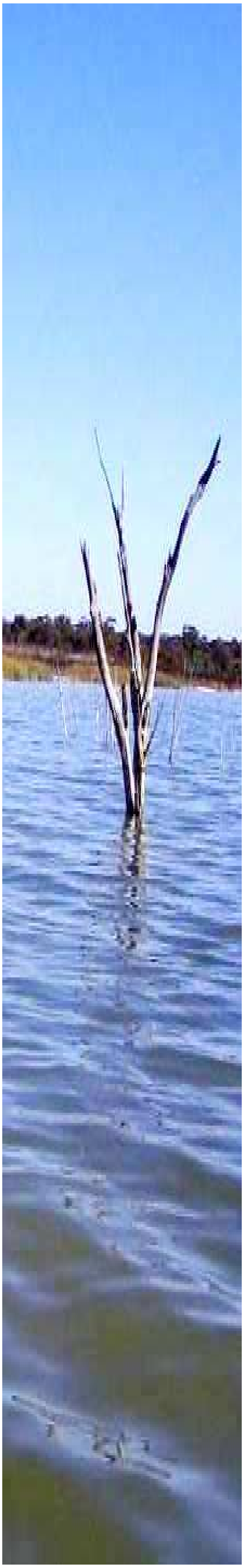

Potential Effects of Willow (*Salix* spp.) Removal on Freshwater Ecosystem Dynamics

Key Issue Assessment and Long Term Monitoring Program

S. Zukowski, B. Gawne, H. Gigney, and L. Huzzey

February 2007

Report prepared for the
North East Catchment Management Authority

The Murray-Darling Freshwater Research Centre

NORTH EAST CATCHMENT MANAGEMENT AUTHORITY

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The Murray-Darling Freshwater Research Centre is a joint venture between the Murray Darling Basin Commission and CSIRO Land and Water, which aims to answer locally relevant research questions to help guide water managers, and ultimately improve the health of our rivers, lakes and wetlands.

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1. INTRODUCTION

In March 2006, the Murray Darling Freshwater Research Centre was commissioned and funded by the North East Catchment Management Authority (NECMA) to develop a literature review and a long term monitoring program detailing the effects of willow removal on freshwater aquatic systems. The literature review was completed in June 2006. The literature review summarised previous literature on willow effects and attempted to predict the potential short and long term effects of willow removal on aquatic ecosystems. This review demonstrated that although anecdotal evidence suggests an overall increase in 'stream health' in the long term following willow removal, there is a consistent lack of literature describing the effects of willows and willow removal on Australian aquatic environments. This made accurate predictions on the possible short and long term affects of willow removal difficult and led to the production of this current report.

This report has developed a protocol for identifying key issues and a monitoring program associated with potential long term effects of willow removal on aquatic systems. These key issues are based on the knowledge available and their importance to stream ecology. The long term monitoring program is based on these key issues. The literature review and the monitoring program are part of a larger project funded by NECMA which will then apply the monitoring designs to willow removal and reference sites to ascertain the key long term effects of willow removal on aquatic systems.

2. EXECUTIVE SUMMARY

2.1 Australian History of Willows

Willows *Salix* spp. (Salicaceae) were introduced to the River Murray in Australia by 19th century European settlers (Cremer 1995; Frankenberg 1995; Smith and Starr 1999), mainly to act as channel markers for river boats and as stabilising agents protecting reclaimed riparian wetlands (Perkins 1903; Ladson *et al.* 1997). Since then, more trees have been planted to stabilize riverbank levees and the margins of the weir pools constructed in 1922-1937 (Walker and Thoms 1993). Today more than 100 species, varieties, cultivars and hybrids of willows are present in Australia (Cremer 1995) with subsequent hybrids still arising (Ladson *et al.* 1997). One of the first species planted, the weeping willow (S. *babylinica*), now rivals the native river red gum (Myrtaceae: *Eucalyptus camaldulensis*) as the dominant riparian tree along some reaches of the River Murray (Walker *et al.* 1994).

In Australia, willows are generally seen as a serious weed threat to stream and wetland environments due to their highly invasive and adaptive qualities (Frankenberg 1995; Ladson *et al*. 1997; Schulz and Walker 1997; Ladson *et al*. 1999). A widely accepted view has emerged that fundamental stream ecological processes may be affected by willow spread, causing a broad range of detrimental impacts to freshwater ecosystems (e.g. Campbell 1993; Frankenberg 1995; Ladson *et al.* 1997; Bobbi 1999; Smith and Star 1999). Such concern has resulted in willows attracting national attention. In 1999 all but three willow (*Salix)* species were included on the ‘Weeds of National Significance’ (WONS) list which declares Australia’s 20 worst weed species (ARMCANZ 2001).

2.2 Existing research

Willow studies have historically focused on allochthonous (leaf litter) inputs, leaf breakdown rates, canopy cover, stream shading and temperature and macroinvertebrate feeding preferences (i.e. Pidgeon 1978; Pidgeon and Cairns 1981; Collier and Winterbourn 1986; Yeates 1994; Parkyn and Winterbourn 1997; Schulz and Walker 1997). In Australia, previous studies on willow effects have included comparisons of willow and native leaf pack decomposition and colonisation and field surveys of aquatic biota and thermal changes at willow and native forest lined reaches (Pidgeon and Cairns 1981; Hardwick *et al*. 1995; Besley 1992; Schulze and Walker 1997; Gawne *et al*. 2005). Few studies have actually examined or quantified the impacts of willows on in-stream fauna, despite reviews by various authors (Mitchell and Frankenberg 1993; Ladson *et al*. 1997). A number of studies comparing biota under native and willow vegetation have been inconclusive (Pidgeon 1978; Besley 1992; Hardwick *et al*. 1995; Schulze and Walker 1997). In fact, to date, only three peer-reviewed journal papers have investigated direct willow-stream interactions in Australia (Pidgeon and Cairns 1981; Cremer *et al*. 1995; Schulze and Walker 1997). Evidence for such interactions is still inconclusive with inconsistent or contradicting results warranting further research.

2.3 Key knowledge gaps

The lack of comparable and consistent data means that key knowledge gaps currently exist. To provide a framework for management, key gaps can be grouped into six strategic themes:

1. Extent of impact on fish community composition and abundance (habitat, shade, temperature, feeding and predator avoidance).
2. Extent of impact on macro invertebrate community composition and abundance (feeding and habitat).
3. Extent of impact on food web (timing, quantity and quality of allochthonous input, shade, temperature and algal production).
4. Extent of impact on water quality (nutrient input and runoff, pH, salinity and dissolved oxygen levels).
5. Extent of impact on riparian habitats (bank soils and erosion, use of riparian corridors by animals, impact of riparian zone fragmentation following de-willowing and riparian vegetation).
6. Extent and timing of impacts and recovery periods.

When examining these themes in research and management programs, the ecological sensitivity of willow removal in different systems (i.e. large rivers, small streams, wetlands, weir pool sites) and at various magnitudes (i.e. whole section willow removal vs. single willow removal) should be carefully considered.

2.4 Future willow management

The decision to remove, leave or otherwise manage willows in Australian streams, rivers and wetlands is a much debated topic between natural resource managers, academics and the broader community. The debate is complicated due to the large knowledge gaps and inconclusive and conflicting findings on the effects of willows on aquatic biota and a lack of literature on the effects of removing willows from aquatic ecosystems. The decision to remove or retain willows along rivers and streams is often left to water resource managers. They are placed in a difficult position, especially as currently there is inadequate information to thoroughly evaluate impacts, benefits and costs of willow removal at multiple scales (Wilson 2001).

The ongoing extent of willow invasion and the large scale movement of asexual propagules downstream from existing stands means catchment and regional planning strategies need to consider willow management in Australia. Priority setting requires quantitative knowledge of impacts, costs and benefits from willow invasion and willow removal at both reach and catchment scales (Wilson 2001). In addition, catchment managers require access to knowledge that will enable willow removal to be undertaken in a manner that minimises detrimental short term impacts and accelerates recovery of the system. Clearly, further research is warranted to quantify these patterns and provide valuable knowledge and resources for the future management of willows in Australia.

3. AN OUTLINE OF THIS REPORT

Given the possible deleterious effects of willows on Australian aquatic processes, it is no wonder that wide scale willow removal projects are currently underway in Australia. However, the debate between various groups as to whether willows should be left in place, removed or otherwise managed and to the potential effects of removing willows on aquatic systems has called for further information to be gathered on the effects of willows and willow removal on Australian aquatic systems. This report identifies and rates potential short and long term issues which may arise following willow removal. The long term key issues are then used in the development of a long term monitoring program for willow removal and reference sites.

4. SHORT VS. LONG TERM EFFECTS OF WILLOW REMOVAL

4.1 Background

The magnitude of potential effects of willow removal on aquatic ecosystems can vary depending on stream size, depth and flow, the current health of the system and the degree of willow infestation and willow removal. These effects can range from minute to significant in disturbance or change and can be either short or long lived. Long term effects on an aquatic ecosystem following willow removal will almost certainly differ from short term immediate effects.

4.2 Short term effects

Short term affects (< 1 year) are important to monitor if drastic ecological disturbances or changes are expected. This monitoring program is based on the assumption that willow root mats will be left in place following willow removal, thereby decreasing the magnitude of any short term disturbances. Gawne *et al.* (2005) undertook an examination of the short term effects of willow canopy removal (willow root mats were left in place) on both the stream temperature and the macroinvertebrate community in the Ovens River. The report demonstrated no evidence of a change in water temperature due to the de-willowing operation despite a significant loss of shade in the de-willow reach. This is contrary to the findings of Rutherford *et al.* (1997), however their studies were conducted in summer, whereas, Gawne *et al.* (2005) conducted their study in autumn. Gawne *et al.* (2005) also found no immediate significant differences in the macroinvertebrate assemblage following the de-willowing operation.

4.3 Long term effects

Long term affects (> 1 year) of willow removal may not be as intense as immediate short term effects, but may be significant. Long term affects could include a gradual change in stream temperature, oxygen, and nutrient levels and in the community composition or structure of invertebrates, fish, macrophytes and riparian plants and in the structure of banks and streams. Long term effects can be more difficult remedy once community structures have changed. Therefore, it is important to monitor long term effects to ensure decisions are made whilst there is still time to put action into play and prevent any serious deleterious environmental effects.

5. WILLOW REMOVAL EFFECTS - ISSUE RANKING

5.1 Ranked Issues

A list of potential issues that may arise following willow removal has been compiled from the outcomes of a NECMA de-willowing workshop held on the 7th of March 2006 and from the literature review 'Potential Effects of Willow (*Salix* spp.) Removal on Freshwater Ecosystem Dynamics. A Literature Review' (Zukowski and Gawne 2006). A listing of the issues can be seen in tables 1 to 3. The issues were chosen based on the current extent of our knowledge, their perceived importance in the aquatic ecosystem including direct, indirect and carry on effects, their perceived importance to tourism, recreation, and management and the magnitude of the potential risk or impact of the issue.

Taking a fish community as an example, there is currently a lack of information available on the specific effects of willow removal on fish communities. This coupled with the potential for willow removal to have a range of effects on the aquatic ecosystem through changes to the fish community (see Zukowski and Gawne 2006) and a perceived impact on the tourism industry, recreational users and fishers, led to fish communities being listed as a key issue for future monitoring following willow removal (see tables 1-3).

5.2 Table descriptions

Tables 1 to 3 summarise this information. Table 1 has a general list of perceived issues, table 2 has a list of the perceived short term issues and table 3 has a list of the perceived long term issues following willow removal. The headings for each of the table columns are explained below.

Category 1 - Category 1 refers to whether the issue is perceived as a risk, objective or both.

<u>Category 2</u> - Category 2 refers to the type of environment the issue may occur in. This may be either aquatic, aquatic referring to the water quality (WQ) or terrestrial.

<u>Issue</u> - The issue refers to the actual ecosystem component which may be affected by willow removal (i.e. fish community, stream bed morphology etc.).

<u>Main Question</u> - The main question refers to the type of problem associated with the issue following willow removal. For example, the extent to which the fish community will be affected, at risk, or otherwise altered.

<u>Knowledge</u> - Knowledge refers to our current level of information available on the extent of effect, be it risk or objective or both, to the issue at hand following willow removal. Issues with a large data and knowledge base received a high score, whilst issues with a low knowledge base received a low score on a scale of 1-5. For example, in table 1, the issue, ‘fish community’ has received a knowledge score of 2. This shows that there is a moderately low level of knowledge of the effects of willow removal on the associated fish community.

