Devilbend Reserve. Phase Three of Freshwater Research Works

REPORT FOR PARKS VICTORIA

Devilbend Aquatic Ecology Monitoring Program

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THE DEVILBEND NATURAL FEATURES RESERVE

Description of the Reserve

The proposal to establish a new Devilbend park was formally announced by the Hon. John Thwaites, Minister for Environment in January 2006. In September 2006, the Minister announced that the park will be reserved as a Natural Features Reserve under the Crown Land (Reserves) Act 1978 and Parks Victoria would be appointed as the Committee of Management. Natural Features Reserves are one of four categories of conservation reserve in Victoria defined by the former Land Conservation Council in 1994. Natural Features Reserves contain natural features worthy of protection such as streamsides, bushland, geological or geomorphological features, lakes or other scenic features. Natural Features Reserves often provide the only suitable habitat for many common and uncommon species that either still use or were once widespread in land types that have been largely cleared. Natural Features Reserves also contribute to our well-being, when used for recreation, relaxation, landscape appreciation, education and protection against land degradation.

Comprising 1005 ha, the Devilbend Natural Features Reserve (DNFR) has high conservation value, supporting more than 150 indigenous terrestrial plant species, including a range of trees, shrubs, ground flora, aquatics, orchids and associated plant communities; and 195 fauna species including threatened FFG listed species such as the White-bellied Sea-eagle and the Blue-billed Duck. The reserve also comprises 11 Ecological Vegetation Classes (EVCs) that are classed as rare, vulnerable or endangered within the Gippsland Plains Bioregion (in which the reserve is located). Restricted public access at Devilbend has created favourable conditions for a wildlife refuge, with evidence including the large population of waterbirds and frogs taking advantage of the range of habitats, lack of disturbance, and water and food supplies. However, the ecological values of DNFR are vulnerable to multiple stresses and pressures, including terrestrial habitat loss and fragmentation, pest plant and animal proliferation, and habitat degradation due to previous land uses, edge effects, changes to hydrology and livestock grazing.

Parks Victoria has prepared a management plan for DNFR in order to determine both short term and long term aims and strategies for the conservation of natural and cultural heritage values. The plan will allow for the provision of recreational use consistent with conservation and protection objectives, and also the provision for on-going community engagement in management.

SCOPE

Parks Victoria (PV) and the Devilbend Foundation Incorporated (DFI) have developed a scope of works which seeks to summarise the values of the DNFR and develop a monitoring program to provide ongoing knowledge of the condition of the aquatic habitats in the DNFR.

Phase One comprised a desktop summary of existing data and a mapping exercise describing the aquatic vegetation communities, addressing the immediate need for information on aspects of the Reserve which were likely to show a relatively small degree of temporal (month to month, year to year) variability.

Outcomes of this phase included:

1. Mapping and describing aquatic vegetation communities according to Wetland Ecological Vegetation Communities including an assessment of condition.

2. Identifying and listing key threatened and significant species based on existing data, including fish, frogs and aquatic and riparian vegetation.

3. Providing an indication of the types of invertebrates in the two main water bodies based on existing data.

4. Identifying and listing exotic species including fish, frogs and aquatic and riparian vegetation based on existing data.

5. Producing an annotated bibliography of existing information on the Reserve.

Phase Two comprised a detailed ecological survey of aquatic habitats in the Reserve including invertebrate life, fish communities and amphibians. This survey was carried out in spring and summer 2008/2009 in order to ensure that fish and amphibian results genuinely reflected the communities present.

The outcomes of this phase were

1. The identification and listing of key threatened and significant species present in the Reserve, including fish, frogs and aquatic and riparian vegetation.

2. An indication of the types of invertebrates currently present in the two main water bodies.

3. Identification and listing of exotic species including fish, frogs and aquatic and riparian vegetation currently occurring around the aquatic habitats in the Reserve.

The results of Phase One and Two were reported in Walker and Thompson (2009). An additional phase of works was proposed to provide additional information and guidance about ongoing monitoring. This report covers the works planned as Phase Three of the investigations into DNFR.

PROJECT OBJECTIVES

Developed in partnership with PV Phase Three provides guidance on development of research and a community based monitoring program designed to assist DFI and local community volunteers to monitor and assess the aquatic habitats in DNFR. Any results identifying changes in conditions can then be used to assist PV in effectively managing the reserve.

Phase Three Objective: To design a monitoring program to measure changes in the aquatic habitats of DNFR and have a genuine understanding of the impacts of any changes in management.

Phase Three: In order to gain an undergoing understanding of the ecology of the aquatic habitats in the Reserve and have a genuine understanding of the impacts of any changes in management, it is proposed that a program of limited ongoing surveys be initiated. At the minimum level it is intended that this should include at least quarterly assessments of water quality, an annual biological survey (Phase Two above) and ongoing synthesis and reporting. This would include the provision of training for community groups to reduce costs to PV. This phase outlines that program and provides indicative costs for the ongoing survey work.

Intended outcomes of this phase:

1. Design of an ongoing, minimal survey program for aquatic habitats in the Reserve, including water quality, fish and amphibian populations and extent of aquatic vegetation.

2. Indicative costing for the provision of survey work outlined in 1 above.

The proposed scope of works outlined here adopts an ecosystem approach to the study of the aquatic ecosystems in the Reserve. This approach is appropriate here because whole of catchment impacts (such as farming in the catchment, and catchment water yields) are considered one of the main drivers of potential risks to aquatic habitats in the Reserve. In addition, fauna such as birds are strongly reliant on the aquatic productivity of the reservoir habitats to maintain diversity and abundance. Implicit in taking an ecosystem approach is that variability will occur on temporal scales that require multiple surveys through time in order to genuinely understand and manage dynamics. In the case of the Reservoir for instance, water quality issues are likely to be most severe in summer, where high nutrients and high temperatures coincide, but may be of more minor importance in the cooler months.

Specifically Phase Three will determine the appropriate methods for:

- **Measurement of indicators that identify potential changes to fresh water habitats: these may include water quality, fish, amphibian, invertebrate and waterbird populations, and the extent of aquatic vegetation.**
- **Quarterly assessments of water quality and edge effects**
- **A second annual biological survey**
- **Procedures for ongoing synthesis and reporting; and,**
- **The scale, content, scheduling and logistics of volunteer training (based on consultations with Devilbend Foundation, the National Trust of Australia (Vic), Friends of Daangean and other interested community groups).**

The report will include;

PART ONE

- An overview of current understanding of the ecology of the aquatic habitats in the Reserve and the possible impacts of any proposed changes in the management

PART TWO

- Identification of the strategic foci for the proposed monitoring program, and clear and measureable objectives that can be used to evaluate and monitor changes in aquatic habitats and impacts on flora and fauna, and can be applied to an adaptive management model.

PART THREE

- Technical and logistical elements of the proposed monitoring program including survey methodology.
- Procedures for ongoing synthesis and reporting.

PART FOUR

- The scale, content, scheduling and logistics of volunteer training (based on consultations with Devilbend Foundation, the National Trust of Australia (Vic), Friends of Daangean and other interested community groups).
- Appropriate administrative and oversight arrangements for the monitoring program.
- Detailed cost estimates for the monitoring program over a two year period, including training of volunteers.
- A review of the benefits and likely costs of continuing the monitoring program in successive years

PART ONE: Synthesis of existing knowledge and background to monitoring

1.1 Summary of aquatic values

DNFR is highly productive, with extensive aquatic and riparian vegetation supporting amphibian, fish and crayfish communities. The benthic zone of Devilbend Reservoir is covered in vegetation, predominantly *Potamogeton* and algae, providing extensive areas of habitat for invertebrates and fish. The flora within Devilbend Reserve is highly diverse and includes some intact wetland vegetation. This is largely due to the minimal amount of human disturbance over several decades. The Reserve contains a rare area of standing water in the Mornington Peninsula which has assisted to make the Reserve highly productive. In addition the Reserve represents an important link within the landscape between reserves to the south and north, facilitating dispersal of bird and flighted invertebrate species within a relatively degraded landscape matrix. A number of studies of the flora and fauna of the Reserve have been completed; in 2001 by Ecology Australia (Ecology Australia 2001), in 2008 by McCaffrey et al. (2008), and a survey of aquatic biota only by Walker and Thompson (2008). This material is summarized in the Devilbend Natural Features Reserve Management Plan (2010). The results of those surveys as pertinent to the aquatic biota are detailed in brief below.

1.1.1 Water quality

There has been relatively little water quality monitoring in the water bodies within the Reserve and this is a significant gap in our existing knowledge. Spot measurements taken by Walker and Thompson (2009) and by Monash University students several times over the last decade (M.Grace pers. com) suggests that the main Reservoir is typically circumneutral (ph 7.0-7.2), with relatively low conductivity. Water clarity is highly variable, with Secchi depths ranging from 0.10-0.72m. Algal blooms have been observed in sheltered parts of all of the major water bodies in the Reserve, but it is not known whether these are associated with particular water quality events.

1.1.2 Aquatic vegetation

Flora surveys to date indicate there are over 150 indigenous terrestrial plant species of regional or higher significance. Most recently Walker and Thompson (2009) found the flora within DNFR to be highly diverse and include some wetland vegetation, although much of that was degraded. The submerged aquatic vegetation present appeared to be in good condition. Identification of key threatened and significant aquatic and riparian vegetation species in the Reserve found that none of the aquatic or riparian vegetation was listed as threatened or rare within the state or nationally. Mapping and descriptions of aquatic vegetation communities according to Wetland Ecological Vegetation Communities found a limited amount of wetland habitat. None the less habitat of this type is rare on the Mornington Peninsula due to drainage and the current drought conditions. The submerged aquatic vegetation present appears to be in good condition. However the wetland habitat was often relatively degraded. The areas that were able to be classified as an EVC often had weeds within or surrounding the patch. Other areas that could not be classified as an EVC were composed of a mix of exotic and native species. Identification of key threatened and significant aquatic and riparian vegetation species currently present in the Reserve found that none of the aquatic or riparian vegetation was listed as threatened or rare within the state or nationally (FFG, 1988 and DSE 2005). All of the aquatic or riparian vegetation found within the Reserve is commonly found in these habitat types. A recent flora survey (McCaffrey 2008) did not identify any further aquatic plant species of interest. Areas of aquatic sedgeland and aquatic herbland indentified in that survey were in poor condition and limited in extent.

1.1.3 Aquatic macroinvertebrates and zooplankton

Indicative surveys of the types of invertebrates currently present in the two main water bodies by Walker and Thompson (2009) revealed diverse macroinvertebrate and zooplankton assemblages typical of standing water habitats in southern Victoria. No species which are threatened or of significant conservation values were identified, although it must be noted that for some groups which may have high endemism (e.g. copepods, ostracods), the current level of taxonomic knowledge is relatively poor.

McGuckin (2001) found two species of freshwater crayfish present; the endemic yabby (*Cherax destructor*) and the noxious Western Australian marron (*Cherax tenuimanus*). Yabbies appeared to have declined from McGuckin's survey (2001) to the survey by Walker and Thompson (2009). In the later survey yabbies appear to mainly be associated with areas with large amounts of cover (woody debris and rubble walls).

Marron
This species which is endemic to Western Australia is considered noxious within Victoria. It is believed that Marron might establish feral populations to the detriment of local biota and may bring with them disease organisms not currently present in Victoria (Victorian Fisheries Notes, 1988). Marron are abundant in the two main water bodies on the Reserve and in the connecting catchdrain. There are numerous anecdotal reports of them also being present in Devilbend Creek downstream of the Reserve. Marron are considered a significant threat to freshwater biodiversity. Within this system there appears to be evidence that they are excluding the native yabby from many areas of the main reservoir and Bittern Reservoir. While yabbies and marron can co-exist, they exhibit considerable overlap in diet and habitat preferences.

1.1.4 Fish

A fish survey conducted in November 2001 (McGuckin 2001) found four indigenous fish species in Devilbend and Bittern Reservoirs (common galaxias (*Galaxias maculatus*), spotted galaxias (*Galaxias truttaceus*), southern pygmy perch (*Nannoperca australis*) and short-finned eel (*Anguilla australis*)), and three exotic fish species (goldfish (*Carassius auratus*), eastern gambusia (*Gambusia holbrooki*) and redfin perch (*Perca fluviatilis*). Walker and Thompson (2009) found a similar number of species although there appeared to be some reduction in number of spotted galaxias (a species considered rare in Victoria). Shortfinned eels were not sampled in that survey, although the sampling techniques used mean that their favoured deep water habitats were not well sampled. Both species require passage to the sea to breed, and it is possible that the current condition of the Reservoir does not allow movement of these fish in and out of the system.

Two native fish species of conservation concern have been recorded in DNFR; spotted mountain trout (*Galaxias truttaceus*) and dwarf galaxias (*Galaxiella pusilla*). The other native fish present in the system (common jollytail and pygmy perch, and potentially shortfin eels) are not considered of conservation concern in this area. Shortfin eels, mountain spotted trout and common jollytail, all undergo breeding migrations. It is unclear to what degree any passage to the sea will be possible at low reservoir levels. Common jollytail can form 'land-locked' populations whereby breeding migrations from tributaries to a lake are possible. It seems like that this has occurred at Devilbend, and this species may be maintained in the system. It is likely that the other two species will be lost unless passage to the sea (via a fish ladder) is maintained from the main reservoir. Amphibian species present in the Reserve likely include growling grass frogs, which are of conservation concern.

Spotted mountain trout (Galaxias truttaceus)
This large native fish (up to 200mm) is considered of conservation concern due to it's vulnerability to competition with exotic fish species (particularly salmonids). Populations in the Reserve appear to be low, which may be a result of interactions with redfin perch and Gambusia (of which little is known), historical or current competition with salmonids (which is known to be intense), or impeded passage to the sea (which is possible). DNFR represents good habitat for spotted mountain trout, and could be used as a site to undertake recovery of this species. Such an effort would require additional research on interactions with exotic fish currently present in the Reserve, and an appraisal of the potential for fish passage to the sea via Devilbend Creek.

