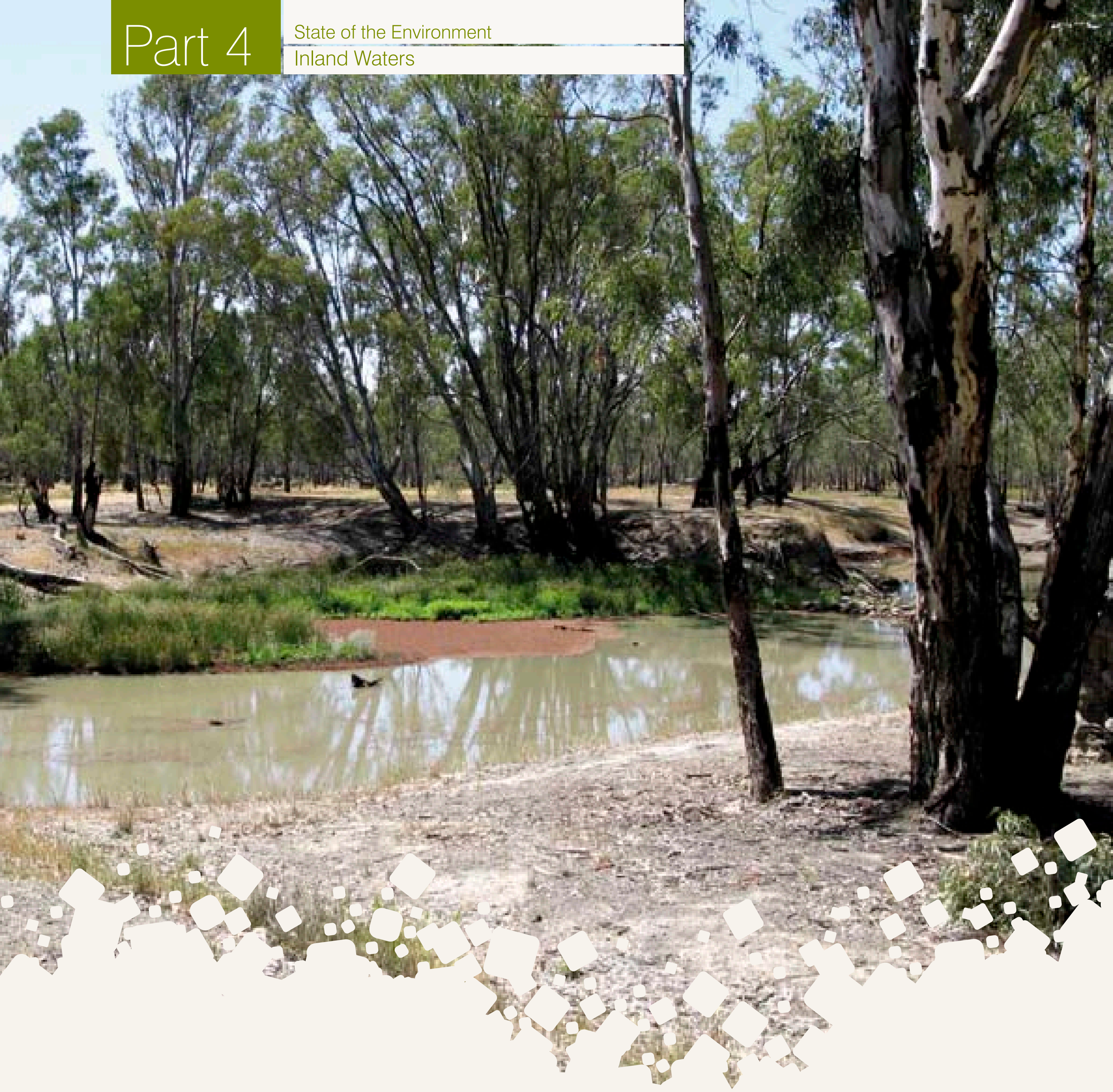


Inland Waters

Key Findings

- Direct pressures to inland waters include the construction of dams, flow regulation and water harvesting; draining of wetlands; desnagging; channelisation and the construction of levees.
- Clearing of almost half of Victoria's native vegetation and associated land use changes have had negative impacts on inland waters including loss of riparian vegetation, altered hydrology, erosion, and increased loads of sediments and contaminants such as salt, nitrogen and phosphorus.
- The 2004 Index of Stream Condition assessment reported that only 21% of major rivers and tributaries in Victoria were in good or excellent condition. Almost half the basins in Victoria have less than 10% of major rivers and tributaries in good or excellent condition.
- The extent of degradation indicated by the 2004 Index of Stream Condition assessment was present before the drought, but low streamflows combined with current levels of extraction have compounded pressures on inland waters since this assessment.
- The Sustainable Rivers Audit reported that 9 out of 10 Victorians basins in the Murray Darling Basin were in very poor ecological health, and one basin was in poor ecological health.
- In over half the river basins in Victoria, less than 20% of major rivers and tributaries have flow regimes in good condition. Changes to low flow events were most widespread, causing numerous pressures ranging from changed breeding conditions to poor water quality. Lack of flooding threatens the existence of tens of thousands of hectares of River Red Gum Forests.
- In 2004, just 6% of major rivers and tributaries had in-stream habitat in good condition based on the presence of large woody habitat, bank stability and barriers to fish passage.
- In 2004, 14% of major rivers and tributaries had riparian vegetation in good condition. Uncontrolled stock access to riparian zones continues to be the major pressure on riparian vegetation statewide.
- By 1994, 37% of naturally occurring wetland area had been lost, mainly due to drainage. A more recent statewide assessment has not been conducted.
- In 2005, water quality objectives for salinity were met at 68% of sites across Victoria, and objectives for total nitrogen, total phosphorus, and turbidity were met at less than half the sites monitored.
- Many species dependent on inland waters are now considered threatened, including 21 freshwater and estuarine fish species, 11 frog species and 29 species of waterbirds.
- In 2004, macro-invertebrate communities were in good condition across almost half of the major rivers and tributaries assessed.
- The total index of abundance for waterbirds in eastern Australia has shown a declining trend over past decades, with 2007 having the second-lowest abundance on record.
- Commitments to provide environmental water were qualified in 40 locations across Victoria in 2006-07, as part of drought contingency measures.
- Under climate change, streamflow is projected to decrease by up to 50% across much of Victoria by 2070. The present degraded state of many inland waters increases the challenge of mitigating the environmental impacts associated with climate change.
- Victoria's inland waters have inherent value, and contribute greatly to the broader environment, community and individual human health. Inland waters provide valuable ecosystem services such as drinking water, cycling of nutrients and maintenance of biodiversity, as well as recreational and cultural opportunities. Many markets fail to protect and may even encourage the degradation of these services, even though they support healthy economies and communities.
- Incremental degradation due to cumulative catchment and instream impacts remains an ongoing challenge. The expense and difficulty of rehabilitation highlights the importance of protecting high value areas.
- Over the past two decades, and particularly in the last decade, there has been increasing knowledge; investment; integration of management; on ground capacity and awareness to drive improvements in the condition of inland waters. In the context of ongoing drought and likely climate change the future health of many inland waters is uncertain and further action is necessary.

IW0 Introduction

Victoria's inland water assets

Victoria's inland waters (rivers, streams, wetlands and groundwater) have inherent value and contribute greatly to the broader environment, communities and their economies, and individual human health. Examples of these values include drinking water, biodiversity, nutrient cycling and water purification, recreation and agricultural productivity.

Water systems – inland waters, estuarine or marine - are all part of and therefore connected through the water cycle. Inland waters are also intimately connected with the land, as all land is part of a catchment, and all catchments have a receiving water body[1]. When these systems are functioning healthily, the ecology of inland waters has both the capacity to resist disturbances and recover from them.

However, if an ecosystem is acutely disturbed beyond the threshold of a key variable, e.g. rate of groundwater recharge, it will behave differently, often with undesirable and unforeseen consequences. Once a threshold has been crossed it is difficult, if not impossible, to rehabilitate the system. Rising groundwater tables, salinisation, landscape-scale erosion and sedimentation, persistent cyanobacterial blooms and species extinction are all signs that resilience has been lost, and potentially irreversible changes to inland waters have occurred.

Over the past two decades, and particularly in the last decade, there has been an increasing effort to improve the condition of inland waters. The benefits of management actions have been demonstrated in many individual and even regional cases, but in the context of ongoing drought and climate change the future health of many inland waters is uncertain and further action is necessary. The expense and difficulty of rehabilitation highlights the importance of protecting existing areas of high value. Incremental degradation due to cumulative catchment and in-stream impacts remains an ongoing challenge.

The issues reported in this section provide a window into the current condition of Victoria's inland waters. Major rivers and tributaries receive most attention as these are most comprehensively monitored. Specific indicators for groundwater and wetlands are also reported.

The term 'inland waters' is used inclusively to cover rivers and streams, wetlands, groundwater, habitat linkages such as riparian vegetation and floodplains, their ecology and associated ecosystem processes. The term 'wetlands' includes coastal wetlands. The terms 'rivers and streams' are used interchangeably and are inclusive of associated habitats, ecology and ecosystem processes. Victoria's rivers and river basin are shown above in Figure IW0.1.

Figure IW0.1 Rivers and river basins in Victoria[2]

Objectives

- Maintain and improve the condition of inland waters, assigning the highest priorities to those water systems with the highest environmental and community values.
- Maintain the capacity of inland waters to provide ecosystem services that support agreed environmental, social and economic values.

Pressures

Inland waters have been transformed into a complex and extensive system for harvesting, storing, transporting and controlling water. Dams are part of this system, as they store water so it can be harvested or released at a later time. In western Victoria and in basins north of the Divide, the drive for State development in an inherently variable climate has resulted in the extensive use of irrigation to support agriculture, widespread construction of storages and the use of river channels to convey water long distances from where it is stored (see Part 3.2: Water Resources). Large proportions of the total surface water in several basins are extracted for consumption, particularly in dry years. Flow regimes have been heavily modified in these rivers, placing pressure on floodplain ecosytems including River Red Gum forests; and in most major rivers throughout Victoria.

Extensive areas of valley floors throughout the State, for example the Latrobe valley, were originally wetland: swampy areas of tea-tree, or chains of ponds which were reclaimed for agriculture by digging drains or ploughing. These drains often eroded into gullies. To reduce the duration and frequency of flooding, larger streams were 'channelised' to convey water more rapidly, by desnagging, straightening, and the construction of artificial levees.

Lowland areas, particularly those near past or current population centres such as Melbourne, have been most affected by changes to the movement of water through the catchment. Both bed and bank stabilisation works, and stream clearing works, tend to increase from west to east across Victoria[3]. Areas with high concentrations of stream clearing works include the lower reaches of the north eastern basins (Upper Murray, Kiewa, Goulburn and Ovens) and the south eastern Yarra, Bunyip, Thomson, Latrobe and South Gippsland Basins (see Figure IW2.7).

A wave of goldrushes in the nineteenth century, and mechanical dredging for alluvial gold which was widespread across Victoria until the late 1980s, affected many rivers and extended into upland areas which have remained otherwise undeveloped. As a result the physical condition of the river channels has degraded, in some cases irreversibly, even when the catchment remains substantially intact.

The ecology of a stream is related to the condition of the catchment[4]. About half of Victoria's native vegetation has been cleared, including 80% of the original cover on privately owned land. Land clearing has resulted in loss and degradation of riparian vegetation (see IW3 Riparian Vegetation) and accelerated erosion and sedimentation (see IW2 In-stream and wetland habitat, IW4 Water Quality).

Clearing of vegetation also has significant impacts on the volume and timing of water delivered to inland waters and has generally increased recharge of groundwater leading to salinisation (see Part 4.2: Land and Biodiversity)[5]. Irrigation has amplified this change, resulting in shallow watertables, waterlogging and increasing salinity (see IW4 Water Quality, State), in approximately 140,000 ha of land in the irrigation districts of northern Victoria[6]. The threat currently posed by salinity has been moderated by improved management practices and rainfall deficits over the past 11 years have but it remains latent.

Pollutants originating in catchments, such as nutrients in fertilisers, domestic and industrial wastewaters, and toxicants from roads, agriculture and industry also place pressure on inland waters.

The extensive modification and fragmentation of inland waters has aided the spread of invasive species, which are now difficult to control (see IW3 Riparian Vegetation, IW5 Aquatic Fauna). Victoria's Flora and Fauna Guarantee Act 1988 lists eight processes as potentially threatening to inland waters (see IW5 Aquatic Fauna, Pressures).

Drought, combined with current levels of extraction compounds pressures on flow regimes, and has implications for all issues subsequently discussed in this part of the report. Climate change, which is already influencing temperatures and rainfall patterns, is another compounding pressure and will further increase competition for water resources. Climate change is a serious risk to the health of inland waters (see IW6 Impacts of Climate Change on Inland Waters).

Overall condition

Almost all rivers and catchments in Victoria, and almost all larger streams, have been modified to some degree. Varying levels of information on current condition are available for the different components of Victoria's inland waters. The most comprehensive condition assessments are available for major rivers and streams, which are assessed every five years using the Index of Stream Condition (ISC). Two assessments (1999 and 2004) have been conducted, with the next due to occur in 2009.