<u>Importance</u> - The importance of the issue is scaled relative to other issues, based on ecology, the magnitude of possible direct and indirect effects, the carry on effect to the ecosystem, public perceptions of the issue and the potential effect on recreation, tourism and management direction. Issues with a high combined importance in these areas received a high score, whilst issues with a low combined importance received a low score on a scale of 1-5.

<u>Score</u> - The score refers to the research priority. This has been calculated using the level of knowledge that is available and the issue’s importance. The score scale ranges from 1 – 20. A high score shows there is a lack of information available on the issue coupled with a high importance. A low score signals an issue with more available information and which may have less critical affects following willow removal. For example, in table 1, the fish community have received a high score due to the lack of information available on possible effects to the fish community following willow removal, and the high perceived importance of fish in an aquatic ecosystem as well as for tourism, recreation and management.

Table 1. Ranking of ecological issues associated with the possible effects of willow removal (based on the degree of current available knowledge and the general importance of the issue).

Knowledge: 1 = low level of knowledge, 5 = high level of knowledge
Importance: 1 = low degree of importance, 5 = high degree of importance
Score: 1 = low research priority, 20 = high research priority

Category 1	Category 2	Issue	Main Question	Know-ledge	Impor-tance	Score
Both	Aquatic	Fish Community	Extent	2	5	20
Both	Aquatic	Bug Community	Extent	2	4	16
Objective	Aquatic WQ	Water Quality	Extent	2	4	16
Risk	Aquatic WQ	Nutrients run-off	Extent	2	4	16
Objective	Terrestrial	Riparian Habitat	Extent	2	3	12
Risk	Terrestrial	Exotic Veg	Change Management	3	4	12
Objective	Terrestrial	Bank Soils	Extent	1	2	10
Risk	Aquatic WQ	Sedimentation	How to minimise	4	5	10
Risk	Aquatic WQ	Temperature	Impact on Fauna	4	5	10
Both	Aquatic	Instream Habitat	Transition	3	3	9
Objective	Terrestrial	Tree Bugs	Extent	3	3	9
Objective	Aquatic	Primary Production	Extent	3	3	9
Objective	Terrestrial	Riparian Understorey	Change Management	3	3	9
Both	Aquatic	Stream Bank	Change Management	4	3	6
Both	Aquatic	Bed Morphology	Change Management	4	3	6
Objective	Aquatic	Hydraulic Capacity	Change Management	3	2	6
Objective		Litter-Fall	Impact of change	5	1	1

Table 2. Ranking of short term ecological issues associated with the possible effects of willow removal (based on the degree of current available knowledge and the strength of the short term importance of the issue).

Knowledge: 1 = low level of knowledge, 5 = high level of knowledge
Importance: 1 = low degree of importance, 5 = high degree of importance
Score: 1 = low research priority, 20 = high research priority

Category 1	Category 2	Issue	Main Question	Know-ledge	Short Term Imp.	Strength	Score
Risk	WQ	Sedimentation	How to minimise	4	5	4	20
Both	Aquatic	Fish Community	Extent	2	4	4	16
Objective	Aquatic	Primary Production	Extent	3	4	4	16
Risk	WQ	Temperature	Impact on Fauna	4	4	4	16
Risk	Terrestrial	Exotic Veg	Change Management	4	4	3	12
Risk	WQ	Nutrients run-off	Extent	2	4	3	12
Both	Aquatic	Bug Community	Extent	2	3	3	9
Objective		Litter-Fall	Impact of change	5	4	2	8
Objective	Terrestrial	Bank Soils	Extent	1	2	2	4
Objective	Terrestrial	Tree Bugs	Extent	3	2	2	4
Objective	Terrestrial	Riparian Understorey	Change Management	3	2	1	2
Both	Aquatic	Instream Habitat	Transition	3	1	1	1
Both	Aquatic	Stream Bank	Change Management	4	1	1	1
Both	Aquatic	Bed Morphology	Change Management	4	1	1	1
Objective	Hydrology	Hydraulic Capacity	Change Management	3	1	1	1
Both		Amenity					0
Objective	WQ	Water Quality	Extent	2			0
Objective	Terrestrial	Riparian Habitat	Extent	2			0

Table 3. Ranking of long term ecological issues associated with the possible effects of willow removal (based on the degree of current available knowledge and the strength of the long term importance of the issue).

Knowledge: 1 = low level of knowledge, 5 = high level of knowledge
Importance: 1 = low degree of importance, 5 = high degree of importance
Score: 1 = low research priority, 20 = high research priority

Category 1	Category 2	Issue	Main Question	Know-ledge	Long Term Imp.	Strength	Score
Both	Aquatic	Fish Community	Extent	2	4	4	16
Objective	Terrestrial	Riparian Habitat	Extent	2	4	3	12
Objective	Terrestrial	Bank Soils	Extent	1	4	3	12
Both	Aquatic	Bug Community	Extent	2	3	4	12
Both	Aquatic	Instream Habitat	Transition	3	3	3	9
Objective	Terrestrial	Tree Bugs	Extent	3	3	3	9
Objective	Aquatic	Primary Production	Extent	3	3	3	9
Objective	Terrestrial	Riparian Understorey	Change Management	3	3	3	9
Objective		Litter-Fall	Impact of change	5	3	3	9
Risk	Terrestrial	Exotic Veg	Change Management	3	3	3	9
Both	Aquatic	Stream Bank	Change Management	4	2	3	6
Both	Aquatic	Bed Morphology	Change Management	4	2	2	4
Objective	WQ	Water Quality	Extent	2	2	2	4
Objective	Hydrology	Hydraulic Capacity	Change Management	3	2	2	4
Risk	WQ	Sedimentation	How to minimise	4	2	2	4
Risk	WQ	Temperature	Impact on Fauna	4	2	2	4
Risk	WQ	Nutrients run-off	Extent	2	1	1	1

5.3 Key Issues examined in the long term monitoring program

The key issues which will be addressed in the long term monitoring program (section 6) have been taken from the four highest ranked issues in table 3. These include the extent of risk and change in the fish community, the extent of change in the terrestrial riparian habitat, the extent of change in bank soils and the extent of the risk and change in the aquatic macroinvertebrate community. Water quality will also be measured through the monitoring program.

6. LONG TERM MONITORING PROGRAM

6.1 The need for a long term monitoring plan

Predicting the potential long term effects of willow removal on aquatic processes is a difficult and complex task (Zukowski and Gawne 2006). The relationship between riparian vegetation and the aquatic system is very intricate and many factors can influence aquatic stream processes. Long-term environmental monitoring is a vital key in identifying physical and biological changes which can take place following an ecosystem disturbance such as willow removal. An accurate assessment of the chemistry and biological health at willow removal sites will assist in identifying potential problems which may arise and measure the success when fixing these problems. It is also vital to differentiate between natural trends and human-caused changes in the environment following willow removal. Establishing consistent and coordinated baseline data will create a comprehensive picture of such changes and is imperative to identifying and assessing such trends over time. Any environmental improvement or deterioration can then be measured and evaluated against this baseline data.

The collection and analyses of the monitoring data will also establish an important information feedback loop which will allow adaptive management and best management practises to be integrated instead of relying on predictions and models. Instead of waiting for things to happen, and then reacting, the information gained in the monitoring program will provide more time for responses to changing conditions, and allow researchers and managers to better evaluate the decisions, leading to proactive management decisions.

A long-term monitoring program can also be a key component for bringing together management organizations, researchers, decision-makers and possibly community groups to underpin dialogue concerning the management of natural resources. The keystones of such ecosystem monitoring are long-term data records that provide the basis for analysis of environmental assessment objectives, predictions and analysis of outcomes which in-turn can be used to modify and improve future restoration projects.

This monitoring program will examine the long term effects to provide an understanding of how the ecosystem will respond to willow removal, leading to informed decisions and actions. The importance of a long-term ecological perspective is well documented, yet the availability of long-term data remains limited. A survey of recent literature on stream macroinvertebrates identified only 46 papers published between 1987 and 2004 that included long-term (i.e. ≥5 years) data (Jackson and Fureder 2006). This monitoring program will help address this scarcity of long term data sets on ecosystem response to management.

The monitoring program will provide important insights into the long term effects of willow removal on water quality including changes in stream temperature and light, salinity, oxygen levels, pH and nutrient levels, changes in fish and macroinvertebrate populations and stream-bank soil and riparian vegetation changes. The effects of willow removal on most of these issues may only become clear after some time, therefore a long term monitoring program is essential for future willow removal to achieve its objectives.

6.2 Objectives of the willow long term monitoring plan

The willow long term monitoring plan aims to:

Monitor long term stream health with a focus on water quality, macroinvertebrate and fish communities, bank soil condition, and riparian vegetation in order to detect and assess potential changes in river health resulting from willow removal.

6.3 Sites

Potential sites have been allocated by NECMA based on their structural works program.

Sites will be examined on the Little Snowy Creek for before and after willow removal monitoring and one temperature logger will be installed at the McCormacks site (Ovens River).

6.4 Water Quality

6.4.1 Background

Water quality and the ecology of streams and rivers are both greatly influenced by any activities that occur in the riparian zone. Monitoring water quality is generally a relatively quick and easy way of gathering information about the health of waterways. It involves measuring *in situ* water quality and collecting, processing and analyzing samples of water. When used in a long term monitoring program, this information can determine changes in the condition of the water over time. For a willow removal project, the comparison of water quality before and after willow removal will provide important information on specific effects of willow removal and long term water quality measurements will ensure any changes in stream health are captured.

6.4.2 Parameters monitored

The water quality parameters which will be monitored through the willow removal long term monitoring program include pH, dissolved oxygen (DO), electrical conductivity (EC), turbidity, temperature and nutrients including Nitrogen and Phosphorus. The amount of light in the water column will also be measured. These parameters are explained below.

6.4.2.1. pH

pH is a measure of the acidic or basic (alkaline) character of a solution, defined as the negative logarithm of the hydrogen ion concentration of a solution. Pure water has a pH of 7, acidic solutions have lower pH values and alkaline solutions have higher values.

Aquatic flora and fauna are adapted to specific pH ranges, generally between 6.5 and 8.0. If the pH of a waterway or waterbody is outside the normal range for an organism it can harm or kill the organism. In plants, the pH of the wet area around roots affects nutrient uptake by the plants. pH can also affect the solubility of heavy metals in freshwater systems and the concentrations of total dissolved solids in streams and rivers.

6.4.2.2. Dissolved Oxygen

DO can be affected by a large number of factors including shade, temperature, nutrients and amount and type of plants and organisms present. Oxygen plays an essential role in metabolism and chemical reactions in aquatic animals, plants and most bacteria. A change in DO levels can lead to stress, relocation or death.

6.4.2.3. EC

EC measures the presence of soluble salts in water or soils which enables it to serve as a channel or medium for electricity. EC is used to measure how much salt is in streams and rivers as salty water conducts electricity more readily than purer water. Salts or ions which can contribute to the EC reading or salinity level are generally a mixture of chlorides, sulphates, carbonates, sodium, magnesium, calcium and potassium.

Aquatic plants and animals generally require a specific range of salt concentration in the water column depending on the species. Salinity that extends beyond the normal range for any species will cause stress or even death to that organism. Salinity can also affect the uptake of nutrients by plant roots.

6.4.2.4. Turbidity

Turbidity is caused by particles of suspended matter and refers to how far light penetrates. Generally, the greater the amount of material that is suspended in water, the greater is the water's turbidity and the lower its clarity. Suspended material can be in the form of particles of clay, silt, algae, plankton, micro-organisms and other substances. Turbidity can affect levels of DO. Turbidity can also indicate sediment runoff where vegetation buffers such as willows have been removed.

Increased turbidity levels in streams and rivers can lead to decreased plant photosynthesis, and therefore to restricted oxygen and food levels for aquatic animals. Suspended silt particles eventually settle into the spaces between willow or other tree roots or in between the gravel and rocks on the bed of a waterbody and decrease the amount and type of habitat available for bugs, fish and crustaceans which may utilise such area for habitat. Increased turbidity can also clog fish gills, inducing disease, slower growth and, in extreme cases, death.

