Index of Gippsland Lakes Health

Stage 1

Framework for an integrated monitoring program for reporting the ecological health of the Gippsland Lakes

View of the entrance to the Gippsland Lakes from Hazel Road lookout

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Executive Summary

Background and scope

In 2005 the Gippsland Lakes and Catchment Task Force established a process to develop an integrated and consistent monitoring program for the Gippsland Lakes.

The process is to be undertaken in three stages:

- *Stage 1*: Consolidate the information to date and specify the program requirements;
- *Stage 2*: Determine the detailed monitoring program, its costs and constraints; and
- *Stage 3*: Determine how the program is to be implemented.

This report addresses Stage 1 of the process.

Stage 1 has the following tasks:

- *Task 1: Framework development*. Develop a framework of an integrated monitoring program for the ecological health of the Gippsland Lakes using the product of the two Gippsland Lakes monitoring workshops;

- *Task 2: Assessment of the State of the Gippsland Lakes Report 2004*. This is to be done in terms of
  - assessing the suitability of the data collected for the 2004 State of the Gippsland Lakes report in terms of its form, level of analysis and ability to be interpreted and analysed, and
  - identifying where no current data are available;

- *Task 3: Identification of constraints or considerations*. This task has three components:
  - document any matters that will add value to Stage 2 and/or require further consideration before commencing Stage 2,
  - document constants or trade-offs that might be required to satisfactorily complete the 2009 State of the Gippsland Lakes report, and
  - document the key objectives for developing Stage 2 of the program; and

- *Task 4: 2009 State of the Gippsland Lakes report*. Provide a mock-up of the 2009 State of the Gippsland Lakes 2009 report using the proposed framework.

Because of the contentious nature of some of the concepts (e.g., ecological health) and confusion about the precise meaning of others (e.g., monitoring), Section 2 of the report provides a detailed critique of what outcomes should be expected from an integrated monitoring program intended to measure the ecological health of the Gippsland Lakes.

What is monitoring?

Monitoring differs from other data-collecting activities, such as surveys and surveillance sampling, in two main ways:

- Monitoring is underpinned by a specific reason for collecting data; and
- The results are compared with a standard or model, which is used to interpret, check or test the data, and a set of actions then arise according to whether or not compliance has been achieved.

A monitoring program for the Gippsland Lakes should be able to detect three types of environmental change:

- Trends in time and space;
- Changes in ecological state; and
- Biogeochemical and trophic consequences of infrequent, but large-scale, events, using continuous and integrative approaches.

Geographic scope

For the purposes of monitoring and preparation of the 2009 State of the Gippsland Lakes report, the term *Gippsland Lakes* should include the following landscape elements:

- The four main lakes of the Gippsland Lakes system: Lakes Wellington, Victoria, King and Reeve;
- The lower, brackish-water reaches of the main rivers flowing into the lakes, such as the Latrobe, Avon, Mitchell, Nicholson and Tambo Rivers; and
- The freshwater and brackish-water wetlands directly associated with the lakes and downstream reaches of the rivers, such as the Heart, Dowd and Clydebank Morasses associated with Lake Wellington, Victoria and Betsy's Lagoons associated with Lake Victoria, and Macleod Morass on the lower Mitchell River.

What is ecological health?

There is little or no general agreement as what the term "health" means when applied to ecological or environmental questions. The term *ecological health* should not be used in the 2009 Gippsland Lakes report. Instead, the term *ecological condition*, which is subject to less variable interpretation, should be used.

Monitoring framework

The devising, development and implementation of a monitoring program for the Gippsland Lakes requires attention to two levels of organisation:

- The underlaying approach that provides the unifying basis for the program; and
- The indicators and individual variables that are measured to detect environmental change.

Three main approaches have been used to provide the underlaying basis for developing an environmental monitoring program:

- Analysis of environmental *structure*;
- Quantification of ecosystem *processes*; and
- Analysis of ecosystem *values*, usually from a perspective of human utilization.

It is recommended that the OECD Pressure-Condition-Response model be used to provide the unifying framework for structuring the 2009 Gippsland Lakes report and the associated monitoring program. This model uses three classes of indicator to show current condition and trend in the environment and the response of natural-resource managers to these variables:

- *Pressure*: the stresses and degree of impact placed on the environment by human activities;
- *Condition*: indicators showing the ecological state of the environment and its response to the stressors and disturbances identified in the Pressure category; *viz* largely the array of traditional and novel variables quantified in environmental monitoring programs; and
- *Response*: a measure of the society's reaction to changes in environmental condition in order to mitigate pressures, e.g., policy developments, management interventions, public awareness campaigns etc.

Review of 2004 State of the Gippsland Lakes report

The 2004 State of the Gippsland Lakes report is a 24-page, glossy A4 document with five main sections. These cover a statement of purpose, scope and method; brief description of the Gippsland Lakes (addressing mainly Lakes King, Victoria and Wellington); a short description of values of the region, addressing environmental, social, economic and cultural values; and a longer description of the Gippsland Lakes ecosystem, focusing on nutrient cycling, algal abundance, water-column stratification and nutrient inputs from the catchment. The main body of the report is divided into three sections, covering estuaries, biodiversity, and inland waters.

The 2004 report putatively used the OECD Pressure-Condition-Response model as a unifying framework, but had the following limitations:

- Poor audience targeting;
- Weak description of geographic scope;
- Conceptual models were not used to advantage;
- A lack of good fit with regional adaptive management frameworks; and
- Emphasis on compliance rather than detection of trends, and the separation of localised human impacts from long-term or regional-scale disturbances.

Objectives for 2009 State of the Gippsland Lakes report

The key objectives for the future monitoring program to generate data for the 2009 Gippsland Lakes report are that it:

- Address *bona fide* monitoring rather than simple survey or surveillance;
- Have a clear and explicit purpose, for example to meet a legislative requirement, aid implementation of a natural-resource management program, increase community awareness, etc;

- Be integrated externally into broader-scale natural-resource management in the region by its incorporation into an adaptive management framework with explicit acknowledgment of the MERGe framework for review activities;
- Be integrated internally, such that its individual components explicitly relate to and inform upon each other;
- Where appropriate, make use of risk-based and multiple-variable structural approaches, as well as addressing process-oriented and value-orientated indicator variables where possible;
- Use a wide range of indicator variables that satisfy the requirements for ease-of-capture, cost effectiveness, relevance, etc;
- Adopt an appropriate experimental design that allows changes in the environment to be detected reliably at the desired level of precision;
- Address key governance issues, including data availability and clearance;
- Have an explicit timeline for data collection and reporting;
- Include a clear interpretation of the data and their implications for environmental condition, including where appropriate implications for scenario building;
- Have a clear target audience(s) in mind, combined with reporting appropriate to that audience(s) ; and
- Include a measure of success of the monitoring program and communication strategies.

The 2009 Gippsland Lakes report should include the following components:

- Statement of the purpose, scope and target audience(s);
- Description of Gippsland Lakes, including:
  - definition of the landscape elements covered by the report,
  - brief history of settlement in the region, including recent changes in agricultural activities and population changes (e.g., recreational uses and the 'sea change' phenomenon), and
  - values of the Gippsland Lakes, including environmental, social, cultural and economic values;
- Overview of current understanding of the ecological structure and processes operating in the Gippsland Lakes ecosystem, including discussion and conceptual models of
  - links between the Lakes and their catchment,
  - hydrological processes,
  - sediment trapping and stabilisation,
  - physical habitat,
  - trophic interactions, and
  - nutrient cycling in the Lakes environment;
- Description of the reporting framework used:
  - Pressure-Condition-Response model, and
  - rationale behind indicators used in National State of the Environment reporting;
- Pressure on the Gippsland Lakes, including
  - indicator variables identified in National State of the Environment reporting,
  - other important catchment-scale indicators not covered by National State of the Environment protocols;
- Condition of the Gippsland Lakes, including

    - indicator variables identified in National State of the Environment reporting, and
    - other indicators of importance, such as those linked with freshwater and brackish-water wetlands and those peculiar to the Gippsland Lakes (e.g., stratification and salinity impacts);
- Responses of management and other agencies to Condition trends, including
    - financial investment,
    - summaries of specific NRM programs in the region (e.g., CMA activities),
    - summaries of significant R&D programs (e.g., university-based and government-agency projects), and
    - engagement of community and volunteer groups;
- Future of the Gippsland Lakes, including a discussion of issues such as
    - likely impacts of climate change,
    - trends in long-term ecological change and possible changes in ecological state, and
    - changes in community expectations and anthropocentric values; and
- Full citation list for reference and data sources.

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1 Introduction

Chapter overview

This chapter has three components:

- A brief overview of the events leading to the present project;
- The project's terms of reference; and
- Description of the main supportive documents: the MERGe program and summaries of two workshops held in 2005 to facilitate the development of an improved monitoring program for the Gippsland Lakes and production of the 2009 Gippsland Lakes report.

1.1 Historical background

In 1998 the CSIRO undertook a preliminary assessment for the Gippsland Coastal Board of the water quality and ecological status of the Gippsland Lakes. The report, *Gippsland Lakes Environmental Audit: Review of Water Quality and Status of the aquatic Ecosystems of the Gippsland Lakes* (Harris *et al*. 1998), reviewed earlier studies on water quality, hydrology and catchment land-use of the Gippsland Lakes region. It concluded that nutrient enrichment was the major threat to the ecological condition of the Gippsland Lakes. The report identified also the lack of a general framework for understanding changes in the ecology of the Lakes in response to nutrient enrichment, salinisation, decreased freshwater inflows and recreational pressures, and recommended that ecosystem modelling be undertaken to assist in their future management.

The Gippsland Coastal Board commissioned a second, more detailed, study by the CSIRO in 1999. This report was released as the *Gippsland Lakes Environmental Study* (Webster *et al*. 2001). It modelled a number of ecological processes in the Gippsland Lakes, focussing on water-column processes, nutrient cycling and algal blooms, and concluded that water quality would deteriorate further and algal blooms would continue to occur unless nutrient inputs were decreased markedly. In the context of the current report, it is worth restating that the scope of the *Gippsland Lakes Environmental Study* centred on algal blooms and the environmental factors that control them. Little attention was given to other aspects of the Gippsland Lakes, such as the ecology of organisms other than algae or the condition of downstream sections of the major rivers and the fringing wetlands.

In the light of the report by Webster *et al*. (2001), the Gippsland Lakes and Catchment Task Force was established by the Victorian Government to develop a "strategic, targeted and practical approach for tackling the ecological issues confronting the Lakes and catchment" (Department of Natural Resources and Environment 2002). *The Gippsland Lakes Future Directions and Actions Plan* (GLFDAP), released in May 2002, was an outcome of the deliberations of the Task Force. A key objective of the GLFDAP was that nutrient loads entering the Lakes system should be reduced by 40 % over the next 20 years. The delivery of the GLFDAP is co-ordinated by the East and West Gippsland Catchment Management Authorities (CMAs) and the Gippsland

Coastal Board; the recent report by URS (2006) provides an overview and critique of these arrangements.

In addition to implementing the GLFDAP, the Task Force is required to undertake two activities:

- Review current monitoring and assessment programs that provide information on the condition and management of the Gippsland Lakes, and
- Report to the Victorian Government each year on the effectiveness of the management of the Lakes and their catchment.

To meet these requirements, the Task Force, together with the two CMAs, developed a framework for monitoring the Gippsland Lakes (Sinclair Knight Merz 2004, 2005a). This framework was used to prepare the *State of the Gippsland Lakes Report 2004* (Gippsland Lakes Taskforce no date; Sinclair Knight Merz 2005b).

It became evident during the production of the *State of the Gippsland Lakes Report 2004* that not all the necessary information was available to formulate a more complete picture of the ecological condition of the Gippsland Lakes. To address this deficiency, in 2005 the Task Force established a process to develop an integrated and consistent monitoring program for the Gippsland Lakes. This program included a set of priority indicators and associated targets aimed to allow better reporting on the health of the Gippsland Lakes. The process is to be undertaken in three stages:

- *Stage 1*: Consolidate the information to date and specify the program requirements;
- *Stage 2*: Determine the detailed monitoring program, its costs and constraints; and
- *Stage 3*: Determine how the program is to be implemented.

This report addresses Stage 1 of the process.

1.2 Terms of reference

Stage 1 is to be undertaken with regard to the relevant steps of the MERGe framework. The MERGe framework is outlined in Section 1.3 of this chapter.

The project involves four tasks:

- *Task 1: Framework development*. Develop a framework of an integrated monitoring program for the ecological health of the Gippsland Lakes using the product of the two Gippsland Lakes monitoring workshops;

- *Task 2: Assessment of the State of the Gippsland Lakes Report 2004*. This is to be done in terms of:
  - assessing the suitability of the data collected for the 2004 State of the Gippsland Lakes report in terms of its form, level of analysis and ability to be interpreted and analysed, and
  - identifying where no current data are available;

- *Task 3: Identification of constraints or considerations*. This task has three components:

- document any matters that will add value to Stage 2 and/or require further consideration before commencing Stage 2,
- document constants or trade-offs that might be required to satisfactorily complete the 2009 State of the Gippsland Lakes report, and
- document the key objectives for developing Stage 2 of the program; and

- *Task 4: 2009 State of the Gippsland Lakes report*. Provide a mock-up of the 2009 State of the Gippsland Lakes 2009 report using the proposed framework.

1.3 Supportive documents

1.3.1 MERGe Framework

Project MERGe is *Monitoring, Evaluation and Reporting for Gippsland's Natural Resources*. It is a partnership between the East and West Gippsland CMAs and the Gippsland Coastal Board, with the objective to design and test a framework that integrates monitoring, evaluation and reporting activities for the condition and stewardship of natural resources in the Gippsland region (Sinclair Knight Merz 2004). The MERGe framework has three main components:

- *Plan*: asking the right questions, planning to find the right answers, and finding the right answers;
- *Deploy*: gather the information, create information with meaning, and create useful reports; and
- *Review*: obtain feedback from providers and users to improve the usefulness of the information.

After these steps have been undertaken, a fourth component – Improve – is invoked, whereby the process reverts to the first step of the planning component. Figure 1 shows key steps in the MERGe framework.

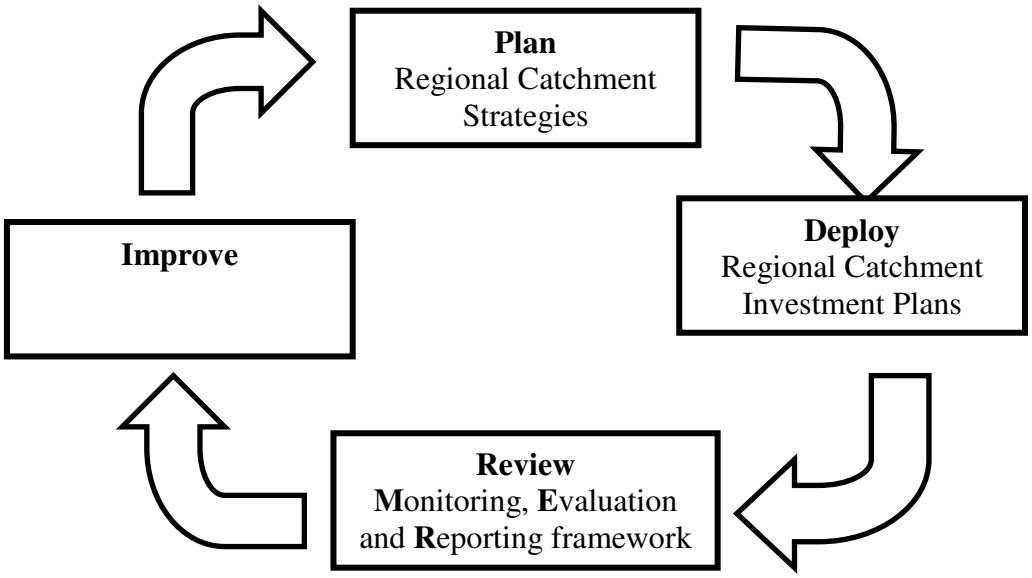

Figure 1. Key stages in the MERGe process.