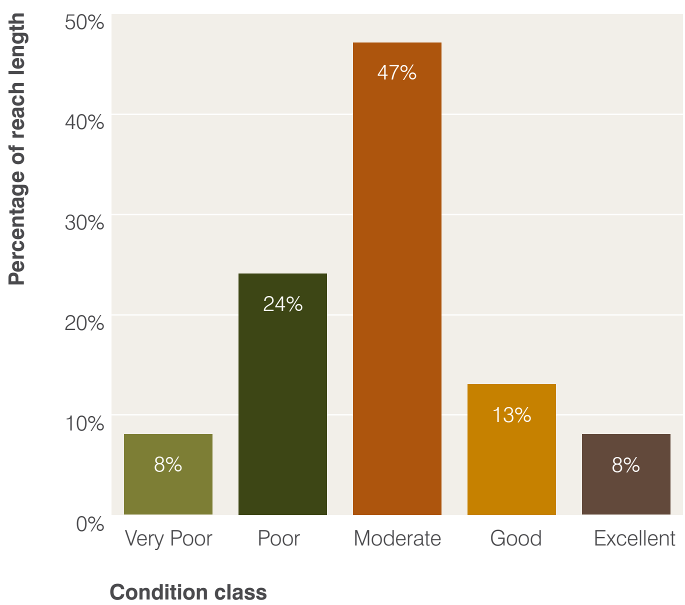
The 2004 ISC assessment reported that about 21% of major rivers and tributaries in Victoria were in good or excellent condition, 47% were in moderate condition and 32% were in poor to very poor condition (see Figure IW0.2, also see Management Responses, Index of Stream Condition). The river basins in poorest condition were mostly in the western half of Victoria, whereas the basins in best condition were in eastern Victoria, particularly in the highland forested areas which have proved unsuitable for conventional agriculture (see Figure IW0.3). In some basins, such as the Thomson, the upper reaches are in good condition, whereas the lower reaches have been highly modified, giving a lower overall score for the basin. Almost half the basins in Victoria have less than 10% of major rivers and tributaries in good or excellent condition.

No major overall changes in condition were identified between the ISC assessment in 2004 and the first assessment in 1999, which occurred at the beginning of the current drought[7]. The degradation of inland waters reported in the 2004 ISC is therefore not due to the current drought, having existed prior to it. Drought and current levels of extraction have compounded existing pressures on rivers and streams since 2004, as the scarcity of water has increased over time.

Additional information on ecological condition of Victorian rivers of the Murray Darling Basin is available through the Sustainable Rivers Audit, another method for assessing the ecological health of inland water which is being applied to the Murray Darling Basin.

The first assessment consisted of Hydrology, Fish and Macro-invertebrate themes, based on data collected between 2004 and 2007. The Audit divides the Basin into valleys which, in Victoria, do not always coincide with the basins used as the main spatial unit in this report (for example, the Mitta Mitta Valley is considered independently). Valleys are further split into zones according to altitude: lowland, slopes, upland and montane.

Figure IW 0.2 The overall condition of reaches assessed in the 2004 Index of Stream Condition[8].



Nine out of 10 Victorian Valleys in the Murray Darling Basin were in very poor ecological health, and one Valley - the Ovens - was in poor ecological health. The Goulburn Valley was considered the least healthy valley in the Murray Darling Basin, along with the Murrumbidgee in New south Wales. The 'upland' and 'montane' zones of the Ovens valley, and the 'Slopes' zone of the Broken Valley, which were in moderate condition, were the highest rated zones in Victoria. The condition of remaining zones ranges from poor to extremely poor.

Across Victoria, an estimated 191,000 ha of natural wetlands, some 37% of the original wetland area, were lost by 1994, according to a statewide inventory conducted in that year[9]. Over 90% of the wetland area lost was on private land. The change in extent of wetlands since 1994 has not been assessed on a statewide basis. An Index of Wetland Condition assessment tool has been developed and is currently being finalised.

The condition of groundwater has historically been observed through levels and quality. Groundwater levels are at record low levels in 12 of the 24 most heavily developed groundwater management units due to lack of recharge and consumptive pressure (see Part 3.2: Water Resources). Groundwater quality, in the context of environmental condition, is linked to salinisation which has occurred throughout western Victoria (see Part 4.2: Land and Biodiversity, Indicator LB29 Area of salt affected land). An index for assessing the condition of groundwater dependent ecosystems is currently being developed.

Due to lack of information, the condition of small streams, anabranch networks and floodplain connections has not been included in this Report. These waterways comprise 93% of the total stream length in Victoria. Small streams are important for water quality, as they filter catchment inputs and aid nutrient cycling. Anabranch networks convey a large proportion of the total flow of lowland rivers. About 34% of the total stream length is in largely intact landscapes and the remaining two-thirds are in fragmented landscapes (see Part 4.2 Land and Biodiversity, LB1 Vegetation loss and modification). Although streams in intact landscapes are more likely to be in better condition than those in fragmented landscapes, condition is also determined by factors such as upstream condition and management activities.

The extent of clearing, wetland drainage and stream modification works emphasises the importance of areas that are relatively unaltered. Victoria's network of parks, which cover 14% of the State, are important refuges that protect remnant vegetation and include important catchment areas[10].

Management responses

Management of inland waters in Victoria is administered by all jurisdictional levels. Commonwealth, State and local governments have input through legislation, policy and funding decisions and implementation of planning provisions. As described in Part 3.2: Water Resources, the Victorian Government retains the overall right to the use, flow and control of water resources, including surface, ground, storm and recycled water[12].

Victoria is divided into 10 catchment management authority (CMA) regions (see Figure IW0.4). The CMAs were established in 1997 under the *Catchment and Land Protection Act 1994* and their structure is described in detail in the Victorian Catchment Management Council's Catchment Condition Report[13]. The role of each CMA is to facilitate and coordinate integrated catchment management relating to land, biodiversity and water resources within each catchment.

Figure IW0.3 Condition of major rivers and tributaries, represented as the percentage of stream length assessed in good or excellent condition in each basin
Source: DSE (2005)[11]

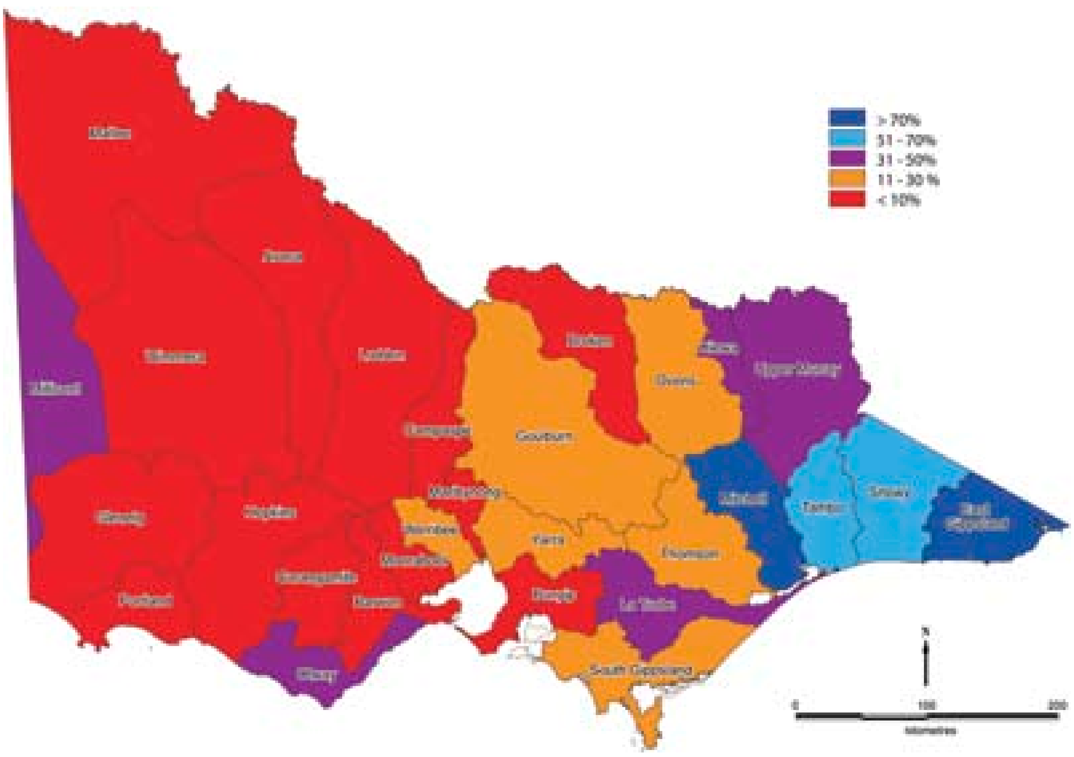


Figure IW0.4 Victoria's catchment management authority (CMA) areas, basins and major rivers
Source: DSE (2007)[14]

CMAs were assigned the role of *caretakers of river health* through the Victorian River Health Strategy (2002) and subsequently gained responsibility for managing the Environmental Water Reserve[15]. Waterway management responsibilities include responsibility for the co-ordination and management of floodplains; stormwater runoff and pollution; rural drainage (including regional drainage schemes); water quality and nutrient management; water supply catchment protection; wetlands; restoration of degraded waterways; and Crown frontages and heritage rivers outside of national parks[16].

Until recently the Murray-Darling Basin was managed by the Murray Darling Basin Commission through the Murray-Darling Basin Initiative, under the Murray-Darling Basin Agreement (1992). Six governments, and many departments and agencies, were involved in the Agreement. An Intergovernmental Agreement on Murray-Darling Basin Reform was signed on July 3, 2008, which transfers the powers and functions of the Murray Darling Basin Commission to a new Murray Darling Basin Authority. A key task for the Authority is the preparation of a new Basin Plan, to be completed by 2011. The Authority reports to the Commonwealth Government Minister for Climate Change and Water[17].

In Victoria, 10 out of 29 river basins are part of the Murray-Darling Basin: Mallee, Wimmera, Avoca, Loddon, Campaspe, Goulburn, Broken, Ovens, Kiewa and Upper Murray.

At the national level, the National Water Initiative (2004) is working towards a nationally compatible system of managing surface water and groundwater resources[18].

The main over-arching policies, strategies and legislation which guide the management of inland waters are summarised below.

Our Water Our Future (2004)

Our Water Our Future is the Victorian Government's main policy for managing water resources. Major initiatives include a revised water allocation framework, the creation of an environmental water reserve (EWR), a policy framework for urban water management and water pricing. See Part 3.2: Water Resources for more information.

One of the guiding principles of *Our Water Our Future* is that a healthy economy and society is based on a healthy environment. *Our Water Our Future* commits the Government to significantly improving the health of Victoria's rivers, floodplains and estuaries to ensure they are capable of delivering a wide range of services to the community[19]. This goal is to be achieved by 2010.

Regional sustainable water strategies

Four regional strategies are being developed for the achievement of sustainable water use in Victoria, including actions to improve river health, over the next 50 years (see Part 3.2: Water Resources).

State Environment Protection Policy (Waters of Victoria)

The State Environment Protection Policy Waters of Victoria (SEPP WoV) sets out the statutory framework for the protection of Victoria's freshwater systems, and is administered by Victoria's Environment Protection Authority (EPA), under the *Environment Protection Act 1970* (see also IW4 Water Quality, Management Responses). The SEPP prescribes[20]:

- Beneficial uses, which are the uses and values of the water environment that the community and government want to protect.
- The objectives and indicators which describe the environmental quality required to protect beneficial uses.
- An attainment program that guides the restoration and protection of water environments so environmental quality objectives are met and beneficial uses protected.

Victorian River Health Strategy (VRHS)

The VRHS, administered by the Department of Sustainability and Environment, is the Victorian Government's framework for improving the health of rivers, floodplains and estuaries. The framework aims to protect high-value rivers, maintain ecologically healthy rivers and achieve an overall improvement in the environmental condition of the rest[21].

Victoria's Biodiversity Strategy (1997)

This strategy fulfils commitments in the National *Strategy for the Conservation* of Australia's Biological Diversity (1996) and requirements under *Victoria's Flora and Fauna Guarantee Act 1988*. Actions for the management of wetlands are also prescribed in this strategy. A new policy document for biodiversity is planned for release in 2009. These documents are described in more detail in Part 4.2: Land and Biodiversity.

Response Name
Victorian River Health Program

Responsible Authority
Department of Sustainability and Environment

Response Type
Policy/strategy

The Victorian River Health Program was established in 2002 with the aim of restoring Victoria's rivers. The program's overall framework, objectives and targets were established through the *Victorian River Health Strategy* (2002) and *Our Water Our Future* (2004).

This framework is supported by regional river health strategies, which each form part of the corresponding regional catchment strategy (see Part 4.2: Land and Biodiversity). Regional river health strategies address fisheries management plans, flow, water quality, waterways management and floodplain management[22].

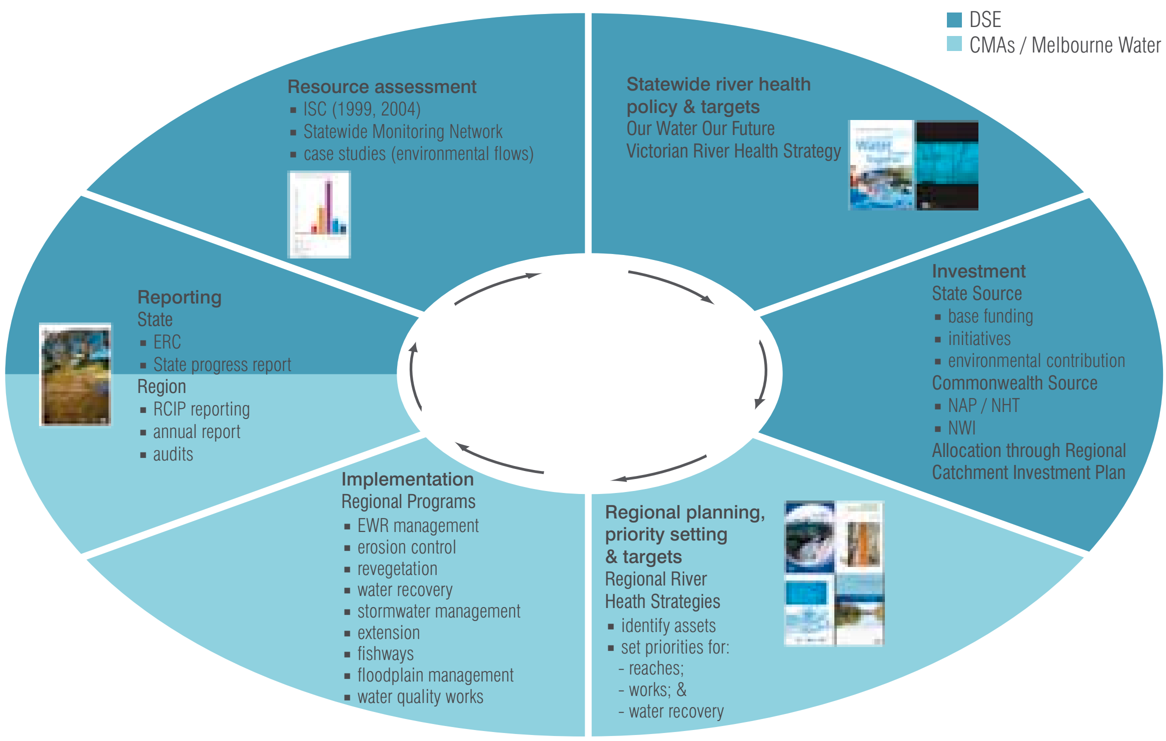
Through the Victorian River Health Program, the State Government invested $100m between 2004 and 2008) in river health, with a focus on protecting and rehabilitating high-priority areas. A monitoring and research program, of which the ISC is a central tool, aims to facilitate adaptive management and the monitoring of environmental condition.

