruitment of fish*

- Determine diversity and abundance of fish larvae on the flooded floodplain, in floodplain lakes and wetlands and in the main stem of the river.

*Access to floodplain resources by channel species, particularly native fish*

- Monitor the distribution of fish on the floodplain during the flood event.
- Measure changes in fish diversity and abundance in floodplain lakes and wetlands prior to- and post- flooding.

*Deliver water to ephemeral floodplain waterbodies, increasing habitat for fish, macroinvertebrates, frogs and birds and increasing diversity of aquatic vegetation*

See Scenario 2

**It is also necessary to monitor for potentially negative effects of the intervention.**

- Is the water quality in the flood water likely to harm organisms on return to the main river channel? Is the floodwater high in organic carbon and/or salt? What is the dissolved oxygen level?
- Does the salt content of the floodplain soil change in response to the flood?

# Appendix 4

## Useful Taxonomic Keys and References

There is a well developed taxonomic literature for many (but not all) of the biotic groups likely to be encountered in Australian wetlands. The following references may be a useful entry point for monitoring biota in Australian wetlands and floodplains.

### Phytoplankton:

Day, S. A., Wickham, R. P., Entwisle T. J., & Tyler, P. A. (1995), *Bibliographic checklist of non-marine algae in Australia*. Australian Biological Resources Study, Canberra.

Entwisle, T.J. & Nairn, L. . *Freshwater Algae - Census of Freshwater Algae in Australia*. http://plantnet.rbgsyd.gov.au/PlantNet/fwalgae.htm

Hötzel G. and Croome, R. (1999) *A Phytoplankton Methods Manual for Australian Waters.* LWRRDC Occasional Paper 22/99 (and references therein.)

### Wetland and Floodplain Vegetation:

Aston, H.I. (1973) *Aquatic Plants of Australia* Melbourne University Press, Melbourne.

Costermans, L.F. (1981) *Native Trees and Shrubs of South-eastern Australia* Weldon Publishing, NSW.

Foreman, D.B., Walsch, N. G. & Entwisle, T.J. (Eds) (1993-) *Flora of Victoria* Inkata Press, Melbourne.

George, A.S. (Ed) (1981) *Flora of Australia* Australian Government Publishing Service, Canberra

Harden, G. (Ed) (1990 – 1993) *Flora of NSW* New South Wales University Press, Sydney

Sainty, G.R. and Jacobs, S.W.L. (1982) *Waterplants of NSW* Water Resources Commission, Sydney

Sainty, G.R. and Jacobs, S.W.L. (1994) *Waterplants in Australia* 3rd Ed. Sainty and Associates, Sydney

### Macroinvertebrates:

Hawking, J.H. (2000) *A preliminary guide to keys and zoological information to identify invertebrates form Australian freshwaters.* Identification Guide No. **2** (2nd Edition),

Pearson M.J and Hawking J.H (2001) *A bibliography to some of the ecological and biological literature of Australian Aquatic Inland Invertebrates.* Identification Guide no. 36. Cooperative Research Centre for Freshwater Ecology.

### Fish:

Allen, G. R., Midgely, S. H. and Allen, M. (2002), *Field Guide to the Freshwater Fishes of Australia,* Western Australian Museum, Perth.

Allen, G. R. (1989) *Freshwater Fishes of Australia.* T.F.H publications, USA.

Cadwallader, P. L. and Backhouse, G. N. (1983). *A guide to the freshwater fish of Victoria.* Victorian government printing office, Melbourne.

Merrick J. R. and Schmida, G. E. (1984). *Australian Freshwater Fishes: biology and management.* Griffin Press Limited, Netley.

Serafini, L. G. and Humphries, P. (2004) *Preliminary guide to the identification of larvae of fish, with a bibliography of their studies, from the Murray-Darling Basin.* Identification and ecology guide No. 48. Co-operative Research Centre for Freshwater Ecology, Albury.