Dwarf galaxias (Galaxiella pusilla)
This species is threatened in Victoria and nationwide. Typically associated with shallow (often intermittent) aquatic habitats, there are known local populations in Tuerong Creek and in the lower reaches of Devilbend Creek. Repeated surveys have now failed to find this species in Devilbend Reserve, including in areas where they formerly occurred. The species is extremely cryptic, and is known to aestivate in muddy areas and reappear after rainfall in intermittent habitats such as those present in the catch drain and upper reaches of Devilbend Creek. It is likely that the species is still present, but at lower levels than previously found. This reduction may be due to reduced flows due to drought, increased abundance of Gambusia (which is known to out-compete dwarf galaxias) or some other factor. However, after the recent rain in August 2010 the catch drain is flowing and a search for this fish could be well be successful now. Dwarf galaxias habitat is present in DNFR and the species may be present. ,

A number of exotic fish species are also present in the DNFR, including eastern mosquitofish (Gambusia) and redfin perch. In 2010 brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) were introduced into Devilbend Reservoir, based on the recommendations of the Translocation Evaluation Panel referring to the Translocation Risk Assessment Report (Lloyd and Newall 2009).

Gambusia
This species was deliberately introduced under government control in an attempt to control mosquito numbers and to help prevent the spread of some human diseases. Gambusia have an extremely effective breeding strategy, being live bearers, out compete native fish especially in degraded systems and harass and nip the fins of other small fish. Gambusia has been implicated in the decline of several small native species (Victorian Fisheries Notes, 1988) but can exist with native species such as pygmy perch. Reductions in water levels within the Reserve are likely to favour Gambusia and this species will represent a significant threat to both native species and any large bodied fish in the system.

Redfin perch
Redfin are the dominant fish by biomass in the main waterbodies in the Reserve. An exotic temperate fish, redfin have a planktivorous juvenile stage, that mainly feeds in the shallow, and a large piscivorous adult phase which is characteristically found in deeper waters. Reductions in water levels are likely to make Bittern Reservoir marginal habitat for this species, but it is likely that significant populations will be maintained in the main reservoir. Ultimate productivity of this species is likely to be in part determined by water quality issues – sediment resuspension and algal blooms can favour zooplankton and ultimately support redfin perch populations. Redfin compete strongly with a number of native species, including native perch and to some degree galaxiid fishes. Under current conditions, it would be expected that redfin would compete strongly with native fish and any large bodied exotic fish in the main reservoir.

Salmonids
Brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) are exotic temperate fish with documented significant negative effects on Australian native fish. Salmonids were introduced into DNFR largely on the recommendations of Lloyd and Newall (2009). The waterbodies in DNFR are unlikely to support a significant fishery of either of the salmonid species, although with stocking both have the potential to cause significant ecological impacts.

1.1.5 Other aquatic vertebrates

Three native frog species were identified by Walker and Thompson (2009), including the common froglet (*Crinia signifera*), southern bullfrog (*Limnodynastes dumerilii*) and spotted marsh frog (*Limnodynastes tasmaniensis*). Growling grass frogs (*Litoria raniformis*) were not recorded in that survey although conditions were not ideal for the identification of these species. Similarly, Walker and Thompson (2009) did not record long-necked tortoise (*Chelodina longicollis*), which were abundant in

McGuckin's, (2001) survey. It is possible that the lower water levels in the reservoirs may be reducing available habitat. McCaffrey et al. (2008) raise the possibility that Southern Toadlets may also be present in the Reserve. The Southern Toadlet is listed as vulnerable in Victoria (DSE 2007b). The species was not detected by Walker and Thompson (2009) but further surveys are advisable.

Growling grass frogs (Litoria reniformis)
Growling grass frogs are a large frog species which commonly predates on other frogs. The species is listed as vulnerable under the EPBC Act 1999, threatened under the FFG Act 1988 and is listed as endangered by DSE (2007b). There are several records of Growling Grass Frogs on the Mornington Peninsula in similar habitats as occur in the Reserve, and it is possible given that at least some individuals are present, although the last published record is 1978. This species is considered in decline, and anecdotally has declined within the Reserve. It would appear that there is abundant habitat for this species in the Reserve, and it is possible that the failure to detect it in the 2008 survey (Walker and Thompson 2009) is a reflection on timing and conditions of the surveys. It is highly likely that the species is still present given available habitat and prey. However competition with, and predation by, Gambusia represents a significant risk to all amphibians in this system, including the growling grass frog.

1.1.5 Overview of aquatic food web

Figure 1 shows an overview of the aquatic food web in the major standing water bodies in Devilbend Reserve. Note that 'macrophytes' are submerged aquatic plants.

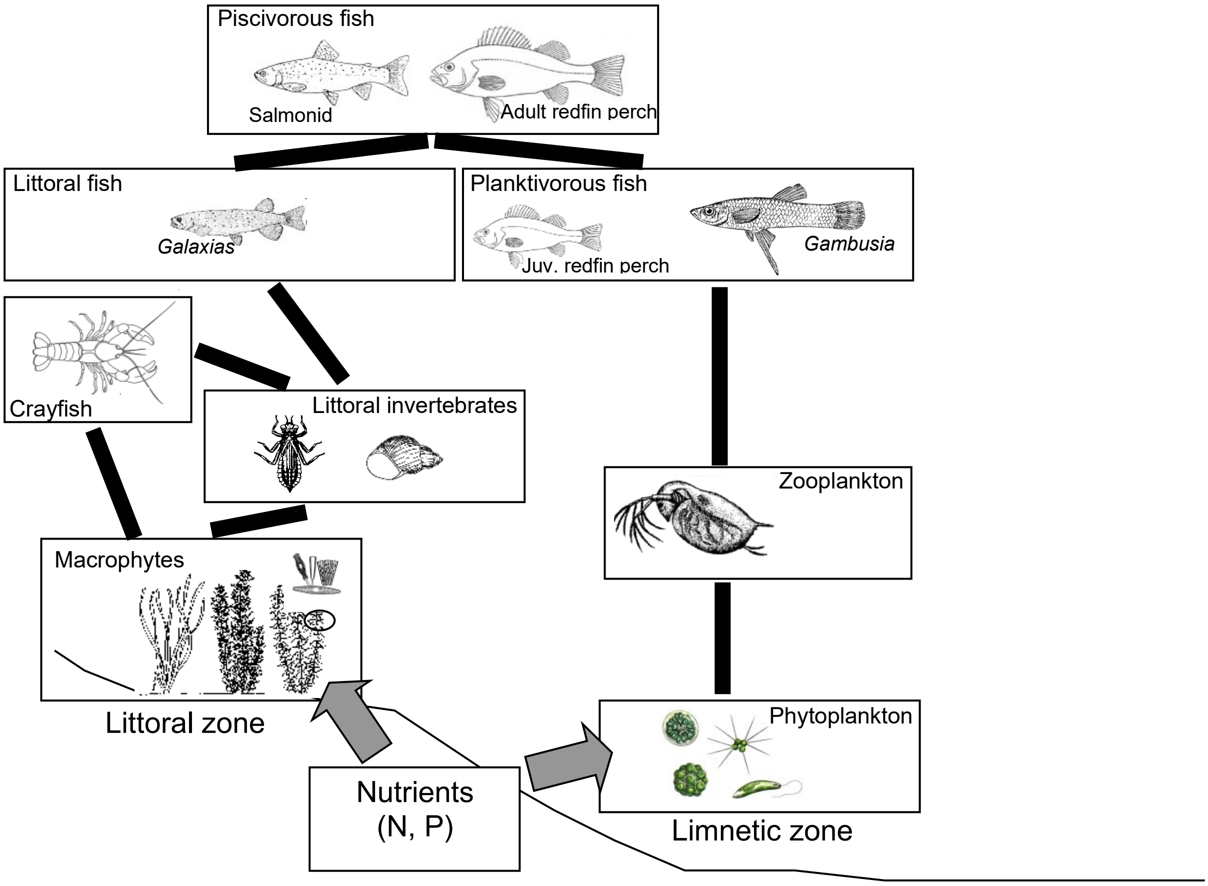

Figure 1: Diagrammatic representation of the food web of the major standing water bodies in the Devilbend Reserve. Boxes around the major functional groups indicate the assumed biomass of each.

1.1.6 Birds

Previous fauna surveys have indicated up to 84 fauna species of regional or higher significance, largely birds (Ecology Australia, 2001; McGuckin, 2001; 2007; Richards, 2006; McCaffrey et al. 2008). Birds Australia has also undertaken monthly surveys since May 2004, and has recorded 155 species including 44 water birds. In addition, the aquatic habitats provide important staging points for near-threatened migratory birds such as the Caspian tern and whiskered tern. Two nationally significant species and 20 state significant species have been recorded in the study area in the last 20 years. Blue-billed Duck (*Oxyura australis*) is listed as threatened under the Flora and Fauna Guarantee Act 1988 and endangered according to DSE (2007b). White-bellied Sea Eagle (*Haliaeetus leucogaste)r* are present in the Reserve and have been observed at Devilbend feeding and breeding (McCaffrey et al. 2008). Australasian Bittern are listed under the FFG Act (1988) and is listed as endangered in Victoria (DSE 2007b). This species favours wetland habitats like those found on the margins of the reservoirs in the Reserve. Detailed information on those species may be found in McCaffrey et al. (2008).

PART TWO: Conceptual basis for monitoring

2.1 Introduction

The scope of this report section is to identify strategic foci for the proposed program, and clear and measurable objectives to monitor changes in aquatic habitats. Monitoring can be defined as “sampling and analysis designed to ascertain the extent of compliance with a predetermined standard or the degree of deviation from an expected norm” (National Framework for the Management and Monitoring of Australia's Native Vegetation, DEH 2001). A monitoring program should be an iterative process that establishes feedback between management and its consequences. The program recommended here has been developed with the following objectives;

1. To provide sufficient information to identify any broad based changes in the aquatic habitats of the Reserve.
2. To minimize costs through selection of aspects of the environment to be monitored in a selective way.
3. To minimize ongoing costs of the monitoring program through the use of volunteers and to engage with community groups and provide opportunities to assist in management outcomes.
4. To provide a program for review of the monitoring information annually.

The information detailed below provides an overview which provides background to the identification of the strategic foci for targeting a monitoring program.

2.2 Conceptual model of ecosystem

Water bodies in the DNFR are generally shallow. Systems such as these are well understood conceptually, and the driving processes well described. Shallow systems are dominated by ‘top down’ effects of fish preying on invertebrates, rates of nutrient inflows and the effects of water level (and thus the impacts of wind and wave activity) (Figure 2). Shallow water systems occur in two states; a ‘clear water’ state dominated by aquatic vegetation and associated invertebrates, and a ‘turbid water’ state dominated by algae in the water column and zooplankton communities.

In ‘clear water’ systems nutrient inputs tend to be low. Nutrients entering the system are quickly taken up by aquatic plants and stored in plant biomass or transferred into sediments. Plants also trap sediments and prevent them from being resuspended by wind and wave action, preventing nutrients from re-entering the water column. Low rates of sediment resuspension, coupled with low water column algal biomass leads to clear water, which in turn facilitates aquatic plants in colonizing, as light is not limited on the lake bed. Algae which do grow in the water column are grazed by zooplankton, which in turn are fed on by fish. Figure 3 shows the predominant drivers of this ecosystem state.

In ‘turbid water’ systems, nutrient inputs are often higher, and exceed the capacity of aquatic plants and sediments to retain them. Availability of nutrients in the water column allows algae to grow, increasing turbidity. This acts to ‘shade out’ aquatic plants in deeper water, which die and release their nutrients into the water column. In addition, the loss of plant cover increases rates of sediment resuspension, further increasing turbidity and nutrient release into the water column. Figure 4 shows the predominant drivers of this ecosystem state.

Transitions between the two states have been observed in a number of systems. Four biological processes have been implicated in shifts from clear water to turbid water states.

1. Destructive grazing of aquatic plants by (most often) waterbirds.
2. Removal of aquatic plants by a major storm event.
3. Increases in the amount of nutrients entering a water body.
4. Increased fish numbers, which destructively graze zooplankton and allow water column algae to proliferate.