The achievements of the program are expressed in terms of progress towards statewide targets, which are discussed in the Management Responses below. The stages of the River Health Program are shown in Figure IW0.5.

Recommendation

IW0.1 Implement consistent statewide reporting and data management of works implementation and condition assessment for rivers, wetlands and groundwater, aggregated at the basin or CMA level, to show the impact of management responses on environmental condition.

Figure IW0.5 Victorian River Health Program[23]



Response Name
Index of Stream Condition

Responsible Authority
Department of Sustainability and Environment

Response Type
Monitoring program

The Index of Stream Condition (ISC) is an integrated, statewide benchmarking of environmental condition, implemented by the Department of Sustainability and Environment (DSE) and the catchment management authorities (CMAs). Most of the indicators in this section are based on the underlying data from the 2004 ISC.

The health of Victorian rivers is assessed every five years. The ISC considers five key aspects of river health for over 1,040 individual reaches. The five aspects assessed are: changes in hydrology (amount, timing and duration of flow); water quality; streamside zone (riparian vegetation); physical form (bank condition and in-stream habitat); and aquatic life. These aspects are rated by comparing the observed condition measured in the field, with a natural benchmark condition established through a desktop analysis. Benchmark conditions can be difficult to establish, particularly for reaches of lowland rivers. Where there is little difference between the observed and the benchmark conditions, the site is considered to be in good condition. A reach is a section of river between 10 km and 30 km long with relatively homogeneous flow, vegetation and landscape characteristics[24].

Data collected at the reach scale are aggregated to provide a snapshot of river health at a basin or statewide scale. Sites are randomly selected for assessment. In some basins, results aggregated to the basin scale (which is used extensively in this report) may be weighted in favour of upland sites, which tend to be in better condition. This is simply because in some basins there is a greater length of upland rivers and streams considered by the ISC, relative to lowland rivers and streams. An assessment of river health using the ISC was first conducted in 1999, followed by an assessment with an improved version in 2004[25].

The capacity to measure integrated river condition statewide is crucial to effective adaptive management at a time of considerable uncertainty and to assess the long-term effectiveness of the Victorian River Health Program. On the other hand, it is necessary to ensure that on-ground works are not driven just by the ISC, which can only provide a partial view of river health.

An ongoing challenge is the inclusion of new knowledge and measurement techniques, while still enabling comparison between assessments over time. This may require the development of new indicators to provide a more sensitive assessment of the forces driving degradation.

Response Name
Ramsar Convention on Wetlands

Responsible Authority
Department of Environment, Water, Heritage and the Arts/Department of Sustainability and Environment

Response Type
International Agreement

The Ramsar Convention on Wetlands (1971) promotes the conservation, repair and wise (i.e. sustainable) use of all wetlands, with particular emphasis on sites listed as 'Wetlands of International Importance', also known as Ramsar sites[26] (see Figure IW2.3).

In Victoria, 10 wetlands were designated Ramsar sites in 1982, with the Edithvale-Seaford wetlands being added in 2001[27]. A Strategic Directions Statement (2002) provides a framework for the management of Ramsar sites[28]. Management plans for each of the sites were prepared in 2003. In 2005, an Ecological Character Description Framework was developed by DSE to guide the development of detailed ecological character descriptions for each site[29] and used to describe the Barmah forest. A new national framework for developing ecological character descriptions of Ramsar wetlands was published in June 2008 by the Commonwealth Government[30].

While the designation of sites under the Ramsar Convention and the preparation of management strategies are important steps, continued active management of these sites is necessary to respond to pressures on environmental condition. Ramsar sites, such as Lake Albacutya, Western District Lakes, Gunbower Forest, Barmah Forest and Gippsland Lakes, have been allowed to degrade. Funding for the management programs is largely provided by the Commonwealth and other land managers including Melbourne Water Corporation, with limited state funding available.

Recommendation

IW0.2 The Victorian and Commonwealth Governments should strengthen and improve management regimes of Ramsar wetlands, to ensure the obligations of the Convention are met.

Evaluation of responses

The past decade has seen the implementation of the policy framework and delivery mechanisms for an integrated approach to improving the condition of inland waters. Through the Victorian River Health Program, much work has been done to halt further degradation in condition of Victoria's rivers. A major challenge is implementing policies and strategies as they were intended, to reverse the degradation.

There have been significant advances in the knowledge and understanding which underpins the management of inland waters since the mid-1990s. Examples include integrated assessments of environmental condition such as the Index of Stream Condition and the Rapid Biological Assessment technique developed by the EPA, the importance of woody habitat, nutrient cycling and transport, and the management of algal blooms. Continued effort to develop good science and proactive, transparent, inclusive decision-making is needed to improve the condition of inland waters.

The assessment of wetland condition has lagged behind that of rivers and streams. This is being addressed through the Index of Wetland Condition which, when fully tested, must be implemented statewide. Similarly, the Index of Groundwater Condition will address the lag in monitoring and assessment of groundwater-dependent ecosystems. The implementation of the National Groundwater Action Plan (2007) should also assist in rectifying knowledge gaps relating to groundwater[31].

Many pressures on inland waters remain, including the legacy of historic management practices, which have been exacerbated by the low streamflows and high temperatures of the past decade. In many rivers and aquifers the current EWR is inadequate and vulnerable, placing environmental values at risk[32]. During times of low streamflow, the water allocation system also reduces environmental flows more than it reduces water for consumptive uses. Lack of water, and increased competition for that which remains, has constrained initiatives to improve environmental flows. (see IW1 Flow regimes). The scarcity of water has dramatically increased public awareness of its management.

Climate change poses a serious threat to inland waters. Due to uncertainty over what may happen, management responses consider multiple scenarios, with an emphasis on risk management and adaptive management frameworks. The Central Region Sustainable Water Strategy and the Victorian River Health Strategy both use adaptive management frameworks to enable the incorporation of new information into management decisions.

Small streams and anabranch networks need to be factored into management plans at some level. The sheer length of these networks has to date made monitoring impractical, but emerging technologies may allow the development of metrics which will assist condition assessment and management. A watching brief should therefore be placed on these technologies.

Incorporating the value of ecosystem services into markets is crucial to maintaining and improving the condition of inland waters. A project to address some current knowledge gaps is underway ('Ecosystem Services: Valuing Improved River Health' managed by DSE) but more effort is urgently required to address market failures. Market instruments for allocating resources to restoration works to maintain ecosystem services have also been successfully trialled (e.g. RiverTender, see section IW3.7).

Recommendations

IW0.3 The Victorian Government should reinforce its commitment to significantly improving the health of Victoria's rivers, floodplains and estuaries by 2010 as set out in Our Water Our Future, and other inter-jurisdictional river health initiatives

IW0.4 Ecosystem services should be recognised as a component of the value of land, so that landholders can treat ecosystem services as an alternative source of income. Knowledge of the interaction between ecosystems and the services they provide to human settlements should be improved.

IW0.5 Institutional arrangements of catchment management authorities and water corporations should be reviewed with the goal of integrating water management to enable better delivery of water for the environment, and adaptation to climate change

IW0.6 The Victorian Government should review reporting cycles of Index of Stream, Wetland and Groundwater condition indexes, and the State Wetland Inventory, to facilitate better integration with Victorian Catchment Management Council and State of Environment reporting.

IW0.7 Implement the Indexes of Wetland Condition and Groundwater Condition on a statewide basis as soon as possible, to enable more accurate reporting to inform decision making

For further information

Index of Stream Condition
http://www.vicwaterdata.net/vicwaterdata/data_warehouse_content.aspx?option=5

Victorian Catchment Condition Report:
http://www.vcmc.vic.gov.au

Victorian Government water and river health programs and publications
http://www.dse.vic.gov.au/dse/wcmn202.nsf/Home+Page/592E2077307FBB0CCA256FE100095CDD?open

Sustainable Rivers Audit Report 1
http://www.mdbc.gov.au/SRA/river_health_check_-_sra_report_one

IW1 Flow Regimes

Key findings

- A flow regime is a specific combination of the timing, size and duration of flow events. It is a key driver of river and floodplain wetland ecosystems.
- The main pressures on flow regimes are the presence of dams and other barriers; regulation of flow; extraction of water for consumption; channel modification; and changes in land use. Drought has compounded these pressures over the past 11 years; and they are likely to be compounded by climate change in future.
- In the past four years, over 75% of the total flow was harvested for consumptive use from a quarter of Victoria's river basins. During times of low streamflow, the water allocation system reduces environmental flows more than it reduces water for consumptive uses.
- Serious rainfall deficiencies over the past 11 years have reduced inflows to storages 30–60% below long-term averages. Water scarcity has been statewide in extent, and has deepened over time, with inflows to the Murray and Melbourne storages reaching record lows in 2006.
- In over half the river basins in Victoria, less than 20% of rivers have flow regimes in good condition. Changes to low flow events are most widespread, resulting in a number of pressures from changed breeding and spawning conditions to poor water quality.
- Due to river regulation and over-extraction compounded by drought, many tens of thousands of hectares of River Red Gum forests and wetlands in northern Victoria are highly stressed. Without adequate flooding in the near future they may be lost, requiring centuries to recover.
- Water availability will be cumulatively reduced by climate change and catchment processes such as forests regenerating after bushfires; the legacy of historic groundwater extraction; small unlicensed domestic and stock farm dams; and plantation forestry.
- In many rivers and aquifers the current environmental water reserve (EWR) is inadequate and vulnerable, placing environmental values at risk. Commitments to provide environmental water were qualified in 40 locations across Victoria in 2006-07, as part of drought contingency measures.

- Significant improvements in the way water is managed for the environment have occurred in the past decade, including the recognition of the environment's right to water in the allocation framework, commitments to improve flow regimes; better water accounting and scientific understanding.

Description

The flow regime is a key driver of river and floodplain wetland ecosystems[33]. Each river has its own flow regime, with a specific pattern of changes in the season, timing, frequency, volume, rates of rise and fall, and duration of flows. These characteristics influence the physical nature of river channels, biodiversity, and the key processes that sustain the aquatic ecosystem and the ecosystem services that inland waters provide[34]. Aquatic plant and animal species have evolved life histories directly in response to the natural flow regimes[35]. Altering flow regimes may change patterns of habitat connectivity essential to the population viability of many freshwater species and facilitate the invasion of exotic species[36].

Rivers and groundwater are connected, and most Australian rivers derive flow from groundwater most of the time[37]. Groundwater level regimes are important for maintaining the health of rivers, floodplain wetlands and other groundwater-dependent ecosystems. These links are yet to be fully integrated into policy and management processes.

Two centuries of works designed to control and change the direction and speed of water as it moves through the landscape has extensively degraded flow regimes and reduced the volume of water available to the environment. Direct modifications to river channels and catchment include the construction of dams, extraction of water, straightening of channels and urbanisation of catchments, and have altered the speed at which water moves through the landscape. Indirect pressures such as the clearing of vegetation, agriculture, groundwater extraction, farm dams, plantation forestry and re-growth following bushfires have also altered catchment hydrology.

Serious rainfall deficiencies over the past 11 years have reduced inflows to storages 30–60% below long-term averages. Water scarcity has been statewide in extent, and has increased over time, with inflows to the Murray and Melbourne storages reaching record lows in 2006. As competition for water resources has increased, the cumulative impacts of water harvesting have become more acute. These pressures have been compounded in the past decade by streamflows well below the long-term average (see Part 3.2: Water Resources) and they are expected to intensify with climate change[38].

Objectives

- Protect natural water regimes and where these have been modified, retain or reinstate as many of the features of the natural water regime as possible.
- Manage wetlands, rivers and groundwater systems as integrated systems to ensure adequate flow to support healthy waterways.

State

The indicators in this section relate to the condition of major rivers and tributaries. The term 'flow regimes' is used in this context, but is inclusive of links to groundwater and wetlands. Trends in regional groundwater levels are also presented. Assessments of groundwater-dependent ecosystems are currently being conducted and should be included in future State of Environment reporting.

There is an urgent need for an agreed and consistent classification system for determining the flow regimes of wetlands in Victoria[39], as the determination of the water requirement for wetlands is an essential requirement for management. The water requirements of all River Murray icon sites have been determined by the respective jurisdictions under The Living Murray program. The water requirements of other important wetlands in the Victorian component of the Murray-Darling basin are currently being documented.

Indicator IW1 Condition of flow regimes of major rivers and tributaries

In 2004, flow regimes were in good condition for 24% of the total reach-length assessed, with a further 45% in moderate condition and 31% in poor condition (Figures IW1.1 and IW1.3). The Mitchell, Upper Murray and East Gippsland basins had flow regimes in best condition, with 80% or more of reach-length with flow regimes rated as 'good'. This is because the Mitchell and East Gippsland basins have no major dams, while most the storages in Upper Murray are downstream of the reaches assessed. The Millicent Coast basin had flow regimes in good condition, but there is very little flow in this basin. Flow regimes in the main part of the Snowy River has been severely modified by the diversion of up to 99% of flow in NSW as part of the Snowy Mountains Hydro-electric Scheme[40]. However, while the main stem of the Snowy River has lost the spring flood which was critical to its ecological integrity, the tributaries of the Snowy River have largely unmodified catchments and stream beds[41], and this has protected the condition of many of the river's reaches. Four basins (Mallee, Maribyrnong, Hopkins and Portland Coast) had no assessed reaches with flow regimes in good condition. The Mallee basin is in poor condition because the only river assessed for this basin, the River Murray, is heavily regulated. Overall, 16 out of 29 basins had no more than 20% of reach length with flow regimes in good condition (see Figure IW1.3). Flow regimes are generally worse below major storages and water diversion points.