1.3.2 Gippsland Lakes monitoring workshops

Two workshops were held in 2005 to clarify the monitoring requirements for the Gippsland Lakes and the possible structure of the 2009 Gippsland Lakes report:

- Workshop 1: Gippsland Lakes Task Force Workshop, held on 4 March 2005; and
- Workshop 2: State of the Gippsland Lakes: Planning for 2009, held on 23 March 2005.

A summary of outcomes of the two workshops is shown in Appendix A.

2 Task 1: Developing a monitoring framework

Chapter overview

The objective of Task 1 is to "develop a framework of an integrated monitoring program for the ecological health of the Gippsland Lakes using the product of the two Gippsland Lakes monitoring workshops".

Chapter 2 consists of four components:

- Clarification of key terms, including a definition of the geographical scope of the study area covered by the Gippsland Lakes, and the meaning of *integrated monitoring* and *ecological health*;
- Overview of the three main approaches to devising environmental monitoring programs: structural, process and values-orientated approaches;
- Brief introduction to factors influencing the choice of indicators and variables used in an integrated monitoring program; and
- Description of the recommended framework for the 2009 report.

2.1 Meaning of key terms

For the purposes of this report, the term *Gippsland Lakes* includes the following landscape elements:

- The four main lakes of the Gippsland Lakes system: Lakes Wellington, Victoria, King and Reeve;
- The lower, brackish-water reaches of the main rivers flowing into the lakes, such as the Latrobe, Avon, Mitchell, Nicholson and Tambo Rivers; and
- The freshwater and brackish-water wetlands directly associated with the lakes and downstream reaches of the rivers, such as the Heart, Dowd and Clydebank Morasses associated with Lake Wellington, Victoria and Betsy's Lagoons associated with Lake Victoria, and Macleod Morass on the lower Mitchell River.

This definition, proposed specifically for the purposes of reviewing the ecological condition of the Gippsland Lakes, excludes the terrestrial catchment and freshwater reaches of main rivers. Nevertheless, it is essential that these two landscape elements are considered fully when interpreting information on the condition of the Lakes and the factors contributing to their improvement or degradation. To meet this requirement, the proposed framework adopts a reporting structure that includes extra-Lake environments explicitly in the interpretation phase. Details are provided in Section 2.6.

2.2 What is meant by "integrated monitoring"?

2.2.1 Differences between monitoring, surveillance and survey

Environmental monitoring can take many forms and be used to a number of ends. Sometimes it is defined so broadly as to include almost any observation of a system (e.g., as defined in Sinclair Knight Merz 2004, page 1). It is useful, however, to

distinguish among three types of data collection commonly considered as "monitoring" (Hellawell 1991; Kennish 2004):

- *Survey work*. Surveys are qualitative observations made without any preconceptions as to the findings. They may include, for example, collecting baseline data as part of an inventory process to describe the condition of a given water body.

- *Surveillance sampling*. Surveillance sampling uses a time series of surveys to determine the variability or range of given variables in the environment. It may include, for example, repeated sampling over time to characterise ecological responses to natural variability in the physical environment, such as seasonal changes.

- *Monitoring*. Monitoring, in the strict sense, is the systematic collection of data over time to gauge compliance with a pre-determined standard or model. The standard could be, for example, a legal compliance value for swimming or other water-contact activities, or the quantitative objectives of a management program.

In their review of monitoring aquatic systems, Finlayson and Mitchell (1999) proposed that monitoring differed from other data-collecting activities in two main ways:

- Monitoring is underpinned by a specific reason for collecting the data; and
- The results are compared with a standard or model, which is used to interpret, check or test the data, and a set of actions then arise according to whether compliance is achieved or not.

This idea was taken further by Paerl *et al*. (2006). In their review of the eutrophication of large estuarine systems, Paerl *et al*. (2006, page 460) argued that,

> "Acute and chronic responses to climatic and anthropogenic perturbations in estuarine and coastal ecosystems underscore the need for long-term, spatially and temporally intensive monitoring, modelling, and assessment of water quality and habitat condition in support of adaptive management aimed at reducing the unwanted symptoms of eutrophication".

Paerl *et al*. (2006) then argued that monitoring should be able to detect three types of environmental change:

- Trends in time and space;
- Changes in ecological state; and
- Biogeochemical and trophic consequences of infrequent, but large-scale, events, using continuous and integrative approaches.

To summarise, some typical reasons for monitoring may include:

- Demonstrating compliance with human-health or environmental-quality criteria as set out in legislation or otherwise formalised, such as State environment protection policies or ANZECC guidelines;
- Use as an early-warning system to detect environmental degradation or change, especially to detect impacts before they become severe or exceed a given trigger value;
- Testing predictions as to the direction and magnitude of temporal trends in water-quality arising from altered management practices. Reliably detecting trends in monitoring data usually requires at least 5, and sometimes 10, years of data (Cottingham *et al*. 1995); and
- Validating a conceptual or mathematical model of how a natural ecosystem functions.

The last three reasons for monitoring an ecosystem often form part of an adaptive management framework for natural-resource management. The integration of monitoring programs into the broader framework of adaptive management is discussed next.

2.2.2 What makes monitoring "integrated"?

The topic of integration in natural-resource management was reviewed in a recent issue of the *Australasian Journal of Environmental Management*. In this issue, Bammer (2005) argued that integration in the resource and environmental domain included six components:

- Integration *for what* and *for whom*?;
- Integration *of what*: the information and human actions involved;
- The *context* of integration: e.g., the political environment;
- Integration by *whom*: what is the integrative decision-making process?;
- *How* is integration undertaken: the theoretical underpinning, methods used, process to ensure transparency and accountability; and
- The *impact* of integration: did it achieve its aims, and were there other positive or negative outcomes?

In terms of developing a monitoring program, an integrated program must show two characteristics:

- It must be integrated internally; and
- It must be integrated externally with other aspects of natural-resource management in the study area.

Internal integration of the monitoring program means that it is internally consistent and its constituent components explicitly relate to, and inform upon, each other. The way this may be achieved is outlined in Sections 2.5 and 2.6 of this report.

The MERGe framework summarised in Section 1.3.1 provides the basis for integrating the monitoring program into the broader process of natural-resource management in the Gippsland region. As shown in Figure 1, the MERGe framework is an essential part of the adaptive management framework, and has a particular importance for the reviewing component. For nearly 20 years, adaptive management

has been recognised as the most effective unified approach to natural-resource management and, in particular, to the integration of monitoring and research (Walters 1986; Gentile *et al*. 2001). The adaptive-management approach is shown diagrammatically in Figure 2.

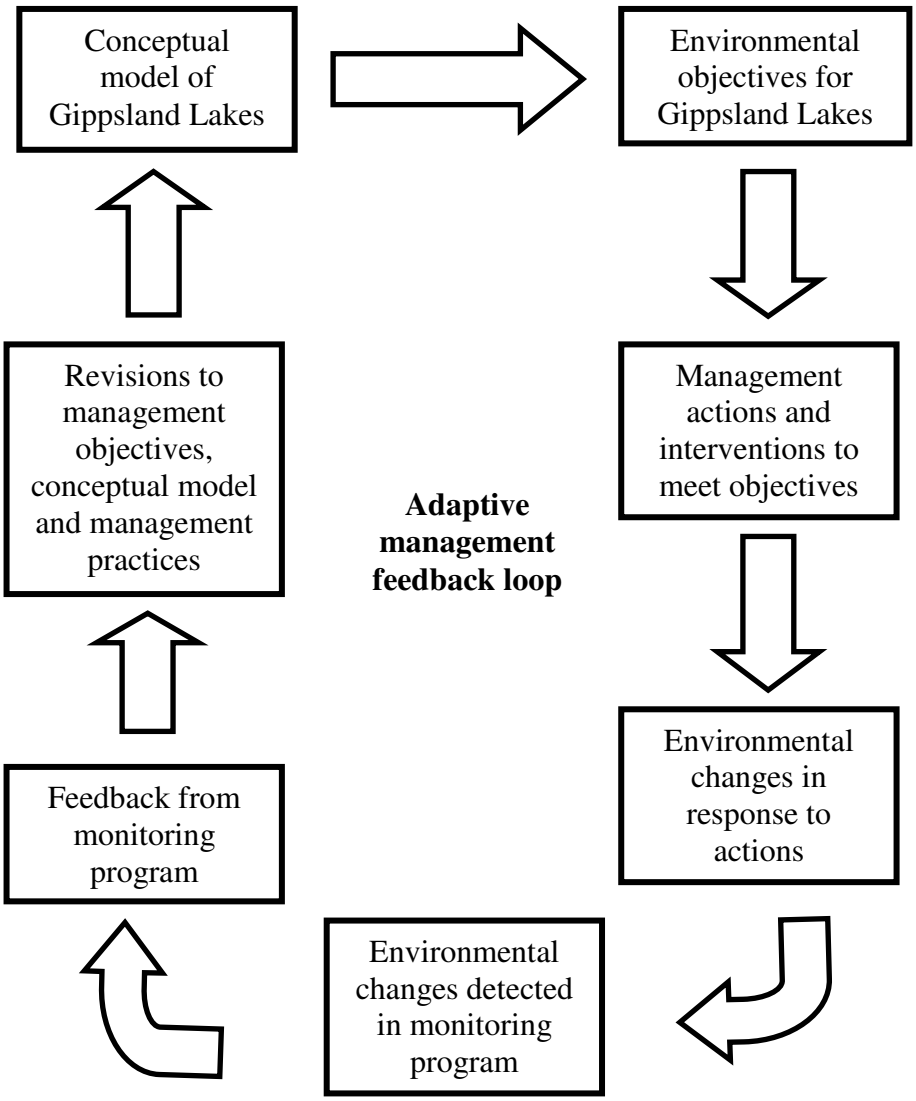

Figure 2: Summary of the adaptive management approach.

Figure 2 shows that the adaptive management approach has a number of inter-related steps:

- Develop a conceptual understanding of how the ecosystem functions;
- Develop management objectives consistent with the fundamental characteristics of the ecosystem;
- Predict the likely direction and, where possible, magnitude of environmental changes under different types of management interventions;
- Undertake the chosen management interventions;
- Monitor the outcomes of these interventions;

- Compare the monitoring results with predicted outcomes;
- Revise the earlier conceptual understanding of the ecosystem; and
- Modify the management plans as necessary in the light of this improved understanding.

Two components of the adaptive management framework shown in Figure 2 are especially important to the current project:
- The value of conceptual models; and
- The integration of monitoring results fully into the process of natural-resource management.

Value of conceptual models. Conceptual models are qualitative, sometimes quantitative, statements of hypotheses concerning the natural of ecological risk (Gentile *et al*. 2001). They can be developed to illustrate a range of ecological structures, processes, responses and interactions, and are highly effective in capturing the current scientific knowledge of an ecosystem and showing likely ecological responses to natural and anthropogenic stresses. Gentile *et al*. (2001, page 234) argued that,

> "Regardless of the application, conceptual models should be incorporated into all types of assessments and recovery activities as a tool for describing the causal relationships among land uses, stressors, valued ecological resources at risk, and their associated end-points and indicators".

An example of a conceptual model relevant to the Gippsland Lakes is shown in Figure 3. This simple model describes a change in ecological state, one of the three types of change proposed by Paerl *et al*. (2006) as being central to an effective monitoring program for coastal waters. The model shows that, with increasing nutrient enrichment, the ecologically most stable plant community in the environment shifts from one dominated by submerged angiosperms (e.g., marine seagrasses and freshwater eelgrasses such as *Vallisneria*) to one dominated by benthic macroalgae (e.g., *Cladophora*, *Enteromorpha*, *Ulva*) at intermediate levels of nutrient enrichment to one, under the most severe eutrophication, dominated by blooms of phytoplankton in the water column.

A number of reviews of aquatic-system monitoring (e.g., Finlayson and Mitchell 1999; Paerl *et al*. (2006)) and specific studies of the Gippsland Lakes (e.g., Harris *et al*. 1998) have argued strongly for the implicit incorporation of models into monitoring programs and day-to-day adaptive management. The degree to which this requirement has been adopted in monitoring of the Gippsland Lakes is discussed in Chapter 3.

There are generalised conceptual models readily available that could be applied to the Gippsland Lakes. The Coastal CRC, for example, has developed a suite of conceptual models for hydrological processes, sediment trapping, physical habitats, trophic linkages and nutrient cycling in estuaries and coastal wetlands (http:/www:coastal.crc.org.au/wetlands/conceptual.html: accessed 20 March 2006).

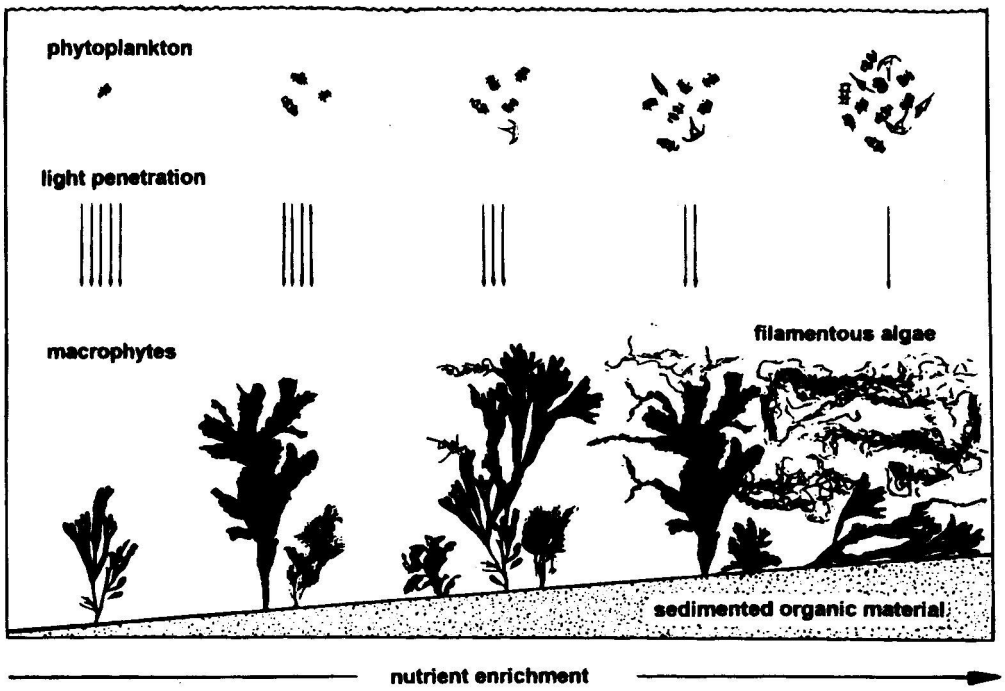

Figure 3. Conceptual model of likely changes in aquatic vegetation with increased nutrient loading. Taken from Raffaelli et al. (1998).