6.4.2.5. Temperature

In an aquatic system, the temperature of the water plays a large role in stream ecosystem structure and function and directly affects many physical, biological and chemical characteristics. Warm waters can exacerbate eutrophication, lower oxygen availablity, and increase salinity concentrations, all of which can affect aquatic life. A change in water temperature, either warmer or colder can also affect the metabolic rate of plants and animals which are suited to live in water of specific temperatures. This can lead to organisms becoming more susceptible to toxic wastes, parasites and diseases and in extreme cases can lead to the death of the organsims. A long term change in the water temperature could also alter population dynamics and the species that are present in the ecosystem.

6.4.2.6. Light

Light is a vital factor controlling stream ecosystems. Riparian vegetation plays an important role in regulating light intensity (Hill 1996; Bunn *et al*. 1999) and spectral qualities (Van Kraayenoord *et al.* 1995). Increased light resulting from de-willowing operations could have long term impacts on water temperature and on various biological aspects of the river system. Possible changes in a system could include increases in germination, establishment, growth and survival of native vegetation and/or weeds, increases in periphyton (algae) biomass (primary production), changes in periphyton composition (Van Kraayenoord *et al.* 1995) and increases in exposure of aquatic organisms to UVB light (280-320 nm). This has been shown to be harmful to the eggs, embryos and larvae of some fish (Gutierrez-Rodriguez and Williamson 1999), attached algae and invertebrates (Bothwell *et al*., 1993).

6.4.2.7. Phosphorus

Phosphorus (P) is a mineral nutrient, found in both surface and ground water primarily as phosphate (chemical formula, PO_4). Phosphate is naturally derived from the weathering of rocks and the decomposition of organic material, but it can also enter waterbodies through soil, fertiliser or sewage runoff and discharges. Phosphate is an important nutrient for animals and plants but an excess can lead to algal and other plant blooms.

6.4.2.8. Nitrogen

Nitrogen (N) is an element which is derived from the atmosphere. Nitrogen compounds such as ammonia (NH_3), nitrate (NO_3) and nitrite (NO_2) occur in dissolved, particulate and gaseous forms and can be found in surface waters and in groundwater. Like phosphate, nitrogen plays an important role in plant growth and is continually used and recycled by both plants and animals. Total nitrogen (TN) and total phosphorus (TP) levels present in an aquatic system can indicate how nutrient polluted (eutrophic) or vulnerable the system is to nuisance plant growth (ANZECC and ARMCANZ 2000)

6.4.3 Methods

6.4.3.1. Water quality

Measure temperature (^oC), pH, turbidity (NTU), electrical conductivity (μS/cm) and dissolved oxygen concentration (mg/L) *in situ* with a HORIBA Ltd U-10 multi-probe water quality checker (Australian Scientific Ltd.).

6.4.3.2. Nutrients

All samples are to be taken in accordance with the AS/NZS 5667.1.1998 standard.

Collect a 200 ml water sample to measure total nitrogen (TN) and total phosphorus (TP). Filter a 10 ml sample through a 0.45 μm filter for determination of oxides on nitrogen (NOx) and filterable reactive phosphorus (FRP) concentrations. Freeze nutrient samples and deliver to the NATA certified MDFRC Chemical Laboratory (Wodonga) for analysis.

6.4.3.2.1.Oxides of nitrogen

Nitrate is reduced to nitrite by passing a buffered sample through a column of copper-coated cadmium. Total nitrite is then converted to the diazonium salt by reacting with sulfanilamide. The 4-sulfanilamide benzenediazonium chloride then couples with N-

(1-naphthyl) ethylenediamine dihydrochloride to form a pink dye. Its absorbance is then measured colorimetrically at a wavelength of 520nm.

6.4.3.2.2.Filterable reactive phosphorus

Orthophoshate present in the sample reacts with ammonium molybdate and potassium antimony tartrate in an acidic medium to form molybdophosphoric acid. This is reduced by ascorbic acid to give a molybdophosphoric blue complex, the absorbance of which is measured spectrophotometrically at 880nm.

6.4.3.2.3.Total nitrogen

Organic forms of nitrogen and ammonia present in the sample are digested in an alkaline solution of NaOH-$K_2S_2O_8$ and oxidised to form nitrate. Nitrate in the digestion sample is then reduced to nitrite by passing a buffered sample through a column of copper-coated cadmium. Total nitrite is then converted to the diazonium salt by reacting with sulfanilamide. The 4-sulfanilamide benzenediazonium chloride then couples with N-(1-naphthyl) ethylenediamine dihydrochloride to form a pink dye. Its absorbance is then measured colorimetrically at a wavelength of 520nm.

6.4.3.2.4.Total phosphorus

Organic forms of phosphorus present in the sample are digested in an alkaline solution of NaOH-$K_2S_2O_8$ and oxidised to form orthophosphate. Orthophoshate present in the sample then reacts with ammonium molybdate and potassium antimony tartrate in an acidic medium to form molybdophosphoric acid. This is reduced by ascorbic acid to give a molybdophosphoric blue complex, the absorbance of which is measured spectrophotometrically at 880nm.

6.4.3.3. Temperature and Light

Three Hobo Pendant Temp/Light Intensity Loggers will be installed at each site and used to monitor the long term stream temperature and light.

Methods: Install three star pickets in the river channel at heavily shaded locations within each reach. These pickets will be used to mark the sites for temperature and light logging for the monitoring period. Attach one Hobo Pendant Temp/Light Intensity Logger (Figures 1 and 2) to each of the star pickets.

Figure 1. Hobo Pendant Temperature / Light Intensity Logger (Diagram: OneTemp Pty Ltd).

Figure 2. Water temperature logger (A) and light logger (B) deployed in the Ovens River (Gawne *et al.* 2005)

6.4.3.4. Equipment list

- Horiba
- Nutrients (2 x 10 ml, per site)
    - TNTP (1 x 250 PET jars)
    - Nutrient filters
    - Syringes
- Hobo Pendant Temp/Light Intensity Loggers x 3
- Star pickets x 3
- Mallet
- MDFRC waterproof tags
  Waterproof data sheets
- Pencil/pen

6.4.4 Costs

Equipment:
MDFRC Horiba will be used

Hobo Pendant Temp/Light Intensity Logger (one off cost)

Loggers	$108
Base station and pendant coupler	$131
Software	$86
Total	**$325**
Total equipment one off cost	**$975 ($325 x 3)**
Nutrient analyses:	
6 nutrient tests @ $10/test	$60
Consumables (field and lab):	$20
Personnel costs:	
1/2 hour 2 people for collection	$100
Total $ /site / sampling event	**$180**

*Travel cost will be included in the total cost of the monitoring program.

6.5 Bank soils

6.5.1 Background

As described in Zukowski and Gawne (2006), trees in the riparian zone stabilize the channel banks by providing resistance to erosion, and potentially trap fine sediments in the edges of the stream and along the banks. Willows in particular have extensive and dense root mats which may also extend into the stream channel modifying the flow patterns and width and depth of the stream, and sometimes trapping large debris. The accumulation of fine sediment around the willow roots will influence the species composition of the benthic community.

It follows that removal of the willows may alter the stream sediments or bank soil conditions. The extent of the changes will depend on the size of the root masses and whether or not they are confined to the bank or extend into bars or islands within the stream. It will also depend on how quickly replacement vegetation becomes established along the banks. It is expected that removal of the willows in the centre of the stream will increase stream velocities locally and possibly redistribute the bed sediments. Removal of willows from the banks will cause an initial release of the fine sediments from the margins of the stream and potentially lead to bank destabilization and erosion. It may also change the velocity of flows close to the bank, the accumulation of leaves and other organic debris near and on the bank, and potentially affect the aquatic and in-faunal communities.

6.5.2 Parameters monitored

The monitoring will focus on documenting erosion, changes in sediment grain size and changes in sediment/soil chemistry. The monitoring will use a 20 metre section of the bank which is not subject to grazing or human use.

6.5.3 Methods

6.5.3.1. Bank Erosion

Erosion will be monitored using erosion pins (20mm PVC pipe); the slope of the bank and the presence of any slumps and scarps will also be noted.

Select three vertical survey lines, each 10 metres apart. Drive erosion pins horizontally into the bank leaving about 10 cm protruding from the surface. Use a total of 3 pins per vertical survey line, one near the top of the bank, one at mid-bank and one near the base of the bank. For all visits after the initial sampling (when pins are put in place), measure the length of exposed section of each of the pins. Measure the along-ground distance between the top and bottom pin, and the horizontal distance between the top and bottom pin. This will give the slope angle of the bank. Note any erosional features such as slides, slumps or bank undercutting, and the size and position of these features relative to the network of erosion pins.

6.5.3.2. Grain size of channel sediments

Samples of the unconsolidated surface sediments will be collected between the survey lines used for erosion measurements. Collect two samples at each position, one at the base of the bank and one 2 metres out into the water. This will make a total of four samples. Sample only the upper 10 cm of the sediment. Put each sample into a ziplock bag. Once in the laboratory, dry the sediment samples in an oven and sieve the samples to determine the bulk grain size distribution.

6.5.3.3. Soil condition and chemistry

Soil cores will be collected mid-way up the bank at the same locations along the bank as the sediment samples described above. Collect a 30 cm core from a location midway up the bank. Note the distance of the sample from the base of the bank. Extrude the core carefully and section into 10cm depth layers and place a 100 gram portion of each layer into a separate ziplock bag. Note the soil type (sand, silt, clay), color (black, grey, brown, etc.), presence and color of any flecs or mottles (orange, black) and texture of soil (loose, soft, firm, hard) in each layer, and if there are any obvious odors. If the color or texture of the soil changes distinctly in the middle of a depth layer note the depth at which the distinct change occurs. Also note the extent of any roots and burrowing organisms in the soil. Double-bag all soil samples in larger zip lock bags (to ensure no water leakage into the samples) and place on ice in an esky while in field and then freeze back at the laboratory for later analysis.

For each soil sample, thaw overnight and then either keep layers separate or pool the top 30 cm by thoroughly mixing equal quantities of each layer together. Then, using sub-samples, follow established procedures to test for electrical conductivity (salinity), pH, bulk density and moisture content, and nutrients of the soil.

6.5.4 Costs

Equipment (one off cost):	
Sediment pins	$45
Set of sieves	$128
Soil pH instrument	$200
Soil EC instrument	$200
Total equipment one off costs	**$573**
Consumables (field and lab):	$100
Personnel costs:	
0.5 days 1 person for collection	$400
Total $ /site / sampling event	**$500**

*Travel cost will be included in the total cost of the monitoring program.

6.6 Riparian vegetation

6.6.1 Background

Riparian vegetation grows at the boundary between terrestrial and aquatic ecosystems (Figure 3). Riparian vegetation includes native and introduced species that ideally form a broad band (the riparian zone) along the edge of a waterbody. Riparian vegetation plays a crucial role in shading streams and rivers, directly affecting the stream water temperature and light. Riparian vegetation also protects the waterbody and its associated flora and fauna from agricultural runoff and other human activities near the stream and provides habitat and protection for bugs, crustaceans, fish, birds and plants.