Figure IW1.1 Percentage of stream length assessed with flow regime in good condition
Source: DSE (2007) [42]

Box IW1.1 Flow Stress Ranking Assessment

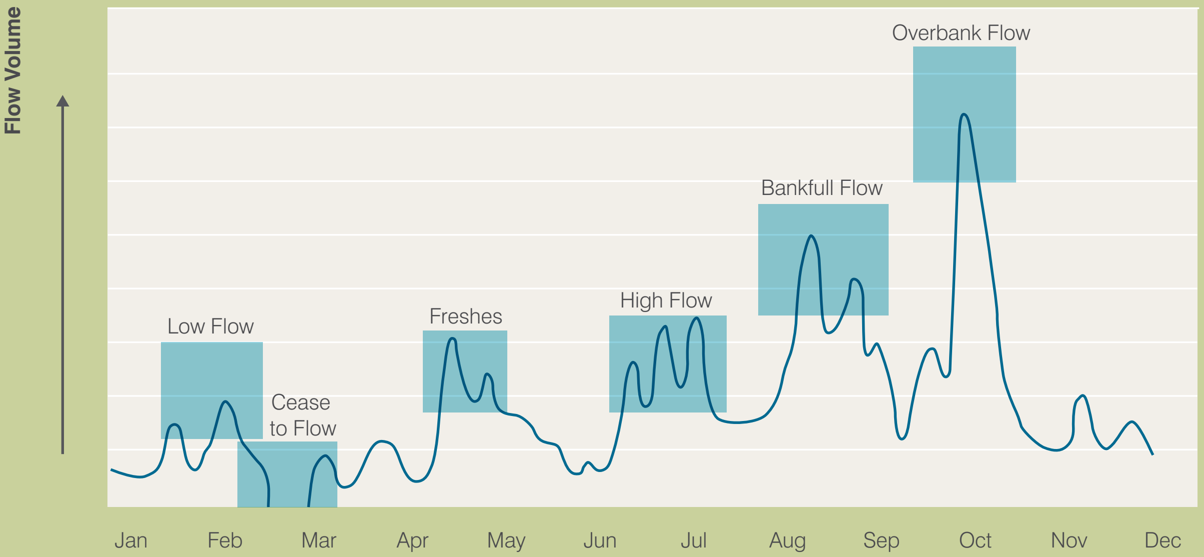
A river's flow regime is made up of different components (see Figure IW1.2). The assessment of flow regime condition, known as a flow stress ranking (FSR) assessment, considers five important components of a natural flow regime:

- Cease to flow, where there is no detectable flow of water
- Low flows, where there is relatively little water available
- High flows, where practically all habitat in a river, such as boulders and logs, is inundated with water
- Seasonality, a measure of the shift in maximum and minimum flow months between natural and current conditions
- Variation in flow, where variability occurs across different time scales[43].

A rating is produced by comparing the observed condition to an estimated natural state for the different components of flow regime. Hence, good condition means relatively little change from the natural state, whereas poor condition indicates significant change. This methodology takes account of the impact of farm dams and sustainable diversion limits, but not variations in flow due to altered catchment hydrology or channel form (e.g. erosion or straightening).

This method uses a minimum of 15 years data in assessing the flow regime condition, so low streamflows are unlikely to be a main determinant of flow regime conditions in the 2004 assessment. Drought is likely to have had more impact on flow regimes since this assessment.

Figure IW1.2 Components of a flow regime
Source: DSE (2008)[44]



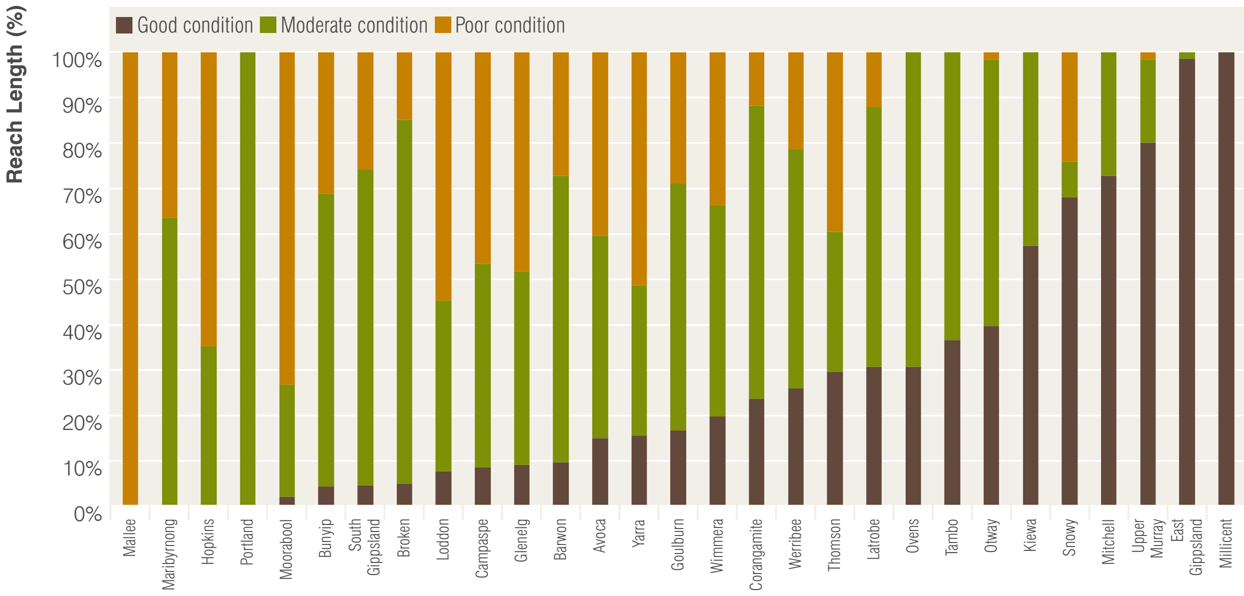
The reaches assessed were most altered from natural flow regimes in summer, with low flows being the most modified flow component (see Figure IW1.3). Of the reaches in poor condition, about 85% are most altered from their natural condition in summer, and the most affected component is low flows. An example of this is seen in regulated rivers used to supply water for irrigation, such as the Macalister and Goulburn Rivers, where water is sent from storage downstream for irrigation during the summer months, creating flows that are much higher than would naturally be seen at that time of year.

The remaining 15% of reaches in poor condition are most altered from their natural condition during winter. In these cases the components of the flow regime most affected are low flows and high flows. This often reflects the effects of major storages, which capture most of the winter high flows and therefore significantly reduce flow downstream (See Part 3.2: Water Resources for more information).

Of the reaches with flow regimes in moderate condition, 93% are more altered from their natural condition in summer than winter with low flows again being the most modified component of their natural flow regime. The remaining 7% of reaches in moderate condition are most altered in winter through modifications to both their low-flow and high-flow components.

Of the river reaches with flow regimes in good condition, only 11% are considered in excellent condition, with no modifications to their natural flow regime. About 84% of reaches in good condition were most altered in summer, with low flows being the most affected component. The remaining 7% of reaches in good condition were most altered in winter, with high flows being the most affected component.

Figure IW1.3 Flow regime condition, by basin[45]
Source: DSE



Indicator IW2 Trends in regional groundwater levels

Long term trends in regional groundwater levels across Victoria have generally remained stable over the past five years[46]. Nine groundwater management units, out of a total of 67, were identified as having declining trends over the five years to 2006-07 (see Part 3.2: Water Resources).

Groundwater levels and trends for August 2008 show more widespread decreasing trends, due to the continuing lack of recharge and increased consumptive pressure[47]. Groundwater levels in 12 water supply protection areas were at their lowest on record.

Pressures

The main pressures on flow regimes are the presence of dams and other barriers; regulation of flow; extraction of water for consumption; channel modification; and changes in land use. These pressures affect groundwater and wetlands, as well as rivers. Over the past 11 years drought has compounded pressures on flow regimes, and climate change is also likely to place pressure on flow regimes in future (see Part 4.1: Atmosphere, Climate Change).

Indicator IW3 Surface water harvested for consumptive use as a percentage of the total water in the basin

Current levels of water consumption increase the pressure exerted by low streamflow on the biota of inland waters, despite their adaptation to high variability. In a quarter of Victoria's river basins, over 75% of the total annual flow was harvested the past four years (2003–04 to 2006–07). The basins experiencing the greatest reduction in streamflow over this time also recorded the highest percentage of water harvested. This indicator is reported in Part 3.2: Water Resources, Pressures on the Environment.

Recommendation

IW1.1 Government should address the disproportionate reduction in water remaining in basins during times of low streamflow, which results from the current system of bulk entitlements defined as a volumetric share of the resource.

Regulation of flow

Major storages, weirs and levees are the most common cause of alteration to flow regimes[48]. At least one major on-stream storage occurs in 65% of Victoria's river basins (19 out of 29)[i]. Storages often result in large decreases in flow immediately downstream. For example, there is a 95% reduction in flow immediately downstream of the Upper Yarra Dam[49]. The release of high-velocity water during weir and dam operation scour away and weaken riverbanks, resulting in bank slumping and instability.

In irrigation areas, flow regimes are dictated by the needs of consumers rather than environmental requirements as rivers are used to convey water released from storages to consumers. Water is also released from storages for hydro-electricity generation.

Levee banks are constructed to reduce flooding and protect property from flooding but they typically isolate the river from the floodplain (locations of levees are shown in Figure IW2.6).

i Major on-stream storages were those included in the State Water Report 2005–06, and are all greater than 1,000 ML in volume.

Extraction of groundwater

Where aquifers are connected to surface waters, harvesting of water from groundwater bores, as well as the excessive extraction of surface water, can lower groundwater levels, leading to a range of environmental impacts (see Part 3.2: Water Resources, Groundwater, Pressures on the Environment). On the other hand, land use changes for agriculture have generally increased recharge to groundwater[50] (see Part 4.2 Land and Biodiversity).

Altered catchment hydrology

Flow regimes are cumulatively affected by changes to runoff and groundwater recharge throughout the catchment. Approximately half of Victoria's native vegetation has been cleared, including 80% of the cover on private land (see Part 4.2 Land and Biodiversity). This has generally increased recharge to groundwater, which has placed pressure on terrestrial systems as well as inland waters (see Part 4.2: Land and Biodiversity, LB6 Salinity). In irrigation areas, the extra water added to irrigated land has accelerated the increase in groundwater levels. The catchment response to rainfall has also been modified, leading to changed groundwater conditions, an increase in surface water run-off and, as a consequence, changed flow regimes[51].

A major pressure is the proliferation of farm dams, which have increased in number from 300,000 in 1988 to 355,000 in 2004–05[52] (see Part 3.2: Water Resources). While farm dams do not regulate flow directly, by intercepting runoff they increase evaporation and reduce streamflow, thereby affecting flow regimes. Farm dams capture a higher proportion of runoff during summer, leading to lower flow and longer low-flow periods[53]. Even with no new dams, the impact of farm dams is expected to increase significantly as inflows decline due to climate change, as they will capture a higher proportion of the available water. Salt interception schemes and improved irrigation efficiency are two recent initiatives that will affect flows in rural areas.

Widespread reforestation, through plantation forestry or smaller-scale agroforestry activities, can change the hydrology of catchments by intercepting groundwater recharge and directly drawing down groundwater though their root systems (see Land and Biodiversity, Indicator LB15). Young, rapidly-growing trees use much more water than mature forest, leaving less to flow into rivers, lakes and dams. Fire may also affect water availability through its effects on vegetation. When regenerating forest reaches a phase of rapid growth, typically 20–25 years after a wildfire, it uses more water than a mature forest. Impacts continue for another 80–100 years after that time[54] (see also Part 4.2: Land and Biodiversity, LB8 Fire in the Victorian Environment). It is estimated that regrowth of vegetation following the 2003 alpine fires will reduce flows to the River Murray by up to 700 GL a year or 10% of mean annual flow[55].

Urbanisation, while affecting a relatively small area of Victoria, represents an intense disturbance to ecosystem function (see Box IW1.2). Urbanisation affects streamflow by making it much more variable, reducing low flow rates and, after heavy rain, increasing peak flow rates and shortening their duration[56]. Another significant impact on flow patterns is that peak flow from small, frequent rain events is dramatically increased, with changes of up to a factor of 20 being observed between undeveloped and developed catchments[57].

Climate change

As the climate changes, Victoria will become warmer, water availability will reduce and extreme events are likely to increase in frequency. The implications of these pressures on flow regimes are discussed in Impacts of Climate Change on Inland Waters.

Implications

Modification of natural flow regimes in Victoria's inland waters has led to significant negative impacts on physical habitat, ecological health, biodiversity, and provision of ecosystem services.