Integration into regional natural-resource management. Monitoring, if incorporated into a *bona fide* adaptive management framework, becomes completely integrated with all other components of natural-resource management in the region. Monitoring then becomes not a stand-alone activity, but an element critical to the process of evaluating the effectiveness of management actions and predicting the outcomes of possible future interventions. In other words, monitoring allows the success (or otherwise) of management interventions to be gauged and provides guidance for future management actions. Incorporation into an adaptive management framework also requires that the monitoring program identify the assets or features that need to be protected and the undesirable outcomes that should be guarded against. These then form the standards against which the success of management can be measured.

Cairns *et al.* (1993) summarised the advantages of integrating monitoring programs fully into an adaptive management framework. They concluded that an integrated program could answer three questions critical in natural-resource management:

- Are stated environmental objectives or outcomes being met;
- If they are not being met, what causes the non-compliance; and
- How can impending non-compliance or undesirable outcomes be predicted before they are actually detected by the monitoring program?

These three issues are used in Chapter 3 as criteria for determining the effectiveness of the 2004 State of the Gippsland Lakes report.

2.3 Exploring the "ecological health" metaphor

2.3.1 Common uses of the term "health" in natural-resource management

The concept of "ecological health, "environmental health" or "river health" is frequently invoked in natural-resource management. Task 1 of the current project, for example, refers to the "the ecological health of the Gippsland Lakes". Actions outlined in the Victorian Government White Paper, *Securing our Water Future Together*, to rehabilitate the Macalister River system aim to "…improve the health of the Thompson River, Macalister River and Gippsland Lakes" (Department of Sustainability and Environment 2004, page 59). Catchment Management Authorities are charged with the responsibility of developing Regional River Health Strategies (Department of Sustainability and Environment 2004, page 163: see also Figure 1). The National Land and Water Resources Audit of 2001 had themes of, among others, river health (Young 1999) and estuarine health (Tait *et al*. 2000). At the national level, there is the National River Health Program (Schofield and Davies 1996). A final example: the slogan of Parks Victoria is *Health Parks, Healthy People*. (Note: underlining was added in the examples above.)

Given the widespread use of the term, it is essential to define exactly what is meant by "health" when the word is used in an ecological or environmental sense. It can then be decided whether the scientific aspects of the 2009 report should seek to address the "health" of the Gippsland Lakes or, indeed, whether the health metaphor should be invoked at all in subsequent reports.

2.3.2 What is meant by the term "ecological health"?

There is little or no general agreement as what the term "health" means when applied to ecological or environmental questions. Meysman and Campbell (2004, page 84) argued that,

> "Organize a debate on the "health of an ecosystem" with a multi-disciplinary group of ecologists, and it takes only one devil's advocate questioning the "ecosystem health" concept to create a flourishing Tower of Babel within minutes".

Young (1999) said that river health was

> "…a "multifaceted concept that seeks to describe the condition or state of a riverine system, using the analogy of the health of a living organism. In particular, the concept of river health seeks to augment traditional physico-chemical condition assessments with biological and/or ecological assessments".

Young (1999) further noted that, "…little ecological theory has been invoked to provide a sound basis for river health assessments, and there is no single widely accepted method for river health assessment". Similarly, Norris and Thoms (1999, page 197) concluded that,

> "… the meaning of 'river health' remains obscure. It is not clear what aspects of river health sets of ecosystem-level indicators actually identify, nor how

physical, chemical and biological characteristics may be integrated into measures rather than just observations of cause and effect".

The term has been heavily criticised since it was popularised by Rapport and his group in the 1990s (Rapport 1992; Rapport *et al*. 1998, 1999). The criticism has come mostly from ecologists (e.g., Calow 1992, 2000; Suter 1993; Wicklum and Davies 1995; Slocum 1998). Their many objections centre around the underlaying assumption that an ecosystem can be treated as an individual organism; that the approach relies heavily on subjective views and value-laden opinions about an original, pristine or desirable condition; and that it is impossible to integrate information across such diverse disciplines as economics and the social, environmental and health sciences.

Many critics go so far as to argue that ecosystems do not possess any health attributes at all: the ecosystem is a sum of its component parts and interactions, hence it is unnecessary to invoke the concept of health in any circumstance. Wicklum and Davies (1995), for example, argued that adopting the concept of ecosystem health required accepting scientific principles that we not supported by empirical evidence. Calow (2000, page 3) went further, and concluded that central tenets of the ecosystem health concept were "not only mistaken but seriously flawed, since [the concept] flouts fundamental ecological and evolutionary principles".

Another common criticism is that seemingly the only way to operationally define ecosystem health is to create indexes of heterogeneous variables. Victorian examples of monitoring approaches that use a synthesis of heterogeneous subindices include the Index of Stream Condition and the Index of Wetland Condition. Overseas examples include the Index of Environmental Integrity for estuaries and wadable streams of the Mid-Atlantic region of the USA (Paul 2003) and South African Estuarine Health Index (Cooper *et al*. 1994). Suter (1993) argued that these integrative indices had no scientific meaning, failed to lead to useful predictions, lacked any diagnostic power, and confused and combined individual impacts. He concluded that the only virtue of biotic or health indices "… is that they reduce the complex array of ecosystem responses to various disturbances to one number with a reassuring name" (Suter 1993, page 1533).

Fairweather (1999b) noted that it is not clear even what constitutes good ecosystem health, let alone what factors can be used to identify a decline in health. In other words, health is not an operational term that can be used unambiguously to generate scientifically useful conclusions. This problem with lack of operational meaning is revisited later in this section, since it creates serious impediments to using the term "ecological health" to assess the environmental condition of the Gippsland Lakes.

The difficulty in establishing unequivocally what signifies a decline in ecosystem health extends not only to what measures should be used to indicate changes in health, but to who should be responsible for collecting the relevant data. The issue pertains both to community monitoring and to assessments made by trained professionals. Wood and Lavery (2000) reported that, even among scientific specialists, health was a respondent-dependant concept and that there were widespread differences among seagrass experts when asked to rank a variety of seagrass beds in terms of ecosystem

health. Fairweather (1999b, page 214-215) examined many of the constraints implicit in making assessments of ecosystem health and suggested that,

> "In ecosystem health, there is also concern about the skills of those doing the assessment. Humans allow only highly qualified professionals to be in charge of our health – not the hospital cleaners, accountants or other medically untrained folk. Therefore, until our understanding of river health is much better developed, its assessment should not be the domain of interest groups involved in Landcare or in other community-based public programs. Good quality control of the data used in river health assessment is of paramount importance…. and good science is needed".

A problem related to the difficulty with identifying those conditions that indicate good ecosystem health is that it is difficult to separate the notion of ecological health from public perceptions of a "preferred state". This means that the concept is especially vulnerable to political manipulation: Rapport *et al*. (1998) provided the North American example of the logging industry promoting unlogged, natural forests as "unhealthy" because they were subject to fire and other natural disturbances.

2.3.3 Does ecological health involve human uses?

Boulton (1999, page 469) argued that the term "river health" was useful because it was readily interpreted by the general public and evoked societal concerns about human impacts. He concluded that the concept of [river] health was founded in the interface between ecological values and human values. Figure 4 (over page) shows the schematic representation of river health as proposed by Boulton (1999).

The model proposed by Boulton (1999) explicitly incorporates a human element into the definition of "ecological health". This is consistent with the original definition of the term (e.g., Rapport 1992) as well as more recent usage. Most recent discussions of ecosystem health by overseas authors also invoke a strong anthropocentric basis. Karr (1999, page 222), for example, stated that an environment is "… healthy when the supply of goods and services required by both human and non-human residents is sustained".

In a widely cited article, Meyer (1997, page 439) defined river health in terms of:

> " A healthy stream is an ecosystem that is sustainable and resilient, maintaining its ecological structure and function over time while continuing to meet societal need and expectations. The concept … explicitly incorporates both ecological integrity (maintaining structure and function) and human values (what society values in the ecosystem)".

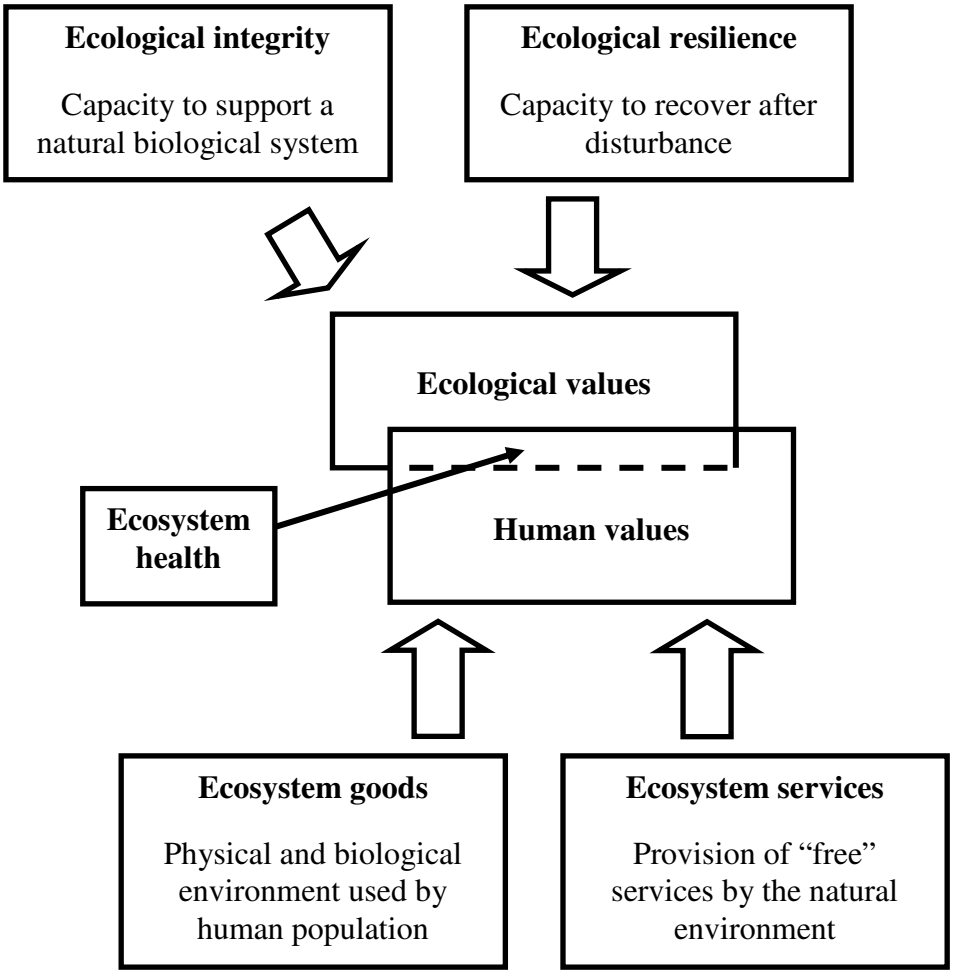

Figure 4. Schematic representation of relationship between ecological values and human values. Modified from Boulton (1999).

Thus there is a consensus among many overseas practitioners that ecosystem health does not equate solely to a narrow description of ecological condition, but necessarily entails subjective assessments that relate to human goals and explicit links to value systems (Fairweather 1999b). This anthropocentric bias has led to further criticism of the ecosystem health concept and, in particular, to its use when describing environmental condition from perspectives other than those of human utility. One of the fiercest critics of the ecosystem health concept, Calow (2000), concluded that the health concept was useful only insofar as it referred to the ability of ecosystems to deliver services to humanity.

In contrast to overseas uses of the term, most Australian natural-resource managers do not include human uses when defining ecological, ecosystem or environmental health. Schofield and Davies (1996, page 39), for example, argued that river health means "… the degree of similarity to an unimpacted river of the same type, particularly in terms of its biological diversity and ecological functioning". This definition makes no explicit mention of human benefit from ecosystem goods or services and equates

roughly to the old-fashioned term "condition". Similarly, Young (1999) described the River Health theme of the National Land and Water Resources Audit without reference to a human-use element. Estuarine health assessments undertaken under the auspices of the National Land and Water Resources Audit (Tait *et al*. 2000) are more concerned with what would traditionally be called "condition assessments" than the human-inclusive term "health".

Conversely, the New South Wales Healthy Rivers Commission noted that "…the community recognises many different dimensions of river health, including water quality and flows adequate to sustain river environments, and the river's ability to support patterns of commercial activity and social amenity to which the community aspires" (Chessman 1999, page 11).

2.3.4 How can ecological health be measured?

Common to most descriptions of ecological health, at least those coming from Rapport's school, is a definition of a healthy ecosystem in terms of one that is "… free from distress and degradation, maintains its organisation and autonomy over time, and is resilient to stress" (Patil *et al*. 2001, page 308). Health is then purported to be assessable in terms of vigour (productivity), organisation and resilience. This raises a further set of problems for those attempting to use the term unambiguously and in an operational sense in routine environmental management. The problem is that ecosystem health cannot be made an operational term, and this drawback is clearly revealed in the paper by Costanza and Mageau (1999), "*What is a healthy ecosystem?*"

Costanza and Mageau (1999, page 106) defined ecosystem health as, "a comprehensive, multiscale, dynamic, hierarchical measure of system resilience, organisation, and vigour". They argued that ecosystem health is a measure of the overall performance of a complex system and that "… measures of ecosystem health imply a weighted summation or a more complex operation over the component parts, where the weighting factors incorporate an assessment of the relative importance of each component to the functioning of the whole". The term was described as being embodied within a more general term of "sustainability", which Costanza and Mageau (1999, page 106) claim is defined as the ability of an ecosystem "… to maintain its structure (organisation) and function (vigour) over time in the face of external stress (resilience)". Table 1 shows the indices of vigour, organisation and resilience invoked by Costanza and Mageau (1999) to measure ecosystem health.

Table 1. Indices of vigour, organisation and resilience as measures of ecosystem health, as proposed by Costanza and Mageau (1999).

Component	Related concept	Related measure	Method of measurement
Vigour	• Function • Productivity • Throughput	• Primary production • Primary production • Metabolism	Empirical measurement
Organisation	• Structure • Biodiversity	• Diversity indices • Average mutual information	Network analysis
Resilience		• Growth • Recovery time • Disturbance absorption capacity	Simulation modelling
Combinations		• Ascendancy • Biotic indices	None identified

Some of these variables have been considered for use in ecosystem-scale monitoring (see Sherman 2000), but it is difficult to see how many of them can be operationalised into the basis of a framework for an integrated monitoring program for the Gippsland Lakes.

2.3.5 Conclusions

Steedman (1994) wrote one of the clearest summaries of what the term ecosystem health could and could not deliver. He argued that ecosystem health is an *idea*, a symbol for a complex set of ecological realities and not a condition that could be measured or monitored directly. He argued that the term "health" could be used to convey a context for interpreting observations, to suggest simple metaphors and analogies for complex realities and to communicate useful generalisations about the goals of natural-resource management. He also stated that the term could not specify unambiguous criteria for interpreting observations, be used to directly measure ecosystem integrity, or substitute for detailed information on specific features or conditions of an ecosystem.

2.4 Developing an environmental monitoring program

The devising, development and implementation of a monitoring program requires attention to two levels of organisation:

- The underlaying approach that provides the unifying basis for the program; and
- The indicators and individual variables that are measured to detect environmental change.

Three main approaches have been used to provide the underlaying basis for developing an environmental monitoring program:

- Analysis of environmental *structure*;
- Quantification of ecosystem *processes*; and
- Analysis of ecosystem *values*, usually from a perspective of human utilization.