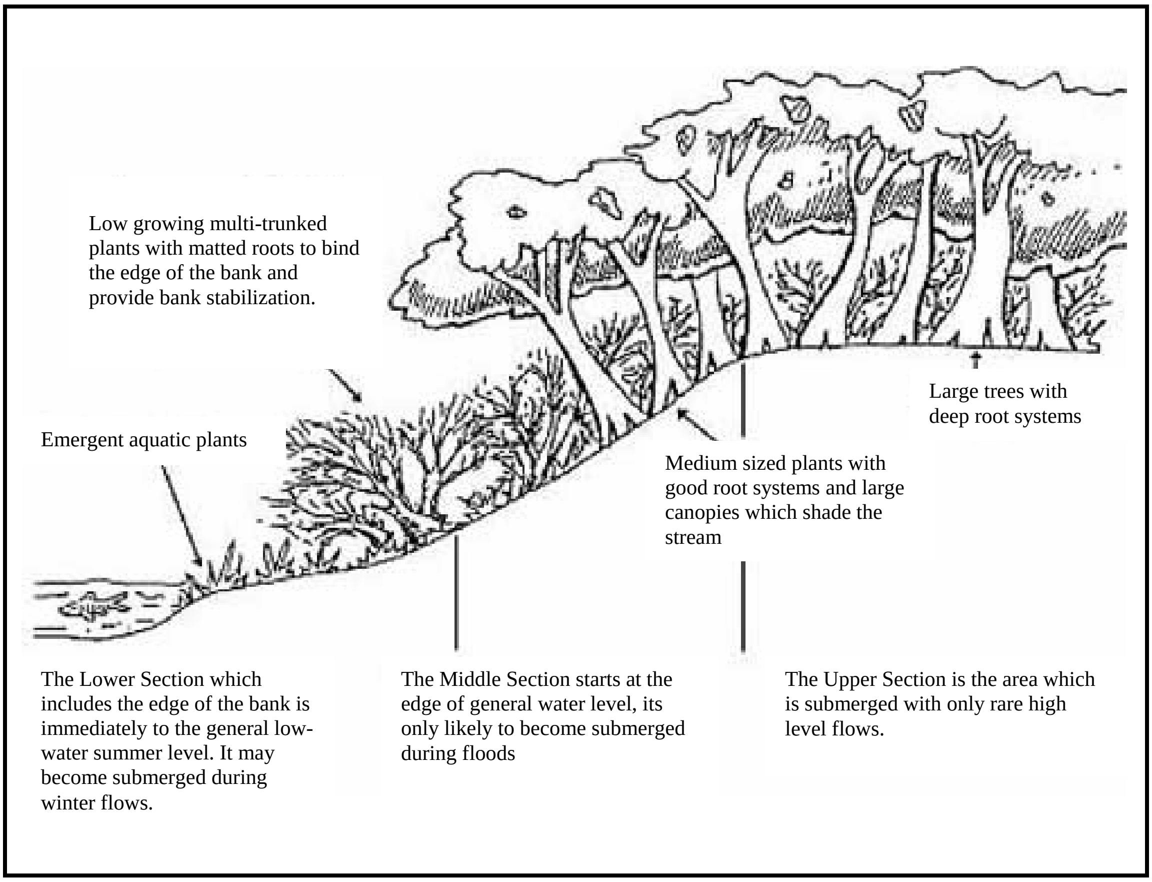


Figure 3. The riparian environment. Source: Munks S, 1996

6.6.2 Parameters monitored

To assess large changes in riparian vegetation over time, a combination of indicators that reflect both the structural and functional aspects of riparian zone ecology, based on the Murray Irrigation Monitoring Program, will be used. The riparian width, canopy continuity, structural composition, proportion native vegetation, regeneration, forest debris (leaf litter and standing and fallen dead trees) and species composition will be assessed using a combination of methods derived from the Index of Stream Condition (White and Ladson 1999), AUSRIVAS (EPA Victoria 2003) and the Rapid Appraisal of Riparian Condition (Jansen *et al.* 2004). As land use on different banks is a major driver of variation in riparian vegetation at a site (Hawking et al. 2006), each bank will be assessed separately at each site.

6.6.3 Methods (adapted from the Murray Irrigation Monitoring Program)

6.6.3.1. Transects

Use established transects on each bank, one longitudinal and one lateral transect (marked using survey pegs and located using the GPS) for the duration of the program The longitudinal transects run parallel to the river channel for the length of the study reach (200 m), and is located within 5 m of the high water mark. The lateral transects are run perpendicular to the river channel and extend to the lesser extent of the riparian zone or 50 m from the edge of the high water mark. The lateral transects are positioned within an area representative of the riparian vegetation on each river bank.

- Record the location of the start and end of the lateral transect on each bank on data sheet 1 while conducting vegetation assessments.

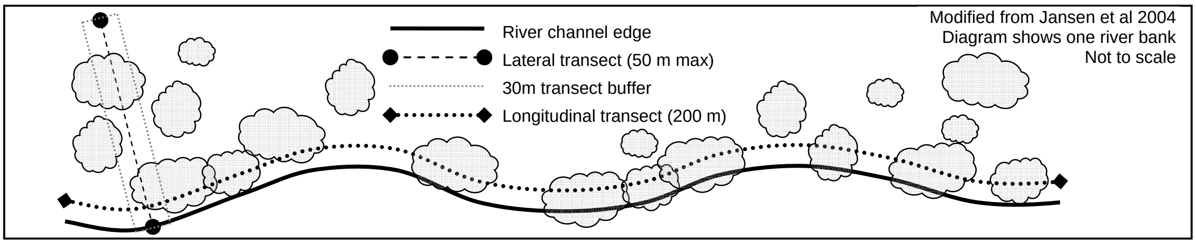


Figure 4. Transect positioning on one river bank (modified from Jansen *et. al.* 2004)

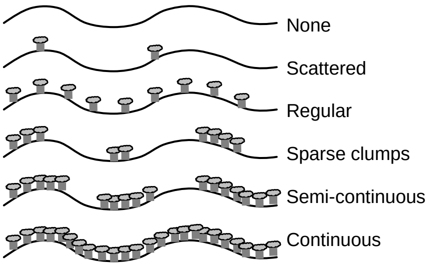
6.6.3.2. Riparian width and canopy continuity

Measure the width of continuous tree/shrub canopy cover along each lateral transect, from the channel edge to an area of significant vegetation change (up to 50 m). Record riparian vegetation width on data sheet 1.

- Where the riparian width is greater than 50m record ("> 50 m") and make additional measurements of riparian width from remotely-sensed imagery (10 measurements evenly distributed along the length of the reach, with average width reported).
- If no vegetation occurs within 15 m of the water's edge record the vegetation width as zero at that point.

Assess the continuity of tree and shrub canopy along the longitudinal transect while walking along the target bank and from observing the target bank's vegetation from the opposite side of the river. Record vegetation continuity for each bank using the tick boxes on data sheet 1 according to the following categories:

- None
- Scattered
- Regular
- Sparse clumps
- Semi-continuous
- Continuous



6.6.3.3.   Structural composition and proportion native vegetation

Structural composition in this monitoring program refers to the percent cover of vegetation canopy and the number of canopy layers present (structural complexity) in a given vegetation community. Percent cover refers to the proportion of surface area occupied by a vegetation stratum (canopy layer). It has been related to the performance of ecosystem functions such as primary production and erosion suppression, and is an important habitat consideration for many animals. The canopy strata assessed include:

- Tall trees: woody plants over 10 m tall, usually with a single stem, e.g. eucalypts, willows
- Trees: woody plants between 3 and 10 m tall, usually with a single stem, e.g. acacias, immature tall tree species

- Shrubs: woody plants less than 3 m tall, frequently with many stems arising at or near the base, e.g. *Melaleuca*, *Leptospermum*, tree ferns, blackberries
- Understorey/Groundcover: non-woody plants less than 1.5 m tall, includes understorey (e.g. sedges, reeds, saltbush), herbs (e.g. *Persicaria*, *Ranunculus*) and grasses
- Litter > 2 cm deep: forest debris (leaves, branches, trunks, fruit, flowers, dead recumbent understorey) forming a layer > 2 cm deep

Measure percent cover for each stratum along the lateral transect on each bank and record on data sheet 1. It is important to note that the total cover for all canopy layers can be >100%, however within a canopy layer percent cover cannot exceed 100%.

The transect line is thought of as a vertical plane perpendicular to the ground. Measure the length of this plane intersected by each stratum, with a designation as native or introduced species (N or I).
Multiply the total decimal fraction of the line covered by each stratum by 100 to give percentage cover and to determine the number of strata with > 30% cover
Express the percent cover by native species for each separate stratum as a proportion of the total cover within that stratum.

6.6.3.4. Regeneration and forest debris

Estimate the amount of regeneration, the occurrence of standing and fallen large woody debris of different sizes (> 20 cm and < 20 cm diameter at breast height – 1.3 m above ground level) and evidence of grazing or regeneration in the transect buffer (30 m on either side of the lateral transect line on each bank) using four categories (N, S, C, A). Record categories using the tick boxes on the riparian vegetation data sheet 1:

- None: no regeneration, grazing of regeneration or large woody debris observed
- Some: occurrence within < 1/3 of the transect buffer area
- Common: occurrence within 1/3 – 2/3 of the transect buffer area
- Abundant: occurrence in > 2/3 of the transect buffer area

6.6.3.5. Species composition

Determine the composition of the vegetation community from identification of the dominant species (those comprising more than about 20% of the canopy cover for a given stratum, excluding grasses) observed within the vegetation area of interest while other tasks are carried out. Record on data sheet 2.

- Compile a species list in the field for those species familiar to the field operator.
- If identification is uncertain, collect a specimen of each species (a good representative of those found at the location, bearing intact leaves attached to the stem/branch and where possible, flowers, fruit and bark) to confirm identification.
- Identify plants to genus or species level using appropriate taxonomic keys.

Take notes to supplement the formal data collection process. Record any obvious disturbances, to clarify distributions of different species, regeneration and forest debris and note other relevant observations on data sheet 2.

6.6.3.6. Equipment checklist

- GPS
- Data sheets printed on waterproof paper
- Pencils, sharpener, eraser
- Measuring wheel
- Transect line on reel with metre intervals marked
- Paper bags, marker pens
- Plant press
- Plant identification guides
  - Harden, G.J. (Ed) (1990) Flora of New South Wales

- Sainty and Jacobs (1988 or 1994) Water plants in Australia
- Sainty and Jacobs (1981) Waterplants of New South Wales
- Costerman L. (1983) Native Trees and Shrubs of South-Eastern Australia
- Lamp and F Collet (1989) Field Guide to Weeds in Australia

6.6.3.7. Data analysis

Each of the parameters assessed (riparian width, canopy continuity, structural composition, proportion native vegetation, regeneration, forest debris and species composition) can be compared across sites in the short term and analysed by site as time series in the longer term.

Riparian vegetation data sheet

Riparian vegetation data sheet (1 of 2)

Vegetation Assessment Sheet	River:	Site:	Code:
	Date:	Staff:	Data entered?

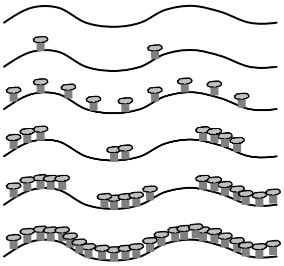
Lateral Transect: Start_____________S End______________S Start____________S End______________S

Start_____________E End______________E Start____________E End______________E

Lateral transect	**Near Bank**										**Far Bank**									
	% Cover					Native or Introduced					% Cover					Native or Introduced				
Tall trees (>10 m) (record intercept length every 5 m)																				
Trees																				
Shrubs																				
Understorey /																				
Groundcover (live)																				
Litter > 2 cm deep																				
Total # strata with > 30% cover						▨										▨				

within 30m of lateral transect	**Near Bank**	**Far Bank**
Tree regeneration	☐ None ☐ Some ☐ Common ☐ Abundant	☐ None ☐ Some ☐ Common ☐ Abundant
Shrub regeneration	☐ None ☐ Some ☐ Common ☐ Abundant	☐ None ☐ Some ☐ Common ☐ Abundant
Grazing of regeneration	☐ None ☐ Some ☐ Common ☐ Abundant	☐ None ☐ Some ☐ Common ☐ Abundant
Standing dead > 20cm DBH	☐ None ☐ Some ☐ Common ☐ Abundant	☐ None ☐ Some ☐ Common ☐ Abundant
Standing dead < 20cm DBH	☐ None ☐ Some ☐ Common ☐ Abundant	☐ None ☐ Some ☐ Common ☐ Abundant
Fallen logs > 5cm	☐ None ☐ Some ☐ Common ☐ Abundant	☐ None ☐ Some ☐ Common ☐ Abundant

	Near Bank	**Far Bank**
Riparian vegetation width (Width of continuous tree/shrub canopy along lateral transect. If greater than transect width, record as > 50m and measure on remotely-sensed imagery)		

Vegetation continuity (continuity of tree/shrub canopy along longitudinal transect)	 None	☐	☐
	Scattered	☐	☐
	Regular	☐	☐
	Sparse clumps	☐	☐
	Semi-continuous	☐	☐
	Continuous	☐	☐

Riparian vegetation data sheet (2 of 2)

Vegetation Assessment Sheet – Species List

Vegetation Assessment Sheet – Notes

6.6.3.8. General mapping and photo points

General site mapping and comments to be recorded for every field trip to indicate the relative location and descriptions of any observed major changes (eg fallen trees, major bank erosion, fire, flood etc).

Digital photographs to be taken from the photopoints identified at each end of the reach.

- Locate physical transect survey pegs on the bank for photo points.
- Take two digital images from each of the four photo points, one from each bank looking across the river and one looking along the reach.
- Record image details on the sampling sheet including GPS location.
- Download images to PC or server as soon as practical and label jpeg image files
- Name folder using date (eg. 2005 sep)
- Name the 4 photo point images with project and site identifiers along with a, b, c or d (e.g. site13a.jpg).
- Name other images with project and site identifiers and specific details (e.g. site13 efishing.jpg)

Digital images will be used to highlight significant observed changes at a site and are for general reference only.