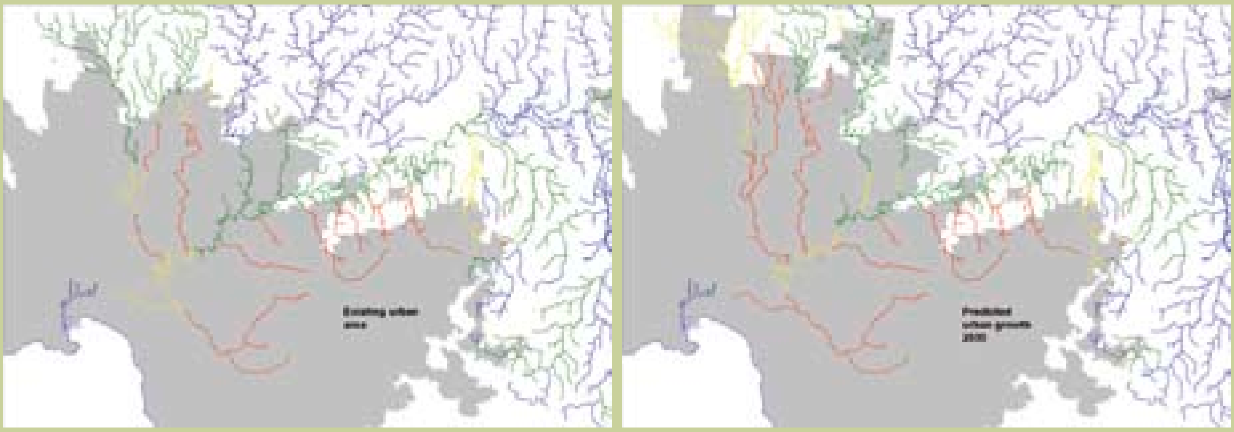
The Snowy River and River Murray exemplify the impacts already caused by altered flow regimes on river systems. The Snowy has suffered a build-up of sediment, weed infestation and reduced habitat for native flora and fauna[58] (e.g. the demise of Australian Bass population), particularly in NSW. Similarly, the Murray is now a heavily regulated system with an inverted flow regime and greatly reduced variability in flow. An assessment by the Victorian Environment Assessment Council of River Red Gum (*Eucalyptus camuldulensis*) forests concluded that the greatest environmental problem was the "imminent loss or degradation of large areas of wetlands and riverine forests as a result of greatly reduced frequency of flooding"[59]. The health of floodplain vegetation in the Hattah Lakes, declared an 'Icon site' by the Murray-Darling Basin Commission and a Ramsar-listed wetland, is of serious concern, with just 5% in good condition and 76% in poor or degraded condition[60]. Emergency pumping of water to Chalka Creek and nine of the 18 lakes in the Hattah complex as part of the Living Murray program in 2005-06, resulted in the improvement in tree condition at these lakes, and a vigorous response from fish and macrophyte communities[61]. In the Barmah-Millewa Forest 75% of the River Red Gums are in decline, although only 5% are currently in poor condition[62]. This study warned that, without adequate flooding in the near future, many tens of thousands of hectares of forests and wetlands may be lost, requiring centuries to recover.

Box IW1.2 The impact of urbanisation on flow regimes in urban streams

Urbanisation increases both volume of runoff from storms and the speed with which water moves through the landscape. The impact of urbanisation on flow regimes can be represented by Effective Imperviousness, which is the proportion of the catchment with hard surfaces directly connected to streams by drains (see Figure IW1.4). Effective Imperviousness ratios above 0.5% have been demonstrated to degrade streams.

Figure IW1.4 The effect of urbanisation on streams in the Yarra catchment, based on an estimation of catchment effective imperviousness.

blue: EI<0.5%: little or no impact; green: 0.5%<EI <5%: detectable impact; yellow: 5%<EI<10% : likely severe impact; red: >10%: certain severe impact
Source: Walsh, et al. (2005)[63], Melbourne Water (2008)[64]



When changes in groundwater levels lead to waterlogging and salinisation, the impact may be severe (see Part 4.2: Land and Biodiversity, LB6 Salinity). Wetlands and surrounding native vegetation are particularly at risk from rising groundwater and salinity because of their low position in the landscape. Between 13% and 22% of all natural wetlands in Victoria occur in landscapes predicted to develop shallow watertables by 2050[65]. Wetlands in the Goulburn Broken and Corangamite catchments are most at risk. Despite this, groundwater is often overlooked and its management has historically been under-resourced.

The legacy of historic groundwater extraction on river flow is an emerging issue. The time lag between the commencement of groundwater extraction and its full impacts being observed in rivers may be decades[66]. Australia still has no agreed method for assessing the sustainable yield of groundwater[67].

Flow variability and volume underpin many ecosystem processes in inland waters, regulating the transport of nutrients, sediment and salt within inland waters and onto associated floodplains[68]. Changes to flow variability and volume, combined with altered land-use practices, have resulted in many inland waters with modified loads and concentrations of natural contaminants such as nutrients[69].

Assessing the future implications of modified flows regimes requires consideration of the cumulative impact of the pressures presented above. Thus future extraction and flow regulation need to be considered in the light of reduced water availability, higher temperatures and evaporation resulting from climate change; increased interception of catchment runoff by farm dams and plantations, reforestation and bushfire re-growth; altered catchment processes due to urbanisation; as well as the impact of historic groundwater extraction. Potential implications of these pressures on the individual components of flow regimes are summarised below.

Changes to cease-to-flow events

When the frequency or duration of cease-to-flow events increase, there is little capacity for aquatic plant and animal species to recolonise. The increased stress from extended periods without flow reduces population viability[70], which is weakened further by the loss of connectivity due to dams and weirs that block the migration of aquatic species. However, reservoirs and weir pools provide some level of refuge habitat but only for some species, notably those which have been introduced.

Changes to low and high flows

River regulation can significantly reduce the volume of low flows below natural levels, and can also increase the duration of low flows, with significant impacts on biodiversity and ecological processes. River regulation has been identified as a primary cause of algal blooms, as the creation of weir pools and low but continuous flows of water effectively convert them to a series of shallow, thermally stratified lakes in summer[71]. Low flows may also create barriers to movement, and reduce in-stream habitat. Very low summer flows can also raise temperatures and cause a build-up of nutrients or saline water in stagnant pools. Over time, deoxygenation may occur, resulting in fish deaths[72].

High flows, bankfull flows and overbank flows, including major floods, have vital roles in maintaining floodplain and wetland ecosystems and allowing fish migration, sediment transport and channel maintenance[73]. When these flows are reduced, dependent ecosystems become fragmented and degraded, and loss of biodiversity can occur.

At present, no environmental entitlement on any of Victoria's northern rivers is sufficient to create a flood, so supplying water to floodplain wetlands often depends on pumping. While pumping has some advantages–for example, excluding carp (*Cyprinus carpio*) and gambusia (Gambusia holbrooki) from Hattah Lakes during recent watering[74]–it subverts natural processes such as migration and transfer of sediment and increases the risk of lethal 'blackwater' events, where high levels of dissolved organic carbon and low levels of dissolved oxygen are present.

Absence of adequate spring floods in recent decades has resulted in an almost-complete cessation of breeding by various species, including the Great Egret (*Ardea alba*), Little Egret (*Egretta garzetta*) and Intermediate Egret (*Ardea intermedia*)[75].

In the spring of 2005, environmental water was delivered to Gunbower Forest, a Ramsar-listed wetland, to maintain several permanent and semi-permanent wetlands, protect and enhance the River Red Gum communities and provide breeding opportunities for colonial waterbirds. The flooding triggered breeding among waterbirds[76] and increased spawning by several native fish species[77].

Changes to seasonality

In temperate Australia, plants and animals in floodplain and riverine ecosystems are generally adapted to floods in winter/spring and low flows in summer/autumn. Changes to these patterns through flow regulation are thought to have caused significant changes in some Victorian ecological communities[78]. Large dams have the potential to capture seasonal floodwaters, which are then stored and released for irrigation during the dry season. This reverses or inverts the seasonality of flow and diminishes the reproductive success of many aquatic species. For example, changing the seasonality of flow may remove the necessary habitat requirements for the spawning and survival of fish such as the Golden perch[79].

Changes to variability

The variability of flow in a river can strongly influence aquatic habitat availability and plant and animal assemblages[80]. A reduction in the daily variability of summer low flows in rivers can reduce opportunities for fish to move between habitats. Exotic species of plants and animals may also benefit from flows with less daily and monthly variation. For example, introduced Carp and Gambusia species are found in greatly increased numbers in regulated reaches where flow varies little, usually to the detriment of native fish species[81].

Management responses

Given the importance of water regimes to ecosystem function, management responses should protect natural water regimes and retain or reinstate as many of the features of the natural water regime as possible. Connections between inland water systems need to be recognised through an integrated approach to the management of wetlands, rivers and groundwater systems. Flow regimes are managed through the water allocation framework, and strategies and plans at a range of scales, from regional down to sub-catchment (see Part 3.2: Water Resources).

Response Name
Creating the Environmental Water Reserve (Our Water Our Future, Actions 2.2, 3.4 and 3.5)[82]

Responsible Authority
Department of Sustainability and Environment

Response Type
Legislation

The environment's right to water, known as the environmental water reserve (EWR), was only given formal recognition in the water allocation framework in 2005[83]. In most rivers and aquifers, the EWR is provided by capping the volume of water available for consumption. In rivers where flow is regulated by dams, water is provided as 'passing flows' for environments downstream[84]. In unregulated rivers, the EWR is delivered through streamflow management plans that manage the diversion of water[85]. Entitlements of water are also held by catchment management authorities for environmental purposes. These entitlements often comprise only a fraction of the overall EWR. In the northern region, for example, only about 4% of the EWR is held as a legal entitlement[86].

The mapping of groundwater dependent ecosystems such as streams and terrestrial vegetation, will be completed by The Department of Sustainability and Environment in 2009. The environmental water requirements of these ecosystems must be specified differently to those of surface water ecosystems. The groundwater level regime is critical, and must be managed according to location-specific factors. The methodology for delivering these water requirements will be trialled in the Glenelg-Hopkins CMA region.

Recommendations

IW1.2 Government should provide environmental water requirements for groundwater-dependent ecosystems once the delivery methodology has been finalised.

IW1.3 Review allocations between all sectors within the current 15-year period, taking into account real and projected water availability.

IW1.4 The cyclical review of water allocations should be conducted on an ongoing basis over a shorter period than 15 years, and the findings made public.

Response Name
Indicator IW4 Delivering the Environmental Water Reserve

Responsible Authority
Department of Sustainability and Environment

Response Type
Policy/strategy

The different components of the surface water EWR are delivered through the allocation framework. Catchment Management Authorities are responsible for the delivery of Environmental Entitlements in accordance with Annual Watering Plans. Water Authorities are responsible for complying with passing flow conditions on Bulk entitlements. Across Victoria, there are some 450 Bulk Entitlements and 600 points at which passing flow conditions are stipulated.

Streamflow management plans have been completed for the Hoddles and Diamond Creeks, the Plenty River, Olinda Creek, Stringybark Creek and the Pauls, Steels and Dixons Creeks.[87] Management plans have been developed for nine high-priority groundwater management areas. These plans do not deliver the groundwater environmental water reserve, which is still in development, but nevertheless manage the extraction of groundwater. A further 15 plans are in progress for high-priority water supply protection areas. Management plans will eventually be written for all 24 groundwater management and 40 groundwater supply protection areas in Victoria[88].

In many rivers and aquifers the current EWR is inadequate and vulnerable, placing environmental values at risk[89]. In 2006–07, about 40 temporary qualifications to environmental flows were made in Victoria[90], as part of the Government's drought contingency response. To date no water has been delivered to the rivers of the Central region as a result of the *Central Region Sustainable Water Strategy*. Additional flow committed to the Yarra River has been delayed by the Minister for Water until storage levels recover[91]. Such delays pose a serious risk to the environment.

The delivery of environmental entitlements in the Northern Region is now dependent on a return to 'normal' rainfall. In the Loddon, Murray, Campaspe and Goulburn Rivers, where the EWR has been recently boosted with low reliability water shares, low streamflows have meant this water is not yet available. This policy appears inconsistent with current projections for climate change, and appears to undermine a major benefit of creating the EWR, which was to give the environment an entitlement with legal status equivalent to that for water allocated to consumption.

During times of low streamflow, the water allocation system reduces environmental flows more than it reduces water for consumptive uses. Some components of the EWR, such as water above the cap, and spills from storages, are also vulnerable to climate change[92] (see Impacts of climate change on Inland Waters, Implications).

If current low streamflows persist, the State Government should be prepared to review allocations between all sectors within the current 15-year period, taking into account real and projected water availability and the financial implications.

Coordination of State and Commonwealth Governments has proved a barrier to improving the condition of the Snowy River and River Murray. An Inter Governmental Agreement (IGA), on the management of the River Murray was signed by the Commonwealth and State Governments on 3 July 2008. Water recovery for the Snowy River is being managed by a joint (Commonwealth, Victoria and NSW) Government Enterprise with 142 GL of water recovery targeted for 2009, but now delayed to 2012. Planned releases for 2006-07 amounted to only 46 GL[93].

The use and carry over of environmental entitlements are annually reported in the Victorian Water Accounts. Water Authorities and Catchment Management Authorities report on compliance with conditions of bulk entitlements for which they are responsible[94]. The standard of compliance reporting is currently being increased through better auditing processes and new instrumentation at a number of these points[95].

Recommendation

IW1.5 The Government should disclose the reasons for, and likely impact of, the qualification of environmental flows.

Response Name
Improving the Environmental Water Reserve

Responsible Authority
Department of Sustainability and Environment

Response Type
Policy/strategy

The Victorian Government has made significant commitments to improve the EWR in 100 high-priority reaches of rivers with dams and weirs[96]. These commitments have been outlined in *Our Water Our Future* and the *Central Region Sustainable Water Strategy*. The Regional *Sustainable Water Strategies* enable investment in programs to increase flows to levels consistent with ecological objectives and provide adaptive responses to the uncertainties associated with climate change. For example, further improvements to bulk entitlements are made through this process. A condition of these programs is that that there should be no impact on existing entitlements. This approach protects the rights of entitlement holders but limits the options available for improving flow regimes.

The Government's policy position in relation to water recovery as outlined in *Our Water Our Future* is to:

- Invest in distribution savings
- Invest in water re-use and recycling
- Change system management
- Enable water donations
- Invest in reconfiguring irrigation systems and other local adjustment projects providing long term environmental and social or industry benefits; and
- Purchase water through the water market

Currently, initiatives are focused on investing in improving the efficiency of distribution networks, enabling donations and investment in reconfiguring irrigation systems. The volumes of water that will be recovered, and the certainty of allocations of this water to the environment, are to be determined. In unregulated rivers, stream flow management plans are to be developed on a priority basis, with government co-investing to increase environmental flows to meet agreed ecological objectives.