### Frogs:

Anstis, M. (2002) *Tadpoles of South eastern Australia; A guide with keys.* Reed New Holland French's Forest.

Barker, J., Grigg, G.C. and Tyler, M.J. (1995). *A Field Guide to Australian Frogs.* Surrey Beatty and Sons, Chipping Norton.

Cogger, H.G. (2000) *Reptiles and Amphibians of Australia.* Reed New Holland, Frenchs Forest.

Environment Protection Agency (South Australia) Frog Census http://www.environment.sa.gov.au/epa/frogcensus/frog_key.html

Frogs of Australia http://frogs.org.au/frogs/index.html

Hero, JM., Littlejohn, M. and Marantelli, G. (1991) *Frogwatch Fieldguide to Victorian Frogs.* DOCE, Melborne

Robinson, M. (2000). *A Field Guide to Frogs of Australia: From Port Augusta to Fraser Island, Including Tasmania***.** Reed New Holland, French's Forest.

### Birds:

CSIRO & NSW Fauna Panel (undated). *Waterfowl in New South Wales.* Produced by CSIRO and the NSW Fauna Protection Panel.

Kingsford, R. (1991). *Australian Waterbirds.* Kangaroo Press Pty Ltd, Kenthurst NSW.

Lane, B.A. (1987). *Shorebirds in Australia.* Nelson, Melbourne.

NSW National Parks & Wildlife Service. *Atlas of NSW Wildlife.* http://wildlifeatlas.npws.nsw.gov.au/wildlifeatlas/about.jsp

Pizzey, G. & Knight, F. (1997). *The Graham Pizzey & Frank Knight Field Guide to the Birds of Australia.* Harper Collins, Pymble.

Simpson, K. & Day, N. (1996). *Field Guide to the Birds of Australia,* 5th edition. Penguin Books, Ringwood, Australia.

# Appendix 5

## S.A. Water Birds - Inland Waters Habitat Preference

*Editor:* Glen Scholz; Senior Ecologist DWLBC

*Source:* South Australian Aquatic Biota Database (DWR 2001)

This information can be used for linking wetland habitat features to waterbird preferences and determining the relative value of wetlands.

This method is useful when:

- There is a need to determine the waterbird species that are most likely to utilise the wetland;
- There is an absence of bird records at the wetland;
- There is a need to compare a number of wetlands with disparate waterbird records; and
- It is only possible to assess the wetlands at dates /times that are inopportune for bird observations or for cross comparison of wetlands.

*Note: Although the information provided in the tables has been sourced from various research papers recorded in the SAAB database, the statements presented are based on simplifications and or generalisations and should be used as a guide only.*