Site Map and Location Sampling Sheet

Site map and location details

River:	**Site:**	**Code:**
Date& Time:	**Staff:**	**Data entered:**

	Near Bank	Far bank
Photo numbers	DS US	DS US
GPS	DS US	DS US

General site map and comments /observations (eg fallen trees, major bank erosion, fire, flood, recent water level rise or fall, wet weather, storms etc)

6.6.3.9. Equipment checklist

- Copy of protocols on water proof paper
- Data sheets “Site map and location sampling sheet” on water proof paper.
- Pencils etc
- Camera
- Hand held GPS (GDA)
- Images from previous field trip
- Site information sheets

6.6.4 Costs

Consumables (field and lab):	$100
Personnel costs: 0.5 days 2 people for collection/identification	$800
Total $ /site / sampling event	**$900**

*Travel cost will be included in the total cost of the monitoring program.

6.7 Invertebrates

6.7.1 Background

Macroinvertebrates are important within a water body because of their ubiquity and their role as fundamental links in the aquatic food web. They play a vital role in the energy and nutrient transfer from terrestrial environments to aquatic ecosystems and act as crucial links between organic matter resources and fish, birds and mammals. Macroinvertebrates are excellent indicators of stream health because they occupy a central role in the aquatic food chain, can live in the water for up to one year, cannot easily escape pollution and are sensitive to even quite mild pollutants, changes in water quality or disturbances.

A disturbance caused by willow removal could affect habitat, light penetration and hence water temperature and organic matter inputs to streams all of which affect the invertebrate community (Figures 5 & 6). These effects may be negligible, positive or negative depending on circumstances and management objectives. Because invertebrates play a crucial role in the food web, changes in the composition and abundance of invertebrate assemblages may also have impacts on other elements of the system.

Recent long-term studies of macroinvertebrates have made major contributions to the understanding of natural and anthropogenic disturbance and recovery, interannual variation and cycles and complex abiotic and biotic interactions (Jackson and Fureder 2006). Without such studies, there would be much less information available about the magnitude of natural temporal variation, the importance of physical and biological disturbance and interactions, the role of pathogens and introduced species, the overall impact of pollution and the effectiveness of protection and remediation efforts (Jackson and Fureder 2006).

This monitoring program will provide much needed long term data to determine the effects of willow removal on aquatic macroinvertebrate communities and stream health.

INVERTEBRATE COMMUNITY

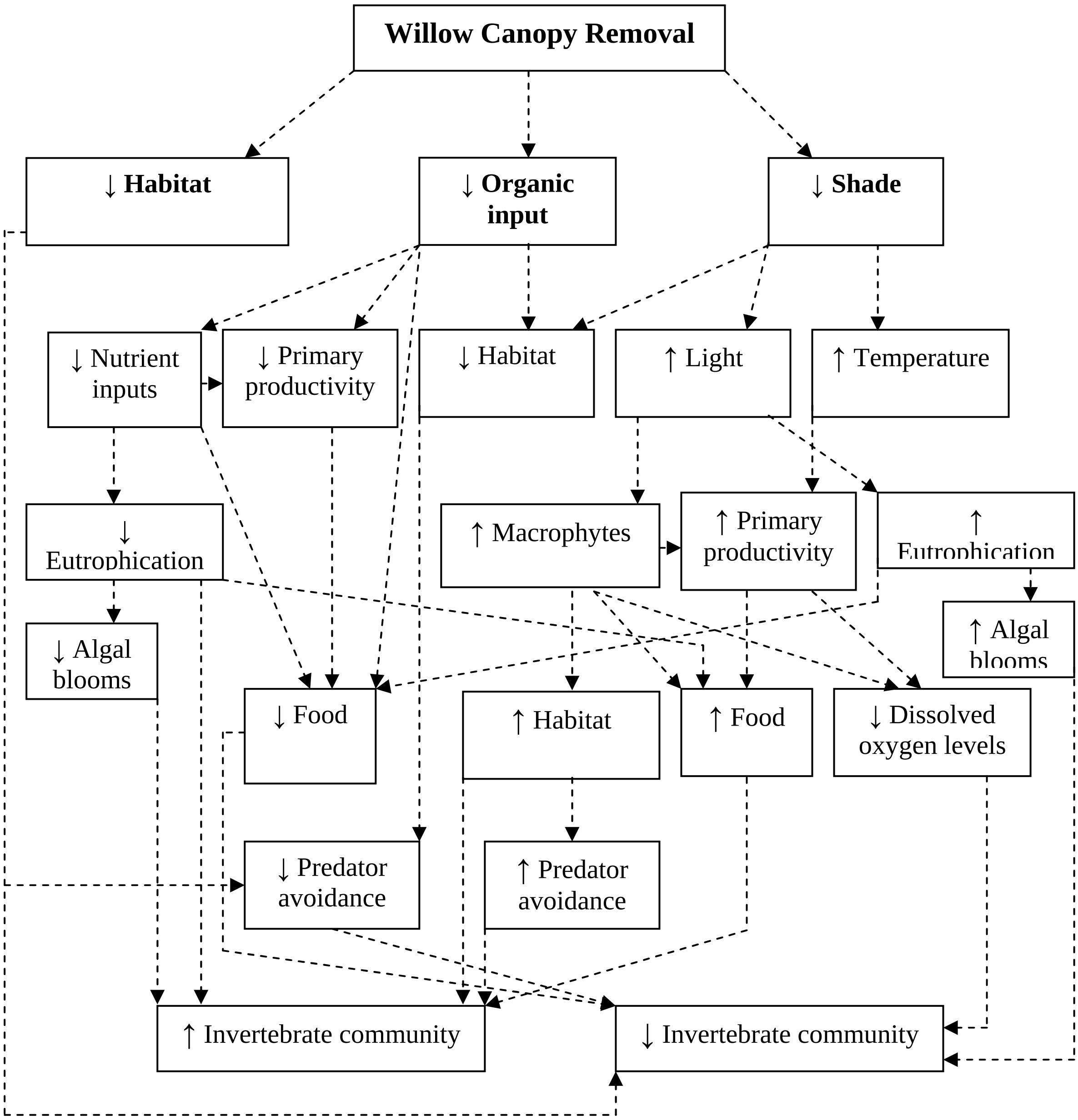


Figure 5. Potential effects of willow canopy removal on an aquatic invertebrate community (Zukowski and Gawne 2006).

INVERTEBRATE COMMUNITY

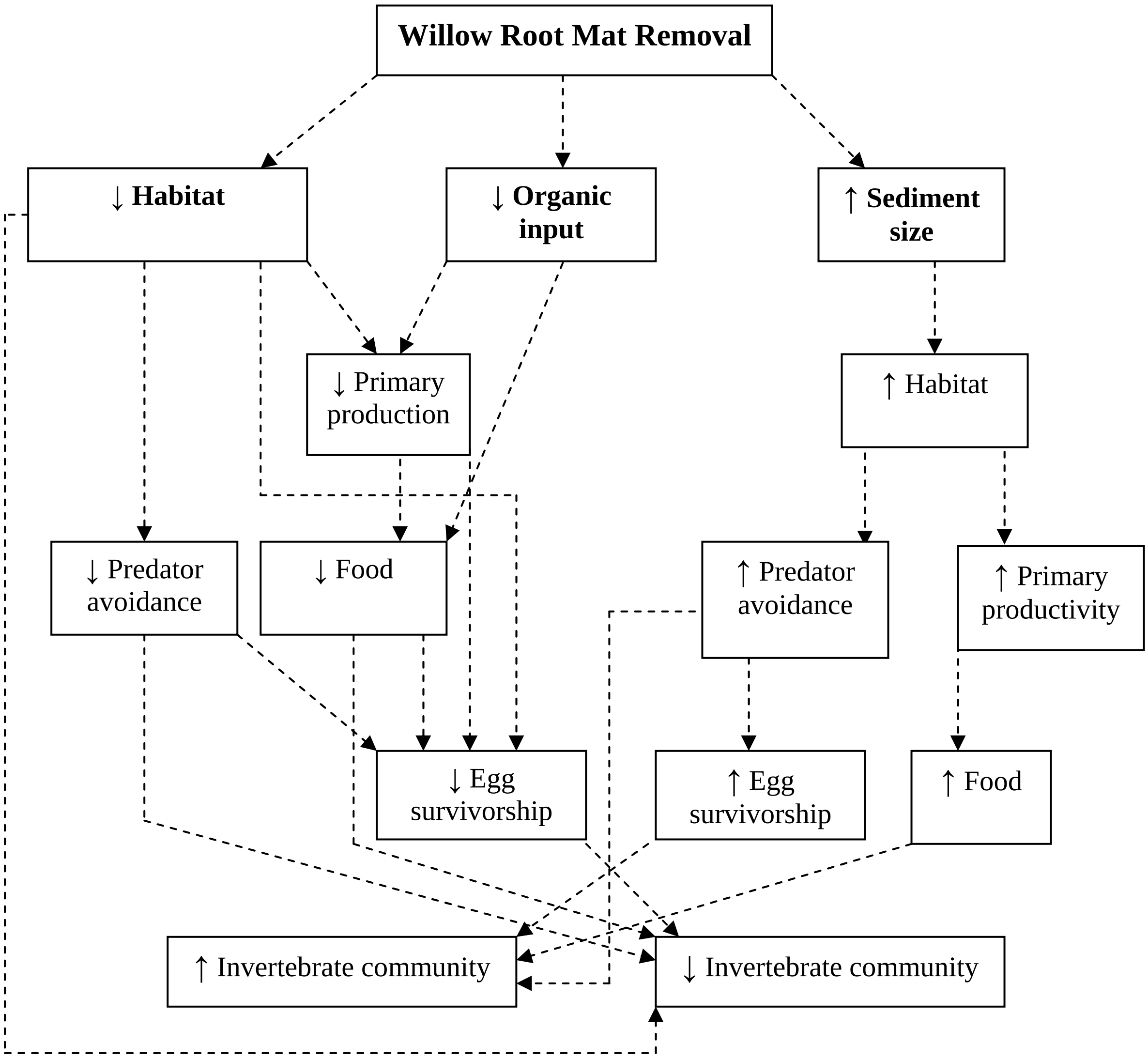


Figure 6. Potential effects of willow root mat removal on an aquatic invertebrate community (Zukowski and Gawne 2006).

6.7.2 Parameters monitored

The aquatic macroinvertebrate community will be monitored before and after willow removal and in reference sites to determine the affects of willow removal on stream health.

6.7.3 Methods

Macroinvertebrates will be sampled within each site using the **AUS**tralian **RIV**er **A**ssessment **S**ystem (AusRivAS) rapid assessment methodology and the standardised, qualitative sampling procedures as outlined in "Guideline for Environmental Management – EPA Publication 604.1 – Rapid Bioassessment Methodology for Rivers and Streams (2003)".

To ensure that results from different sites and different studies can be compared, the same procedures for the collection and sorting of the macroinvertebrate samples must be followed between sites and dates (EPA 2003). For a complete site assessment, samples must be collected in consecutive spring and autumn seasons (for example within the same year, or in consecutive years) (EPA 2003). Autumn sampling will be used to collect recruitment in the population and the spring sampling will be used to collect emergence of adults in the population, as per the AusRivAS methodology.

Kick samples will be used to dislodge benthic animals from the substrate in flowing sections and edge sweeps will be used to sample the slow or non flowing edge habitats. One 10m kick sample and one 10m sweep sample will be collected from each site using an "A" frame net with a mesh size of 250um.

6.7.3.1. Rifle habitat methods

- Kick using sweep net, from 10 metres of stream bed and takes typically five to ten minutes to collect.
- Sample to be collected from several areas in the riffle, to increase the varieties or microhabitats (range of depth, current velocities and substrates).
- Record habitats sampled as per AUSRIVAS data sheets.

6.7.3.2. Edge habitat methods

- Sweep using a sweep net, from 10 metres of edge.
- Sample to include the major emergent and submerged vegetation types at a site.
- Record habitats sampled as per AUSRIVAS data sheets.

The samples will be live picked in the field, preserved in 95% ethanol and identified to Family level in the laboratory according to the laboratories invertebrate keys.