Some environmental entitlements were also increased as part of the revised allocation framework, in particular 120,000 ML for the River Murray and 96,000 ML for the Goulburn River (see Figure IW.5). However, these shares are 'low reliability shares' which may not always be available. Under climate change, their availability is likely to decrease. For example, low reliability water shares in the Goulburn River are expected to be available only seven years in 100 by 2055[97]. Although improvements to the EWR have been made on paper (as per Figure IW1.5), water scarcity and qualifications to environmental flows have constrained delivery of this water in recent years.

Recycled water is increasingly being considered as a means by which environmental flows can be increased to meet ecological objectives and reduce demand on surface water supplies (See Part 3.2: Water Resources).

Recommendations

IW1.6 Government should act with urgency to increase environmental water reserves where they are currently insufficient to keep rivers in a sustainable condition, including buying back water. In particular, floodplains need floods to continue functioning as floodplain ecosystems.

IW1.7 Review water trading rules to remove impediments to buying water to add to the environmental water reserve.

IW1.8 Adopt a new term for environmental flows that does not have connotations of being 'just for the environment', and expresses the importance of maintaining water quality and river health. For example, "essential baseflow" could be used to describe minimum flows required during low-flow periods to maintain water quality and river health.

Response Name
Restoring the Balance in the Murray Darling Basin Program

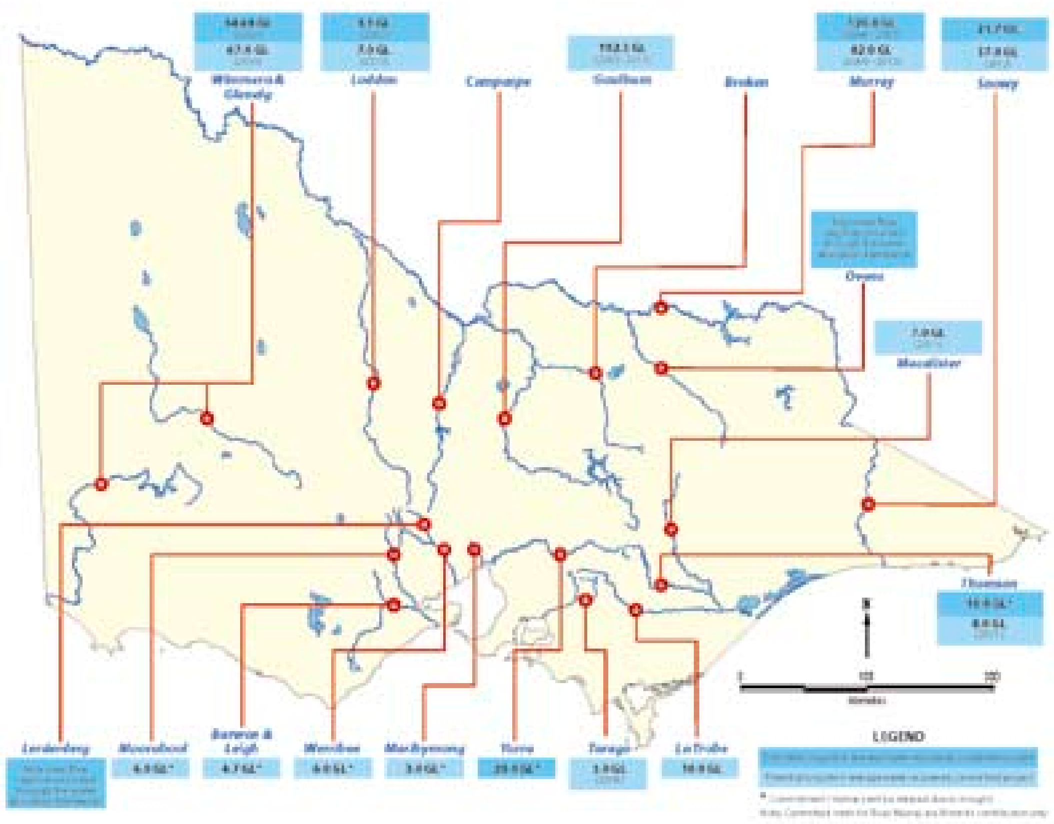
Responsible Authority
Department of Environment, Heritage, Water and the Arts

Response Type
Water Entitlement Buy-back

The *Restoring the Balance* Program is a $3.1 billion program to buy back, over 10 years, entitlements from willing sellers in the over-allocated Murray Darling Basin. It a priority action of the Commonwealth Government's $12.9 billion *Water for the Future* initiative, which also includes actions for climate change, water conservation and efficiency measures including nearly $6 billion to refurbish irrigation schemes, and securing urban water supplies.

Restoring the Balance recognises the need for immediate action to address over-allocation, and aims to acquire water from willing sellers, and use the water allocated to them to improve the health of rivers, wetlands and floodplains.

Figure IW1.5 Proposals to improve the Environmental Water Reserve in Victoria's major river systems
Source: DSE (2008)[98]



An initial $50 million water buy-back in 2007-08 aimed to secure entitlements to 35,000 ML of water. A new round of purchases worth $400 million was announced in September 2008, focusing on the northern Murray-Darling Basin in New South Wales and Queensland.

In Victoria, the volume of water which can be permanently traded out of a particular irrigation area in any one season is limited to 4%[99]. This trading rule limits the social impacts of water leaving an area, but may also limit opportunities to quickly purchase water for the environment.

It is important that water is bought strategically, and before re-furbishing infrastructure, to ensure the outcomes of these programs do not conflict. The broader and longer term social and economic implications of these decisions may be regionally significant, and measures to identify and address them must be considered.

Response Name

Victorian Environmental Flows Monitoring and Assessment Program

Responsible Authority

Department of Sustainability and Environment

Response type

Monitoring program

The Victorian Environmental Flows Monitoring and Assessment Program (VEFMAP) was established to coordinate the monitoring of ecosystem responses to environmental flows in eight stressed rivers[100]. These rivers, where delivery of environmental flows is expected or underway, are the Broken, Goulburn, Loddon, Campaspe, Wimmera, Thomson, McAlister and Glenelg[101]. VEFMAP is in three stages, the first two of which are complete: The development of an overarching Victorian framework for monitoring ecosystem responses to environmental flow releases; and the development of targeted monitoring and assessment plans for individual river systems. The third stage, which is underway, includes implementation of monitoring, data collection and analysis, interpretation and program review after three years.

Due to current water shortages, releasing water for environmental purposes has become increasingly difficult, yet water managers are expected to show short-term benefits from environmental flows in rivers that have been subject to decades of degradation. Programs such as VEFMAP are required to demonstrate the benefits of environmental water in order to counter purely cost based arguments for qualifying or diminishing environmental flows. Water managers should continue to build knowledge and expertise at prioritising water-dependent environmental assets, and protecting those of highest value.

Evaluation of responses to flow regimes

Streamflow in Australia is highly variable. In response, human settlements have transformed inland waters into a complex and extensive system for harvesting, transporting and controlling the movement of water[102], with the highest levels of per-capita storage in the world[103].

Recognition of the reality of irretrievable ecological damage caused by past and current management practices, a burgeoning population, prolonged drought and the threat of climate change have increased the urgency for Government action.

Significant improvements in the way water is managed for the environment have occurred in the past decade. These include the adoption of a revised allocation framework which recognises the environment's right to water and caps the maximum of water that can be harvested from each basin; the designation of catchment management authorities as managers of the environmental water reserve; funding commitments to recover water for the environment; the adoption of the FLOWS methodology for assessing environmental flows; and improved water accounting through the Victorian Water Accounts.

The current level of development of water resources, and ongoing drought, greatly constrain actions both to further modify and to improve the condition of flow regimes. New instream storages are not supported under current government policy and further direct physical changes to rivers such as channelisation and the construction of levees, are now limited in extent, aside from rehabilitation works (see Part 3.2: Water Resources, Major storages). Existing infrastructure can be upgraded, for example to reduce unaccounted water, but is largely fixed and needs to be managed to achieve the best outcomes for the entire system.

In all basins water needs to be shared between competing consumptive and non-consumptive uses, within the context of catchment impacts on hydrology, drought and climate change. Management is coordinated at a range of scales, from regional down to sub-catchment, through inter-related strategies and plans. Important programs to overcome knowledge gaps, such as the assessment of groundwater dependent ecosystems, are relatively recent and are yet to be fully incorporated into management planning. The actual sharing of water between competing users, however, occurs through the allocation framework, which is therefore central to efforts to improve flow regimes, particularly in over-allocated basins.

The principle of protecting private rights to water is central to the Victorian allocation system[104]. Entitlements to the use of water, which were ongoing in tenure, were granted as water resources were developed. The allocation framework was revised in 2004 through the *Our Water Our Future* White Paper, but entitlements were not reviewed in terms of environmental requirements or projected resource availability. The only mechanism by which entitlements can be directly adjusted is the Statewide Water Resource Review, which occurs on a 15 year cycle. The first Statewide Water Resource Review is to be completed in 2019, but this is too late in the context of the condition of inland waters, water scarcity and climate change[105].

The development and implementation of Regional Sustainable Water Strategies will help to improve flow regimes and provide adaptive responses to the uncertainties associated with climate change, in order to minimise any adjustments required under the Statewide Water Resource Review.

Given the centrality of the allocation framework to water resource management, it is vital that this system does not hinder the establishment of adequate flow regimes, nor further disadvantage environmental flows under a drying climate. A greater range of options for improving flow regimes needs to be considered, including adjustments to the allocation framework and entitlement buy-backs from willing sellers, to sufficiently meet the seasonal flow requirements of many rivers in Victoria.

Allocation decisions are made in the context of meeting customer requirements but also in the context of the degradation of inland waters and likely climate change. Caps on surface and ground water extraction across Victoria were established under the *Our Water Our Future* White Paper, in addition to those already in place in the Murray-Darling Basin. Caps prevent further water resource development in over-allocated or fully allocated systems, but do not address current levels of over-allocation, or the impacts of altered flow regimes.

Investment in water infrastructure and water recovery by the Victorian government, as well as other states and the Commonwealth, needs to be coordinated to the highest level, to avoid projects with conflicting outcomes. Both Victorian and Commonwealth Governments are making substantial investments to refurbish irrigation infrastructure. The Commonwealth Government, however, has also prioritised entitlement buy-backs; whereas the Victorian Government has placed less priority on entitlement buy-backs, and has used rural water to improve the security of supply for the urban centres of Ballarat and Bendigo, and soon Melbourne.

The Index of Stream Condition assessments and independent reports on the health of the River Murray River clearly indicate that these improvements are absolutely necessary, and in some cases must go further. Even the highest volume of water recommended for return to the Murray (1,500 GL) is only given a moderate chance of restoring the river to a healthy condition[106].

In many rivers and aquifers the current EWR is inadequate and vulnerable, placing environmental values at risk[107]. In 2006–07, about 40 temporary qualifications to environmental flows were made in Victoria[108], and environmental flows were also qualified in 2007-08 as part of the Government's drought contingency response. From the perspective of the environment, withholding flow at these times poses a serious risk, and should not be used on an ongoing basis.

Where over-allocation has occurred, water must be recovered to augment the flow regime. The current State Government policy is to protect existing entitlements from any impacts, including adjustment to entitlements and entitlement buy-backs. Other approaches such as improving the efficiency of water supply systems and reducing demand are used to augment environmental entitlements (see Management Responses). While this approach protects the rights of entitlement holders, it also limits the options available for improving flow regimes, and to date has not sufficiently met the seasonal flow requirements of many rivers in Victoria.

Recommendation

IW1.9 Improve the awareness and understanding within the community of the importance of environmental flows for inland waters, and provide regular, consolidated reports on progress against the actions and outcomes within *Our Water Our Future* and the regional sustainable water strategies

For further information

Monthly Water report, Victorian Water Accounts

http://www.ourwater.vic.gov.au/monitoring

IW2 In-stream and Wetland Habitat

Key findings

- River channels and instream habitat, including wetlands, were historically modified without an understanding of the consequences. Many large-scale changes such as erosion and draining of wetlands are irreversible, and the historic legacy of channel modification still places pressure on in-stream habitat.
- In 2004, just 6% of the major rivers and tributaries assessed by the Index of Stream Condition had in-stream habitat in good condition, based on the presence of large woody habitat, bank stability and barriers to fish passage.
- By 1994, 37% of naturally occurring wetland area had been lost, mainly due to drainage. An inventory showing the extent of wetlands has not been updated since then.
- The statewide condition of remnant naturally occurring wetlands are not available in detail. An Index of Wetland Condition assessment technique has been developed and is currently being finalised.
- River channels and wetland habitats are now managed with much greater sensitivity to, and understanding of, the ecological significance of their various components and processes. Remnant naturally occurring wetlands, particularly those on private land, remain vulnerable to incremental loss and degradation in quality.
- In many cases, restoration works involve putting back what was taken away many years ago. The ongoing investment and effort required show the benefits of avoiding damage in the first place.

Description

In-stream habitat describes the physical form of a waterway and the features of the habitat. Changes to in-stream habitat can significantly influence the distribution, population abundance and community structure of aquatic biodiversity[109].

River channels and in-stream habitat were historically modified without an understanding of the consequences, and the historic legacy of channel modification still places pressure on the in-stream habitat of rivers and wetlands. Clearing of catchment and riparian vegetation and changes in land use have led to bed and bank erosion, severely modifying channel structure. Deposition of sediments on river channels and floodplains has covered and removed major habitat features such as riffles and pools in streams. Activities that physically disturbed the substrate, such as gold mining, dredging and bridge building, also contributed to this problem.

There is increasing evidence that many rivers in Victoria previously contained woody material, such as large branches and whole trunks, along their banks and within their channels. In the past, this material was removed from many rivers to allow boat passage and increase channel capacity. The removal of trees from riparian areas has significantly reduced the amount of large woody habitat available for aquatic biota, particularly in lowland areas where clearing has been more extensive. The critical importance this habitat plays in the physical and ecological health of rivers was only realised later.