**Key – (M):** Movement – *D- distributary; S – Sedentary; M – migratory; N- Nomadic*

| Common Name | M | Habitat Preference | Nesting preference | Diet | Feeding |
|---|---|---|---|---|---|
| **Australian Pelican** | **D** | Large open water | Low islands or sand spits, on ground | Carnivore, fish mostly, also insects and crustaceans | Herding fish into shallows to feed |
| **Black Swan** | | Large open water, particularly with submerged macrophytes. | Not specific, on islands, in reeds, mounds of accumulated macrophytes, or among shrubs | Herbivore, mostly leaves and shoots of aquatic plants also grasses | Can secure food to depth not exceeding 1m |
| **Australian Wood Duck** | **D** | Grasslands and pasture associated near wetlands (terrestrial) | Tree hollows | Herbivore, mostly grasses, also grains and insects | Mostly grazing on land |
| **Pacific Black Duck** | **S** | Open water with dense fringing vegetation, not specific | Often in tree hollows, less on the ground amongst bushes | Omnivore, mostly seeds and vegetative material, sedges smartweeds and grasses | Not specific, dabble water surface, sift mud, strip seeds |
| **Australian Shelduck** | **M S** | Large open water, along the shoreline of shallow habitats (known to inhabit salt affected wetlands) | Often in tree hollows, less on the ground amongst bushes and rabbit burrows | Omnivore, mostly vegetation and invertebrates, some molluscs | Not specific, dabble water surface, sift mud, strip seeds |
| **Grey Teal** | **D** | Large shallow inland waters, not specific | Often in tree hollows, less on the ground amongst bushes and reeds | Omnivore, mostly seeds and vegetative material, sedges smartweeds and grasses | Not specific, dabble water surface, sift mud, strip seeds |
| **Pink Eared Duck** | **D** | Large shallow inland waters, (aquatic) | Usually over water in trees, cane grass, lignum, chenopods | Omnivore, mostly invertebrates also algae and floating seeds | Filter feeder limited to water and sifting mud |
| **Hardhead** | **D** | Open deep water with dense fringing vegetation, (aquatic) (uncommon on salt affected wetlands) | In dense reeds, on islands and lignum, melaleuca | Omnivore, mostly aquatic plants also molluscs and crustaceans | Mostly from diving also dabbling and strip seeds |
| **Blue-billed Duck** | **M** | Large open water permanent with fringing vegetation (aquatic) | In dense vegetation, reeds, lignum, melaleuca, occasionally on ground | Omnivore, plant material and insects also molluscs and crustaceans | Mostly from diving also surface of the water and strip seeds |
| **Australasian Shoveller** | | Large open water permanent with fringing vegetation (aquatic) | On the ground in grassy sites usually close to waters edge | Omnivore, mostly insects also seeds | Feed off the surface of the water |
| **Pacific (white necked) Heron** | **D** | Shallow inland waters and flooded lands, with sparse grasses, herbs, sedges, rushes, Eleocharis. Not specific | Nest on limbs in trees | Carnivore, small aquatic and terrestrial animals (rarely fish) also molluscs and crustaceans | Standing, stalking and striking prey. Feed in shallow water <7 cm and steep banked waters. |

| Common Name | M | Habitat Preference | Nesting preference | Diet | Feeding |
|---|---|---|---|---|---|
| **White-faced Heron** | **N** | Not specific, river systems, floodplains, swamps, fresh and saline | Nest in trees not necessarily near water | Carnivore, a wide range of vertebrates and invertebrates also crustaceans | Standing, stalking and striking prey in shallow waters. |
| **Great Egret** | | Open shallow floodplain waterbodies permanent, not specific | Nest in upper parts of trees standing in water 7-15m above ground | Carnivore, mostly fish also insects, crustaceans, molluscs and birds | Standing, stalking and striking prey in shallow waters. Forage in shallow waters <30cm deep |
| **Little Egret** | | Open shallow floodplain waterbodies, with abundant aquatic veg. and little to no emergent veg. | Nest on limbs in trees from water level to 7m above | Carnivore, mostly fish (mainly <2cm) also insects, crustaceans | Standing, stalking and striking prey in shallow waters. Forage in shallow waters <10 –15cm deep |
| **Nankeen Night Heron** | **N** | Open shallow floodplain waterbodies permanent, with wooded edges and / or tall sedges and reeds | Nest in trees, on top of shrubs, lignum and reed beds | Carnivore, mostly fish also animals, insects and crustaceans | Nocturnal. Standing, stalking and striking prey in shallow waters and pursue prey on land. |
| **Glossy Ibis** | **M** | Floodplain waterbodies, along the shoreline of shallow habitats with abundant aquatic flora. (Prefer freshwater, avoid dry ground | Nest on top and in lignum at 10-50 cm above water level | Carnivore, mostly aquatic invertebrates, also molluscs, crustaceans and insects | Slowly walking sifting mud, water surface and from grasses |
| **Straw-necked Ibis** | | Shallow wetlands, grasslands with trees, shrubs and reeds | Nest amongst lignum, reeds and sedges, on ground on islands or over water<1m deep | Omnivore, mostly a wide range of vertebrates and invertebrates also crustaceans, molluscs some seeds and plant material | Feed by probing into ground or vegetation into shallow water |
| **Royal Spoonbill** | | Not specific, wetlands, grasslands along shallow margins | In trees, lignum, reeds and rushes usually over water 0.5 to 1.5m deep in trees 1 to 15m high or reeds 0.5 to 1.5m high. | Omnivore, mostly fish also crustaceans, aquatic insects and vegetable matter | Wading sweeping, probing, grabbing in shallow water <40cm. Substrate of sand, mud and clay |
| **Yellow-billed Spoonbill** | | Shallow wetlands, with abundant aquatic flora with sparse or low vegetation | Nest often in tree side branches 2 – 8m high over water | Carnivore, mostly aquatic insects also crustaceans and fish | Wading sweeping, probing, grabbing in shallow water <40cm. Substrate of sand, mud and clay |
| **Brolga** | **S** | Near open shallow wetlands (swamps and marshes) <2m deep | Prefer nesting in marshes <50cm deep and meadows <30cm deep, on the ground or small island, sedge and rushes, grasses or cane grass / lignum, occasionally floating nests | Omnivore, mostly tubers of sedges (particularly Eleocharis) and pasture, also insects molluscs and crustaceans | Slowly walking grazing and digging, also striking prey |