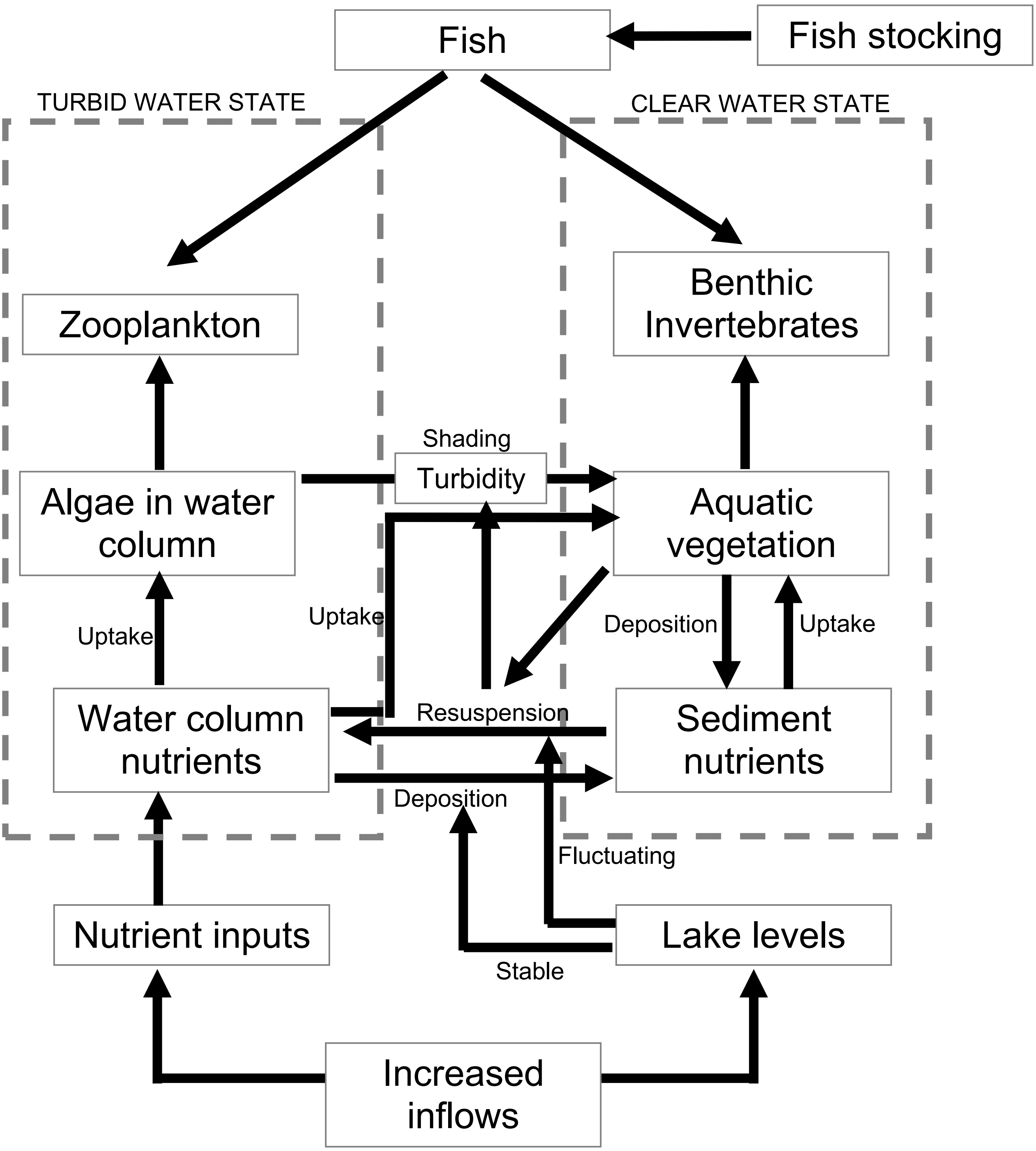

Figure 2. Conceptual model of the major drivers affecting shallow lake ecosystems. The two major management interventions likely in DNFR (fish stocking and increased inflows to the reservoirs) are shown to indicate likely causative relationships.

The two large waterbodies in DNFR are both characertised by generally clear water, with emergent and submerged aquatic plants. At some times of the year and in parts of the main Devilbend Reservoir, algal blooms have been observed. These are likely to be result of warm summer water temperatures (which favours algal growth), potentially in combination with resuspension of sediments due to wind and wave action.

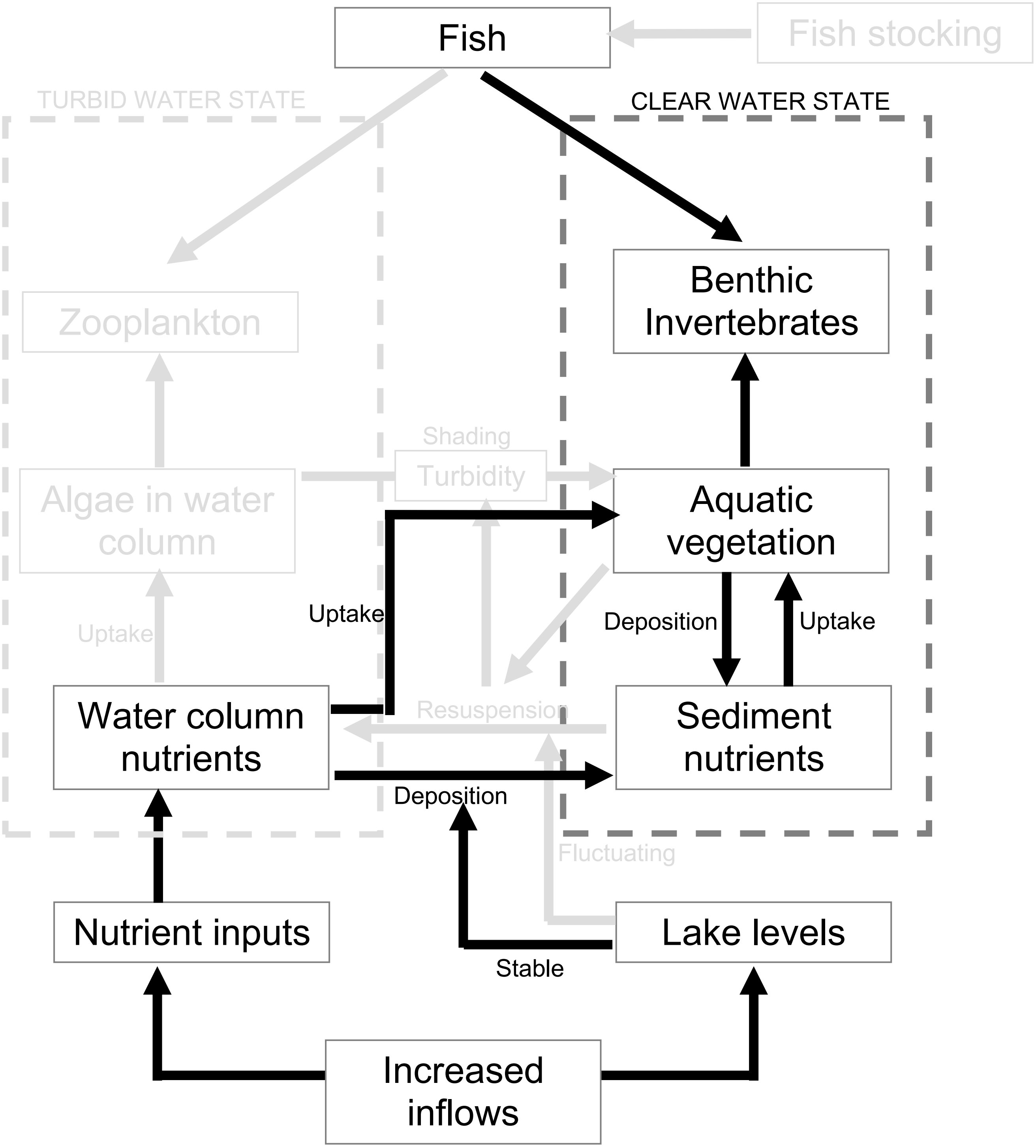

Figure 3. Conceptual model of the major drivers operating when shallow lake ecosystems are in a clear water state. Note the positive feedback where aquatic vegetation takes up nutrients from the water column and stores it in biomass and sediments, starving water column algae of nutrients and keeping turbidity low. Similarly, aquatic plants trap sediment, preventing resuspension into the water column, which also acts to keep water column nutrients and turbidity low. Note that in this model fish stocking is excluded and the heightened lake levels are associated with a reduction in fluctuation.

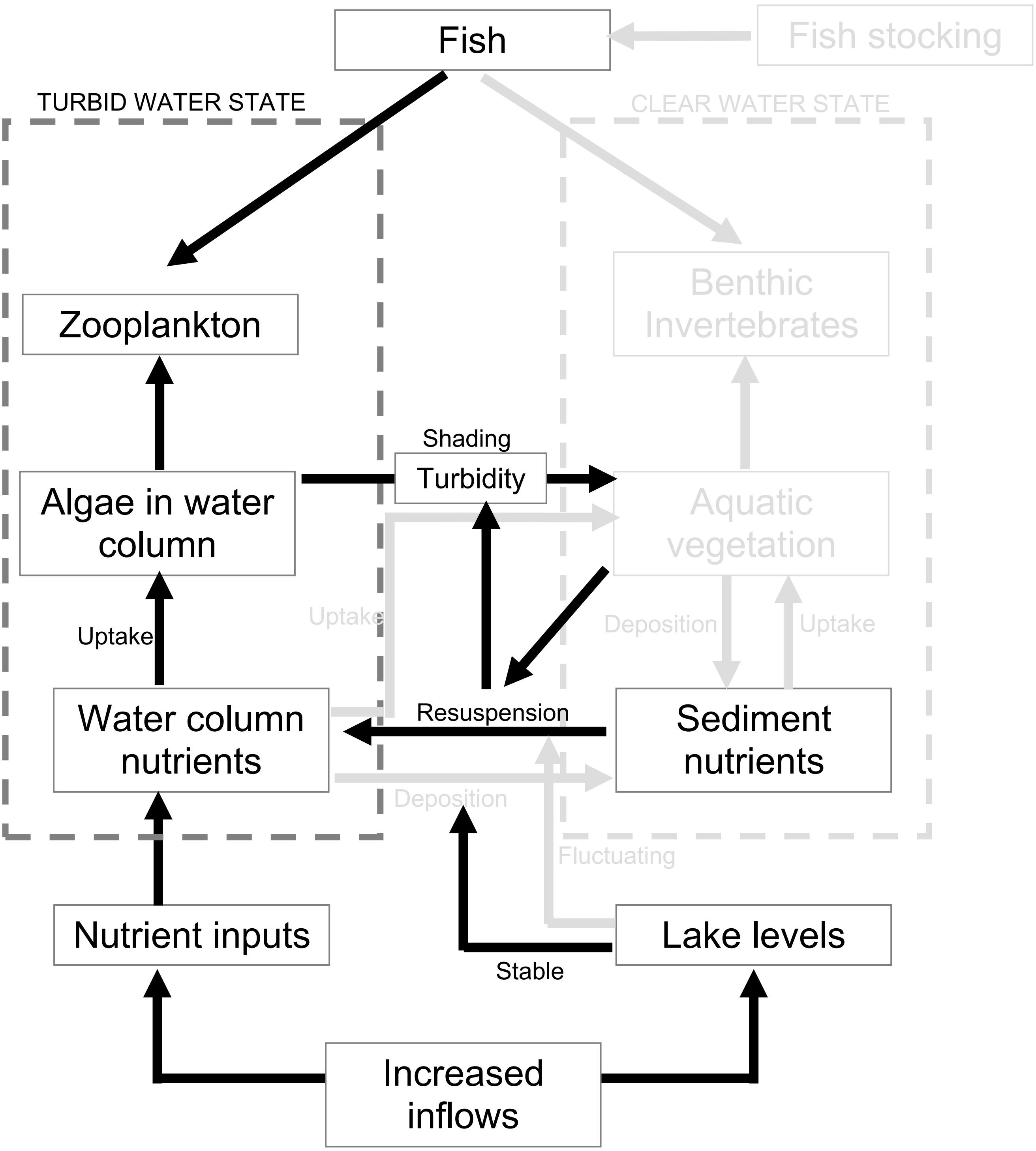

Figure 4. Conceptual model of the major drivers operating when shallow lake ecosystems are in a turbid water state. Note the positive feedback where increased algae in the water column increase turbidity and 'shade out' aquatic vegetation. The loss of this vegetation then releases nutrients, and allows sediment to be resuspended, further increasing water column nutrient levels and turbidity. Note that in this model fish stocking is excluded and the heightened lake levels are associated with a reduction in fluctuation.

The role of fish in the ecosystem dynamics of Devilbend Reservoir is not clear, although it is known that there are large populations of redfin perch present. Fish can affect ecosystem state, through predatory pressure on zooplankton. Reductions in zooplankton numbers can allow algal blooms, which may then shift the ecosystem from a clear water to a turbid water state (Figure 5).