These three approaches are discussed in the following sections.

2.4.1 Structural approaches

Thayer *et al*. (2003, page 69) defined the structural components of an ecosystem as "… the physical, chemical and biological characteristics that define that habitat". Analysis of structural elements provide the simplest and most common approach to developing monitoring programs, even if their adoption is rarely acknowledged explicitly.

Traditionally, measurements have been made of two main sets of structural attributes in aquatic monitoring programs:

- Physico-chemical attributes; and
- Biological attributes.

Physico-chemical monitoring considers single variables, such as water pH, electrical conductivity (as a surrogate for salinity), concentrations of dissolved oxygen and nutrients, turbidity and water colour, as indicators of ecological health. Biological monitoring attempts to infer the condition of a given water body by assessing the abundance of a particular species, sometimes termed an *indicator species*, or by examining the community composition of aquatic biota, especially macroinvertebrates but sometimes plants, fish or birds (Cranston *et al*. 1996).

Although both approaches are useful, neither has been regarded as generating a consistent and comprehensive assessment of the condition of a water body, or providing great insights into the ecological state of aquatic systems (Schofield and Davies 1996; Finlayson and Mitchell 1999). In their review of monitoring aquatic ecosystems, Cottingham *et al*. (1995) concluded that, despite the large amount of monitoring undertaken by State agencies over the past ~50 years, monitoring programs were rarely adequate to meet even the simplest expectations.

It has also been argued that a reliance on structural attributes, especially on biodiversity, has led to consistent failures in the conservation of aquatic systems. Finlayson (2006), for example, argued that appeals to biodiversity attributes have not served well the interest of wetlands, and a more fruitful approach would be quantify, and show to the community, the ecological services that wetlands provide.

Because most existing monitoring programs have failed to deliver their expected benefits, a number of new approaches have been introduced to revise methods for monitoring aquatic systems in Australia. There have been four main developments, the latter two of which have led to the development of non-structural monitoring approaches.

First, the revised ANZECC and ARMCANZ (2000) guidelines for water quality adopted a risk-based approach for seven ecosystem types (upland rivers, lowland rivers, lakes and reservoirs, wetlands, estuaries, coastal systems, and marine systems). The new guidelines – even though remaining fundamentally a structural approach – are based on ecological risk assessments, a process that determines the level of risk posed by threats such as toxicants, nutrients and inorganic materials to the health of aquatic ecosystems (Hart *et al*. 1998). The ANZECC and ARMCANZ guidelines focus on the potential problems that can develop in an ecosystem, rather than simply relying on whether the concentration of a particular substance is above or below a given value.

This development, however, still fails to address in full the potential impact of multiple threats. It is rare for an aquatic ecosystem to be affected by a single environmental threat, and most are affected by multiple stressors (e.g., nutrient enrichment combined with shifts in salinity and toxicants, complicated even further by the presence of noxious species). Ultimately, all these factors interact to degrade a given ecosystem and management interventions that address them individually are bound to fail. In such cases it is often argued that it is better to monitor the ecosystem at higher levels of organisation (e.g., plants and/or fish) rather than to monitor individual water-quality variables alone.

The second development in structural analyses seeks to answer this limitation. A strong case can be made for using multiple tools and methods to indicate the structural condition of aquatic systems (Bunn 1995; Schofield and Davies 1996; Barton 2003). A wide range of organisms (e.g., aquatic macrophytes, macroinvertebrates, fish, algae, microbes, etc) are monitored and the results integrated with data on physico-chemical variables. The choice of a diverse range of biota is predicated on the idea that each group will respond to environmental threats in a different way and over different time scales. It is believed the monitoring data obtained for different groups will, together, allow the condition of the system to be described more accurately than if single groups alone were studied (e.g., merely macro-invertebrates).

Third, there has been a move away from monitoring *structural* components of an ecosystem to monitoring the *ecological processes* that drive the ecosystem (Bunn 1995). In the fourth development, the process-orientated approach is expanded to include also *values* provided by the water body to human populations, usually in terms of beneficial uses to the community. For example it would be possible to assess the extent to which a given water body provides recreational fishing opportunities or aesthetic amenity. Both these developments are discussed in subsequent parts of this report (Sections 2.4.2 and 2.4.3).

The biological components of a monitoring program based on structural features are overwhelmingly taxonomic. Numbers may be invoked to achieve a quantitative analysis, but simple presence-absence data are also commonly used for taxa of interest (e.g., for rare or threatened species). From a physico-chemical perspective, a structurally-based program usually reports on static concentrations of a given constituent at a single time. Trend analyses (e.g., rates of change) are made possible only by repeated measurements at a single monitoring station and the fitting of, for example, a regression equation to the data.

A monitoring program for the Gippsland Lakes based on structural features might be expected to include a suite of variables such as:

- Presence of threatened, rare or endangered species of plants and animals;
- Abundance of species that are deemed desirable by the community, e.g., species of fish, such as Southern Bream (*Acanthopagrus butcherii*), commonly sought by recreational anglers;
- Charismatic of flagship species of bird, e.g., White-bellied Sea Eagle (*Haliaeetus leucogaster*);
- Taxa considered to have "umbrella" importance: species, usually of large and long-lived individuals, which are thought, if protected, will lead to the conservation of smaller and less obvious species;
- Presence and spread of undesirable species of plant, such as Brazilian Milfoil (*Myriophyllum aquaticum*) or animal, such as Carp (*Cyprinus carpio*);
- Frequency and spatial extent of noxious algal blooms, for example by cyanobacteria or dinoflagellates, which limit consumption or recreational use;
- Presence of bacterial indicator species, such as faecal coliforms or *E. coli*, that suggest the presence of faecal contamination;
- Salinity of the water column of the main lakes and upstream extent of salinity into the main rivers;
- Frequency, severity and spatial extent of hypoxic (i.e., low-oxygen) events that lead to fish kills; and
- Nutrient status of the water column, in particular the concentrations of nitrogen and phosphorus and how they relate to trigger values as set out in, for example, the ANZECC guidelines.

2.4.2 Process-orientated approaches

In contrast to the more-or-less static nature of structural approaches to formulating monitoring programs, assessments made with a process-orientated approach to monitoring stress the measurement of *rates* of key ecological processes (Bunn 1995; Fairweather 1999b). The term "function" is often used interchangeably with "process" to describe this approach. Thayer *et al*. (2003, page 69) defined the functional components of an ecosystem as "… the processes occurring within and between habitats as a result of their structural components".

It has been suggested by Schofield and Davies (1996) that the advantage of monitoring key processes rather than simple structures in an aquatic system is that the process-orientated approach gives a more direct and holistic measure of the health of a water body. It is also more suited to providing early warning of environmental stress and undesirable changes in the ecosystem being managed. Thayer *et al*. (2003) argued that the aim of restoration projects for aquatic systems should be to return function, and not merely build structure.

The typical question asked in a process-orientated monitoring program is "What are the rates of the key ecological processes that underpin the structural elements of the ecosystem and how have they altered with human impacts?" Since this is a more difficult question to answer than the relatively simple one of describing ecological structure, it has been invoked only rarely in monitoring programs in Australia. It is, however, the underlaying principle of the applied research undertaken to better

understand the operation of complex aquatic ecosystems: examples include the Port Phillip Bay study (CSIRO 1996) and Moreton Bay study (Dennison and Abal 1999). In both cases, the results have had major applications to ongoing management of the two water bodies.

The types of variables that might be measured in a function- or process-orientated approach to monitoring of the Gippsland Lakes include rates of:

- Nutrient loading into the Lakes ecosystem, including inputs from the catchment via rivers as well as internal inputs, such as rates of N_2 fixation by cyanobacteria;
- Nutrient removal from the ecosystem, including by coupled nitrification-denitrification, export to the sea, and burial in sediments;
- Rates of primary production by different classes of aquatic plants, including submerged angiosperms, epiphytes and phytoplankton, leading to an assessment of the degree of eutrophication (see Nixon 1995); and
- Shifts across stable states that form alternative vegetation types, such as dominance by submerged angiosperms to dominance by benthic macroalgae and phytoplankton (e.g., see Figure 3 of this report and Harlin (1998) for more information).

2.4.3 Values-based approaches

A monitoring program that is values-centred seeks to answer the question: "Can we manage the Gippsland Lakes in order to provide the services and values wanted by the human population?" Inevitable, the values are those that are of amenity to the human population; the anthropocentric nature of values components in an ecological health assessment has been discussed earlier in Section 2.3. As noted earlier, there are strong arguments for invoking value-based assessments, particularly of the ecosystem services rendered to the community by aquatic systems, to help conserve and rehabilitate these habitats (Finlayson 2006).

A wide suite of variables can be invoked in a value-orientated monitoring program to answer questions such as:

- Is the water of adequate quality to allow various grades of use, ranging from non-contact recreation at the lowest level to human consumption at the highest?
- Are species of fish important for recreational angling present in sufficient numbers?
- Is the Lakes environment satisfying from an aesthetic perspective, or is it visually degraded by algal blooms and mats of rotting algae washed up along the shoreline? or
- Are the Gippsland Lakes in good enough ecological condition not to unduly limit economic returns from commercial activities?

In many cases there is an obvious overlap among these three broad approaches to environmental monitoring. For example, the presence of algal blooms (detected in a structural analysis) will be evident also in a process-orientated analysis in terms of a shift in the importance of different types of primary producers, and in a values-orientated monitoring program in terms of impacts on recreational uses and economic returns to the human community.

2.5 Choice of indicators and variables

Section 2.4 outlined the three broad ways in which a monitoring program can be conceived. The second level of organisation is at a lower level, and relates to the choice of attributes such as the chosen indicators and individual monitoring variables. Although the scope of this project excludes the specific identification of individual indicators or variables, the following points need to be made with reference to the process of developing the monitoring framework. They are revisited when the 2004 State of the Gippsland Lakes report is reviewed in the following chapter.

2.5.1 Differences between indicators and variables

Although the two terms are often used interchangeably, it is often useful to discriminate between a monitoring *indicator* and a monitoring *variable*. The scoping report by Sinclair Knight Merz (2005a) made such a distinction, but then confused the issue by introducing the term *parameter* to mean the same as variable.

A monitoring indicator integrates a large quantity of data as a meaningful description of a physical, chemical, biological or socio-economic aspect of a complex system. In contrast, a monitoring variable is the specific characteristic or attribute of the system that is measured. A parameter is the description of the statistical summary of the data. For example, a useful monitoring *indicator* might be water quality. The related monitoring *variables* are concentrations of total nitrogen, total phosphorus and dissolved oxygen, as well as pH and turbidity. The *parameters* used to report these variables are some measure of central tendency such as mean or median, and measures of variance such as standard deviation or standard error.

2.5.2 What makes a good environmental variable?

There is a large literature on factors to be considered in the selection of monitoring indicators and variables (e.g., Noss 1990; Cairns *et al*. 1993; Cranston *et al*. 1996: Jolly *et al*. 1996; Fairweather and Napier 1998; Ward *et al*. 1998a; Fairweather 1999a; Niemi and McDonald 2004).

There is general agreement that the best indicator variables have, *ipso facto*, the following characteristics:

- Biologically relevant: the variable reflects a process that is important in maintaining the condition of the system under study;
- Socially relevant: it is obvious and important to stakeholders;
- Ease of capture: the measurements are easy to make;
- Cost: the measurements are cheap to make;
- Measureable: is the variable capable of being operationally defined?
- Standard method: is there a standard method for making the measurements?
- Interpretation criteria: can the data be interpreted easily?
- Scale-appropriate: is the variable measurable at a scale consistent with biological proceses or management interventions?
- Error rate: is the variable likely to be associated with a high error in measurement?

- Response time: is the variable sensitive enough for measurement to respond adequately to the changes expected in environmental condition?
- Stability: is the variable relatively stable over time, or does it fluctuate wildly?;
- Non-redundant: does the variable provide unique information that is not supplied by other indicator variables; and
- Context: is the variable relevant within the broader context of the monitoring program and regional natural-resource management?

Although it is desirable that indicators and variables are selected objectively, there are a number of subjective issues that commonly weigh heavily on the selection process. Fairweather (1999a) observed a tendency to select indicators according to whatever perspective was most popular at the time, leading to a haphazard monitoring program in which other, perhaps more useful, variables were overlooked. Indicators may be chosen merely because a given approach is better developed than others: Fairweather (1999a) cited as examples the EMAP monitoring program of the USA EPA and Australia's AusRivAs system for river health.

2.5.3 Development of novel indicators and variables

Niemi *et al*. (2004) outlined a rationale for using a new generation of indicators to measure the condition of coastal waters. Many of the current analytical measures (e.g., water clarity, algal biomass, nutrient concentrations, species richness, etc) are cost prohibitive if applied to large-scale monitoring programs. A new set of sophisticated and diagnostic indicators are becoming available which can be used to assess, for example, eutrophication, toxicant exposure, faecal pollution and landscape-scale changes, across various spatial and temporal scales. Barton (2003) also argued for the inclusion of novel indicators to monitor estuarine systems, and placed an emphasis on microbiological variables.

2.5.4 Indicators of human use and values

Section 2.3 demonstrated that the term "ecological health" is often defined to include human-based values as well as purely ecological aspects of environmental condition. If the "health" term is used as a basis for future monitoring and reporting of the Gippsland Lakes, a suite of indicators that reflect human uses, and satisfaction with those ecosystem goods and services provided by the Gippsland Lakes, will need to be included in the monitoring framework (e.g., see Figure 3). A precedent for the use of human-use indicators is the management program developed for the Great Lakes on the USA-Canada border (Cairns *et al*. 1993). Drawing in part from this program, Cairns *et al*. (1993) concluded that environmental quality must be sufficient to ensure:

- Human health;
- Reasonable human uses of resources; and
- Favourable public perception of the quality of life and the environment.

Protection of human health is, to most people, the single most important goal of environmental management and monitoring. Table 2 summarises the range of indicators that could be used to quantify the response of human use to decreasing environmental quality. Note that indicators associated with drinking water quality are not included, since the Gippsland Lakes (as defined in Section 2.1) does not provide potable water.

Table 2. Potential indicators of the response of human use to environmental degradation. Adapted from Cairns et al. (1992).

General category	Specific indicator or application
Commercial fisheries	Quantity • Stock • Harvesting • Recruitment Quality • Abundance of preferred species • Restrictions of consumption • Incidence of deformities Valuation • Pricing • Employment and income
Recreation	Quantity • Visitor numbers • Boat registrations • Marina and beach use • Vacancy rates Quality • Incidence of restrictions on use (e.g., closed waters) • Catch per unit effort for recreational angling and commercial fishing Valuation • Employment and payroll • Sales • Admission fees
Industrial uses	Quantity • Stock, withdrawal and replenishment rates Quality • Productivity • Costs of pre-treatments Valuation • Compensation for loss of use • Increased product cost due to degradation
Aesthetics	Quantity • Subjective valuation • Length of undeveloped shoreline Quality • Incidences of odours, algal blooms etc Management costs • Costs for water treatment etc
Transportation	Management costs • Dredging • Pollution costs
General economic wellbeing	Regional GDP, unemployment, income distribution

It is important to distinguish between the assessment of environmental *condition*, which ideally is an objective process, with the assessment of environmental *quality*, which relies more heavily on individual perceptions and values. The distinction is important, because it is the perception of environmental quality that determines stakeholders' satisfaction with management efforts (Cairns *et al*. 1993). Assessments of public perceptions of environmental quality may, however, yield responses that are not easy to include in adaptive management frameworks. Burger (1998), for example, reported on a survey of public perceptions of environmental quality along the highly industrialised New Jersey coastline of the USA. By far the most significant environmental problem reported by participants was the disturbance generated by jet skis and other personal watercraft; these ranked even higher than chemical pollution, junk [rubbish], oil and overfishing. In terms of broader-scale environmental impacts, however, noisy recreational watercraft were probably a minor environmental stressor.