| Common Name | M | Habitat Preference | Nesting preference | Diet | Feeding |
|---|---|---|---|---|---|
| **Great Cormorant** | **N**<br>**D** | Deep open lakes / marshes and major rivers, permanent | Not specific, trees, bushes, lignum, rocks, on ground near water | Carnivore, predominantly fish also crustaceans and insects | Most taken by pursuit diving, also wading in shallows |
| **Pied Cormorant** | **S** | Deep open lakes / marshes and major rivers, permanent, with fringing trees and islands | In trees and dense shrubs (lignum) | Carnivore, predominantly fish also insects | All food taken by pursuit diving |
| **Little Black Cormorant** | **D** | Deep open lakes / marshes and major rivers, permanent >1m deep, 90% on wetlands >100ha | Flooded trees away from land in vegetated swamps and lakes | Carnivore, predominantly fish also crustaceans | Most taken by pursuit diving<br>In trees, bushes, lignum and |
| **Little Pied Cormorant** | **D** | Open lakes / marshes and major rivers, use smaller wetlands than other cormorant sp. | In trees, bushes, lignum and snags around 2.8m above water | Carnivore, prey on crustaceans more and take fish taken less often than other cormorants | Food taken by a succession of dives taking more sedentary prey in shallow waters |
| **Australian Darter** | | Open lakes / marshes and major rivers, permanent smooth water >50cm deep | In branches of flooded trees around 3.5m above water | Omnivore, predominantly fish also insects and occasionally vegetable matter | All food taken by pursuit diving |
| **Hoary-headed Grebe** | **D** | Open lakes / marshes and major rivers, 100-500m wide and 0.5 –3m deep with submerged veg. (avoid dense waterweeds) | Off shore in floating waterweeds or amongst sedges, saltmarsh, lignum and canegrass | Carnivore, primarily aquatic arthropods also fish | Most taken by deep diving pecking inverts from sediments and vegetation |
| **Australasian Grebe** | **D** | Shallow wetlands, along steep gradient shoreline with fringing reeds and submerged vegetation | In shallow water among emergent plants and bushes or attached to overhanging branches | Omnivore, aquatic arthropods, fish, molluscs, vegetable matter and seeds | Wide range of methods, diving, picking from surface water, snatching insects from emergent veg. |
| **Dusky Moorhen** | | Open waterbodies permanent, with fringing emergent and submerged vegetation also adjacent grassed areas | In dense vegetation, lignum, cane grass, reed beds, rushes and sedges | Omnivore, vegetable matter, seeds, molluscs, insects, carrion | Feed on land and shallow water (up to 30cm deep) amongst floating veg. or in open water 100m from cover |
| **Purple Swamphen** | | Not specific, around the margins of wetlands with dense fringing vegetation and adjacent grasslands. Prefers to refuge in tall emergent reeds or cumbungi. In reed beds and rushes | Omnivore, mainly aquatic veg. also seeds, insects, fish animals | Feed in dense reed beds gleaning insects and seeds, dig roots and rhizomes also graze grass | |