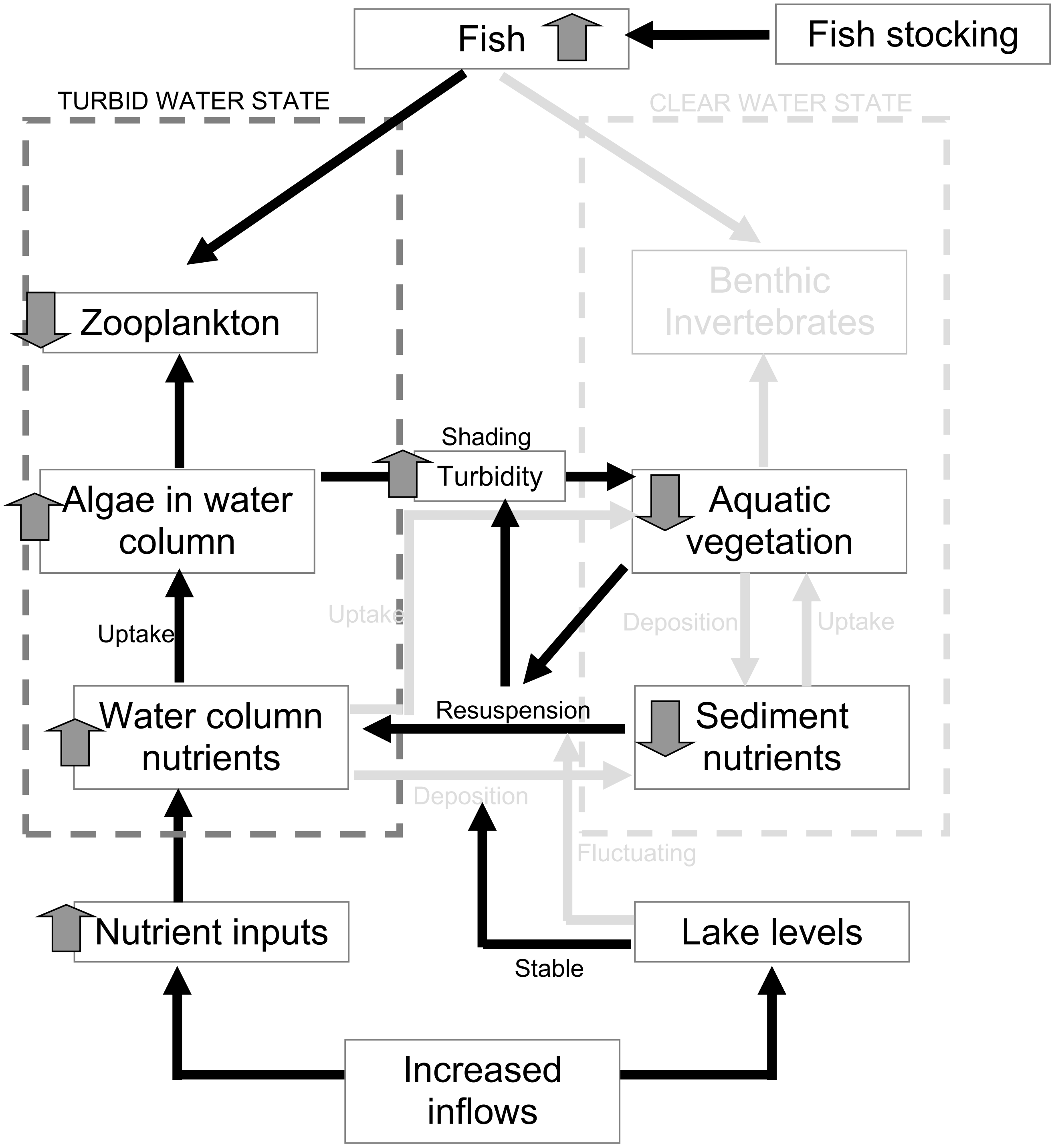

Figure 5. Conceptual model of the potential impacts of fish stocking on the large water bodies in the DNFR. Note that increased fish predation reduces zooplankton abundance, allowing algae to proliferate in the water column. Increased water turbidity from algae acts to 'shade out' aquatic plants, triggering a negative feedback which results in further nutrient release and sediment resuspension. Note that the in this model the heightened lake levels are associated with a reduction in fluctuation.

2.3 Identification of management focii

A large number of attributes can be monitored in shallow lake ecosystems of the type present in DNFR, and are summarized in more detail in Appendix One. The objective here is the ability to detect broad changes in ecosystem state in response to changes in management of the water bodies. Based on the DNFR Management Plan (2010), there are two major changes proposed to lake management.

1. Managing water levels in Bittern and Devilbend Reservoirs. The Management Plan proposes altering the inflows to the lake through re-routing inflows from the existing bypass channel. This will impact both on water levels within the water bodies but also on water quality (considered separately below).
2. Introduction and maintenance of a recreational fishery of salmoniids.

The summary below provides an overview of the proposed changes to management and their potential effects on a range of ecosystem factors in the DNFR. Section 2.4 then summarises the variables selected as monitoing foci.

2.3.1 Water levels

In their report for Melbourne Water titled Abandonment of Devilbend Reservoir 2004, Stage 2 Hydraulics, Water Quality and Management Plan, GHD made the following conclusions from conducting a number of studies pertaining to water level:

- Maintaining high water levels in Bittern Reservoir are not sustainable with its existing catchment runoff.
- Maintaining high water levels in Devilbend Reservoir reservoir is sustainable under existing catchment runoff conditions, but provision of diversion works will enhance the operator's ability to control water levels in the reservoir.
- Potential for reduced water released downstream.

The levels of both of the main reservoirs in the Reserve dropped between 2005 and 2010, but rose considerably over the winter of 2010. Lower water levels in the main reservoir are of some concern because of an increasing disconnection between marginal wetland vegetation (which provides important habitat for aquatic species) and the standing water in the reservoir. This is of a lesser concern in Bittern Reservoir, where overall shallower water levels have allowed the development of emergent vegetation in the water body itself. In both water bodies macrophyte species are able to extend their range as the waterbodies shallow, and provide important habitat for aquatic species.

The Devilbend Natural Features Reserve Management Plan (2010) recommended that environmental flows be restored to the two Reservoirs through allowing part of the flow of Devilbend Creek to enter the reservoirs. These flows are intended to:

- Maintain existing water dependent vegetation communities
- Maintain habitat values for waterbirds and shore birds
- Maintain habitat values for native fish
- Prevent excessive shore erosion

This change in management by diversion of the catch drains to maintain water levels will aim to maintain a range between which levels will fluctuate and which ensure agreed downstream flows. This change in management may result in a range of impacts/influences through direct modification of habitat, but the effects of increased and more consistent water levels alone are likely to be positive for waterbird numbers, retention and establish of submerged aquatic plant communities, shoreline vegetation and habitat. The impacts of increased stability in water levels through time are not considered in an more detail here.

2.3.2 Water quality

In their report for Melbourne Water titled Abandonment of Devilbend Reservoir 2004, Stage 2 Hydraulics, Water Quality and Management Plan, GHD made the following conclusions from conducting a number of studies pertaining to water quality.

- There is a high risk of water quality problems occurring in Bittern Reservoir under existing catchment conditions.
- There is a moderate risk of water quality problems occurring in Devilbend Reservoir under existing catchment conditions.

The water quality in the reservoir has not been measured in any comprehensive way over time. However anecdotal observations of algal growth are consistent with reasonably high levels of inputs into all of the water bodies. Reinstating the Devilbend Creek inflow to the reservoirs is likely to negatively impact on the water quality in both water bodies. Historically Devilbend Creek has had poor water quality (high in both nitrogen and phosphorus). Reinstating the creek's flow into the Reservoirs may create a risk of algal blooms. Given the past history of land-use in the area, there is also a possibility of residual organochlorine insecticide and heavy metal residues accumulating in the aquatic food chain. Any such management should be preceded by monthly sampling of creek water quality for a full year, and then review of the water quality data to allow modeling of the likelihood of algal blooms. There is provision in the DNFR Management Plan (2010) to use biofiltration wetlands to treat the water entering the reservoirs from Devilbend Creek. This has a number of difficulties, including the high cost of creating efficient biofiltration wetlands. Wetlands impacts by high levels of nitrogen and phosphorus are likely to have less of the high value wetland vegetation characterizing parts of the DNFR (these are mainly associated with nutrient poor conditions), and are a likely to contain exotic species (which more readily adapt to high nutrient conditions). In addition, treatment wetlands are likely to require significant disturbance (mainly plant biomass removal) in order to maintain their nutrient absorbing capacity. This disturbance may be at odds with other management objectives for the DNFR.

1.2.5 Recreational fishery for salmonids

Walker and Thompson (2009) found that redfin perch were the only angling fish present in large numbers in the Reserve. In 2010 brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) were introduced into Devilbend Reservoir, based on the recommendations of the Translocation Evaluation Panel referring to the Translocation Risk Assessment Report (Lloyd and Newall 2009). It is unclear what other impacts recreational fishing, and associated activities will have on other aquatic biota in Devilbend.

The maintenance of a stocked salmonid fishery, and its impacts on aquatic ecosystems are unclear at this point, and would warrant investigation that is subjected to scientific peer review. Highly stocked fisheries are often characterised by high levels of competition between stocked fish, native fish and aquatic invertebrate reliant waterbirds. High rates of stocking of Devilbend Reservoirs will create a risk of promotion of algal blooms through impacts on algal feeding invertebrates. In addition to competition between fish and aquatic birds for food, it is unclear to what degree fishing activity would interfere with breeding activity of waterbirds in this area. Several species which breed in the Reserve, including white-bellied sea eagles, are considered relatively shy breeders, and it is possible that their breeding is enhanced or maintained by low levels of public access. Provision is made in the DNFR Management Plan (2010) for some areas to be put aside as refugia in order to minimize the impacts of public access.

Both brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) species are exotic temperate fish with documented significant negative effects on Australian native fish. Salmonids were introduced into DNFR largely on the recommendations of Lloyd and Newall (2009). The waterbodies in DNFR are unlikely to support a significant fishery of either of the salmonid species, although with stocking both have the potential to cause significant ecological impacts.

Salmonids in general are adapted two relatively cool waters. Lloyd and Newall (2009) correctly identified the critical thermal maxima (CTM) for rainbow trout as approximately 24 - 26°C with 10-22°C as an optimal range, and brown trout as 23.5°C - 26.7°C, with an optimal range of 8 - 17°C. It is important to note that the CTM vales represent hard upper limits for these fish, who are stressed at temperatures above 22 and 17 degrees Celsius. The Victorian Department of Primary Industries identifies the optimal range for brown trout as between 4-19 degrees Celsius and for rainbow rout as 10-22 degrees Celsius (http://new.dpi.vic.gov.au/fisheries/). These values can be considerably lower when dissolved oxygen levels are low (Molony 2001). There has been no detailed summer mapping of water temperatures in Devilbend, but it is likely that the vast majority of the Reservoir is warmer than 22 degrees in summer, or that there is only a very small area (in the deepest part of the lake) which might act as a thermal refugia. Beyond their optimal range both salmonid species exhibit poor growth and increased susceptibility to disease (particularly fungal infections). A number of international reviews have shown that salmonids are unlikely to persist in waters warmer than 20 degrees Celsius (Jonsson and Jonsson 2009). The recent review of the effects of climate change on Australia, identified salmonid fisheries as likely to be unsustainable in mainland Australia in the short to medium term, particularly at lower altitudes (Garnaut 2008).

The report by Lloyd and Newall (2009) suggests that salmonids will have minor effects in Devilbend if introduced. In part this is because undue emphasis is placed on the benthic macroinvertebrate portion of their diet. Rainbow trout in particular feed heavily on zooplankton and therefore can suppress zooplankton numbers, allowing increased phytoplankton growth, potentially to bloom levels. In addition the interactions between salmonids and perch are largely unknown in a system like Devilbend. One potential scenario is that the redfin perch adults will be subsidized by being able to feed on stocked trout, allowing increased breeding of the redfin perch. Large numbers of redfin could in turn provoke a trophic cascade and the risk of algal blooms. The conclusion that "Stocking alone (at the levels contemplated with the large Devilbend and Bittern Reservoirs) is unlikely to result in the complex ecosystem level impacts such as restructuring food webs…" appears to be largely speculative. There is certainly no published literature which would lead to such a conclusion and the papers referred to by Lloyd and Newall (2009) are two conceptual papers without field data (Lloyd et al 1998 & 2000) and two Northern Hemisphere studies of entirely different species. (Berg et al 1997; Benndorf 1990). It is not at all clear that salmonids would behave in similar ways to the existing redfin perch in the system.

The other potential risk identified by Lloyd and Newall (2009) is that of predation on, and competition with, native fish species in the Devilbend catchment. They conclude "In the event of escape the introduction of new predators to the creek system are likely to have ongoing consequences for the existing fish community" and that "The introduction and survival of new predators to the creek system will have consequences for the existing Dwarf Galaxiid population." The conclusion (Lloyd and Newall 2009) that redfin perch will be displaced by salmonids that will feed in the same way as the perch is unsupported by any international or national study and is very unlikely considering the large differences in fish form and life history. They conclude that the lake stocking has potential to result in salmonids impacting on the remainder of the catchment and that "…stockings are likely to trigger a referral to DEWHA to assess if this is a controlled action on Dwarf Galaxias (under the EPBC Act), given the current spill frequencies."

Salmonids are considered a cold water fish, meaning they require low water temperatures and high levels of dissolved oxygen in order to survive. Appraisal of the habitats present in the Reserve suggests that salmonids would not perform well due to the potential for high water temperatures and poor water quality leading to low oxygen levels. In addition, these species are known to have strong negative effects on the rare *Galaxias truttaceus*, which is present in low numbers in the system. This system is likely to be unsuitable for a salmonid fishery due to the nature of the habitats and water quality, in addition to the risk to native species. We are in agreement with Lloyd and Newall (2009) that predicting impacts of salmonid stocking is "… complex to understand and little information is available to provide valid input to "… risk assessment. There appears little basis therefore to conclude that there will be no ecosystem consequences of the recent salmonid introduction.

An additional concern for management of a recreational fishery at DNFR is that increased access would facilitate the spread of marron from the Reserve. It would be extremely challenging, but desirable, to remove marron from the system with regards to the broader biosecurity of nearby standing waters in Victoria. Marron are abundant in the two main water bodies on the Reserve and in the connecting catchdrain. There are numerous anecdotal reports of them also being present in Devilbend Creek downstream of the Reserve. Marron are considered a significant threat to freshwater biodiversity. Within this system there appears to be evidence that they are excluding the native yabby from many areas of the main reservoir and Bittern Reservoir. While yabbies and marron can co-exist, they exhibit considerable overlap in diet and habitat preferences. It would be extremely challenging, but desirable, to remove marron from the system with regards to the broader biosecurity of nearby standing waters in Victoria. The provision for increased access to the reservoirs in the DNFR Management Plan (2010) increases the likelihood of accidental or deliberate translocation of animals to other areas in Victoria.

2.4 Potential monitoring targets

2.4.1 Water quality monitoring

Details on approaches to water quality monitoring appear in Appendix One. The likely water quality parameters of interest are indicated in Table 1. Water quality is of broad interest here as it is likely to be relatively sensitive to management interventions.

Reductions in water levels may increase wave action on the sediment which can resuspend nutrients (measured as N and P, with a concomitant increase in conductivity) and sediment (measured as turbidity). Nutrients may also increase as a result of changes to the inflows to the water bodies. Large increases in these variables are likely to indicate major changes in the aquatic habitats and favour the dominance of phytoplankton over aquatic plants. Changes in fish communities may also increase phytoplankton and result in algal blooms. Algal blooms may be measured both by direct observation (and collection for further analysis where necessary) and by presence/absence tests. Blooms of blue-green algae may pose a risk to human health and can be identified by the distinctive colour. Excess growth of algae can result in reduced oxygen levels in the water, which can have negative impacts on fish and other aquatic animals.