6.7.3.3. Live pick methods

- Pick 200 animals in 30 minutes
- If new taxa are found in the 25-30 minute period, continue for 10 minutes and if new taxa are found in this period continue in additional 10 minute blocks up to maximum 60 minutes
- If less than 100 animals are collected in 30 minutes, continue picking for an extra 10 minutes. If new taxa are found, continue as previously described
- Maximum of 30 individuals of any single taxa to be collected, with a minimum of 20-30 chironomids should be collected to represent the sub-families.

6.7.3.4. Data analysis

Community composition will be analysed using presence absence data and cluster analysis in “Primer 5” (v 5.2.1). Taxa richness and environmentally sensitive taxa (Plafkin *et al*. 1989) will be identified and graded (Chessman 2001) to indicate the overall water quality and community health.

6.7.3.5. Equipment list

- Kick and sweep nets
- Waders x 2
- Buckets x 4 – with lids
- Alcohol (5 lt) of 70% ethanol
- Containers
  - Macroinvertebrate (2 x 250 PET jars per site)
- Pens and/or pencils
- Marking pen (ethanol proof for writing on labels)
- Permanent marker
- Scissors
- Live pick equipment
  - Field sorting table
  - White plastic tray x 2
  - Forceps x 2

  - Pipettes x 3
  - Counter x 2
  - Timer or watch
- Camera (digital)
- GPS
- Field Book
- Field sampling and habitat assessment sheets (as per 'EPA Vic 604.1 (2003)')

6.7.3.6. QC checks

10% of randomly chosen biological samples will be re-identified by a senior taxonomist with no prior knowledge of previous identifications. Taxonomic errors are determined based on the comparison between identification by the original taxonomist and the QC taxonomist. Acceptable, taxonomic error must be below 10%.

6.7.4 Costs

Equipment (one off cost):
Equipment will be supplied by the MDFRC

Total equipment one off costs	**$0**
Consumables (field and lab):	$100
Personnel costs:	
0.5 days 1 person for field collection	$400
1 day 1 person for lab identification	$800
Total $ /site / sampling event	**$1300**

*Travel cost will be included in the total cost of the monitoring program.

6.8 Fish

6.8.1 Background

Fish are a regular and well-known component of freshwater environments and can be used as valuable indicators of the stream ecological condition or 'river health'. Fish communities are a direct measure of biological organization and can reflect a range of disturbances and provide an integrated measure of stream conditions due to their long life, mobility and place near the top of the food chain.

In Australian streams and rivers, the invasion of willows may have altered the composition of many fish assemblages. The removal of willows may represent an important step in restoration but it could also result in long term changes to fish population characteristics through an alteration of fish habitat, changes to light penetration, water temperature and food availability (Figures 7 and 8). These include reducing potential fish habitat, creating new habitat, affecting fish mate finding and predator evasion, and impacting on egg, embryo and larval growth and survivorship rates. These effects are likely to be more significant in small streams or situations where willows represent the only source of shade or habitat (Zukowski and Gawne 2006). The monitoring program will monitor adult fish populations following willow removal to provide an early diagnosis of any changes which may occur to fish populations.

FISH COMMUNITY

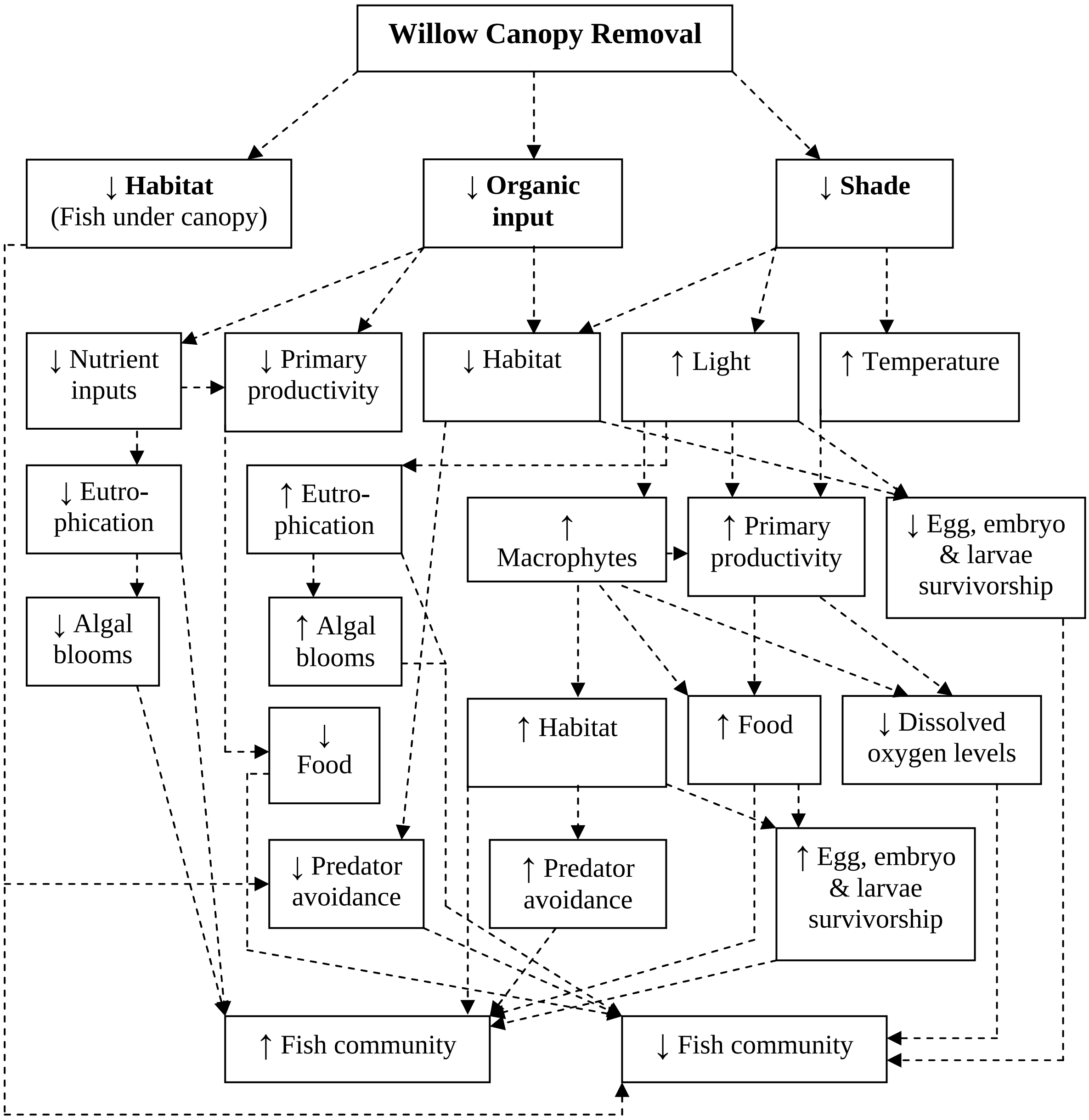


Figure 7. Potential effects of willow canopy removal on a fish community (Zukowski and Gawne 2006).

FISH COMMUNITY

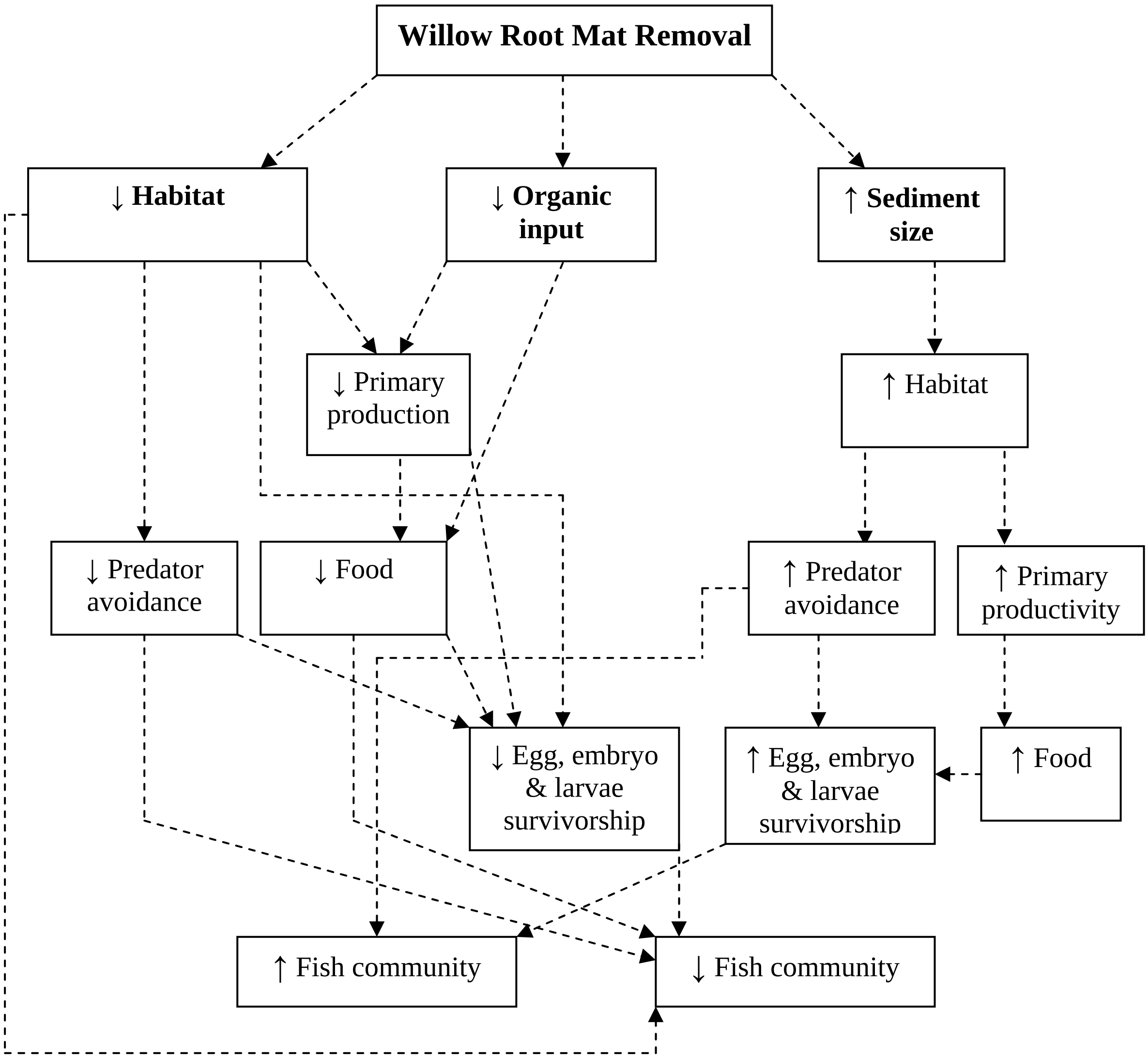


Figure 8. Potential effects of willow root mat removal on a fish community (Zukowski and Gawne 2006).

6.8.2 *Parameters monitored*

The monitoring program will identify adult fish numbers before and after willow removal. Small native (i.e. Australian smelt (*Retropinna semoni*), flat-headed gudgeon (*Philypnodon grandiceps*), western carp gudgeon (*Hypseleotris klunzingeri*), Murray rainbowfish (*Melanotaenia fluviand*)), and exotic (i.e. gambusia (*Gambusia holbrooki*)) fish species, as well as large native (i.e. golden perch (*Macquaria ambigua*), Murray cod (*Maccullochella peelii peelii*)) and introduced (i.e. carp

(*Cyprinus carpio*), goldfish (*Carassius auratus*), redfin (*Perca fluviatilis*)) fish species will be targeted.

6.8.3 Methods

The monitoring program will sample freshwater fish using a combination of backpack electrofishing (or boat electrofishing where the water depth exceeds 1m) and where possible, seine netting. This sampling protocol has been designed to capture as many different species and individuals as possible. Small fish species will be captured through the eletrofisher and seine nets and large fish will be captured using the electrofisher. The method has been shown to be effective in characterising native fish communities (Pusey *et al*., 1998).

6.8.3.1. Backpack electro-fishing following SRA protocols

- Measure phys/chem parameters, particularly conductivity and adjust settings accordingly.
- Record site, gear, set up and shot position information on fishing data sheet 1
- Sample using a total of 8 x 150 second shots (MDBC 2005).
- Catch stunned fish as they rise to the surface a landing net and transfer them to a bucket.
- Process the catch from each shot once the shot is completed
- Record the data for each shot separately on fishing data sheet 3
- Return native fish to the river and kill noxious pests
- Repeat this process until 8 shots have been completed.