| Common Name | M | Habitat Preference | Nesting preference | Diet | Feeding |
|---|---|---|---|---|---|
| **Black-tailed Native-hen** | **D** | Open shallow wetlands to more saline conditions, not specific | Near water in swamps of red gum, lignum, cane grass, chenopod shrubs, grasses and small islets | Omnivore, seeds, vegetable and insects | Gleans from ground and water surface |
| **Eurasian Coot** | **D** | Open shallow wetlands with fringing emergent and submerged vegetation, often with open deep water >2m | In lignum, sword grass, rushes and forks of shrubs (melaleuca) | Herbivorous, mainly aquatic veg. seeds and grasses. | Graze on land and glean from water surface, dive for shoots and scrape algae |
| **Australian Spotted Crake** | | Not specific, around the margins of wetlands (<5cm water) with dense fringing vegetation | In dense vegetation, bushes, lignum, rushes, sedges and grass | Omnivore, seeds (sedges, chenopods, legumes), also insects, molluscs and crustaceans | Foraging on the ground, wading, gleaning and probing |
| **Spotless Crake** | | Not specific, around the margins of wetlands with dense fringing vegetation | Usually over water in dense vegetation, reeds, rushes, grass tussocks and bushes | Omnivore, seeds, grasses, insects, molluscs and crustaceans | Mostly foraging on the ground, gleaning mudflats, reedbeds, shallow water |
| **Ballion's Crake** | **M** | Not specific, around the margins of wetlands with dense fringing vegetation and abundant floating vegetation (may prefer fluctuating water levels) | In dense vegetation above shallow water within 20m of waters edge | Omnivore, mostly aquatic insects also seeds, molluscs and crustaceans | Gleans among floating veg. reeds and marshy ground |
| **Masked Lapwing** | **S** | Open shallow wetlands, with short grassed areas at the margins, also adjacent open plains | Nest on ground in short grass (<12cm) or stony ground also on small islands and floating reeds | Omnivore, molluscs, worms, insects, crustaceans and occasionally seeds | Stalk, run, glean and probe |
| **Banded Lapwing** | | Not specific, near water open plains and margins of dry swamps | On ground in a range of open dry habitats | Omnivore, seeds, leaves, molluscs, worms, insects | Stalk, run, glean and probe, seldom wade in shallow water |
| **Red-Kneed Dotterel** | | Open floodplain wetlands along the open shallow margins, avoid tree lined and/ or the more saline wetlands | Not specific, on ground along the shore or islets where samphire and shrubs can conceal nests | Omnivore, seeds, molluscs, worms, insects | Glean and probe and tremble feet to disturb prey in wet sand / mud |
| **Black-Fronted Dotterel** | **S** | Open floodplain wetlands along the shallow margins | Nest on ground in stony areas or stone strewn sand | Omnivore, worms, molluscs, and crustaceans also insects, occasionally seeds | Forage at waters edge glean and probe into mud |
| **Red-capped Plover** | | Saline wetlands along the open shallow mudflats with sparse fringing vegetation | Not specific, on ground along the shore or islets, usually near water >40m | Omnivore, worms, molluscs, and crustaceans also insects, and vegetable matter | Forage stop-run-peck, seldom wade in shallow water |