2.4.2 Wetland vegetation monitoring

Wetland vegetation represents an important natural value for the Reserve. Detailed vegetation surveys require taxonomic knowledge which can make such surveys expensive. In addition, rates of change for vegetation are often relatively slow and so may not be sufficiently sensitive to guide management.

2.4.3 Monitoring of aquatic invertebrates

Aquatic invertebrates (both zooplankton and benthic invertebrates) are commonly used to indicate the health of waterways. In many stream systems this is appropriate because sensitive taxa such as stoneflies and mayflies are heavily impacted by reductions in water quality. Lake faunas are generally less sensitive to water quality impacts, and in the case of the standing water bodies in DNFR the communities are typified by a generalist fauna with relatively few sensitive taxa.

2.4.4 Monitoring of fish communities

Fish communities in the Reserve are of great interest and include a number of species of interest. However the main species of concern are extremely difficult to survey due to their low densities and cryptic nature. Changes in populations of the main predatory fish (redfin perch, salmonids) would require broad scale quantitative sampling in the main water bodies. This would require considerable effort by trained staff.

2.4.5 Monitoring of waterbirds

Monthly bird surveys have been conducted by Birds Australia and PENBOC since May 2004. Bird communities have been used to indicate ecosystem health, but gaining a quantitative assessment of their responses to management can be difficult due to high background variability in bird numbers and the relatively slow response time in these long lived animals. Birds may however provide an indicator of the effects of disturbance, providing there is sufficient long term data (as there is in this case).

Table 1: Commonly used parameters for monitoring aquatic habitat condition (see Appendix 1 for further detail.)

Characteristic or parameter	Reason for monitoring
Conductivity	Dissolved salts in the water (conductivity) affect the survival of aquatic life. High levels of conductivity indicate the presence of ions – which may be nutrients or metals.
Dissolved oxygen	Oxygen in the water is essential for the survival of most organisms. It can also indicate organic contaminants and over-enrichment of lakes.
pH	Acidity or alkalinity of the water affects the survival of aquatic life.
Phosphates	Amount of phosphate in the water indicates nutrient status, organic enrichment and consequent health of the waterbody.
Nitrates	Amount of nitrate in the water indicates nutrient status, organic enrichment and consequent health of the waterbody.
Temperature	Rapid temperature changes of the water stress aquatic life. Temperature is also important for the interpretation of dissolved oxygen concentrations and as an indicator of the formation of layers of water in lakes.
Turbidity	Cloudiness of the water caused by suspended particles affects the survival of aquatic life. It indicates erosion and habitat destruction.
Algae	Depending on their abundance and type, algae can indicate good environmental health, or over-enrichment of a waterbody with nutrients, or poor condition of the catchment. Some blue-green algae can pose a risk to human health.
Riparian vegetation	Quality of shore line vegetation affects ecosystem health, amount of erosion, etc.
Invertebrates	Abundance and diversity of aquatic invertebrates can indicate the health of waterways.
Fish	Abundance and diversity of fish species can indicate health of waterways, and are often of conservation interest.
Other waterway fauna (ie. Water birds)	Waterbirds are of conservation interest, and can indicate effects of anthropogenic disturbance.

2.5 Strategic foci of aquatic ecosystem sampling in DNFR

The aim of this report was to identify clear and measureable objectives that can be used to evaluate and monitor changes in the aquatic habitats and impacts on flora and fauna, and can be applied to an adaptive management model. In addition, we sought to minimize cost and maximize the potential for local community groups to be engaged in the sampling. Figure 6 indicates the main factors responding to the proposed and current management interventions.

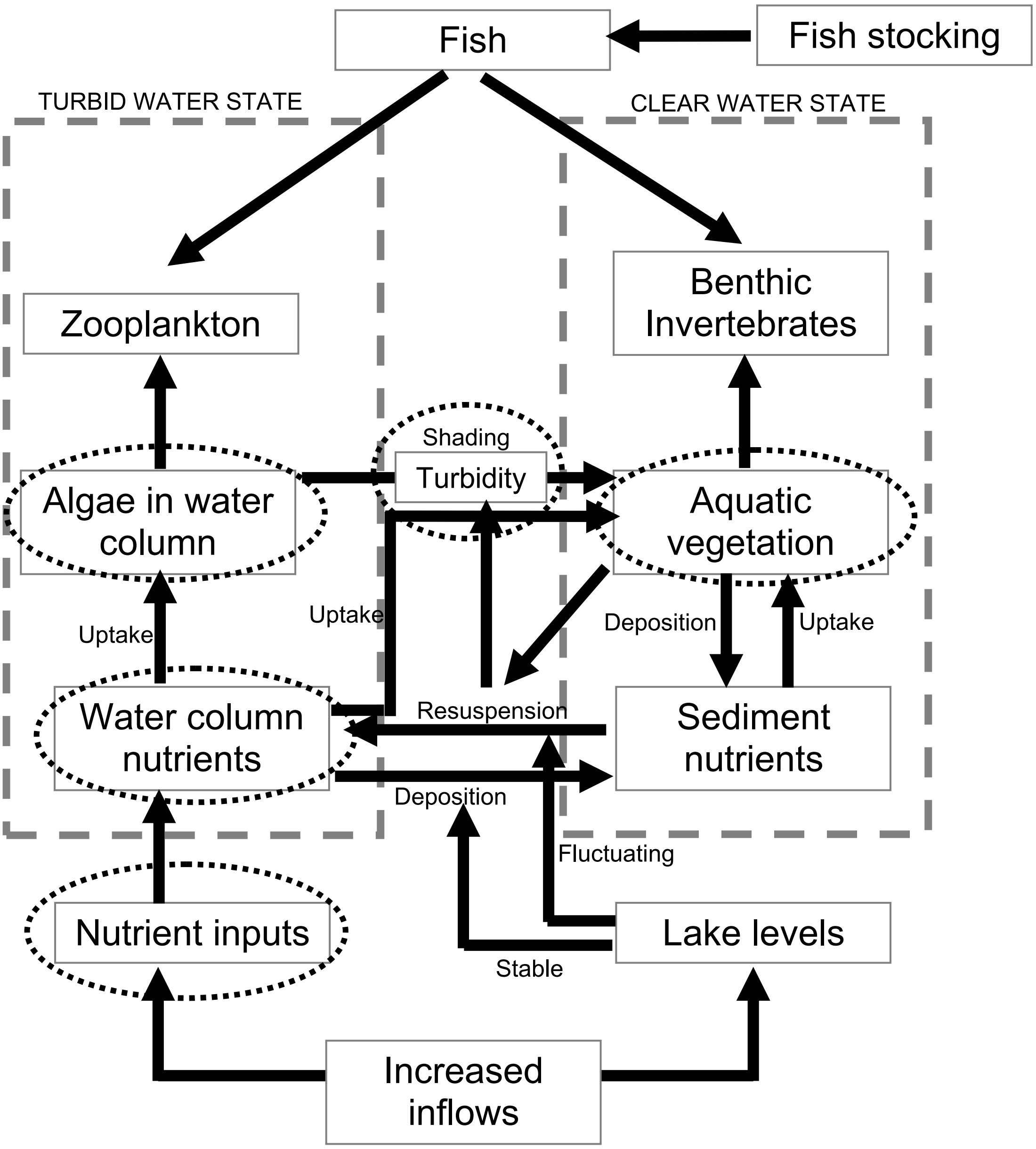

Figure 6. Conceptual model of the potential major drivers of ecosystem condition in the large water bodies in the DNFR. Targetted monitoring variables are indicated by dotted ellipses.

Water quality parameters were included due to their relative ease of measurement, and critical causative role in inducing ecosystem shifts. Measuring water quality in the inflow waters and in the major water bodies will allow an early indication of the potential for algal blooms and the efficacy of any water treatment used as per the DNFR Management Plan (2010).

Algae in water column are a relatively sensitive indicator of ecosystem condition, particularly where there are concerns over potentially high nutrient inputs. Measuring algal biomass (as chlorophyll in the water column) is suggested here as it will indicate not only the effects of nutrient inputs, but also the potential food chain impacts of increases in fish predation. Algal biomass will differ considerably through the year, and long time series of monthly data are likely to be needed to clearly interpret patterns.

Turbidity indicates the amount of light which is able to pass through the water column. Turbidity is a sensitive indicator of potential loss in water clarity that may result from increased algal biomass or from resuspension of sediments due to loss of aquatic plants.

Areal extent of emergent and submerged aquatic plants as outlined above may respond to increases in nutrients or indirect effects of fish predation in the aquatic food chain. Reductions in the extent of aquatic plants, particularly in the deeper part of the lake may indicate potential ecosystem shifts.

Detailed sampling of zooplankton and macroinvertebrates is not recommended as a part of regular monthly sampling. The generalist nature of the communities found in the DNFR means that they are unlikely to show strong effects of changes in management, unless the taxa were indentified to a very high level of taxonomic resolution. We do not consider that this is justified for this system, where the attributes indicated above are likely to be adequate to assess broad changes in ecosystem condition.

Sampling fish populations is also very difficult to do in a quantitative manner unless it is carried out by experts. We do not recommend sampling the fish communities unless it is carried out in a highly quantitative way by qualified fisheries biologists.

2.6 Integrated monitoring program

Determining a monitoring program for the water bodies in the DNFR requires balancing the need for high temporal resolution sampling (monthly) and the need for detailed (and relatively expensive) detailed sampling of communities. In order to reconcile those two objectives we recommend the following:

1. A repeat of the detailed survey carried out by Walker and Thompson (2009) in order to assess the potential impacts of the introduction of salmonids into the reservoirs. This should be repeated again if the Devilbend Creek inflow is restored to the reservoirs. See Section 3 for the proposed methods.

2. Ongoing high temporal resolution studies (monthly) of the water bodies in DNFR with the assistance of community groups. See Section 4 for the proposed methods.

Table 2. Summary of ecosystem attributes (drivers and responses) proposed as monitoring foci for the water bodies in the DNFR.

Management change	DRIVERS			RESPONSES/VALUES			
	Ecosystem attribute	Predicted change	Appropriate indicator	Ecosystem value	Predicted change	Appropriate indicator	Appropriate monitoring approach
Introduction of flows from Devilbend Creek	Nutrient concentrations (N and P)	Increased	Monthly water quality (lakes and inflow)	Submerged aquatic vegetation	Possible decline	Areal extent	Annual survey
	Water column algae	Increased	Monthly chlorophyll	Clear water conditions	Possible ecosystem shift	Water clarity	Monthly water clarity
	Turbidity	Unknown	Monthly water clarity				
Continued stocking with salmonids	Water column algae	Increased	Monthly chlorophyll	Submerged aquatic vegetation	Possible decline	Areal extent	Annual survey
	Turbidity	Unknown	Monthly NTU	Native fish biodiversity	Probable decline	Fish abundance	Annual survey
	Disturbance	Increased	N/A	Native bird biodiversity	Possible decline	Bird diversity	Ongoing surveys

PART THREE: Second annual biological survey

3.1 Introduction

The aim of this report is to identify clear and measureable objectives that can be used to evaluate and monitor changes in the major aquatic habitats as a result of changes in management. This section outlines a detailed surveying methodology which would be executed by an external consultant with training and experience in freshwater ecology. We do not consider that the detailed research proposed here is appropriate for community groups, and consider it desirable that sampling should be carried out by an impartial third party. The sampling protocols and methodologies outlined here largely follow Walker and Thompson (2008), which should be referred to for more detail. Any survey completed should follow all of those methods, allowing comparison with all aspects of that previous study. As such, it is not appropriate to prioritise particular parts of the surveying methodology. It is our recommendation that detailed surveys should be carried out as follows:

- In the summer of 2010 in order to assess the immediate effects of salmonid introductions.
- In the summer immediately after the restoration of inflows from Devilbend Creek.

3.2 Frequency and timing of sampling

The monitoring program recommended here requires intensive sampling annually. This is particularly critical as management interventions (such as stocking with sports fish) are likely to generate rapid changes in the system. Sampling should take place in late spring/early summer (late October) annually, in order to maximize the potential to detect species of interest such as amphibians, and to incorporate plant flowering and seeding (to facilitate identification) and macroinverterbate productivity.

3.3 Survey methodology

3.3.1 Background information required

The existing reports on the Reserve have carried out the majority of background information needed to inform the development of ongoing sampling regimes. Previous material outlines the major land uses, pollution sources, 'hot spots' with the potential to affect the health of the waterway, and provide maps of the Reserve (Part One). Monitoring can be carried out within the context of the information provided in those reviews.

3.3.2 Survey locations

Sampling locations have been selected to represent the major habitats present in the main reservoirs, and in order to allow comparison to the earlier work by Walker and Thompson (2008).

3.3.3 Water quality monitoring

Water quality has been traditionally poorly sampled in Devilbend Reservoir. Water quality is of broad interest here as it is likely to be relatively sensitive to management interventions. The proposed sampling here is more detailed than that carried out by Walker and Thompson (2008). The objectives of the sampling are to ascertain the nutrient status of the lake, and also to identify any ecotoxicological issues in the water body.

We recommend a once-off sampling for heavy metals and pesticides in the water column and the sediments of Bittern and Devilbend Reservoirs. This would constitute a separate study, and may or may not lead to ongoing monitoring of toxicants, depending on the report's recommendations. This is recommended to provide some indication of the potential longer term impacts of poor water quality from the Devilbend Creek inflow.

The intensive surveys should include sampling of water quality should include pH, temperature, conductivity, ammonia, nitrate/nitrite, total nitrogen, dissolved reactive phosphorus, total phosphorus, water column chlorophyll and Secchi depth (turbidity). Because the lakes are generally shallow, it is likely that both waterbodies are well mixed, and therefore sampling is only recommended at a small number of locations (Figure 7). These more detailed surveys would allow an external validation of the higher intensity, but less accurate techniques used as part of the community-based sampling (Part Four).