6.8.3.2. Catch processing

- Identify fish according to McDowall (1996) but Carp gudgeons only to genus level (i.e. *Hypseleotris* spp.) owing to the current taxonomic uncertainty at the species level.
- Photograph any unknown specimens and record image number or preserve in 90% ethanol. Then label and record collection details on data sheet 3
- Measure up to 100 fish from each species (25 per run) using standard length (snout to hypural crease (Figure 9, McDowall 1996)) as well as total length (as

appropriate for each species) to the nearest millimetre and weigh to the nearest gram.

- If more than 100 individuals of a species, then count remainder of catch for that species.
- Batch weigh small fish to the nearest tenth of a gram.
- Assess fish for abnormalities (Table 4)

6.8.3.3. Fish health and condition

Indicate the presence of any of the of abnormalities listed in table 4 if sighted on any part of a measured fish and record on fishing data sheet 3.

Table 4. Reportable abnormalities exhibited by handled fish*

Health Code	Abnormality Description
D	**D**eformity (skeleton deformities, blindness, fin deformities, asymmetrical etc)
F	**F**in condition poor (broken, eroded fins)
S	Le**s**ions (skin abnormality with raised and or discoloured scales)
U	**U**lcers (skin is broken, crater like, redness)
E	**E**maciated (abnormally thin)
T	**T**umour (localised abnormal growth)
W	**W**ounds (bird strikes, hook wounds etc)
G	Fun**g**us
L	**L**ernaea (but only where an unusual/notable number of Lernaea are present)
M	Other **m**acro-ectoparasites
O	**O**ther: the abnormality must be photographed and described and/or a specimen preserved
yes	Either of these codes can be used when an abnormality is observed but the above list has, say, been misplaced or lost and the health code has been forgotten.
true	

*** SRA Protocols (MDBC 2005)**

6.8.3.4. Equipment list

- Valid permits/ Licences (Animal Ethics and Fisheries)
- Copy of protocols document
- Data sheets
- Pencils etc.
- Hand held GPS (GDA)

- Backpack electrofisher (Smith-Root -12 or equivalent plus high voltage safety equipment including high voltage gloves and waders)
- Landing nets
- Large holding tubs or tanks (3)
- Scales (for small and large fish)
- Measuring boards (for small and large fish)
- Benzocaine (anaesthetic)
- Sample jars
- 90% ethanol for preservation
- Camera
- McDowall (1996) Freshwater fishes of South Eastern Australia

6.8.3.5. Data analysis

Generate the summary statistics (outlined below, MDBC 2003b) to describe the sites, and to provide the basis for regional site comparisons.

- ***Total taxa richness*** - a measure of biodiversity.
  Calculate the total number of taxa present for each site
- ***Catch per unit effort*** - a measure of fish density,
  Calculate taxon abundance from the number of fish of each taxon caught
  Calculate total abundance from the total number of fish caught.
- ***Nativeness*** **–** a measure of the proportion native fish abundance
  Calculate the % of all fish caught that are native
- ***Fish with abnormalities*** **–** a measure of fish health
  Sum the number of fish (native and alien) with abnormalities at a site.

Fishing Data Sheets

Fishing data sheet (1 of 4) Gear

River:	**Site:**	**Code:**
Date& Time:	**Samplers:**	**Data entered:**

Water Quality:
Conductivity______uS/cm2, pH_______; DO_______mg/L; Temp______C;
Turbidity_______NTU

Electro fishing gear type: [tick]
[ ] Mildura boat, [ ] SKM boat, [ ] Albury Back Pack, [ ]
Other____________________

Electro fishing setup:
Output: [ ] volts, [ ] amps, [ ] Hz, [ ] pulses per second

Shot	Start time	Start position	End time	End position
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

Fishing data sheet (2 of 4) Habitat

River:	**Site:**	**Code:**
Date& Time:	**Staff:**	**Data entered:**

FISH SURVEY HABITAT DATA (courtesy, Arthur Rhylah Institute)

WATERBODY TYPE **(tick)**

Stream (width <5m) ______
River (width >5m) ______
Artificial channel ______
Lake - natural ______
Lake - artificial ______
Impoundment (dam) ______
Billabong/swamp ______
Estuary ______
_____________ ______

SUBSTRATE **(=100%)**

Sheet rock ______
Boulder ______
Cobble ______
Pebble ______
Gravel ______
Coarse sand ______
Fine sand ______
Silt ______
Clay ______

LAND TYPE / USE **(tick)**
LB RB

Pasture/grassland ___ ___
Agriculture ___ ___
Heathland ___ ___
Shrubland ___ ___
Eucalypt Forest ___ ___
Rain Forest ___ ___
Pine Forest ___ ___
Other exotic forest ___ ___
State Forest ___ ___
State Park ___ ___
National Park ___ ___
Other Conserv. reserve ___ ___
Urban park or reserve ___ ___

NOTES:

FLOW TYPE **(= 100%)**

Rapid/cascade ______
Run ______
Riffle ______
Glide ______
Pool ______
Backwater ______
Reservoir/lake ______
Tidal ______
______________ ______

INSTREAM COVER **(=100%) wetted area**

Substrate (Rock etc.) ______
Logs ______
Log jams ______
Branches ______
Branch piles ______
Leaves, org. deb. ______
Bank o/hang ______
Veg. o/hang ______
Urban rubbish ______
Aquatic veg. ______
_____________ ______

RIPARIAN VEG. **(=100%)**

Native trees (>30m) ______
Native trees (<30m) ______
Willows ______
Pines ______
Other exotic trees ______
Native shrubs ______
Exotic shrubs ______
Blackberry ______
Sedges/rushes ______
Ferns ______
Grasses ______
______________ ______

FLOW LEVEL **(circle)**

V. Low Low
Medium
High V. High

DISTURBANCE

Rating: **(tick)**
Extreme ______
Very high ______
High ______
Moderate ______
Low ______
Very low ______

Type: **(tick)**

Bank Erosion ______
Riparian cleared ______
Parallel road ______
Bridge ______
Culvert ______
Ford ______
Urban rubbish ______
Drain ______
Pump inlet ______
Sand/gravel mine ______
Sedimentation ______
Exotic vegetation ______
______________ ______

AQUATIC VEG. **(= 100%)**

Submerged ______
Floating ______
Emergent ______
Algae ______
Algae-filamentous ______

WEATHER **(tick)**

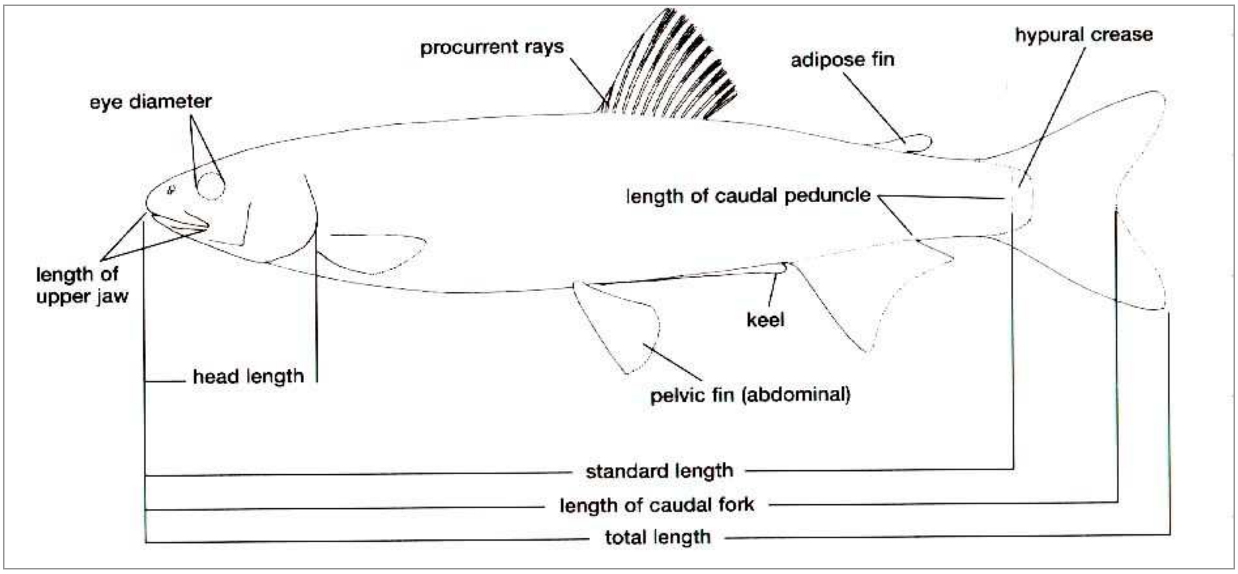
Cloud cover ______
Wind ______
Rain ______
Sunny _______

Fishing data sheet (3 of 4) Catch

River:	**Site:**	**Code:**
Date& Time:	**Samplers:**	**Data entered:**

Shot	Species & number	Length (mm)	Weight (g)	Health or comment *		Shot	Species & number	Length (mm)	Weight (g)	Health or comment *

Fishing data sheet (4 of 4) Catch



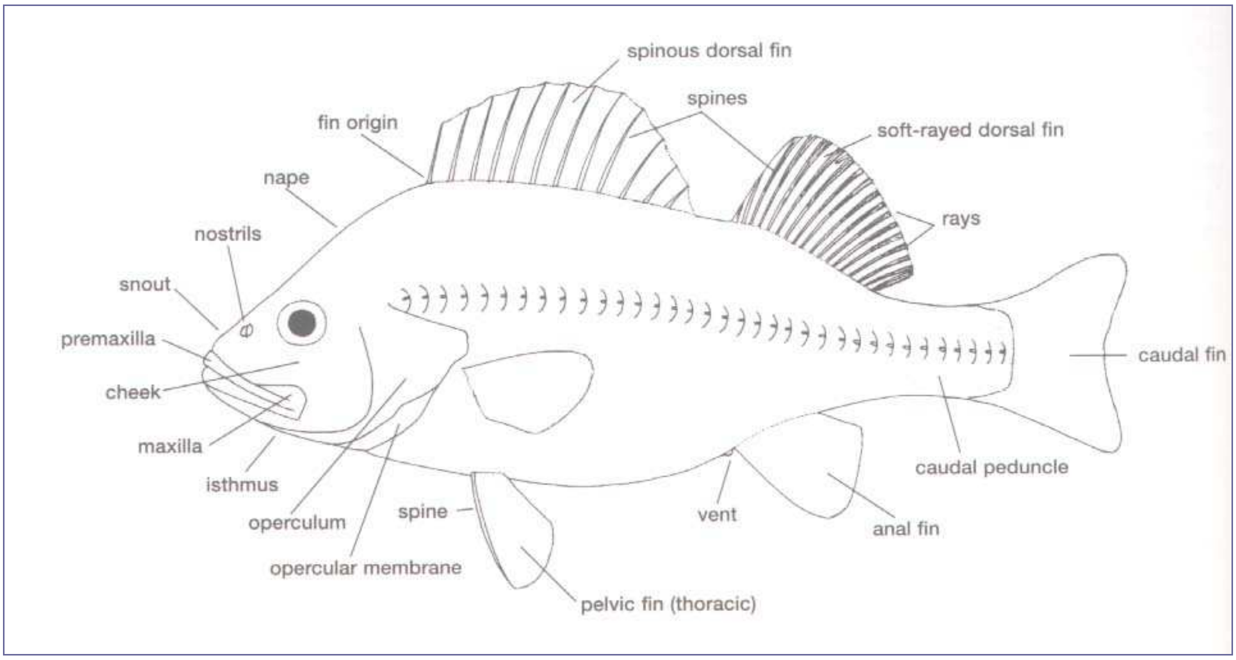


Figure 9. A typical soft rayed fish (top) and spiny rayed fish (bottom) showing diagnostic features (From McDowall 1996).

6.8.3.6. Costs

Equipment:
MDFRC will use their electro-fishing backpack/boat and seine nets

Consumables (field and lab):	$100
Personnel costs:	
3 hours x 2 people for electrofishing	$600
1 hour x 2 people for seine netting	$200
Total $ /site / sampling event	**$900**

*Travel cost will be included in the total cost of the monitoring program.