2.6 Proposed framework for an integrated monitoring program

2.6.1 Recommended framework

The objective of Task 1 is to "develop a framework of an integrated monitoring program for the ecological health of the Gippsland Lakes using the product of the two Gippsland Lakes monitoring workshops". The proposed geographic limits of the study area were outlined in Section 2.1. Section 2.2 showed how monitoring differed from other data-collecting activities, such as survey work and surveillance sampling. Section 2.3 showed the many problems created by referring to the term "ecological health" in the project brief.

If the monitoring program is to address ecological health, it should include not only quantitative indicators/variables of environmental-ecological condition but also an explicit analysis of the degree to which the Lakes ecosystem provides the goods and services expected by the human population. The limitations of this approach have been described in Section 2.3.3. There is also the difficulty of explicitly incorporating landscape-scale and whole-of-catchment considerations when the regional definition of the Gippsland Lakes specifically excludes these hinterland areas (e.g., see Section 2.1).

A solution to the dilemma is to use the OECD Pressure-Condition-Response approach as the framework for future monitoring and reporting.

2.6.2 OECD Pressure-Condition-Response model

The OECD Pressure-Condition-Response model uses three classes of indicator to show the current condition and trend in the environment and the response of natural-resource managers to these variables (Environment Australia 1996, 2001; Fairweather and Napier 1998; Fairweather 1999b). The Pressure-Condition-Response framework is shown in Figure 5.

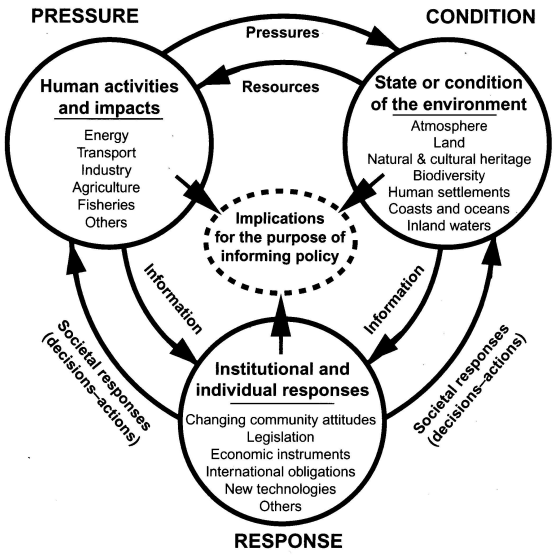

Figure 5. OECD Pressure-Condition-Response reporting framework. Taken from Environment Australia (2001).

The three classes of indicator are:

- *Pressure indicators*: the stresses and degree of impact placed on the environment by human activities;
- *Condition indicators*: indicators showing the ecological state of the environment and its response to the stressors and disturbances identified in the Pressure category; *viz* largely the array of traditional and novel variables quantified in environmental monitoring programs; and
- *Response indicators*: measures of the society's reaction to changes in environmental condition in order to mitigate pressures, e.g., policy developments, management interventions, public awareness campaigns etc.

The framework has been adopted for National State of the Environment reporting (Environment Australia 1996, 2001) and a suite of indicators have been developed to this end (e.g., Ward *et al*. 1998a). It also formed the putative basis of the 2004 State of the Gippsland Lakes report (Sinclair Knight Merz 2005a, b; Gippsland Lakes Taskforce no date); the degree to which the model was utilized fully in the 2004 report is reviewed in Section 3. It was the approach recommended by Barton (2003) in her review of estuarine monitoring and assessment across Australia.

The Pressure-Condition-Response model has the following advantages if used to provide a unifying framework for developing an integrated monitoring program for the Gippsland Lakes:

- Forms the basis of current National State of the Environment reporting, so data and interpretation should be fully transferable across the various forms of reporting;
- Clearly demonstrates the current ecological condition of the Gippsland Lakes;
- Uses a set of previously-developed indicators, with the following characteristics:
  - definition and rationale are available for all indicators,
  - relevant data sources and collection procedures have been identified, and

- methods for analysis and interpretation have been described;
- Clearly shows the link between causes and effects in environmental degradation or improvement;
- Facilitates the inclusion of broader catchment-scale stressors on the ecological condition of the Gippsland Lakes; and
- Incorporates a strong human element into the assessment, principally through descriptions of the response of natural-resource managers to changes in environmental condition.

Although the Pressure-Condition-Response model is an appropriate framework for the 2009 Gippsland Lakes report, it is unlikely that the individual indicators developed for National State of the Environment reporting (e.g., for Estuaries and the Sea, Biodiversity, and Inland Waters) will be sufficient by themselves to adequately describe ecological condition of the Gippsland Lakes. The likely need to use a complementary suite of indicators is discussed in Section 4.

3 Task 2: Assessment of the 2004 State of the Gippsland Lakes report

Chapter overview

The objective of Task 2 is to:

- Assess the suitability of the data collected for the 2004 State of the Gippsland Lakes report in terms of its form, level of analysis and ability to be interpreted and analysed, and
- Identify where no current data are available.

The 2004 report (Gippsland Lakes Taskforce no date) is reviewed, along with the two consultant's reports that were used in its preparation (Sinclair Knight Merz 2005a, b). The review is undertaken from two perspectives:

- In broad terms, in the light of the type of the general types of outcomes expected from an effective monitoring program embedded within a regional adaptive-management framework; and
- In more specific terms, with particular reference to the range and suitability of the indicator variables used in the monitoring program and whether suitable data are available for future reports.

Aspects of both topics were provided as background material in Chapter 2.

There are many similarities between the expectations from the 2004 State of the Gippsland Lakes report and those of the recent report of the Victorian Catchment Management Council (VCMC), *The Health of our Catchments > A Victorian Report Card 2002* (Victorian Catchment Management Council 2002). The Chapter concludes with a short discussion of the perceived strengths and limitations of the VCMC report and their relevance to the 2004 and planned 2009 Gippsland Lakes reports.

3.1 Structure of the 2004 State of the Gippsland Lakes report

The 2004 State of the Gippsland Lakes report (Gippsland Lakes Taskforce no date) is a 24-page, glossy A4 document with six main sections:

- An introductory statement of purpose, scope and method;
- Brief description of the Gippsland Lakes, addressing mainly Lakes King, Victoria and Wellington;
- A 1-page description of values of the region, covering environmental, social, economic and cultural values;
- A 3-page description of the Gippsland Lakes ecosystem, focusing on nutrient cycling, algal abundance, water-column stratification and nutrient inputs from the catchment. This section also includes a very basic conceptual model of the Lakes ecosystem and the relationship of the lacustrine systems with the surrounding catchment;
- The main body of the report, extending from pages 10-21 and divided into three sections (Estuaries - 6 pages; Biodiversity - 2 pages; and Inland Waters - 3 pages; and

- A concluding section of 2 pages on the future health of the Gippsland Lakes.

The Pressure-Condition-response model was putatively used as a framework for the report and indicators drawn from National State of the Environment protocols are used to report on ecological condition (Sinclair Knight Merz 2005a).

3.2 Critique of the 2004 report: general issues

3.2.1 Comments from workshop meeting of Gippsland Task Force

Appendix A provides a summary of outcomes of the meeting of the Gippsland Task Force of 4 March 2005. Reactions to the report varies from "excited" to "irritated" and "disappointed".

The Task Force was disappointed that the 2004 report did not adequately reflect community values or the extent to which the community thought natural-resource managers were successfully managing the Gippsland Lakes ecosystem. Criticism was raised at the lack of a clear perceived audience for the report, an excessive emphasis on algal blooms and a related neglect of catchment impacts, and that areas where ecological condition had, or had not improved, were not clearly outlined. Some concern was expressed that the report did not fulfil an educative role in informing the general community about key ecological processes.

There was perceived to be a lack of emphasis given to the financial and human (both paid staff and volunteer) resources being spent in better managing the Lakes ecosystem, including the return on investment. The choice of specific indicators and monitoring variables was not made explicit, nor were emerging issues and knowledge gaps. There was little attention given to predictive ability. On the other hand, positive aspects of the report were that it was quick and easy to read, and that the MERGe framework had been used.

3.2.2 Adoption of Pressure-Condition-Response model

The 2004 State of the Gippsland Lakes report putatively used the OECD Pressure-Condition-Response model as its unifying framework (Sinclair Knight Merz 2005a, b). As outlined in Section 2.6.2, this framework uses three classes of indicator to quantify environmental condition:

- *Pressure*: the human-created stresses that are placed on the environment;
- *Condition*: indicators showing the response of the environment to these stressors; viz the traditional array of variables quantified in environmental monitoring programs; and
- *Response*: society's reaction to the change in environmental condition, e.g., policy developments, public awareness campaigns etc.

The 2004 report, however, was not explicitly structured along these lines. A strong emphasis was given to Condition indicators, to the detriment of Pressure and Response indicators. These criticisms are consistent with the report's negative reception by the Gippsland Task Force, where it was perceived that little attention had

been given to catchment influences (i.e., Pressure indicators) or to the investment and actions of natural-resource managers (i.e., Response indicators).

A criticism raised by the Task Force (Section 3.2.1), that the 2004 report did not address recent investment decisions and improved natural-resource management activities, could have been answered had the report included a strong section on Response indicators. An outline of natural-resource management initiatives and community involvement would show the value placed on the Lakes ecosystem by the regional and wider community: for example, the extent of community involvement would show the work undertaken by WaterWatch and other groups. Such involvement should not be underestimated: Bender (2006), for example, reported that volunteer input accounted for some 8 % of total input by paid workers to Parks Victoria in 2004-2005.

The degree to which the 2004 report used National State of the Environment monitoring indicators and variables is discussed later in Section 3.3.

3.2.3 Use of ecosystem health metaphor

The 2004 State of the Gippsland Lakes report refers on page 10 to "lake health" and "wetlands health". There was no attempt to distinguish between ecological condition and ecological health, and in particular whether the latter term included an explicit element based on the degree to which the Lakes ecosystem served human needs.

3.2.4 Target audience

It is not clear what audience was targeted in the 2004 report. Feedback from the two workshops held in 2005 (Appendix A) shows the wide range of possible audiences for the report. The simple conceptual models used in the 2004 report suggest the target audience was the general community, but many of the terms used required considerable scientific expertise to understand or interpret the findings. For example, the way cyanobacterial species and trigger levels for chlorophyll *a* concentrations were invoked on pages 14 and 16 suggests a good familiarity with algal taxonomy and pigments and the ANZECC process of determining unacceptable water quality.

3.2.5 Geographic scope and spatial extent

The geographic scope of the Gippsland Lakes was not made clear in the 2004 report. The Purpose section of page 4 states that the Gippsland Lakes Future Directions and Actions Plan requires the production of a regular "State of the Lakes and Catchment Report". The report, however, concentrated on a poorly defined subset of this region, and focused on the three main lakes of the Gippsland Lakes ecosystem. Lake Reeve was not included, and the fringing wetlands were mentioned but not specifically delimited. Data were presented on freshwater sections of the main rivers that drain into the Gippsland Lakes (e.g., Lake Glenmaggie tail gauge on the Macalister River, page 21), but no definition given of how far up these rivers the "Gippsland Lakes" was expected to apply. Catchment-related issues, such as changes in population and land use, were hardly covered.

3.2.6 Expected outcomes of an effective monitoring program

As noted in Chapter 2, Paerl *et al*. (2006) argued that monitoring of coastal systems affected by excessive nutrient inputs should be able to detect three types of environmental change:

- Trends in time and space;
- Changes in ecological state; and
- Biogeochemical and trophic consequences of infrequent, but large-scale, events, using continuous and integrative approaches.

Only one of these three components – trends – was addressed in detail in the 2004 State of the Gippsland Lakes report. Temporal trends in fish stocks and chlorophyll *a* concentrations (as an indicator of phytoplankton biomass) were reported, but these were the only attempts at trend analysis. It was stated on page 12 of the report that there have been no clear trends or marked deterioration in water quality in Lakes Victoria or King since the mid 1980s, but no data were shown to support the conclusion. Spatial patterns were not discussed in detail: again Lake Reeve was neglected.

The report did not address possible changes in ecological state in vegetation or fish populations. Figure 3 in Section 2.2.2 of this report, for example, shows a likely scenario for the loss of desirable seagrass beds and their replacement with phytoplankton or benthic macroalgae under chronic nutrient enrichment. There is a mention of seagrass condition on page 17 of the report, but no information was presented on trends or possible change in ecological state if future patterns of nutrient enrichment were to continue. Possible changes in the fringing wetlands (e.g., loss of Common Reed and replacement by Swamp Paperbark, subsequent to salinisation) were not discussed despite their being noted over 40 years ago (Bird 1962).

The separation of infrequent, large-scale events (such as weather or climatic events) from human-induced effects also was not addressed in depth, except for a short section on bushfires and climate change on page 23 (Gippsland Lakes Taskforce no date). Such a discussion is imperative to explain not only monitoring findings in a country with as variable a climate as Australia, but to educate the lay reader about the importance of random events, such as storms, on the ecological condition of the Gippsland Lakes.

3.2.7 Fit with adaptive management frameworks

It was argued in Section 2.2.2 that for the monitoring program to be integrated it needed a clear relationship with regional natural-resource management. An important aspect of the adaptive management framework is that monitoring and interpretation effort be informed by conceptual models with the appropriate level of complexity.

The 2004 report included a number of very simple conceptual models, but they offered no predictive ability and were not used to interpret the data generated by the monitoring programs. A brief discussion of limiting nutrient and algal blooms in the Gippsland Lakes illustrates the problem. The *Gippsland Lakes Environmental Study* (Webster *et al*. 2001) concluded that phytoplankton in the Gippsland Lakes were most likely limited by the availability of dissolved inorganic nitrogen. Hence, a discussion

of the incidence and location of algal blooms in the 2004 report (which occupies 5 pages) should have included an explanation of why the blooms occurred when and where they did, and how they were linked to either local (e.g., stratification of the water column) or broader-scale (e.g., weather, catchment land use) issues. Understanding the ecological processes that account for algal blooms, especially in estuarine systems where N_2 fixation is unlikely to occur if the salinity exceeds about 10-12 (Howarth and Marino 2006), would have added much understanding to the 2004 report.

As noted in Section 2.2.2, there are appropriate conceptual models available for use in a future report on the Gippsland Lakes. Figure 6 shows, as an example, a conceptual model developed for nutrient cycling in coastal environments by the Coastal CRC (http:/www:coastal.crc.org.au/wetlands/conceptual.html, accessed 20 March 2006).