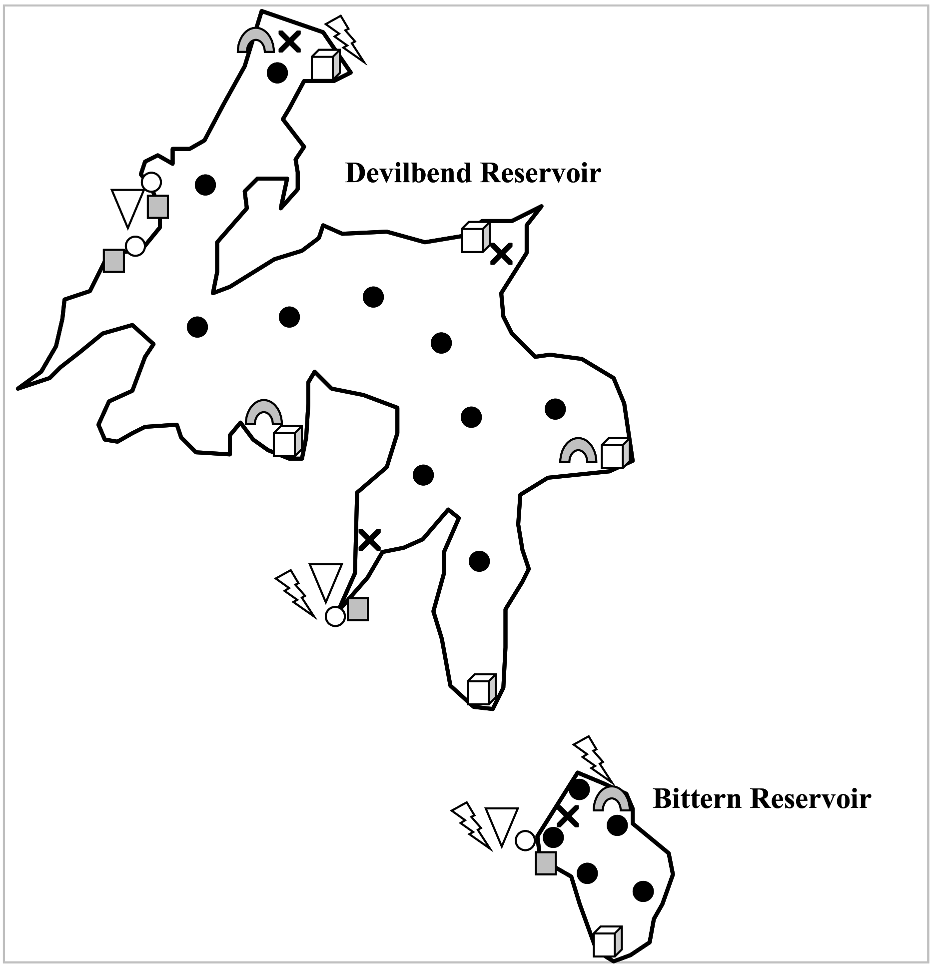

Figure 3.1: Recommended sampling locations on the two main waterbodies in DNFR.

✕ ***Water quality sampling locations***
○ ***Benthic macroinvertebrate sampling locations***
▽ ***Amphibian sampling locations***
ϟ ***Electro-fishing locations***
● ***Zooplankton sampling locations***
▨ ***Freshwater crayfish sampling locations***
☐ ***Fish trapping locations***
◠ ***Seine netting locations***

3.3.4 Wetland vegetation monitoring

Wetland vegetation represents an important natural value for the Reserve. Detailed vegetation surveys were carried out in Walker and Thompson (2008). Surveys of areal extent of vegetation should be repeated as part of the detailed surveys, consistent with the recommendation of McCaffrey et al. (2008). Surveying of wetland communities should include all of the Reserve.

3.3.5 Monitoring of aquatic invertebrates

Aquatic invertebrates (both zooplankton and benthic invertebrates) are commonly used to indicate the health of waterways. Lake faunas are generally less sensitive to water quality impacts, and in the case of the standing water bodies in DNFR the communities are typified by a generalist fauna with relatively few sensitive taxa. However detailed surveys of these components of the community may indicate large changes in the lake food web, particularly if sports fish are introduced. Declines in the main zooplankton algal grazers (particularly *Daphnia* spp.), may provide an early indication of an algal bloom in the lake. Sampling should follow the methods of Walker and Thompson (2008) at the locations indicated in Figure 3.1.

3.3.6 Monitoring of fish communities

Fish communities in the Reserve are of great interest and include a number of species of interest. However the main species of concern are extremely difficult to survey due to their low densities and cryptic nature. Changes in populations of the main predatory fish (redfin perch, salmonids) will require broad scale quantitative sampling in the main water bodies. This was not carried out by Walker and Thompson (2008) but is recommended in future surveys. As the perch and salmonids in this system are the most likely source of risk to management of the indigenous fish species in the DNFR, it is imperative that they are adequately surveyed in future work. This should include gill net surveys of the main Reservoir in addition to the seine net, electro-fishing and fish trapping surveys (following Walker and Thompson 2008, Figure 7). Electrofishing and fish trapping should be targeted to locations such as the catch-drain in order to determine whether dwarf galaxias is still present. This issue will need to be addressed in implementation of catch drain diversions and associated works – on-going sampling locations will need to be reviewed.

3.3.7 Monitoring of amphibians

An amphibian survey was conducted in early to mid October and again in late November by Walker and Thompson (2008), using recordings of frog calls. This survey should be repeated annually, with the intention of assessing the status of amphibians in all of the water bodies in the Reserve. In particular surveys should target growling grass frog habitat. Given the high conservation value of this species and its relatively cryptic nature, these surveys should be carried out by an appropriately qualified and experienced researcher in the first instance. If numbers of this species increase in the future then it may be appropriate to carry out ongoing survey work via programs such as the community-based Frog Watch Program.

3.3.8 Monitoring of waterbirds

Monthly bird surveys have been conducted by Birds Australia and PENBOC since May 2004. It is assumed that these surveys will continue and will be included in future reporting (see Section 4.4.1 below).

3.4 Ongoing synthesis and reporting

3.4.1 Synthesis and reporting methodology

The contracted consultant will each year summarize monitoring data collected through community monitoring (see Section 4, below), and analyze for events which exceed water quality thresholds. Similarly bird data will be summarized annually. Should data suggest the need for additional monitoring or a more detailed study; this will be determined at the discretion of Parks Victoria, in consultation with relevant experts where needed.

3.4.2 Administrative and oversight arrangements

A full report will be supplied to Parks Victoria by the end of May each year. Contracts for provision of services by the external consultant will be managed by Parks Victoria and in consultation with community groups as agreed.

3.5 Costings

The nature of these surveys, and their need to be consistent with the previous study by Walker and Thompson means that it is not appropriate to indicate particular priorities. The survey recommended is the minimum needed to provide data appropriate to an assessment of the type of management interventions suggested in Part 2. The costings provided are for a single survey, which should be repeated in association with any major changes in management as proposed earlier in this section.

Costings are indicative and supplied by EcoWise Consulting. They are not binding quotes and may fluctuate.

Toxicology sampling and analysis (one off cost)	*$ 5 000.00*
Water quality sampling and analysis	*$ 5 880.00*
Macroinvertebrate sampling and analysis	*$ 5 720.00*
Fish survey	*$ 3 120.00*
Amphibian survey	*$ 1 040.00*
Wetland plant mapping	*$ 1 760.00*
TOTAL COST (single survey)	**$17 520.00**
Summary of community data (annually)	*$ 500.00*
Analysis and reporting(annually)	*$ 1 000.00*
TOTAL COST (review and summary of community data)	**$ 1 500.00 p.a.**

PART FOUR: Community based monitoring

4.1 Introduction

The aim of this report is to identify clear and measureable objectives that can be used to evaluate and monitor changes in the major aquatic habitats and impacts on flora and fauna, and can be applied to an adaptive management model. In many cases the approaches needed to sample some parts of the system (Part 2) are likely to be costly and may not be needed to monitor changes in the major aquatic habitats.

4.2 Survey scope

4.2.1 Water quality monitoring

Details on approaches to water quality monitoring appear in Appendix One. The likely water quality parameters of interest are indicated in Table 1. Water quality is of broad interest here as it is likely to be relatively sensitive to management interventions. In addition, many parameters can be simply measured using readily available materials (see Section 4.3 below). Reductions in water levels may increase wave action on the sediment which can resuspend nutrients (measured as N and P, with a concomitant increase in conductivity) and sediment (measured as turbidity). Nutrients may also increase as a result of changes to the inflows to the water bodies. Large increases in these variables are likely to indicate major changes in the aquatic habitats and favour the dominance of phytoplankton over aquatic plants. Changes in fish communities may also increase phytoplankton and result in algal blooms. Algal blooms may be measured both by direct observation (and collection for further analysis where necessary) and by presence/absence tests. Blooms of blue-green algae may pose a risk to human health and can be identified by the distinctive colour. Excess growth of algae can result in reduced oxygen levels in the water, which can have negative impacts on fish and other aquatic animals.

4.2.2 Wetland vegetation monitoring

Wetland vegetation represents an important natural value for the DNFR. Detailed vegetation surveys require taxonomic knowledge which can make such surveys expensive. In addition, rates of change for vegetation are often relatively slow and so may not be sufficiently sensitive to guide management. We do recommend monitoring of the areal extent of vegetation but not of composition. This may be able to be carried out by the community monitoring program. We recommend that at four locations in the Devilbend Reservoir (see 1-4 on Figure 8), the extent of aquatic vegetation be marked with permanent stakes, and the extent of the beds be monitored through time in this fashion. If there are available aerial photographs of the area (or equivalent regularly updated images via media such as Google Earth ©) it will be possible to map changes in areal extent of aquatic plants on at least annual scales.

4.2.3 Monitoring of aquatic invertebrates

Aquatic invertebrates (both zooplankton and benthic invertebrates) are commonly used to indicate the health of waterways. Lake faunas are generally less sensitive to water quality impacts, and in the case of the standing water bodies in Devilbend Reserve the communities are typified by a generalist fauna with relatively few sensitive taxa. It is our opinion that monitoring these communities adequately would require extensive effort and the involvement of trained taxonomic experts. We believe that this cost is not justified, and do not propose any macroinvertebrate monitoring as a part of the community monitoring program. Monitoring as a part of a Waterwatch program in the DNFR may be carried out, but is unlikely to provide useful information on this system, which is largely characterized by tolerant taxa.

4.2.4 Monitoring of fish communities

Fish communities in the Reserve are of great interest and include a number of species of interest. However the main species of concern are extremely difficult to survey due to their low densities and cryptic nature. Changes in populations of the main predatory fish (redfin perch, salmonids) would require broad scale quantitative sampling in the main water bodies. Such sampling would require considerable effort and the involvement of trained fish biologists (see Part 3).We believe that this cost is not justified, and do not propose any fish monitoring as a part of the community monitoring program.

4.2.5 Monitoring of waterbirds

Monthly bird surveys have been conducted by Birds Australia and PENBOC since May 2004. It is assumed that these surveys will continue and will be included in future reporting.

4.3 Technical elements and survey methodology

4.3.1 Background information required

The existing reports on the Reserve have carried out contain (or present) the majority of background information needed to inform the development of ongoing sampling regimes. Previous material outlines the major land uses, pollution sources, 'hot spots' with the potential to affect the health of the waterway, and provide maps of the Reserve (Part One). Monitoring can be carried out within the context of the information provided in those reviews.

4.3.2 Survey locations

Sampling locations have been selected to represent the major habitats present in the main reservoirs. As the reservoirs are generally shallow and exposed to winds, the water in the reservoirs is likely to be well mixed, meaning that sampling at a small number of conditions is sufficient. We recommend sampling according to the methods outlined below at four locations (Figure 8; 1-4) and a single location on Bittern Reservoir (Figure 8; 5). Note that the small water bodies in the Reserve are of lower natural value than the two main reservoirs and are not recommended for regular sampling. In addition, sampling at three locations on the catchdrain (Figure 8; A-C, when flowing).

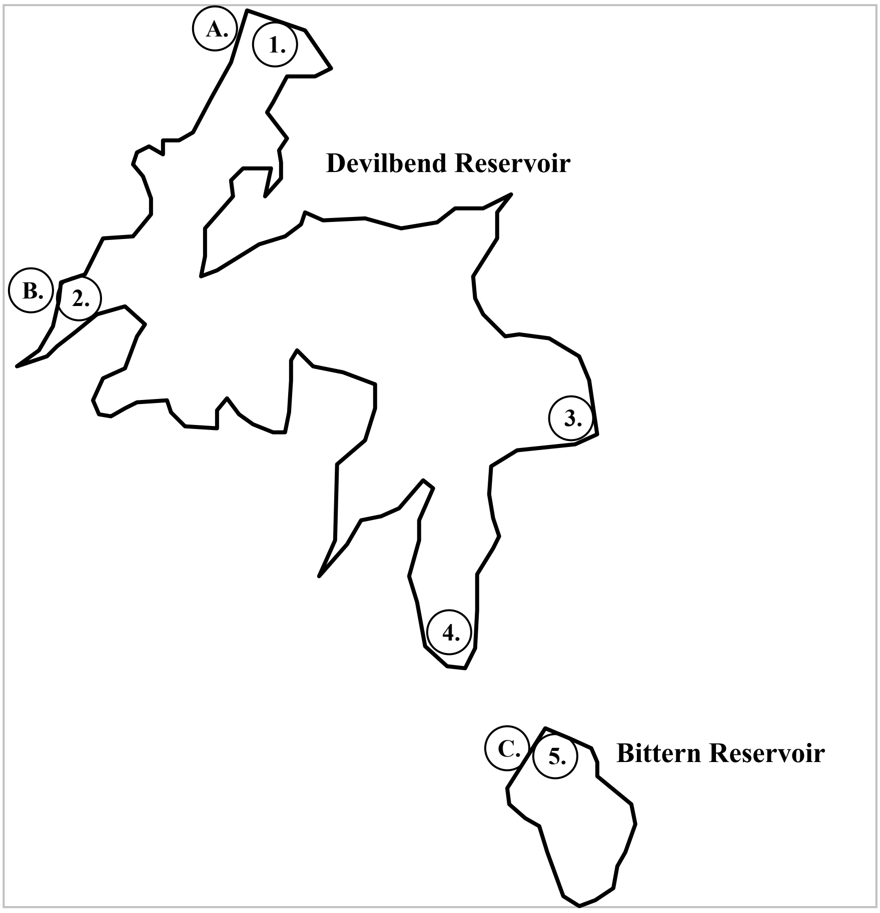

Figure 8: Recommended sampling locations on the two main waterbodies (1-5) and the catchdrain (A-C) in Devilbend Natural Features Reserve.