6.9 Project quality assurance and quality control

6.9.1 QC checks

- 10% of randomly chosen biological samples are re-identified by a senior taxonomist with no prior knowledge of previous identifications. Taxonomic errors are determined based on the comparison between identification by the original taxonomist and the QC taxonomist. Acceptable taxonomic error must be below 10%.
- The measurements are taken using a Hydrolab, *in situ* and the meter is calibrated regularly according to internal calibration schedules, against known laboratory solutions and prior to use for pH, Temperature, Electrical Conductivity, Turbidity and Dissolved Oxygen.
- The chemical analysis (total phosphorus, nitrate and nitrite, Total Kjeldahl Nitrogen) will be conducted in the MDFRC's NATA accredited laboratory, in accordance with its quality control manual.

6.9.2 Data checks

- Results of biological analysis are entered into the database and must be verified by another biologist before the data is accepted.
- Physico-chemical data is archived in hard copy for future reference.

6.10 Monitoring program summary costs

Costs – Water Quality

Equipment:
MDFRC Horiba will be used

Hobo Pendant Temp/Light Intensity Logger (one off cost)

Loggers	$108
Base station and pendant coupler	$131
Software	$86
Total	**$325**

Total equipment one off cost	**$975 ($325 x 3)**

Nutrient analyses:

6 nutrient tests @ $10/test	$60

Consumables (field and lab):	$20

Personnel costs:

1/2 hour 2 people for collection	$100

Total $ /site / sampling event	**$180**

Costs – Bank Soils

Equipment (one off cost):

Sediment pins	$45
Set of sieves	$128
Soil pH instrument	$200
Soil EC instrument	$200

Total equipment one off costs	**$573**

Consumables (field and lab):	$100
Personnel costs:	
0.5 days 1 person for collection	$400

Total $ /site / sampling event	**$500**

Costs - Vegetation

Consumables (field and lab):	$100
Personnel costs:	
0.5 days 2 people for collection/identification	$800
Total $ /site / sampling event	**$900**

Costs - Invertebrates

Equipment (one off cost):
Equipment will be supplied by the MDFRC

Total equipment one off costs	**$0**
Consumables (field and lab):	$100
Personnel costs:	
0.5 days 1 person for field collection	$400
1 day 1 person for lab identification	$800
Total $ /site / sampling event	**$1300**

Costs - Fish

Equipment:
MDFRC will use their electro-fishing backpack/boat and seine nets

Consumables (field and lab):	$100
Personnel costs:	
3 hours x 2 people for electrofishing	$600
1 hour x 2 people for seine netting	$200
Total $ /site / sampling event	**$900**

*Travel and report preparation costs will be included in the total cost of the monitoring program.

6.11 *Total monitoring program costs*

This monitoring program is designed to undertake the long term monitoring of willow removal reaches and reference reaches. Monitoring is recommended to be undertaken in spring and autumn annually in at least one willow and one reference reach site (costing is for one willow and one reference reach site) before and after willow removal and for an ongoing period of >5 years following willow removal. The total cost for two sites monitored once in spring and once in autumn including all initial one-off equipment costs and sampling costs (Table 5) for these two sites, travel and report preparation (See below) has been calculated below:

Equipment one off cost = $1548 x 2 sites (one reference and one willow site) = $3096
Equipment cost for Ovens site = $325
Sampling cost = $3780 x 2 sampling seasons (spring and autumn) x 2 sites = $15,120
Travel cost = $312 x 2 sampling seasons x 2 sites = $1,248 (Lt Snowy Ck) + $112 (Ovens) = $1360
Report production = $10,000

TOTAL WILLOW MONITORING COST = $29,901
(based on monitoring 2 sites (one reference site and one willow site) on two sampling occasions (once in Spring and once in Autumn)) in Lt Snowy Ck and setting a temperature logger in the Ovens site.

Table 5. Monitoring program costs per site

Parameter monitored	**Equipment one off cost / site**	**Sampling cost / site / sampling event**
Water quality	$975	$180
Bank soils	$573	$500
Riparian vegetation	$0	$900
Macroinvertebrates	$0	$1300
Fish	$0	$900
TOTAL	**$1548**	**$3780**

Travel costs / sampling event

- Wodonga to McCormacks site (temperature logger) 140km one day round trip
- 140km @ 80c/km = **$112 / 1 day temp logger instalment**
- Wodonga to Lt Snowy Creek 130km one day round trip
- 130km x 3 days / sampling event = 390km
- 390km @ 80c/km = **$312 / 3 day sampling event**

Report production
$10,000

7. REFERENCES

ANZECC, ARMCANZ (2000) *Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand*, Australian Water Quality Guidelines for Fresh and Marine Waters, National Water Quality Management Strategy, Australian and New Zealand Environment and Conservation Council, Canberra.

ARMCANZ (2001) Agriculture and Resource Management Council of Australia and New Zealand. Australian and New Zealand Environment and Conservation Council and Forestry Ministers. In: *Weeds of National Significance Willow (Salix taxa, excluding S. babylonica, S. x calodendron and S. x reichardtii). Strategic Plan.* National Weeds Strategy Executive Committee, Launceston, Tasmania.

Besley, C.H. (1992) *Macroinvertebrate Assemblages in the Riparian Tree Roots of the Murrumbidgee River, New South Wales. Bachelor of Applied Science (Honours) Thesis*, Charles Sturt University, NSW.

Bobbi, C. (1999) River management arising from willow removal (where there's a willow there's a way). In: *Proceedings of the Second Australian Stream Management Conference*, 69-73, Adelaide.

Bothwell, M. L., Roberge, A. C., Daley, R. J. (1993) Influence of natural UV radiation on lotic periphytic diatom community growth, biomass accrual, and species composition, *J. Phycol*., **29**, 24-35.

Bunn, S.E., Davies, P.M., Mosisch, T.D. (1999) Ecosystem measures of river health and their response to riparian and catchment clearing. *Freshwater Biology*, **41**, 333-346.

Bunn, S.E., Mosisch, T.D., Davies, P.M. (1999) Temperature and light. In: *Riparian Land Management Technical Guidelines, Volume 1: Principles of Sound Management* , 17-36, Land and Water Resources Research and Development Corporation, Canberra, Australia.

Campbell, I.C. (1993) Riparian stream linkages: an Australian perspective on in-stream issues. In: *Ecology and Management of Riparian Zones in Australia*, 21-30, LWRRDC, Canberra.

Chessman, B. (2001) SIGNAL 2. A scoring system for macroinvertebrates (‘waterbugs’) in Australian rivers. User Manual. NSW Department of Land and Water Conservation. Parramatta, NSW, Australia.

Collier K.J., Winterbourn M. J. (1986) Processing of willow leaves in two suburban streams in Christchurch, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, **20**, 575-82.

Cremer, K., Van Kraayennoord, C., Parker, N. and Streatfield, S. (1995) Willows spreading by seed: implications for Australian river management. *Australian Journal of Soil and Water Conservation*, **8**:18-27.

EPA (2003) Guideline for environmental management. Rapid bioassessment methodology for rivers and streams. EPA Victoria.

Frankenberg, J. (1995) Willows: the species, their biology and control. In: *Willows, Weeds and Native Fish (Ed: Anon)* Proceedings of the River Basin Management Society summer conference, Geelong.

Gawne, B., Gigney, H., Cook, R. (2005) *Trial Monitoring Program for a River Restoration Project: Ovens De-willowing*, Murray-Darling Freshwater Research Centre, Wodonga, Victoria.

Gutierrez-Rodriguez, C., Williamson, C.E. (1999) Influence of solar ultraviolet radiation on early-life history stages of the blue-gill sunfish, *Lepomis macrochirus*. *Environmental Biology of Fishes*, **55**, 307-319.

Hardwick, L., Wood, H., Hillman, T., Robertson, D. (1995) *The relationship between macroinvertebrate communities and riparian vegetation in Tarcutter Creek, a lowland tributary of the Murrumbidgee River, NSW*, Abstracts, Australian Society of Limnology 34th Annual Congress, Hobart.

Hill, W.R. (1996) Factors affecting benthic algae: effects of light. In: *Algal Ecology: Freshwater Benthic Ecosystems*, 121-148, Academic Press, San Diego, CA, USA.

Jackson, J. K., Fureder, L. (2006) Long-term studies of freshwater macroinvertebrates : a review of the frequency, duration and ecological significance. *Freshwater Biology,* **51**(3): 591-603.

Jansen, A., Robertson, A., Thompson, L. and Wilson, A. (2004) *Development and application of a method for the rapid appraisal of riparian condition*, River Management Technical Guideline No. 4, Land and Water Australia, Canberra.

Ladson, A.R., Gerrish, G., Carr, G., Thexton, E. (1997) Willows along Victorian Waterways. Department of Natural Resources and Environment, Melbourne.

Ladson, A., Tilleard, J., Ewing, S. (1999) Successful stream rehabilitation: first set the goals. In: *Proceedings of the Second Australian Stream Management Conference, Vol 2, Adelaide, February 1999.* CRC for Catchment Hydrology, Melbourne.

McDowall, R.M. (ed) (1996) *Freshwater Fishes of South-eastern Australia* Reed, Sydney

Mitchell, D.S., Frankenberg, J. (1993) Willows in Australia: Weeds or beneficial plants, Murray-Darling Freshwater Research Centre, paper.

Munks, S. (1996) *A Guide to Riparian Vegetation and its Management;* Department of Primary Industry and Fisheries, Tasmania.

Parkyn, S.M., Winterbourn, M.J. (1997) Leaf breakdown and colonisation by invertebrates in a headwater stream: comparisons of native and introduced tree species. *New Zealand Journal of Marine and Freshwater Research*, **31**, 301-312.

Perkins, A. (1903) Irrigation of the Murray: utilization of the swamplands. *Journal of Agriculture and Industry*, **6**, 489-494.

Pidgeon, R.W. (1978) *Energy Flow in a Small Stream Community: an Evaluation of the Effects of Different Vegetation. Ph.D. Dissertation,* University of New England, Armidale, New South Wales.

Pidgeon, R.J.W., Cairns, S.C. (1981) Decomposition and colonisation by invertebrates of native and exotic leaf material in a small stream in New England (Australia). *Hydrobiologia*, **77**, 113-127

Plafkin, J.L., Barbour, T.M., Porter, K.D., Gross, S.K and Hughes, R.M. (1989) Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish. USEPA, Washington, D.C.

Pusey, B.J., Arthington, A.H., Read, M.G. (1998) Freshwater fishes of the Burdekin River, Australia: biogeography, history and spatial variation in assemblage structure. *Environmental Biology of Fishes*, **53**, 303-318.

Rutherford, J.C., Blackett, S., Blackett, C., Saito, L., Davies-Colley, R.J. (1997) Predicting the effects of shade on water temperature in small streams. *New Zealand Journal of Marine and Freshwater Research,* **31**, 707-721.

Schulze, D.J., Walker, K.F. (1997) Riparian eucalypts and willows and their significance for aquatic invertebrates in the River Murray, South Australia. *Regulated Rivers-Research & Management*, **13**, 557-577.

Smith, T., Starr, B. (1999) Willows - friend or foe? An historical perspective. In: *Proceedings of the Second Australian Stream Management Conference*, 573-577, Adelaide.

Van Kraayenoord, C.W.S., Slui, B., Knowles, F.B. (1995) Introduced forest trees in New Zealand. 15. The Willows, New Zealand Forest Research Institute, Bulletin, no. 124., 32 .

White, L. J., Ladson, A. R. (1999) An Index of Stream Condition: Catchment Managers' Manual. Waterways Unit, Department of Natural Resources and Environment, Melbourne, Victoria.

Walker, K.F., Boulton, A.J., Thoms, M.C., Sheldon, F. (1994) Effects of water-level changes induced by weirs on the distributions of littoral plants along the River Murray, South Australia. *Australian Journal of Marine and Freshwater Research*, **45**, 1421-1438.

Walker, K.F., Thoms, M.C. (1993) Environmental effects of flow regulation on the lower River Murray Australia. *Regulated Rivers Research and Management*, **8** 103-119.

Wilson, M.E. (2001) *Organic Matter Dynamics in Willow and Eucalypt lined Central Victorian Streams*, Thesis submitted in total fulfilment of the requirements for Doctor of Philosophy, School of Science,University of Ballarat, Victoria.

Yeates, L.V. (1994) *The Role of Invertebrates and Microorganisms in the Breakdown of Willow and Eucalypt Leaves in a Tasmanian Stream. BSc Hons Thesis*, University of Tasmania, Hobart.

Zukowski, S., Gawne, B. (2006) Potential effects of willow (*Salix* spp.) removal on freshwater ecosystem dynamics. A Literature Review. Report prepared for the North East Catchment Management Authority. Murray-Darling Freshwater Research Centre, Albury.