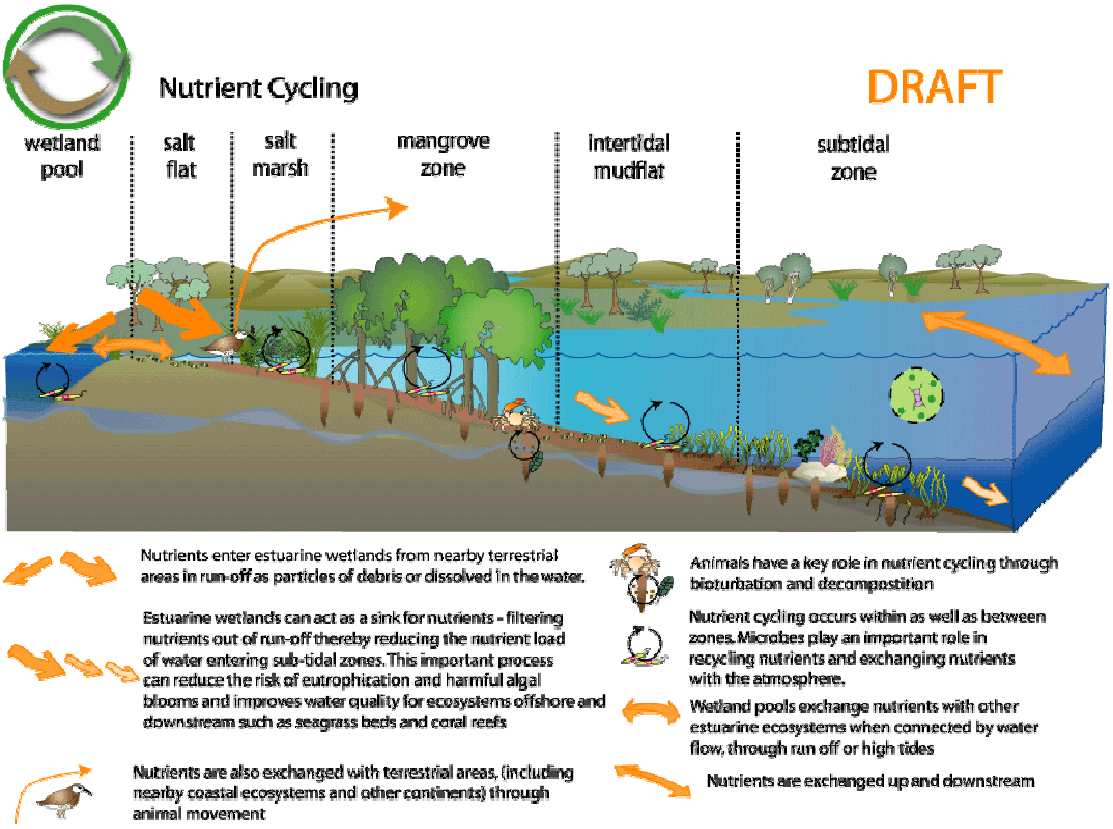

Figure 6. Conceptual model of nutrient cycling in coastal environments. Source: Coastal CRC (http:/www:coastal.crc.org.au).

3.2.8 Emphasis on compliance

Rather than address process-orientated phenomena, the emphasis of the 2004 State of the Gippsland Lakes report was on compliance with SEPP and ANZECC guidelines. As such the 2004 report satisfies the first of the three questions that Cairns *et al.* (1993) expected a monitoring program to be able to answer: "Are stated

environmental objectives or outcomes being met?" The report, however, did not allow the other two questions to be answered clearly:

- If environmental objectives are not being met, what causes the non-compliance; and
- How can impending non-compliance or undesirable outcomes be predicted before they are actually detected by the monitoring program?

The third topic, lack of testable ecological predictions, was raised also at the workshop of the Gippsland Lakes Task Force (Section 3.2.1). Part of the reason for the failure of the 2004 report to address this topic is a function of the poor use of conceptual and/or mathematical models. Part derives also from the choice of indicator variables, a topic discussed in the following section. The chosen indicators were largely compliance indicators (*sensu* Cairns *et al*. 1993) and little attention was given to diagnostic indicators or early warning indicators.

3.3 Critique of the 2004 report: range and suitability of indicator variables

The indicators and variables used in the 2004 report were drawn from three themes developed for National State of the Environment reporting: Estuaries and the Sea (Ward *et al*. 1998a), Biodiversity (Saunders *et al*. 1998) and Inland Waters (Fairweather and Napier 1998).

The specific indicators used in the 2004 report were:

- Estuaries and the Sea:
  - wild fish stocks,
  - water quality (dissolved oxygen, pH, nitrogen and phosphorus concentrations), and
  - algal blooms (alert levels, chlorophyll *a* concentrations – trends and ANZECC trigger levels);
- Biodiversity:
  - carp abundance,
  - seagrass condition, and
  - wetland vegetation;
- Inland Waters:
  - environmental flows, and
  - river water quality.

The choice of particular indicators must have been based, at least in part, on the availability of suitable data within the financial and reporting constraints of the project. The Sinclair Knight Merz (2005b, page 2) report noted that "There appears to be no consistent framework and approach to ensure an adequate supply of appropriate data upon which to base future State of the Gippsland Lakes reports".

Nevertheless, only three main sets of indicators were chosen from the much larger set available under the National State of the Environment protocols (Fairweather and Napier 1998; Saunders *et al*. 1998; Ward *et al*. 1998a). For example, 61 key indicators (grouped under eight classes) have been developed for monitoring Estuaries

and the Sea (Ward *et al*. 1998a). Table 3 shows the eight classes and the most relevant of the 61 nominated indicators.

Table 3. Summary of indicators used for National State of the Environment reporting for Estuaries and the Sea. Key: C = condition indicator; P = pressure indicator; R = response indicator. Modified from Ward et al. (1998a).

Issue	Indicator	Condition, Pressure or Response
Class 1: Cited species	• Rare, threatened or endangered species • Protected species • Seabird populations	R C C
Class 2: Habitat extent	• Algal bed area • Beach/dune area • Coral reef area • Dune vegetation • Intertidal reef area • Intertidal sandflat/mudflat area • Mangrove area • Saltmarsh area • Seagrass area	C C C C C C C C C
Class 3: Habitat quality	• Algal bed species • Algal blooms • Beach species • Coral reef species • Dune species • Fish populations • Intertidal reef species • Intertidal sandflat/mudflat species • Island and cay species • Mangrove species • Pest numbers • Saltmarsh species • Seamount species • Seagrass species • Species outbreaks • Subtidal species • Chlorophyll concentrations	C P C C C C C C C C C C P C C C C P C C
Class 4: Renewable products	• Aquaculture effort • Aquaculture production • Fish stocks • Seafood quality (contamination) • Trawl area • Fishing gear	P C C C P P
Class 5: Non-renewable products	• Exploration and mining	P

Class 6: Water & sediment quality	• Sediment contaminants • Sentinel accumulation • Turbidity • Nutrients (nitrogen) • Seabird egg contaminants	P P P P P
Class 7: Integrated management	• Beach stabilisation • Catchment development • Catchment management programs • Coastal care community groups • Coastal discharges • Coastal population • Coastal tourism • Fishing effects on non-target species • Management integration • Marine network participation • Marine protected areas • Ship visits • Shipping accidents • Commonwealth and State marine management	R P R R P P R R R R R R R R R
Class 8: Ecosystem-level processes	• Sea level • Sea surface temperature	C C

It is not clear why some indicators/variable were used in the 2004 report and others were not. A similar case could be made for the Biodiversity and Inland Water indicators, if indeed the latter are relevant to the Gippsland Lakes.

3.4 Conclusions regarding 2004 report

Although this section reads very harshly on the authors of the 2004 report, the difficulty they undoubtedly faced in collating the necessary information within budget and reporting time constraints should not be underestimated.

Since the scope of this review does not extend to identifying the specific monitoring variables that should be included in the 2009 report, it is not possible to determine whether the required data are currently available. Chapter 4, on identifying possible constraints, addresses the types of indicators and variables that might need to be collected for the 2009 State of the Gippsland Lakes report and whether, in principle, they could be made available for reporting in 2009.

3.5 Lessons from the 2002 Victorian Catchment Management Council report

The report of the Victorian Catchment Management Council, *The Health of our Catchments > A Victorian Report Card 2002* (VCMC 2002), is the result of the statutory requirement of the Victorian Catchment Management Council to report every five years on the condition and management of the States' land and water resources. The 2002 report followed the inaugural report of 1997, *Know Your Catchments*, which provided an initial benchmark of environmental condition but demonstrated major problems with collating data from disparate sources and, in many cases, the absence of relevant data. It is recognised as being a preliminary report: for example it did not "… address biodiversity condition pressures and trends at any meaningful level (VCMC 2002, page 26).

The 2002 report used a suite of catchment indicators to address eight themes: socio-economic landscapes; biodiversity; rivers, wetlands and estuaries; water resources; land; pest plants and animals; greenhouse-gas emissions; and community attitudes and involvement. Specific details on the indicators used in the assessments were provided in Department of Sustainability and Environment (2001), *Victorian Catchment Indicators*. As an example, the two indicators used in the Biodiversity theme were a) Conservation status of native vegetation types at the State and bioregional level, described in terms of Ecological Vegetation Classes; and b) the conservation status of rare or threatened species. In the Rivers, wetlands and estuaries theme, there were three indicators: a) Index of Stream Condition; b) the number of environmental flow assessments incorporated into streamflow management plans or bulk water entitlements; and c) water quality in terms of pH, total phosphorus and total nitrogen concentrations, electrical conductivity, and turbidity. For estuaries, the assessment was merely a qualitative measure of condition in terms of degree of modification.

A noteworthy aspect of the 2002 VCMC report is the system used for reporting the findings. Condition was reported with a simple four-level index (optimal; good; moderate; poor), usually at a regional (catchment) level. Trend in condition also was reported at four levels (positive; negative; stable; unknown). Data quality was displayed as good (consistent, with > 5 years of data), fair, or poor-limited, using a series of colour-coded stars. The management response was quantified by describing whether or not the indicator was subject to a State strategy or plan; if the strategy contained clear performance targets; if the strategy was being implemented at the catchment level; and if monitoring and evaluation were a clear component of the strategy.

A workshop was held on 7 September 2005 to examine the 2002 report and plan for the 2007 report (Patricia Geraghty, *pers. comm.* December 2005). It concluded that the 2002 report served a very useful function in being unique, comprehensive and widely regarded as being credible, especially considering the huge amounts and complexity of the data. On the negative side, it had a political life of "about 3 weeks", in many cases failed to have an impact even at the State level, and probably failed to fully engage with the community.

The workshop concluded that the challenges facing production of the 2007 report included:

- Communication: how can the 2007 report receive the public and policy attention it deserves, how can the data be summarised in a meaningful way that tells a story but retains the technical accuracy?
- Co-ordination and integration: how can duplication be prevented, existing projects be co-ordinated and integrated, and the 2007 report be an advance on earlier reports?
- Audience: what is the right audience, how is the "grassroots" involved, what evidence is required to influence decision makers at a range of levels?
- MER approach: what are the key questions to answer, how to ensure that the focus be outcomes, how can we separate the short-term (5 years) from the long-term (150 years)? and
- Information systems: how is it possible to make connections across the diversity of ecological issues and responses, how is the knowledge managed?

4 Task 3: Identification of constraints or considerations

Chapter overview

The objectives of Task 3 are to:

- Document any matters that will add value to Stage 2 and/or require further consideration before commencing Stage 2;
- Document constants or trade-offs that might be required to satisfactorily complete the 2009 State of the Gippsland Lakes report; and
- Document the key objectives for developing Stage 2 of the program; and

(The aim of Stage 2 is to determine the detailed monitoring program, its costs and constraints.)

This Chapter outlines the main constraints likely to be encountered in developing the monitoring program leading to the 2009 State of the Gippsland Lakes report. The topic is addressed from three perspectives:

- General requirements for the monitoring program, leading to identification of the key objectives;
- Constraints created by adopting the Pressure-Condition-Response model; and
- Issues with the choice of indicator variables used in the monitoring program and whether suitable data are available in principle or could be made available from future monitoring efforts.

4.1 Key objectives for future monitoring program

Key objectives for the future monitoring program should include:

- Address *bona fide* monitoring rather than simple survey or surveillance;
- Have a clear and explicit purpose, for example to meet a legislative requirement, aid implementation of a natural-resource management program, increase community awareness, etc;
- Be integrated externally into broader-scale natural-resource management in the region by its incorporation into an adaptive management framework with explicit acknowledgment of the MERGe framework;
- Be explicitly integrated internally, such that its individual components relate to and inform upon each other;
- Where appropriate, make use of risk-based and multiple-variable structural approaches and address process-oriented and value-orientated indicator variables where possible;
- Use a wide range of indicator variables that satisfy the requirements for ease-of-capture, cost effectiveness, relevance, etc;
- Have an appropriate experimental design that allows changes in the environment to be detected reliably at the desired level of precision;
- Address the key governance issues, including data availability and clearance;
- Have an explicit timeline for data collection and reporting;
- Include a clear interpretation of the data and their implications for environmental condition, including where appropriate implications for scenario building;

- Have a clear target audience in mind, combined with appropriate reporting appropriate to that audience; and
- Include a measure of success of the monitoring program.

4.2 Limitations created by adopting the Pressure-Condition-Response framework

Although the Pressure-Condition-Response framework was invoked for the 2004 State of the Gippsland Lakes report and is recommended for the 2009 report, the 2004 document was not coherently structured along these lines. Advantages of using the Pressure-Condition-Response framework were described in Section 2.6.2.

Although it forms the recommended framework for the 2009 report, there are two potential limitations in using the Pressure-Condition-Response framework:

- *Complexity of interactions among threats, condition and responses*. In any reporting structure there is the problem of how to classify the findings. The Pressure-Condition-Response framework attempts to group data into three discrete areas, but the results could equally be classified along other lines, such as interactions among threats and ecological responses. The 2009 report will need to make explicit the interactions among pressures and ecological responses: for example, excessive nutrient loads contribute not only to algal blooms but to water-column deoxygenation and shifts across trophic states.

- *Understanding by lay audience*. The Pressure-Condition-Response framework probably will be familiar to academics and those working at a high level in natural-resource management agencies. It will need to be explained to those working at a lower level in such agencies and to the broader community. Linked with this constraint is the issue of identifying the target audience for the 2009 report.

A significant consideration in the reporting of any monitoring activity is the target audience for the report, and a perceived problem with the 2004 report was the lack of an explicit audience. Table 4 shows the possible range of possible audiences for the 2009 report, drawn from feedback of the meeting of the Gippsland Lakes Task Force (Appendix A). It is likely that different products will have to be developed for subsets of the complete possible audience of the 2009 report.

Table 4. Range of possible audiences for 2009 report. Source: Gippsland Lakes Task Force meeting of 4 March 2005 (Appendix A).

Community	Industry	Government
Recreational water users	Land and water managers	Government – Federal, State and Local
General public- Gippsland region	Academic researchers	Leaders of Opposition
General public – Melbourne	Tourism industry	Local members
Sporting clubs	Fishing – commercial	Catchment management Authorities
Indigenous community	Fishing – recreational	Agencies (e.g., EPA, DSE, DPI)
Conservation groups	Transport sector	
Chambers of Commerce	Developers and investors	
	Manufacturing industries	
	Primary industries	

4.3 Range and suitability of indicators and monitoring variables

The type and quality of data available for reporting will be a major constraint in the generation of the 2009 report. There are two aspects to the issue:

- Inherent characteristics of data generated by aquatic monitoring programs; and
- Characteristics of data generated by past and current monitoring undertaken in the Gippsland Lakes.

4.3.1 Inherent characteristics of data from aquatic monitoring programs

Data collected from the monitoring of aquatic systems typically have the following characteristics (Ward *et al*. 1998b):

- Static temporal scale: many surveys are undertaken at only one or a few times, and thus represent at best a snapshot in time;
- Limited spatial scale: often only a very small proportion of the total area is surveyed;
- Variability: most aquatic phenomena are highly patchy and the combination of limited spatial and temporal sampling makes for high variability in the data;
- Limited range of variables assessed.