4.3.3 Sampling intervals

Water quality monitoring should occur on a **<u>monthly basis</u>**, at a regular time of day (some water quality attributes change with time of day) according to the methods outlined in Section 4.3.4, with results synthesized and summarized as indicated in Section 4.4. The original brief suggested quarterly sampling, but the sampling proposed here is realistic in terms of cost and effort to be carried out monthly. Event based sampling of water quality in detail, fish communities, algal communities or aquatic vegetation may be required if threshold values are exceeded for key monthly indicators (see Section 4.4.1).

4.3.4 Survey methodology

The methods recommended for reasons of simplicity and consistency are based on those applied by the Australian Waterwatch program. This uses the LaMotte © brand Smart Streamwatch Water Quality Kit, with some additional tests for algae and nitrogen. Considerable literature on application of these tests is provided with the kit. Some external training is available by Melbourne Water (http://www.waterwatchmelbourne.org.au/). At the locations and sampling intervals outlined above the following should be carried out

- digital photograph taken of lake at each location
- water quality samples taken at each location according to the methods provided with the kit.
- data is entered in an appropriate fashion agreed upon with the external consultant completing the review (Section 3 above).
- where unusual features are obvious (e.g. fish kills, discoloured water, algal blooms) photograph these areas and collect samples of water or fish for freezing and later laboratory analysis. Inform Parks Victoria.

4.3.5 Equipment required

The LaMotte © Smart Water Quality Kit contains a colorimeter and tests for: dissolved oxygen, pH, phosphate, temperature, electrical conductivity and turbidity. Additional tests for algae and nitrate can be added.

The equipment is available from the Australian supplier for LaMotte, Vendart (http://www.vendart.com/smartkit.html)

Code 00258 LaMotte Smart Streamwatch Water Quality Kit
Code 6662/AWL LaMotte Algae Presence/Absence Kit
Code 5891 LaMotte Nitrate Nitrogen TesTab® Zinc reduction
Code WS-01 LaMotte Water sampler with extendable pole

4.3.6 Volunteer training

Training on the application of the tests and data entry and interpretation could be provided by external consultants, as determined by Parks Victoria, for community volunteers as requested by the Devilbend Foundation, the National Trust of Australia (Vic), Friends of Daangean and other interested community groups. However at the time of writing there was sufficient support via Melboure Water materials (http://www.waterwatchmelbourne.org.au/) to not require external training for the type of work proposed here.

4.4 Ongoing synthesis and reporting

4.4.1 Synthesis and reporting methodology

Data will be summarized in data sheets agreed upon between the community groups and the external consultant in charge of the annual review (Section 3 above) and entered into an ongoing database. This will include thresholds for the key water quality parameters, which, if exceeded will trigger contact from the community group to Parks Victoria. Such events may require additional monitoring or a more detailed study; this will be determined at the discretion of Parks Victoria, in consultation with relevant experts where needed. Annual review and synthesis will be provided by an external consultant who will be provided with the data in October of each year.

4.4.2 Administrative and oversight arrangements

Data will be collected and hosted by a community organization in consultation with Parks Victoria. Data will be backed up in full monthly and supplied to Parks Victoria by email. Where any water quality threshold is exceeded it is the responsibility of the community group to immediately inform the contact at Parks Victoria who will decide on further action.

4.5 Costings

4.5.1 Establishment costings

Initial purchase of Water Quality Kit.

Code 00258 LaMotte Smart Streamwatch Water Quality Kit	$ 200.00
Code 6662/AWL LaMotte Algae Presence/Absence Kit	$ 56.00
Code 5891 LaMotte Nitrate Nitrogen TesTab® Zinc reduction	$ 56.00
Code WS-01 LaMotte Water sampler with extendable pole	$ 70.00

4.5.2 Ongoing costs (2 year period)

Ongoing water quality consumables	$ 200.00

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APPENDIX 1. SUMMARY OF MAJOR WATER QUALITY PARAMETERS

Note that this Appendix provides considerable background on the major water quality parameters and includes some sampling methodologies which are not those recommended in the main text. These are included for completeness but are not recommended for the proposed community monitoring scheme in this report.

DISSOLVED OXYGEN

Dissolved oxygen (DO) is the amount of gaseous oxygen dissolved in water. Oxygen enters the water via either diffusion from the surrounding air, by aeration (the rapid movement of water), or as a product of photosynthesis. Adequate dissolved oxygen is necessary for good water quality, as oxygen is an essential element to all forms of life and is used up through the respiration of animals and bacteria. Bacteria are the most important users of oxygen, as they break down organic matter in the water body. DO therefore needs to be maintained at sufficient levels in order to sustain healthy and diverse aquatic ecosystems. Any significant reductions in DO levels may result in the decline or absence of some aquatic species, and any significant increases in DO levels may result in supersaturation which can be harmful to fish. Supersaturation can cause the oxygen concentration in the blood of fish to rise, which may then bubble out quickly (embolism) if the fish was to move to water with a lower DO level.

DO is usually expressed as percent saturation, which compares the proportion of oxygen dissolved in the sample water to the theoretical level of dissolved oxygen capable of being held in pure, still water. The level of saturation can exceed 100% in some cases, such as during an algal bloom. Using percent saturation is generally a better measure of oxygen availability to aquatic organisms than milligrams per litre, and also allows direct comparisons of DO results between sites with different salinity and temperature values.

Still waters are likely to have reduced oxygen levels, particularly at deeper levels, as the speed at which oxygen can enter and mix through a water body depends on how turbulent the water is. Oxygen is produced in the top portion of the lake where photosynthesis is driven by sunlight, and is consumed the greatest near the bottom of the lake, where sunken organic matter accumulates and decomposes. In shallow lakes, the water may be easily mixed by the wind, but in deeper stratified lakes, the difference in DO between the top and bottom of the water column may be dramatic. To avoid bias in the results, ensure that all samples are taken from a consistent depth in the water column.

The concentration of DO is also affected by water temperature, as cold water holds more oxygen than warmer water. As water becomes warmer, it can hold less and less DO. Therefore, during the summer months, the total amount of oxygen held in the warmer top portion of a lake may be limited by temperature. Similarly the concentration of DO fluctuates over the course of a day, with levels highest in the afternoon and lowest just before sunrise each day. It is thus important to record the time of day and water temperature on the results sheet when testing for DO, since the levels can fluctuate quite substantially, and a temperature reading will enable the calculation of percent saturation. Samples should also try to be taken at the same time each sampling day to allow comparisons to be made between data collected on different days.

Monitoring methods

This is a field test that should be conducted immediately on site, as DO levels are most likely to change over any prolonged period of time. Results may be measured either directly within the water body or from a representative sample, but regardless of the method used, particular care should be taken to avoid unduly agitating the water surface or disturbing sediments during sampling, as this may add more oxygen to the sample. A constant water depth for each of the samples taken should also be maintained (ie. submerge your arm to wrist level and ensure that the mouth of the sampling bottle is away from any surface contaminants).

Note that nutrient pollution causes increased algal growth, and this changes the 24-hour DO cycle, giving higher maximum and lower minimum DO values. Measuring the difference between dawn and mid-afternoon values may provide a measure of the amount of algal activity, and any critical fluctuations in DO levels that may adversely affect aquatic biota. Since minimum levels occur at dawn, measurements of DO at this time are a good indicator of the maximum stress to aquatic biota.

DO can be determined by:

- Titration
- Colorimetry
- DO meter (electrode)

Safety if using chemical analysis kit for DO

The procedures for dissolved oxygen require the use of potentially hazardous chemicals including manganous sulphate, alkaline potassium iodide azide, sulphuric acid and sodium thiosulphate. If procedures are followed correctly and the necessary safety precautions carried out the risks are significantly reduced. Ensure to wear safety gloves at all times when handling these chemicals, and strictly adhere to manufacturer guidelines.

ELECTRICAL CONDUCTIVITY

Electrical conductivity (EC) is a measure of the amount of total dissolved salts (TDS) or dissolved ions in the water, and represents the capacity of a sample of water to conduct an electrical current. The more salts present in the water, the greater the capacity of the solution to conduct a current (QLD MANUAL). EC is therefore a good measure of salinity.

Salinity, when pushed beyond the normal range, has the potential to cause harm and/or death in aquatic plants and animals, and thus maintaining appropriate salt concentrations are vital for the survival and longevity of aquatic organisms.

EC is generally controlled by:

- geology (rock types)
- the size of the watershed or basin relative to the area of the lake
- other ionic sources (eg. waste water from sewage treatment plants and septic systems, urban runoff from roads, nutrients and pesticides from agricultural drainage water, and atmospheric inputs - particularly within 50-100km of coastal zones).
- evaporation of water from the water surface
- bacterial metabolism in the hypolimnion (dense saline bottom layer in water column) when thermally stratified for long periods of time

Monitoring Methods.

EC should ideally be measured in the field, though it is possible to take a water sample to analyse later.

EC is measured by immersing a conductivity meter (electrode) in the water, which measures the water's capacity to conduct an electric current across a known distance. This capacity depends on the number of ions (salts) in the solution, and the more ions present, the greater the charge that can be conducted (QLD MANUAL).

Most electrodes are temperature-compensated, however water temperature should still be recorded when taking EC measurements or water samples, as ions in solution become more active as water temperature rises, thus increasing the capacity to conduct an electrical current. This temperature compensation is usually expressed when reporting the data.

EC is usually expressed as microsiemens per centimeter (µS/cm) or millisiemens (mS/cm).
Conversion: 1000 µS/cm = 1mS/cm.

pH

pH is a measure of the proportion of hydronium ions (H_3O^+) to hydroxide ions (OH^-) in a substance or, more simply, a measure of the relative acidity or alkalinity of a substance. The pH scale ranges from 0 (highly acidic) to 14 (highly alkaline), where a pH of 7 is considered neutral.

In general, the pH of water determines the solubility and biological availability of chemical constituents (eg. nutrients phosphorus, nitrogen and carbon) and heavy metals (eg. lead, copper, cadmium etc) in the water. Many compounds are more soluble in acidic waters than in alkaline waters.

All aquatic animals and plants are adapted to a certain pH range, and most freshwater biota fall in to the range 6.5 to 8.0. Changes in pH outside the normal range of a water body may have direct impacts on stream biota such as physical stress and increased susceptibility to disease or death, or indirect effects such as an increase in the toxic, un-ionized form of ammonia (NH_3), which coincides with an increase in pH.

Large changes in pH can result from the respiration and photosynthetic activities of aquatic plants and algae. Carbon dioxide produced during respiration dissolves in water to form carbonic acid (H_2CO_3), a weak acid which further acts to reduce pH by releasing free hydrogen ions (H^+). Photosynthesis on the other hand acts in the opposite way, by removing carbon dioxide and ultimately increasing the pH. For this reason, pH may be higher during daylight hours around mid-afternoon when photosynthesis is at a maximum, and lower overnight when respiration and decomposition processes are prominent. Due to such significant natural changes in pH, you should always sample at the same time of day, taking particular care to avoid disturbing sediments or scums during sampling.

Monitoring methods

pH should be measured directly in the field as samples cannot be stored to measure later as the pH will alter rapidly by biological activity and temperature.

pH can be measured using:

- a pH meter (generally most appropriate, instantaneous in situ results, reasonable cost)
- colorimetry (best performed on-site, time-consuming)
- pH test strips (cheaper alternative, lack accuracy, suitable for indicative measurements)
- titration (best performed on-site, time-consuming)

If using a portable pH probe, ensure that the pH meter is calibrated and that the protective sheath (if it has one) is removed from the sensor. Switch on the unit and if recommended by the manufacturer, allow it to warm up for the period of time indicated (~ 15 mins). Place the probe into the water, ensuring it is fully immersed and wait for the reading to stabilize. Record the reading. Repeat this at each of the sampling sites you visit.

WATER TEMPERATURE

Temperature affects physical, chemical and biological processes within a body of water and therefore plays a very important role in the health and quality of a water body. Changes in water temperature may affect DO, the rate of photosynthesis in plants and algae, the metabolic rate of animals, the rate of decay by bacteria, reproductive success, and the sensitivity of animals to toxic wastes, parasites and diseases.

In lakes, dams and ponds, the temperature of the surface water is often several degrees warmer than the water near the bottom. This occurs because warmer surface water is less dense than cold water and therefore floats on top of the colder water. This creates a distinct body of warm water. The two bodies of water are said to be separated by a *thermocline*, which may be disturbed by strong winds or through seasonal variations in air temperature. Because of the lack of mixing at the thermocline, oxygen diffuses slowly from the upper layer into the lower layer. As bacteria, animals and chemical processes in the bottom layer consume DO, oxygen levels may drop to near zero (anoxic conditions). Under anoxic conditions, several chemical reactions can commence, including the release of biologically available phosphorus from the sediment to the water, and the production of hydrogen sulfide (rotten egg gas).