Large woody habitat influences the shape, depth and flow of water in inland waters. It provides a surface upon which microscopic plants can grow, and habitat for in-stream invertebrates such as snails and insect larvae. Large woody habitat also provides shelter from predators and forms an essential spawning habitat for several native fish species, including the river blackfish (*Gadopsis marmoratus*)[110].

Even though the removal of woody habitat in rivers and streams is listed as a potentially threatening process under the *Flora and Fauna Guarantee Act* 1988, until recently the removal of snags was widespread in many rivers. The challenge today is to demonstrate the positive benefits of maintaining woody habitat and recognise the need for restoration works. Restoration itself may be difficult in many instances as the source of woody habitat (i.e. riparian vegetation) is often degraded.

The introduction of barriers has severed the connectivity of inland waters, preventing the longitudinal and lateral movement of fish and other biota, and interrupting the transport of organic materials and sediment. Barriers include dams, weirs, causeways, culverts, levee banks, erosion control structures and regulators. The lateral movement of water onto the floodplain is essential, but these links have been lost throughout the State. The presence of fish barriers in Victorian rivers and streams is also listed as a potentially threatening process under the *Flora and Fauna Guarantee Act 1988*.

Objectives

- Protect and restore in-stream habitat through activities such as re-snagging, bank and bed stabilisation, revegetation and the reconstruction of habitat diversity
- Maintain and, where possible, restore longitudinal (upstream-downstream), lateral (stream-floodplain), and vertical (surface-groundwater) connectivity
- Manage the catchment to protect against and reduce degradation of in-stream habitat

State

Indicator IW5 Condition of in-stream habitat in major rivers and tributaries

Important aspects of in-stream habitat are substrate type and diversity, channel shape, presence of woody habitat, and connectivity. Assessment of in-stream habitat (the Physical Form Index of the ISC) measures three factors: the impact of artificial barriers to fish passage, the presence of large woody habitat and the level of bank stability. The presence of riparian vegetation is discussed separately in IW3 Riparian Vegetation.

In 2004, just 6% of in-stream habitat assessed was found to be in good condition with the majority of reach length assessed as being in moderate (69%) or poor condition (25%).

The Snowy and East Gippsland basins have the highest proportion of reach length with in-stream habitat in good condition (see Figure IW2.1). In contrast, 12 basins had no assessed reaches with in-stream habitat in good condition, and a further 11 basins had less than 10% of reach length in good condition. The basins with the greatest proportion of reach length in poor condition were the Hopkins, Thomson, Loddon and Avoca basins, with 49% or more of reach length in poor condition (see Figure IW2.1). While the northern two-thirds of the Thomson basin are forested, the lowland reaches have been all been desnagged in the past, and the surrounding land is heavily used for agriculture[111]. As a result, in-stream habitat was assessed as being in a poorer condition in this basin than may be otherwise expected.

Barriers to fish passage

Across Victoria, 49% of river reaches assessed were affected by at least one artificial barrier that completely blocks fish migration. Fish passage to almost 25% of reaches was only intermittent, while only 27% of reaches were not affected by barriers, indicating that this remains a serious issue for many Victorian streams. Artificial barriers, such as dams and weirs, have had a serious impact on the distribution and abundance of many native fish species (see Part 3.2: Water Resources)[112].

Presence of large woody habitat

Large woody habitat was in poor condition in 52% of the reaches assessed, with only 20% of total reach length in good condition and 28% in moderate condition. In basins where large woody habitat was mostly in good condition—for example, the Mallee, East Gippsland and Mitchell—this reflected the presence of areas of largely unmodified rivers where little riparian vegetation was removed in the past. Basins in mostly poor condition, such as the Millicent Coast, Barwon and Kiewa basins, contained large tracts of heavily modified waterways with poor riparian tree cover and a history of clearing.

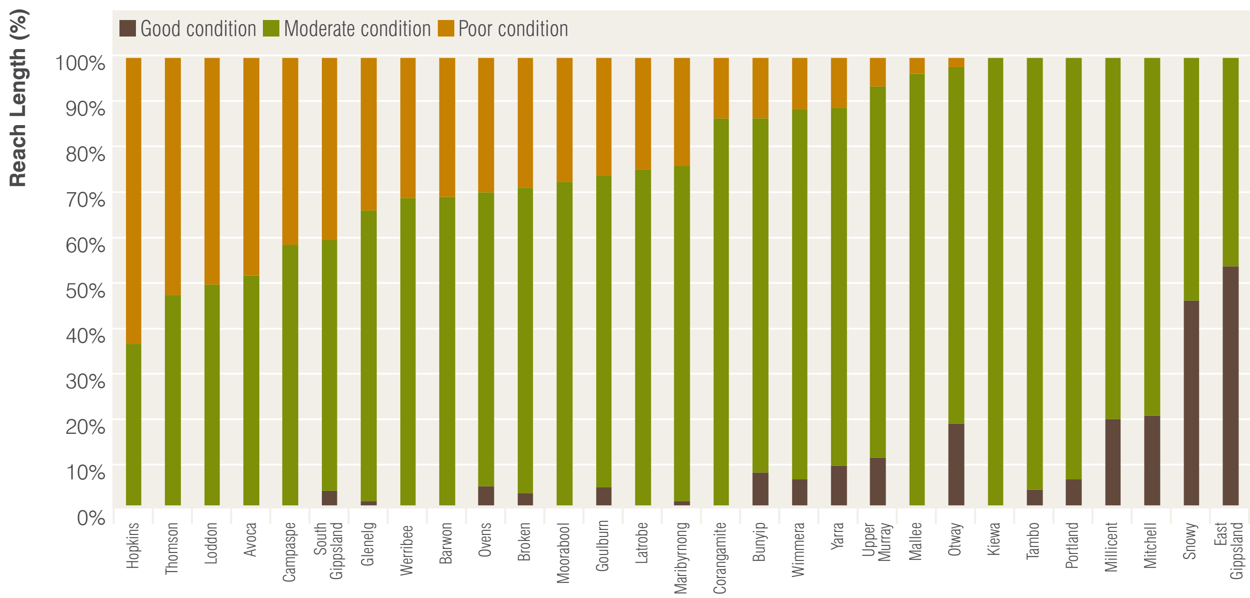
Bank stability

Bank stability in over 40% of the reaches assessed was in good condition with 49% being in moderate condition and the remainder in poor condition. Channel instability and bank erosion still pose a threat to in-stream habitat condition.

The Snowy, Bunyip and Millicent Coast basins had over 80% of all reach length assessed with bank stability in good condition. This result reflects the remoteness and the rocky nature of bed and banks, which helps to stabilise the in-stream habitat of some rivers. Riparian vegetation also stabilises riverbanks, and those reaches where minimal clearing has occurred will generally be the most stable.

Many examples of rivers and streams in Victoria have undergone catastrophic erosion. Within Melbourne, there are examples of streams (e.g. Gardiners Creek and Koonung Creek) where modifications have increased the stream's dimensions up to 100-fold[113] (see Box IW2.1). The lower sections of the Latrobe River, downstream from Yallourn Weir, have been extensively de-snagged and cleared and shortened from 165 km to 139 km by straightening the river channel[114]. A major motivation for this work was to limit flooding but extensive erosion of the river channel has resulted. The Ovens River valley has had bank stability reduced by alluvial gold mining and gravel extraction[115].

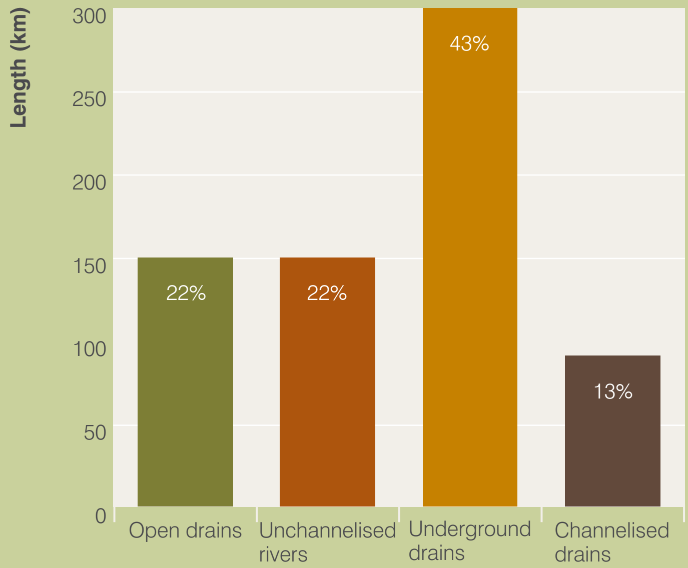
Figure IW2.1 Condition of in-stream habitat, by basin
Source: DSE (2007)



Box IW2.1 Modification to stream habitat in urban Melbourne.

Few natural streams remain in the central urban area of Melbourne. Smaller streams have been piped, and larger streams have now been channelised and eroded. Despite this, these stream systems may have high social, economic and environmental values.

Figure IW2.2 Changes to channel form in urban Melbourne
Source: Rutherfurd and Ducatel (1994), based on MMBW Drainage Record Plan (1985)



Indicator IW6 Extent of wetlands compared to pre-European settlement

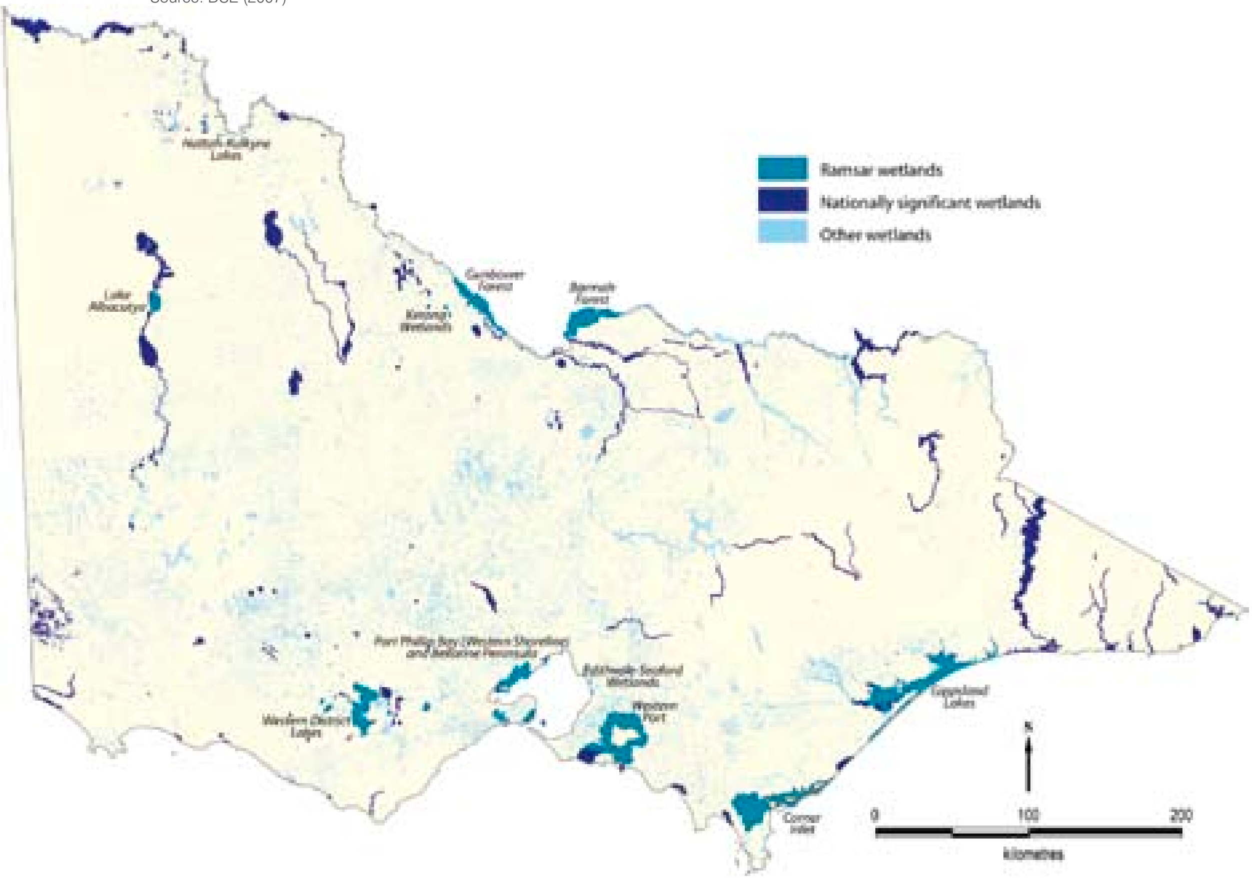
An inventory completed in 1994, which presents the most recent data available, showed that 37% of naturally occurring wetland area has been lost (see Table IW2.1 and Figure IW2.3)[116]. The extent of wetlands includes coastal marshes, for example much of Western Port, Corner Inlet and Gippsland Lakes.

Deep freshwater marshes (70% lost by area), shallow freshwater marshes (60% lost by area) and natural freshwater meadows (43% lost by area) have declined by the greatest extent. This is because their temporary and shallow nature makes these wetlands relatively easy to drain. Temporary ponds, for example, have been converted to agricultural land by ploughing and subsequent cropping.

Some of the areas most affected by wetland drainage in Victoria are the South West and the irrigation areas around Kerang and Shepparton[117]. Closer to Melbourne, drainage of the Koo-Wee-Rup swamp, which originally covered 40,000 ha, has caused ongoing damage to the ecology of the rivers and streams of the Bunyip basin, and also to Western Port (see Figure IW2.5).

Alpine mossbeds, a type of shallow freshwater wetland, were not mapped and classified in the 1994 wetlands inventory. These wetland environments are unique to Victoria's alpine and sub-alpine areas. Subsequent mapping has estimated that alpine mossbeds have reduced in area by up to 50% since European settlement. Various types of disturbance such as weed invasion, especially by willows, and trampling and grazing by livestock, threaten the condition of mossbeds. Once disturbed, recovery of alpine mossbeds is very slow. With their elevated and restricted distribution, alpine mossbeds are at risk of further contraction from climate change.