Almost all of these limitations are illustrated in the monitoring data available for the Gippsland Lakes, as discussed in the next section.

4.3.2 Monitoring data available for the Gippsland Lakes

Table 5 shows the range of monitoring data available for the Gippsland Lakes, drawn from the meeting of March 23 2005 (Appendix A).

Table 5. Key aspects of existing monitoring data for the Gippsland Lakes since the 1890s. Source: Gippsland Lakes monitoring meeting of March 23 2005 (Appendix A).

1890 – 2005	▪ Hydrographic surveys
	▪ Tides last 25 years
1960's – present	▪ Shorebird monitoring ▪ Visitor numbers
1975	▪ EPA monitored by the marine unit
1975	▪ Victorian Water Quality Monitoring Network
1975 – 2003 (?)	▪ Water level at Lakes Entrance by Gippsland Ports
1985	▪ EPA fixed sites ongoing ▪ Re recruit surveys
1991	▪ EPA fixed sites: ongoing ▪ Lake Wellington contamination survey
1994	▪ Waterwatch
1996	▪ EPA spatial (underlay?) monitoring with fixed sites ▪ Gippsland Regional Monitoring Partnership first thought about
1997	▪ Recreational Fishing surveys
Mid 1998	▪ Mid drain monitoring begins
Nov 1998	▪ Water level observations @ approx 15 locations around Lakes
2000	▪ Regular monitoring of blue green algae ▪ Community monitoring of water quality in Lake King
2001	▪ Lake Wellington wetlands project ▪ Sediment Nutrient flux investigation monitoring ▪ MAFRI mercury investigation
2002	▪ DSE fire load monitoring
2003	▪ River load monitoring
2004	▪ EPA/CSIRO Sediment sources study
December 2004	▪ The State of The Gippsland Lakes Report released
January 2005	▪ Monitoring program
March 2005	▪ This workshop to plan for monitoring of The Gippsland Lakes

It would seem that many of the monitoring data available are short term and have a limited spatial coverage. Data are often available for only a single monitoring period, perhaps representing the output of an individual monitoring project covered by episodic funding. Three illustrations demonstrate the problem.

Water-quality monitoring. The EPA currently monitors water quality of surface and bottom waters at 10 sites in the Gippsland Lakes. A wide range of variables are quantified (e.g., dissolved oxygen, temperature, chlorophyll *a*, total and dissolved inorganic nitrogen and phosphorus) and one-two weekly intervals, but monitoring commenced only in early 2006 (Warren Davies, *pers. comm*. March 2006).

Seagrass monitoring. Change in the area of seagrasses is one of the recommended National State of Environment indicators for Estuaries and the Sea (see Table 3). The 2004 State of the Gippsland Lakes report noted the review by Roob and Ball (1997) on historical changes in seagrass cover since the 1950s. It is not evident that comparable data are available to update the findings since 1997.

Wetland monitoring. Wetland vegetation was invoked as one of the key indicators in the 2004 State of the Gippsland Lakes report. The conclusion – that no data were available for all the wetlands – is likely to be modified for the 2009 report. The

outcomes of the Index of Wetland Condition for the Gippsland Lakes (Ecos Environmental Consulting 2003) should be available, as well as outputs from the state-wide Index of Wetland Condition assessments (Department of Sustainability and Environment 2005) and finalised data from the R&D projects on Dowd, Clydebank and Macleod Morasses undertaken by Victoria and Monash Universities.

4.3.3 Types of monitoring data required for 2009 report

The workshop of 23 March 2005 (Appendix A) identified the range of core indicator variables that should be monitored to meet the requirements of the 2009 State of the Gippsland Lakes report. Table 6 shows the workshop's ranking of the indicators. Note that the ranking is approximate only, and reflects strongly the specialisations of the workshop delegates and the structure of the workshop's question-discussion period.

Three variables were given a "High" importance ranking were a) water quality (algal blooms), b) fish biodiversity and abundance and c) land-use changes in the catchment (Table 6). Variables accorded a "Medium" ranking were a) salinity and sediment condition, b) waterbird numbers in Ramsar-listed wetlands, c) wetland condition assessments, d) fish kills, e) nutrient loads and f) recreational boating use of the Lakes. These are a relatively limited set of monitoring variables, and a fuller set – as envisaged under National State of Environment Reporting – is considered in the next section.

Table 6. Core indicator variables proposed for 2009 State of the Gippsland Lakes report and their importance ranking. Source: Gippsland Lakes monitoring meeting of 23 March 2005 (Appendix A).

Indicator type	Indicator variable	Ranking
Water quality	Algal blooms	High
	Salinity	Medium
	Sediment health	Medium
	Sediment movement	Low
	Residence time	Low
Wetland vegetation and biodiversity	Water birds	Medium
	Condition assessment	Medium
	Carp numbers and distribution	Low
	Historical changes in vegetation	Low
Fish	Biodiversity and abundance	High
	Fish kills	Medium
	Recreational harvest	Low
Catchment inputs	Land-use changes	High
	Nutrient loads	Medium-High
	Groundwater inputs	Low
Social impacts	Recreational boating	Medium-High
	Visitor numbers and usage	Low

4.3.4 Availability of data to meet National State of the Environment reporting requirements

The Pressure-Condition-Response system is the proposed framework for the 2009 State of the Gippsland Lakes report. It is based on indicator variables drawn from National State of the Environment protocols (Fairweather and Napier 1998; Saunders *et al*. 1998; Ward *et al*. 1998a; Barton 2003). Table 7 shows the likelihood of suitable data being available. It uses the protocols developed for Estuaries and the Sea (Ward *et al*. 1998 a) as the example, but could be extended to Biodiversity and Inland Waters protocols.

Table 7 shows that the indicators used in National State of the Environment reporting for Estuaries and the Sea are, in principle, available for use in the 2009 State of the Gippsland Lakes report. The development of a monitoring program in Stage 2 of this project should consider in detail the availability of these data and whether efforts should be put into developing appropriate strategies to collect any data that are currently not collected.

Table 7. Likelihood of data being available for the Gippsland Lakes 2009 report using indicators developed for National State of the Environment (Estuaries and the sea). Key: Y = Yes; N = No; NR = not relevant. Values in bold font are indicators added to the original list for Estuaries and the Sea, to take into account specific requirements for the Gippsland Lakes. List is modified from Ward et al. (1998a).

Issue	Indicator	Data available?
Class 1: Cited species	• Rare, threatened or endangered species • Protected species • **Waterbird** populations	Y Y Y
Class 2: Habitat extent	• Algal bed area • Beach/dune area • Coral reef area • Dune vegetation • Intertidal reef area • Intertidal sandflat/mudflat area • Mangrove area • Saltmarsh area • Seagrass area • **Wetland area** • **Subtidal macroalgal area**	Y NR NR Y NR Y NR Y Y Y Y
Class 3: Habitat quality	• Algal bed species • Algal blooms • Beach species • Coral reef species • Dune species • Fish populations • Intertidal reef species • Intertidal sandflat/mudflat species • Island and cay species	Y Y C NR NR Y Y Y NR Y NR

	• Mangrove species • Pest numbers • Saltmarsh species • Seamount species • Seagrass species • **Wetland species** • Species outbreaks • Subtidal **(macroalgal)** species • Chlorophyll concentrations	NR Y Y Y NR Y Y Y Y Y Y
Class 4: Renewable products	• Aquaculture effort • Aquaculture production • Fish stocks • Seafood quality (contamination) • Trawl area • Fishing gear	Y Y Y Y Y Y
Class 5: Non-renewable products	• Exploration and mining	Y
Class 6: Water & sediment quality	• Sediment contaminants • Sentinel accumulation • Turbidity • Nutrients (nitrogen) • Seabird egg contaminants	Y NR Y Y Y
Class 7: Integrated management	• Beach stabilisation • Catchment development • Catchment management programs • Coastal care community groups • Coastal discharges • Coastal population • Coastal tourism • Fishing effects on non-target species • Management integration • Marine network participation • Marine protected areas • Ship visits • Shipping accidents • Commonwealth and State marine management	Y Y Y Y Y Y Y Y Y Y Y Y Y Y Y
Class 8: Ecosystem-level processes	• Sea level • Sea surface temperature	Y NR

5 Task 4: 2009 State of the Gippsland Lakes report

5.1 Target audience and distribution channels

The objective of this task is to provide a mock-up of the 2009 State of the Gippsland Lakes 2009 report using the proposed framework. There is a danger, in providing a detailed mock up, to be too prescriptive and possibly constrain the ingenuity of the group chosen to fulfil Stages 2 and 3 of this project. Nevertheless, it is recommended that the 2009 have two forms:

- A detailed (30 - 40+ page) technical report, made available as a printed hard-copy version and a digital version available on CD and the internet; and
- A shorter (4 page A4) version intended for wide distribution among the community and other groups with less specialists requirements.

Table 8 shows one plan for the distribution of the two document types among the range of audiences identified earlier in Table 4.

Table 8. Model for distribution of detailed and shorter versions of 2009 State of the Gippsland Lakes report among different audience groups.

Target audience group	Version of report
Community	
• Recreational water users	Short
• General public- Gippsland region	Detailed and Short
• General public – Melbourne	Short
• Sporting clubs	Short
• Indigenous community	Short
• Conservation groups	Detailed and Short
• Chambers of Commerce	Short
Industry	
• Land and water managers	Detailed
• Academic researchers	Detailed
• Tourism industry	Short
• Fishing – commercial	Detailed
• Fishing – recreational	Short
• Transport sector	Detailed
• Developers and investors	Detailed and Short
• Manufacturing industries	Detailed and Short
• Primary industries	Detailed and Short
Government	
• Government – Federal, State and Local	Short
• Leaders of Opposition	Short
• Local members	Detailed and Short
• Catchment Management Authorities	Detailed
• Agencies (e.g., EPA, DSE, DPI)	Detailed

5.2 Proposed report contents

The following is a general outline of what the 2009 State of the Gippsland Lakes report should contain. The document intended for wide-scale distribution among the general community and other groups should be a subset of the information contained in the more detailed report targeted at natural-resource professions.

Main sections of the detailed report should be structured along the following lines:

- Statement of the purpose, scope and target audience for the 2009 report;

- Description of Gippsland Lakes, including:
  - definition of the landscape elements covered by the report,
  - brief history of settlement in the region, including recent changes in agricultural activities and population changes (e.g., recreation and the 'sea change' phenomenon), and
  - values of the Gippsland Lakes, including environmental, social, cultural and economic values;

- Overview of current understanding of the ecological structure and processes operating in the Gippsland Lakes ecosystem, including discussion and conceptual models of:
  - links between the Lakes and their catchment,
  - hydrological processes,
  - sediment trapping and stabilisation,
  - physical habitat,
  - trophic interactions, and
  - nutrient cycling in the Lakes environment;

- Description of the reporting framework used:
  - Pressure-Condition-Response model, and
  - rationale behind indicators used in National State of the Environment reporting;

- Pressure on the Gippsland Lakes, including:
  - indicator variables identified in National State of the Environment reporting, and
  - other important catchment-scale indicators not covered by National State of the Environment protocols;

- Condition of the Gippsland Lakes, including,
  - indicator variables identified in National State of the Environment reporting, and
  - other indicators of importance, such as those linked with freshwater and brackish-water wetlands and those peculiar to the Gippsland Lakes (e.g., stratification and salinity impacts);

- Responses of management and other agencies to Condition trends, including:
  - financial investment,
  - summaries of specific NRM programs in the region (e.g., CMA activities),
  - summaries of significant R&D programs (e.g., university-based projects), and
  - engagement of community and volunteer groups;

- Future of the Gippsland Lakes, including a discussion of issues such as:
  - climate change,
  - long-term ecological change and possible changes in ecological state, and
  - Changes in community expectations and human values;

- Full citation list for reference and data sources.

The range of Pressure, Condition and Response indicators that should be considered for use in the 2009 State of the Gippsland Lakes report are shown in Table 9.

Table 9: Range of Pressure, Condition and Response indicators that should be considered for use in the 2009 State of the Gippsland Lakes report. Note that some indicators/variables may be considered under more than one type of indicator type. Please refer also to Table 3.

Indicator type	Possible indicator or variable
Pressure	• Catchment development (agricultural and forestry) • Urban (and tourist) development • Patterns of land-use and recent land-use changes • Population changes (resident and tourist) • Coastal discharges • Algal blooms (frequency, duration and intensity) • Abundance and distribution of pest plants and animals • Intensity of commercial trawling activities • Changes in fishing techniques and boat numbers • Developments in aquaculture • Numbers of recreational anglers • Nutrient and sediment loads • Water extractions and hydrological changes to inflowing rivers • Sediment contaminants • Seabird egg contaminants • Climate change and sea-level rise

Condition	• Protected and rare, endangered or threatened species • Seabird populations • Area and condition of beach or dunes • Area and condition of intertidal mudflats/sandflats • Area and condition of seagrass beds • Area and condition of saltmarshes • Area and condition of fringing wetlands • Changes in state of vegetation communities • Biodiversity in key habitats (e.g., waterbird numbers) • Abundance and distribution of pest plants and animals • Aquaculture production and quality • Fish stocks (commercial and recreational) • Seafood quality (contamination) • Water quality (nutrients, salinity, turbidity, anoxia) • Nutrient loads in inflowing rivers • Salinity intrusions in inflowing rivers • Algal blooms (frequency, duration and intensity) • Sea level and storm surges (including beach erosion etc)
Response	• Policy developments • Staff numbers and funding to NRM agencies (e.g., CMAs and Parks Victoria) • Catchment management and conservation programs (aims, funding, duration etc) and management plans • Significant on-ground achievements and examples of policy implementation • Integration across NRM organisations and programs • Marine and other protected areas • Changes in tourist numbers and localities • Activities of community groups • Research and development activities • Significant publications and communication activities

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Appendix A

1. Outcomes from workshop of Friday 4 March 2005

Gippsland Lakes Task Force Workshop 4/3/05

Reactions

- Concern/Disappointment
  - Wanted to see Community values and assurance that we are acting – good/bad/other – indicators
  - Doesn't tell us how we have progressed – or not – in 1st page or so
  - Doesn't give idea of areas of improvement
- Disappointment
  - We hadn't done what we said we would do in 1999
  - Don't repeat mistakes
  - Effort not reflected in report
  - Snapshot of what we are doing
  - No community input
  - 2004 baseline – 7/10
  - too much emphasis on BGA – not catchment
  - is it appropriate to be educating people about the system/process in this document
- Excited – hopeful – quick to read, starting block to better monitor/report
- Does quickly show condition of Lakes – but was this the intention? Audience??