Monitoring Methods

Most pH meters and some DO meters will also measure temperature, so an additional temperature probe may not be necessary to purchase. Utilize either of these if available and record the temperature at the same time as the pH or DO recording. In deep areas, several measurements from the top to the bottom of the water column can be made to obtain a temperature profile.

If a temperature probe is required, alcohol-filled rather than mercury-filled thermometers are more preferable as they are less hazardous if broken in the field. Similarly armoured thermometers are more practical for field use than unprotected glass thermometers.

If using electronic temperature probes, it is ideal to use one with a good length of cable to allow temperatures to be taken out in the waterbody and at varying depths. At the sampling site, lower the probe to 10cm below the surface for about a minute.

TURBIDITY

Turbidity is a measure of water clarity and is caused by materials entering the water via natural or human-induced processes, through run-off and erosion, or as a result of physical, chemical or biological activity within the waterway. To the naked eye, turbid water appears cloudy or muddy, as suspended particles such as clay, silt, sand, algae, plankton, micro-organisms and other substances scatter the passage of light through the water. It can indicate a range of issues in the aquatic ecosystem.

The energy of falling and flowing water is the primary way that sediment becomes dislodged and carried into waterways, and therefore turbidity often increases sharply during and after a rainfall event. Turbidity levels may influence light penetration and optical properties of water. High turbidity may reduce the amount of light passing through water, thus reducing the rate of photosynthesis among

aquatic plants and algae and ultimately reducing dissolved oxygen levels. Reduced light penetration may also alter optical properties, affecting predation, reproduction and photosynthesis of organisms. Likewise, as particles causing turbidity settle out of suspension, they can cause smothering problems by clogging fish gills, or by settling into the stream bed and spaces between the rocks on the bottom, reducing the amount and type of habitat available. Suspended particles also provide a place for harmful bacteria to breed, and can transport attached pollutants such as nutrients and toxic materials to other areas in the catchment.
Turbidity levels may also influence water temperature, such that under some circumstances, higher turbidity can raise water temperature due to increased thermal mass, reducing dissolved oxygen levels. In other cases, increased turbidity may reduce solar penetration, thus reducing water temperatures.

Potential sources of turbidity may include:

- waste discharges
- run-off
- eroding banks
- bottom feeders stirring up bottom sediments
- biological growth such as excessive algal, diatom or plankton growth
- physical disturbance to the surrounding land
- salinity concentrations

As turbidity is a measure of the presence of suspended particles in the water column, it can be used as an indirect indicator of transparency and total suspended solids (TSS). Therefore turbidity measures are used when the direct measures of transparency or TSS are not logistically, financially or statistically appropriate.

Turbidity is most commonly recorded in nephelometric turbidity units (NTU). This is an open-ended scale commencing at zero for clear (filtered) water.

Monitoring Methods

Turbidity can be determined using a:

- turbidity meter
- secchi disc
- turbidity tube

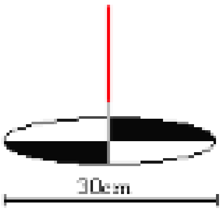
Turbidity Tube

Sample is collected in a clean bucket or sample bottle and gradually poured into a turbidity tube. Looking down the tube, the depth at which the black mark on the bottom of the tube is just visible is taken from the scale on the side of the tube and recorded as the NTU reading.

N.B. if the reading is above 200, the sample is diluted 1:1 with distilled water, the process is repeated and the final result is multiplied by 2. If the tube is filled to the top of past the last reading and the black lines are still visible, the reading is taken as less than the last number on the scale (ie. <10 NTU).

Secchi Disk

The secchi disc consists of a circular white plate made of non-corrosive rigid material, and is painted in four black and white quadrants (see below). The disc is usually attached to a pole or non-stretch rope which is marked with intervals of depth, and lowered into the waterbody. The point at which the disc can no longer be seen is generally where effective light penetration is extinguished.



High Secchi depth readings correspond to high water clarity, as do low secchi depth readings indicate reduced water clarity – often associated with the presence of suspended particles and algal blooms, or limited light penetration and limited primary production.

It is important to remember that the secchi disc is prone to error if strong flows and clouds casting shade are present. Optimal conditions for measuring secchi disc depth are clear skies, sun directly overhead, minimal waves or ripples, and the same person recording the secchi disc depth during the sampling day to ensure consistency across the readings. Any differences or changes in conditions from the ideal situation described should be mentioned or described in the field notes.

NUTRIENTS

Phosphorus and nitrogen are naturally occurring nutrients that are crucial to ecosystem health at certain concentrations. They may be present in the system either 'dissolved' in the water column, or 'particulate' (attached to particles either free-floating or in the sediment). Once suspended however, these nutrients can maintain eutrophic conditions (increased plant growth) in the waterway for many years.

Some factors influencing the amount of nutrients in the waterway either dissolved or particulate include: environmental factors (rainfall events), catchment characteristics (ie. slope, vegetation cover, soil type and moisture content), and management practices (ie. fertiliser application with soluble phosphate used in agriculture). Excess levels of either can have negative implications for a waterway, and thus monitoring these nutrients can provide valuable insights into the condition of the aquatic ecosystem.

• PHOSPHORUS

Phosphorus is a mineral nutrient essential to all forms of life. It is widely distributed in many rocks, soils and living organisms, though is relatively scarce in the aquatic environment. This is due to its low solubility and tendency in the dissolved form to bind with suspended soil particles in the water column, which later settle out and bury in the bottom sediments leaving the water relatively devoid of phosphorus. Therefore, the growth of algae and other biological organisms that require phosphorus for function and growth tends to be limited.

As there is no gaseous form of phosphorus present in the atmosphere, its entry into the water column is via phosphorus-bearing sediments, animal wastes or decomposing organic material falling, washing or blowing into the waterway. Disturbances such as high flows or anoxic conditions may also re-release phosphorus back into the water column from bottom sediments. The phosphorus found in surface and groundwater is usually phosphate (PO_4^{3-}).

Effects on water quality

Sudden increases in phosphorus can stimulate large increases in aquatic plants and algae. An algal bloom may cause an initial increase in dissolved oxygen (due to increased photosynthesis), reduction in water clarity or increase in pH. However, once the available phosphorous has been consumed, the algae die and are consumed by bacteria, ultimately decreasing levels of dissolved oxygen available to other organisms in the river system.

Lake systems are particularly susceptible to the effects of increased nutrient inputs as the nutrients are not readily removed from the system. This may potentially cause vast increases in weed growth, lower oxygen levels or eutrophic conditions.

Factors affecting phosphorus …

- rock type and geology
- soil types
- rates of erosion
- climatic factors such as wind and precipitation
- flow rates and water levels
- human and animal wastes
- phosphate-containing fertilisers
- discharge from sewage treatment plants
- urban run-off

There are two main forms of P, which are routinely measured as part of water monitoring – Total P and orthophosphate.
Total P – represents the total amount of P present within a water sample on both organic and inorganic forms.
Orthophosphate – represents the amount of inorganic P readily available in the water column for uptake by plants.

Monitoring methods

Phosphate can be determined using a:

- field test kit
- laboratory analysis

Field analysis
Field analyses for phosphate have relatively low accuracy but will indicate large changes in water quality. The protocol for the use of the field kits is included on the CD-ROM in Appendix Two.

Laboratory analysis
Ideally, nutrients should be measured at each site, however this can become costly and it may be advisable to use a bulked sample. To make a bulked sample take the same quantity of water from each of the sites sampled on the day and pour them all together into a clean bucket. Mix the water well and then, for total P, place a small amount of water into a clean bottle labeled with the date, site name or number (if applicable) and the nutrient to be analysed (total P). Then place the sample into the freezer to store until analysis.

For orthophosphate filter a small quantity of water through a 0.45mm filter and pour it into a clean bottle. Label the bottle with the same information as for total P and freeze the sample until analysis. These samples can then be taken to an analytical laboratory for testing.

• NITROGEN

Nitrogen is the fourth most common element found within living organisms and is crucial for many biological processes. It can be taken up and utilised for biological activity in the form of nitrate (NO3), nitrite (NO2) and ammonium (NH3 and NH4), with nitrate and ammonium being the most bioavailable forms of nitrogen as they do not evaporate from the waterway. Nitrates and ammonium are therefore often responsible for nuisance plant growth.

Natural entry sources of biologically significant nitrogen into a waterway:

- weathering of nitrogen-rich minerals
- nitrogen fixation by bacteria and cyanobacteria
- lightning reacting with atmospheric nitrogen precipitated in rain.

Unnatural entry sources:

- manure from livestock
- sewage discharge

Under natural conditions, populations of aquatic plants and algae are regulated by the limited supply of nitrogen available, as it is an essential element for organism growth. Normal levels of nitrogen are vital to maintain a natural population of aquatic organisms, and some factors influencing the concentration of nitrogen in a waterbody include rock type and geology, soil types, vegetation, climatic and seasonal factors, and organic decomposition. Human activities such as fertilization, livestock manure, automobile emissions and wastewater treatment release are all factors which may also accelerate the entry of nitrogen into a waterway. If nitrogen within a waterway exceeds natural levels, algal blooms and nuisance plant growth may be triggered. Therefore monitoring nitrogen and phosphorus provides insight into whether there is risk of an algal bloom occurring. Algal blooms can cause dramatic decreases in dissolved oxygen, altered pH, altered water temperature and increased turbidity.

Nitrogen occurs in a number of forms, and the following are the types that are routinely measured.
Total N – refers to the amount of nitrogen present in a sample in both the organic and inorganic forms.
Ammonium – this is the main form of nitrogen produced by the breakdown of organic material and urea. Ammonium is one of the forms of N most commonly utilized by aquatic plants. This form of N is readily oxidised to nitrite and then to nitrate.
Nitrite/Nitrate – nitrate is one of the forms of N most commonly utilised by aquatic plants.

Monitoring methods

Nitrate can be determined using a:

- field test kit
- laboratory analysis

Field analysis
Field analyses for nitrate have relatively low accuracy but will indicate large changes in water quality. The protocol for the use of the field kits is included on the CD-ROM in Appendix Two.

Laboratory analysis
The sampling methodology is the same as for P.

For total N, use unfiltered water and freeze the sample for later analysis.
For ammonium and nitrite/nitrate filtered water is utilised and the samples are frozen. Remember to label the bottle clearly with either total N, nitrite/nitrate or ammonium, the wetland name, sample date and site number.

If there are constraints on the amount of nutrients that can be analysed then it may be necessary to analyse fewer forms of nutrients. In this case the recommended nutrients to test are total P and total N. Over time this will still give a good indication as the nutrient status of the waterbody being tested.

CHLOROPHYLL A

The amount of chlorophyll a in a waterbody is a good measure of phytoplankton productivity, which in turn provides an indication of the potential food resources available to invertebrate grazers.

Monitoring methods

Chlorophyll can be determined using a:

- field observations
- field test kit
- laboratory analysis

Field observations
Field observations should include visual estimates of the extent and colour (ideally with photographs), Where an extensive bloom occurs, a sample should be taken and provided for laboratory analysis.

Field analysis
Field analyses for chlorophyll have relatively low accuracy but will indicate large changes in water quality. The protocol for the use of the field kits is included on the CD-ROM in Appendix Two.

Laboratory analysis
As soon as possible after collection filter a known quantity of water through a 47 micron glass microfibre filter. Ideally a litre should be filtered however this can rarely be achieved, usually 500 or 250ml is filtered. Use tweezers to carefully fold the filter paper in half and then in half again. Take another filter paper and fold it around the sample filter paper. Place the filter paper in an envelope with the date, site location/number and amount of water filtered. Place the envelope into a plastic clip-seal bag and freeze the sample in the dark until analysis. Chlorophyll a can be measured from a bulked sample if required.

Before commencing nutrient monitoring it is advisable to contact the laboratory that will be used for analysis to ensure that their standards for sample collection will be followed.

Where blooms occur (particularly if there is concern over the presence of blue-green algae), then taxonomic assessment of samples for taxonomic composition will be required.

MACROINVERTEBRATES

Macro-invertebrates are useful indicators of stream health because they play a central role in food chains of aquatic systems, they cannot easily escape pollution, and they are sensitive to even quite mild pollutants or changes in water quality. They are also relatively easy and inexpensive to sample. Algae, especially blue-green algae, are also important to monitor because of their potential impacts on human and animal health. The number and diversity of macro-invertebrates found in a water body can be used to indicate the general health of a waterway, and may indicate the presence of pollution in the system. Chemical testing can then be conducted to confirm the presence of pollution and potentially identify a particular type of pollution.

Macro-invertebrate sampling compliments chemical sampling because it can detect the presence of most environmental stresses and may provide general indications about the type of pollutant. By contrast, chemical and physical tests are highly specific (for example, a test for pH or one for soluble phosphate levels). If the pollutant is not measured by one of the chemical or physical tests conducted at the site then it may go undetected if you only conduct these tests.

Furthermore, with a lifespan of up to one year and a relative lack of mobility, macroinvertebrates make useful indicators of intermittent pollution. Unlike spot measurements of physiochemical water quality, macroinvertebrates provide information of longer-term trends and impacts from short-term single pollution events such as a chemical spill.

Monitoring methods

Ideally, macroinvertebrate sampling should occur at least once in each season to allow for seasonal changes in the fauna. At a minimum, sampling should occur twice a year, with recommended times being spring and autumn. Autumn sampling will collect larger specimens of insects that emerge during summer, making them easier to identify and will show the macro-invertebrate fauna during a period of lower flows and higher temperatures, when pollution inputs may have a greater impact.