| Common Name | M | Habitat Preference | Nesting preference | Diet | Feeding |
|---|---|---|---|---|---|
| **Black-winged Stilt** | **D** | Open shallow wetlands, with short grassed areas, not specific | Not specific, on ground | Omninivore, mainly invertebrates, also molluscs and crustaceans, occasionally vegetable material and seeds | Diurnan and nocturnal wide range of foraging, pecking, pursuit, filtering, probing and raking |
| **Banded Stilt** | **D** | Saline wetlands along the open sahllow mudflats | On ground on small islands in slat lakes with scattered samphire, occasionally on sand pits 1-1.5m above water level and besides shallow water 10-60cm deep | Omninivore, mainly crustaceans, also molluscs, insects vegetable material and seeds | Forage at waters edge wading, pecking, scything and probing into mud |
| **Red-necked Avocet** | **D** | Saline wetlands along the open sahllow mudflats, not specific | Not specific, on ground along the shore or islets of salt lakes above water level | Omninivore, invertibrates, molluscs and crustaceans, occasionally vegetable material and seeds | Wading in shallow water scything, gleaning from water surface |

## Example

*Date: 1/11/04*

*Site: Mira Mitta; Birdsville Track*

*GPS Location:*

*Time: 12:30 pm*

Wetland Value: B
Priority: 5

*Wetland features:*

*Permanent shallow wetland maintained by bore, established 1901*

*Size: Approx 30ha*

*Depth: shallow <20cm depth across the wetland*

*Landscape: Stony plains chenopod shrubland*

*Soils: Medium clay loam across site*

*Vegetation: Primarily wetland meadow (low salinity) of Elocharis, bordered by chenopod shrubland composed of Atriplex vesicaria, Nitraria billarderi and Maireana pyramidata.*

*Isolated small stands of Acacia sp. along the fringe of the wetland.*

*Waterbird Value: This wetland ecosystem is most likely favoured by:*

With suitable nesting sites

*Brolga, Black- tailed native-hen, Masked Lapwing, Banded Lapwing, Red-kneed dotterel, Black-fronted dotterel, red-caped plover, Black-winged stilt.*

With low value nesting sites

*Pacific white necked heron, White-faced heron*

## Feedback Form

'Recommended Methods for Monitoring Floodplains and Wetlands'

In order to improve the usability and technical content of the Monitoring Handbook, we request users of the document to copy this page, complete and fax to the Murray Darling Basin Commission.

Fax No. (02) 6230 7579 or post to GPO Box 409 Canberra ACT 2601

Name:

Position:

Agency:

Use of the Handbook:

Comments:

Layout of the document:

Technical Content:

Suggestions for additional technical information or improvements.

## Murray-Darling Basin Commission

We will manage and conduct our business in a highly professional and ethical manner, and according to the values jointly agreed with the Community Advisory Committee. These values require particular behaviours that will cement our relationships with our stakeholders and the wider community, and will underlie all decisions, actions and relationships we enter into. We will promote the values so that all people and organisations which have dealings with the Commission know what to expect from us and what we expect from them.

### Our values

- We agree to work together, and ensure that our behaviour reflects the following values.

*Courage*

- We will take a visionary approach, provide leadership and be prepared to make difficult decisions.

*Inclusiveness*

- We will build relationships based on trust and sharing, considering the needs of future generations, and working together in a true partnership.
- We will engage all partners, including Indigenous communities, and ensure that partners have the capacity to be fully engaged.

*Commitment*

- We will act with passion and decisiveness, taking the long-term view and aiming for stability in decision making.
- We will take a Basin perspective and a non-partisan approach to Basin management.

*Respect and honesty*

- We will respect different views, respect each other and acknowledge the reality of each other's situation.
- We will act with integrity, openness and honesty, be fair and credible, and share knowledge and information.
- We will use resources equitably and respect the environment.

*Flexibility*

- We will accept reform where it is needed, be willing to change, and continuously improve our actions through a learning approach.

*Practicability*

- We will choose practicable, long term outcomes and select viable solutions to achieve these outcomes.

*Mutual obligation*

- We will share responsibility and accountability, and act responsibly, with fairness and justice.
- We will support each other through necessary change.


SIX GOVERNMENTS WORKING IN
PARTNERSHIP WITH THE COMMUNITY