Community	Industry	Government
Rec water users Gippsland general public Melbourne general public Sporting Clubs Indigenous Community Media Field Nats Field and Game Chambers of commerce	Land Management Academic researchers Water managers Tourist industry Tourist operators Fishing – Rec & comm. Offsite impacts Farmers Power Paper Forestry Rec Water users Transport sector Developers – proposed investors Oil and gas Manufacture/infrastructure For rec industry	Ministers – field and state Treasurer Leader of opposition Local members Public land managers Academic researchers Water managers Local government On-site managers CMA's Agencies DHS EPA DSE DPI PV

Themes/Synergy

State of Catchment reporting and links to SoGL report

- How are the dollars being spent?
    - What is the return on expenditure?
    - Was it value for money? C/B
- What is the condition and trend of Lake health?
    - Sea grass, fish populations, freshwater inputs etc
- Context and interpretation of monitoring results – telling the story
    - Linking values to indicators
    - Stating assumptions about why we measure certain things
- Confidence in report – indicators – monitoring
- What has happened in last 5 yrs and what does this mean for next 5 yrs?
- Flag emerging issues and knowledge gaps
- Algal blooms
    - Role in prediction of results from all our work?
    - How do we explain
    - Educate public on other indicators

Double Good

- Good to see MERGe used

Good

- Achieved aim for the day
- Good struggle
- Leapt over this a bit a few times
- Discussed more what we needed r.t. what we already had
- Good review – prepared to accept criticism
- Need to check that steps 2 and 3 will answer questions
- A proforma report – does this answer the questions – give back to this group

Negative

- Timeframe for workshop a bit short
- Proof will be in next 2 steps
- Need some overlap

A second set of notes is available for the workshop of Friday 4 March 2005. Note that the summary provided below incorrectly gives the date of the workshop as Friday 5 March; the correct date is Friday 4 March.

Gippsland Lakes Monitoring

Friday 5th [sic] March 2005

Who	What	Why
	What are the key questions? What does this group want the SoGL Report 2009 to say?	Exactly how will this info be used to make better decisions for the Gippsland Lakes
Community	• Are the lakes getting healthier? • What is the state of the lakes? • Are the lakes declining or improving? • That the lakes are being looked after and that the responsible agents will know how to do it. • That the values the community want are being preserved and enhanced • Are they safe? • How many $$ spent? • What are they spent on?	• So their concerns are addressed • So they know something is going on • Not from 5yr Report- need to manage perception • Shows level of care • Shows value for money

Who	What	Why
	What are the key questions? What does this group want the SoGL Report 2009 to say?	Exactly how will this info be used to make better decisions for the Gippsland Lakes
Agencies/ managers Industry/public	• Sell effort ie. Increase volunteerism, extra foreshore replanted – measurable outputs • Are the Lakes OK, are the increasing, decreasing? • Is investment worthwhile? • What works/works well? • What works do we do where? • Best bet investment • Justification/confidence in reported results	• Recognition/advocacy/ PR, public awareness • Accountability • General Interest • Adaptive Management • Planning • $ return • Confidence in reported results

Who	What	Why
Industry	What are the key questions? What does this group want the SoGL Report 2009 to say?	Exactly how will this info be used to make better decisions for the Gippsland Lakes
Tourism Operator Comm Fisheries Rec Fisheries	• Is my business threatened? • Is there any good news I can use? • What are the trends (+, -)/risk • Are there new requirements/regulations (as a result of management requirements) • Are the fish there? Why are numbers down?	• Investment/planning • Regional product/reputation • Investment/cost production • Risk management from comm. Perspective
Academic	• Knowledge gaps _____ • Casual links understanding	• Research requirements/ finding opportunities • Planning
General Community	• Why/have algal blooms increased in frequency, size, numbers etc.	• Perception of increase • Business risk
U/S businesses	• Can I be blamed? • Do I have liabilities/can I claim credit • Regulation/ capacity limitation/ will it _____	• Business liability/ risk management • PR/ reputation, public perception • Business management/ liability
Developers – housing/commercial industry	• Is my investment profitable/ will that change? • Likelihood of increased risk? • Emerging trends/issues identified Ie- bank erosion, environmental flows • If I am helping cause a problem/ what can I do to fix? • Context of indicators/ measurements • Casual relationships – ID of need to know casual relationships	• Long term security • Investment, planning/policy adaptive management • Advocacy/planning • Planning

Who	What	Why
Industry	What are the key questions? What does this group want the SoGL Report 2009 to say?	Exactly how will this info be used to make better decisions for the Gippsland Lakes
Government	• Are my $ being spent well? • Does this report convince government? • Credible is it? Use it as a political tool • What's being achieved and next to be implemented • What are timeframes to get the best outcomes? • Is scope broad enough beyond Blue-green algae • Are the actions leading to positive/ negative results? (short/mid term trends)	• Political advantage policy delivered • ERC bids – C/W co-invest + partnership investment • Identify knowledge gaps • Clear understanding of risks to match expectations • Informs and advises/ guides investment decisions

Some Information Users

- Investment
- Policy and Planning
- Adapting on-ground projects
- Accountability and governance
- Publicity and promotion
- Public awareness
- Advocacy
- General interest

Reactions to the 2004 State of the Lakes Report

- Excited
- Interested
- Disappointed
- Hopeful
- So so
- Positive
- Irritated

2. *Outcomes from workshop of Wednesday March 23, 2005*

Report from the workshop:

State of the Gippsland Lakes: Planning for 2009

Wednesday March 23 2005, 10 am – 1 pm
Facilitator Gillian Hayman for Carol Jeffs

1. Background

Key players involved in scientific monitoring of The Gippsland Lakes met for a workshop at Traralgon on March 23. The aims were as follows;

- **Rational Aim:** To gain consensus on the core indicators required for the production of the 2009 State of the Gippsland Lakes Report. This includes an opportunity to identify current gaps in monitoring.
- **Experiential Aim:** Coming together for common good, to match the Gippsland Lakes monitoring activities with the reporting requirements for the State of the Gippsland Lakes Report.

The following information resulted from the workshop. It is simply a download of information discussed throughout the workshop. No interpretation has been undertaken.

It is important to note that discussion occurred at the beginning of the workshop to assist with definitions. Monitoring and studies were noted to be two different things, monitoring being an ongoing collection of data whilst studies are usually a one off collection of information.

Monitoring & surveillance were also talked about. It was suggested that monitoring involves a hypothesis to be tested and some statistical analysis. Trend & variation were also noted as separate issues.

A further point of clarification involved The Lakes themselves & the catchment of The Lakes. It was agreed to work on catchment issues that Impacted on The Lakes health.

2. History of Monitoring of the Gippsland Lakes

A brief activity was undertaken to understand the history of monitoring of The Gippsland Lakes and to highlight that a collection of people have undertaken a collection of tasks over time.
Participants were asked to contribute any key aspects of the monitoring of The Lakes over time. Below is a summary of the timeline created.

1890 - 2005	▪ Hydrographic surveys
	▪ Tides last 25 years
1960's - present	▪ Shorebird monitoring ▪ Visitor numbers
1975	▪ ----------EPA monitored by the marine ---------- unit
1975	▪ Victorian Water Quality Monitoring Network
1975 – 2003 (?)	▪ Water level at Lakes Entrance by Gippsland Ports
1985	▪ EPA fixed sites ongoing ▪ Re recruit surveys
1991	▪ EPA fixed ---------- sites ongoing ▪ Lake Wellington contamination survey
1994	▪ Waterwatch
1996	▪ EPA spatial (underlay?) monitoring with fixed sites ▪ Gippsland Regional Monitoring Partnership first thought about
1997	▪ Recreational Fishing surveys
Mid 1998	▪ Mid drain monitoring begins
Nov 1998	▪ Water level observations @ approx 15 locations around Lakes
2000	▪ Regular monitoring of blue green algae ▪ Community monitoring of water quality in Lake King
2001	▪ Lake Wellington wetlands project ▪ Sediment Nutrient flux investigation monitoring ▪ MAFRI mercury investigation
2002	▪ DSE fire load monitoring
2003	▪ River load monitoring
2004	▪ EPA/CSIRO Sediment sources study
December 2004	▪ The State of The Gippsland Lakes Report released
January 2005	▪ ---------- Monitoring Program
March 2005	▪ This workshop to plan for monitoring of The Gippsland Lakes

3. Brainstorming Core Indicators

In order to achieve the aim of the workshop and gain a list of key indicators for monitoring and inclusion in the 2009 State of The Gippsland Lakes Report, a brainstorming session was run. Workshop participants were asked to consider the following scenario;

It's 2009, we are all at the launch of the State of the Gippsland Lakes Report. You have not seen the report yet. You are sitting amongst key players from government, industry & the community. They are excited with the anticipation & some people will be expecting a clear statement or headline that will indicate the health of The Lakes.

Remembering it is 2009…
What is the list of <u>core indicators</u> (key things/factors/measures) that <u>have been monitored</u> over the last 4 years allowing this report to be given?

Participants noted that the following list was a starting point, not an agreed & set list of measures or indicators to be monitored. Core indicators were not prioritized formally, however 'green dots' were allocated to points where participants felt strongly in alignment with an indicator and 'red dots' to indicators that made participants uncomfortable. Core indicators were grouped to assist in sorting and managing the information generated.

Below are the core indicators identified in the brainstorming activity March 23 2005.

Lake Water	Local climatic conditions in & around The Lakes (light intensity, air temperature, wind direction & intensity, rainfall)	
	Lake depth	1 green
	How much sand has come in from outside & it's impact on water flow into The Lakes	1 green
	Water levels both within The Lakes & outside Lakes Entrance	2 green
	Residence time of water in each of The Lakes	1 green
	Sediment Health in Lakes, nutrient flux from sediment	2 green
	Salt levels in profile & traverse (transverse?) lateral throughout the water column	2 green
	Algal Blooms – where? When? How many? How far?	5 green
Lake Water Quality	The quality & quantity of water going out of The Lakes system	
	Dissolved Oxygen Trends	
	Effects of wetland filtration of nutrients on The Lakes area of fringing wetlands	
	Total Suspended Solids (TSS), Nitrogen levels, Total Phosphorous	
	All nutrients	
Wetlands, Vegetation, Biodiversity	Birds: numbers, health & population	2 green
	Carp numbers & distribution	1 green
	Pest invasions	
	Benthic macro algae	
	Aquatic vegetation: extent & distribution, species composition & abundance	
	Changes in shoreline vegetation	1 green
	Natural value condition of… eg. Wetland condition	2 green
	Index value of surrounding wetlands (IWC) Health of RAMSAR wetland	

Catchment Inputs	Flow load nutrient concentration	2 green
	Landscape/ Land Use changes throughout the catchment	3 green
	Groundwater Interaction	1 green 2 red
	Sediments going into The Gippsland Lakes from the river systems	
	Nutrient loads going into the Gippsland Lakes	
Fish	Recreation al fish harvest from Gippsland Lakes – size & shape	1 green
	Fish kills	2 red
	Species composition & biodiversity of fish stocks in The Lakes	4 green
	Abundance of fish in The Lakes	1 red
Sediment Quality	Area of Lake bed subject to anoxia annually	1 red
	Heavy metals (eg. Mercury) in fish	
Social Impacts	Recreational boating numbers	3 red
	Visitor numbers & usage of Lakes	1 green
Other	How close have we got to the envisaged picture of The Gippsland Lakes?	1 green

4. Group Work

In order to add detail to the core indicators identified by the workshop participants some group work was undertaken. The purpose of the group work was to generate a list of actions required to ensure the right things are monitored (& how) over the next 4 years.

Three small groups formed and answered the question;
It's 2009 – what has been done to ensure that data is available for these core indicators? (what, where, how).

The work generated from the discussions follows;

Group 1: Lake Water & Sediment Quality

Core indicator	*What*	*Where*	*How*
Algal blooms	Clor A species & counts Spatial location Frequency Intensity Duration	Existing fixed sites & Identified high risk sites	In site continuous sampling & opportunistic reporting according to agreed protocols. Satellite images
Sediment health	Nutrient dynamics Benthic – type, abundance, activity	Representative areas	Benthic chamber sediment sampling nutrient
Hydrodynamic conditions	Water levels >>> Inflows & outflows >>> Water residence time Sediment deposition >>>	For each Lake River mouth & Entrance & outside Entrance For each Lake	Gauses & tidal information (easy!!) Bathinetric survey (simple!)

Group 2: Fish, Wetlands, Vegetation & Biodiversity

Core indicator	*What*	*Where*	*How*
Fish	Diversity (spp.) Abundance Recruitment Fish kills Non target species	Deep water in Lakes Victoria & King. Tambo, Mitchell, Avon & Nicholson Rivers Shallows	Trawl surveys Acoustic surveys Continue current program Recreation surveys Creel, catch methods
Wetlands (intrinsic value, ecological services, integral part or mere interactor?, Relevance to Gippsland Lakes)	Extent (hectares) Vegetation changes Recruitment Spp. Diversity – plants Dieback Nutrient interception Weeds	Lake Wellington MacLeod Morass Sale Common	Area – satellite, aerial photos B.Hille's vegetation & bird work On ground surveys Weed surveys Community feedback
Vegetation Submerged & shoreline, erosion, habitat & nutrient interception	Loss of phragmites, area of sea grass & f.w angiosperms, epiphyte cover, macro algae	Shoreline: Lakes King, Wellington, Victoria Lakes: everywhere	3D underwater video Satellite? Ground truthing

Group 3: Catchment Inputs & Social Inputs

Core indicator	*What*	*Where*	*How*
Load into Lakes from major rivers	Continuous flow Nutrients (react/totals) Sediments Salt – more for western rivers Heavy metals/ pesticides 'Pollution" R.B approach	Bottom of catchment of major rivers	Flow – continuous. Water Quality parameters at intervals relevant to power of calculation
Land use/ Landscape change in catchment	Change/ increase in riparian vegetation Change in agricultural land use intensity Change in urban development "Health" of native vegetation Sustainability/Productivity synergy EMS uptake, BMP's, Whole Farm Plans	Everywhere, dependant on private land in catchment	Regular satellite photos Better integration & cohesion between agencies – coordination, information sharing
Social (Recreational boat users)	No. permanent berths No. launched visitors No. visitors No. boats/registrations No. fishing/hunting licenses Boat pump out usage	Ports Ramps Litres of effluent pumped	

5. Workshop Summary

A concluding discussion allowing participants to consider what they have achieved & to identify the pathways forward was held.

Where did you struggle today?

- With placing the red dots
- The Big Questions: What do we want the picture of The Lakes to be? Will it be what it is? Or will the natural process of change shape it?
- Where do The Lakes begin & end? Geographic distinctions/definitions
- Names, terms, definitions

What have been the high points?

- Enthusiasm of participants – need to ensure the enthusiasm can move us all in the same direction
- There is a great deal of knowledge available it just needs integration
- The knowledge of people in the room is good
- Identify funding & match it with monitoring that needs to be done (a group directive to The Gippsland Lakes Taskforce)

How would you summarise today's workshop outcomes to someone who was unable to be here?

- It's a start
- We have done the easy bit
- Concern about the next steps
- See potential for collaboration that I had never thought of before
- Balance ideals with pragmatic issues

Where to from here?

- Project design
- Gippsland Lakes Monitoring Institute
- Big decisions: what are the objectives? Fresh water or saline?
- A careful look at the structure/logic of the 2009 report hierarchy & process
- The drivers here today are Chris & Carol – Who is on the bus?

6. Who Attended the Workshop?

Gippsland Lakes Monitoring Workshop

Jodie Halliwell – E&WGCMA
Isabelle Gabas - SRW
KS Tan and Teri Etchells (Melbourne Uni) instead of David Fox
Andy Stephens – EPA
Paul Boon – VU
Lee Charman - GRWMP
Peter Hinksman – Gippsland Ports
Rex Candy – EGCMA
Brett Millington – GCB
Dick Brumley – DPI
Rebecca Jol – DPI
Greg Parry - DSE
Andy Longmore
Tom Noble – Thiess
Di Rose – EPA
Brett Millington - GCB

Apology

Warren Davies - EPA