Figure IW2.3 Existing natural wetlands in Victoria
Source: DSE (2007)



In addition to natural wetlands, there are some 3,900 constructed wetlands which cover approximately 108,100 ha[118]. Some constructed wetlands have high environmental significance, such as the lagoons of the Western treatment plant at Werribee, which form part of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsular Ramsar site[119]. The multiple benefits that wetlands offer, such as filtration and nutrient cycling are being designed into drainage and effluent treatment systems. Melbourne Water Corporation has a constructed wetland program which aims to achieve a 100 t per year reduction in total nitrogen loads in Melbourne's urban stormwater by 2010[120]. Opportunities for the construction of these wetlands are increasingly constrained by the availability and costs of good sites.

Box IW 2.2: Index of Wetland Condition

Detailed information is not available on the statewide condition and trends for the remaining wetlands in Victoria. An Index of Wetland Condition (IWC) assessment technique has been developed by DSE and is currently being tested. A condition score is used, which is based on the level of departure of a wetland from a reference condition, being the condition that existed at the time of European settlement. The IWC is designed for naturally occurring inland (non-marine) wetlands. Testing of the IWC has included assessing 175 wetlands in selected catchment management areas using the provisional methodology (see Figure IW2.4).

Figure IW2.4 Provisional results of Index of Wetland Condition assessment
Source: DSE & CMAs (2007)

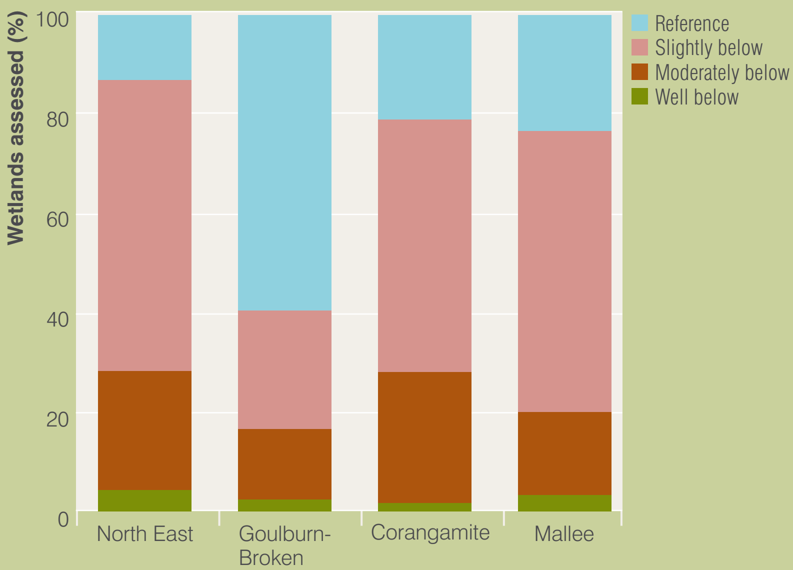
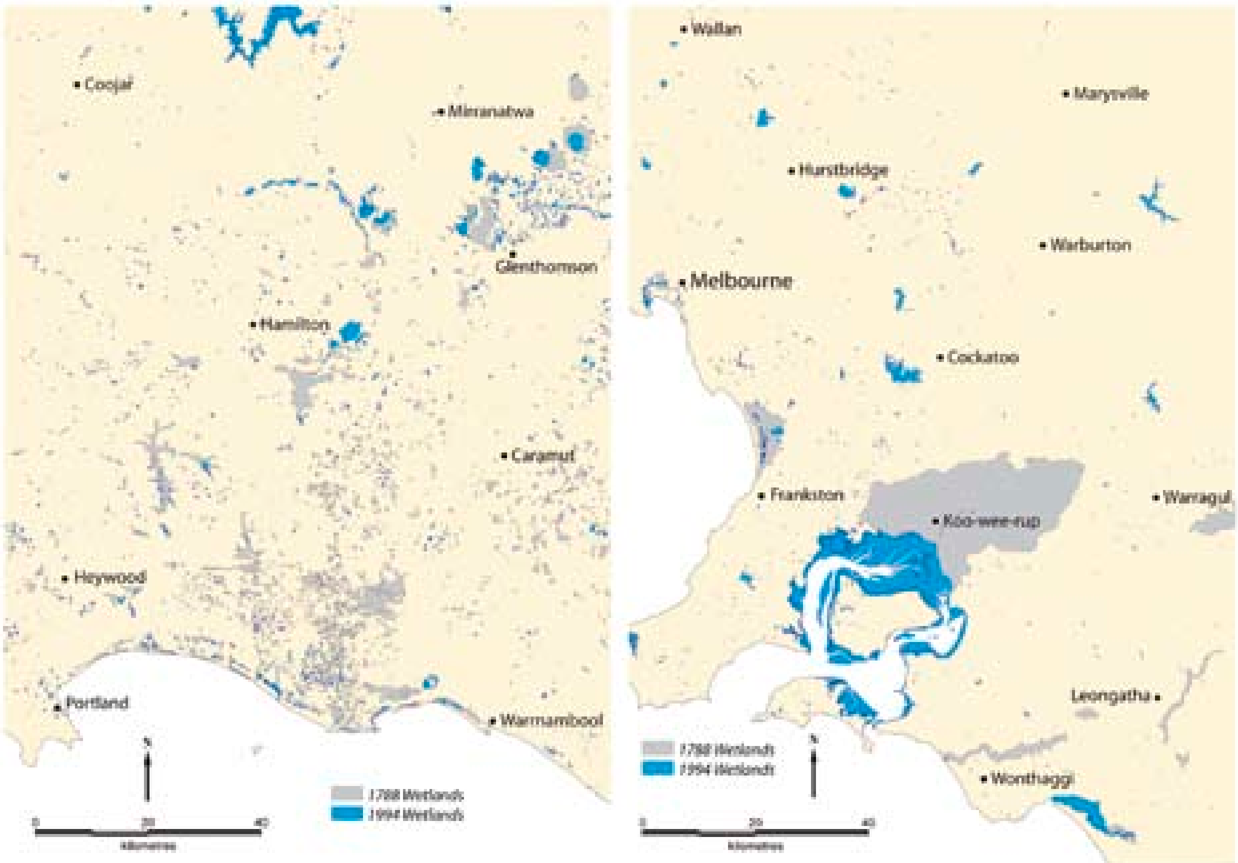


Table IW2.1 Wetland categories, pre-European extent and percentage remaining based on inventory completed in 1994
Source: DSE (2007)[121]

Category	Description	Example	Pre European Area (ha)	1994 Area Remaining (% pre-European)
Freshwater meadow	These include shallow (up to 0.3m) and temporary surface water (less than four months a year), although soils are generally waterlogged throughout winter.	Killara System, near the Glenelg River	172,700	98,439 (57%)
Shallow freshwater marsh	Wetlands that are usually dry by mid-summer and fill again with the onset of winter rains. Soils are waterlogged throughout the year and surface water up to 0.5m deep may be present for as long as eight months a year.	Black Swamp, north of Wangaratta	15,800	6,320 (40%)
Deep freshwater marsh	Wetlands that generally remain inundated to a depth of 1–2m throughout the year.	MacLeod Morass, near Bairnsdale in Gippsland	154,800	46,440 (30%)
Permanent open freshwater	Natural or artificial wetlands that are usually more than 1m deep,. Wetlands are described as permanent if they retain water for longer than 12 months; however they can have dry periods.	Third, Middle and Reedy Lakes in the Kerang Lakes area	79,100	74,354 (94%)
Semi-permanent saline	These wetlands may be inundated to a depth of 2m for as long as eight months a year. Saline wetlands are those in which salinity exceeds 3,000 mg/L throughout the year.	Oxbow Lake, in the mouth of the Glenelg River	61,300	57,009 (93%)
Permanent saline	These wetlands include coastal wetlands and part of the intertidal zone. Saline wetlands are those in which salinity exceeds 3,000 mg/L throughout the year.	Lake Corangamite, near Geelong	142,200	139,356 (98%)

Photo: Jane Tovey

Figure IW2.5 Estimated extent of wetlands at the time of European settlement, and observed extent in 1994, in western Victoria (left) and Westernport/west Gippsland (right)
Source: DSE (2008)



Recommendation

IW2.1 Improve protection for wetlands on private land

Pressures

Pressures on in-stream and wetland habitat reported elsewhere in this Report include uncontrolled stock access to riparian zones (IW3 Riparian vegetation, Pressures); River regulation (IW1 Flow regimes, Implications); water quality (IW4 Water quality, Implications) and Climate Change (IW6 Impact of climate change on Inland Waters, Implications).

Channelisation

Channelisation was historically used to reduce the duration and frequency of flooding in floodplain areas, and involved one or more of the following:

- De-snagging, or removing the wood naturally present in streams (see below)
- Straightening, by cutting through river bends to steepen the channel. The most extreme example is the Latrobe River in Gippsland, where the swampy floodplain was saturated for up to half of the year until drains were installed
- Artificial levees. Many lowland streams in Victoria have artificial levees to reduce the frequency of flooding on the floodplain (see Figure IW2.6)

As well as directly modifying in-stream habitat, these works often caused extensive erosion (for more information on erosion see below). The locations of historical channelisation works, as well as works to reduce erosion, are shown in Figure IW2.7. Urbanisation has resulted in extensive modifications to in-stream habitat (see Box IW2.1).

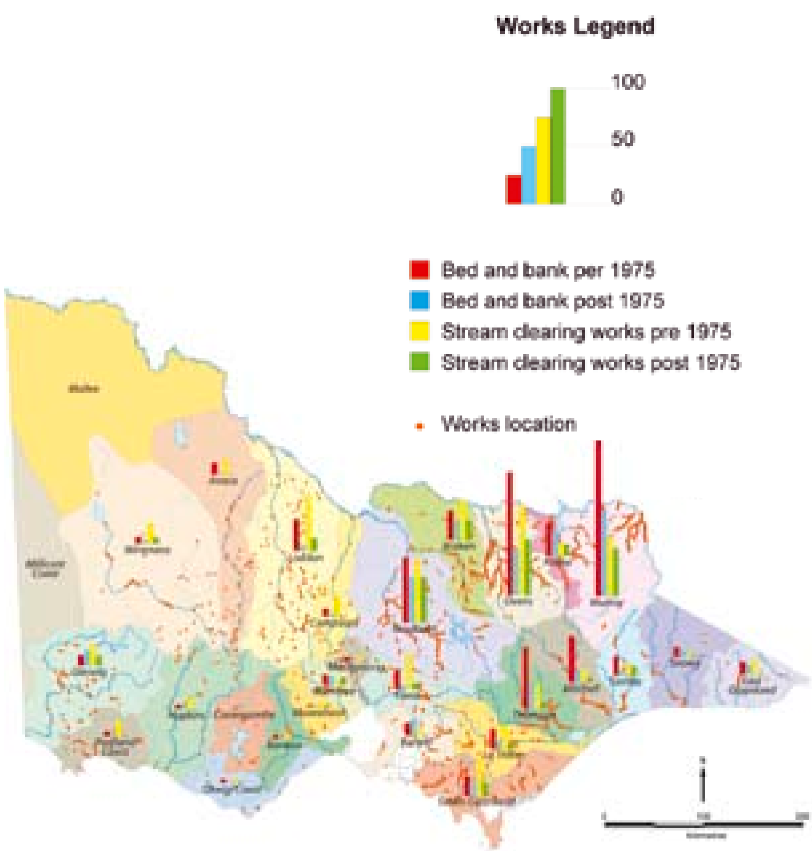
Concerted efforts to improve the management of river channels and floodplain management, and restore damage from past practices, have started to control these pressures on habitat. However, the legacy of these practices is still evident in many streams.

Wetland drainage

Wetlands have been drained to reduce waterlogging in agricultural land. Much of the alluvial area of the State (the valley floors) was originally wetland. These areas were reclaimed by digging drains, which often eroded into gullies122. Temporary ponds, which are important habitats, have been lost through ploughing and subsequent cropping.

Figure IW2.6 Location of levee banks.
Source: Department of Sustainability and Environment

Figure IW2.7 Historic stream management works
Source. Department of Water Resources (1989), Robertson, S.V. (2007)[123]



Removal of woody habitat

Removal of woody habitat from in-stream areas, often referred to as de-snagging, was once considered an essential component of good river management (see Figure IW2.7). De-snagging was believed to improve streamflow, reduce the severity and extent of flooding, improve navigation, make recreation safer and assist with substrate removal (sand, gravel and gold extraction)[124]. As recently as 2003, it was reported that removal of snags, or realigning them to reduce perceived problems with erosion or changes in stream alignment, continued in many rivers and streams across Victoria[125]. There is now a general policy that wood should not be removed from rivers.

Removal of trees, shrubs and groundcover from riparian areas has significantly reduced the amount of large woody habitat available for aquatic biota, particularly in lowland areas where clearing is more likely to have occurred.

Recommendation

IW2.2 Increase protection of floodplain habitat, including wetlands, wood on the floodplain and in floodplain channels.

Erosion and sedimentation

Erosion is a natural process that contributes to turbidity, phosphorus and nitrogen concentrations in surface waters. Within catchments mostly undisturbed by human activity, the level of sediment input is relatively low but can naturally vary with geology, soil type, rainfall and landform. Flushes of high sediment loads can occur naturally from the consequences of extreme weather and climate variability (e.g. bushfire, floods, landslips and vegetation loss during drought). See Part 4.2: Land and Biodiversity, Erosion for more information.

Sediment inputs into aquatic systems have increased considerably since European settlement of Victoria[126], largely as a result of land clearing and removal of riparian vegetation. This has been particularly detrimental as plants bind the soil and retain coarse sediments. The increased intensity of flow events in urban catchments has also dramatically increased rates of erosion (see IW1 Flow regimes, Pressures; Box IW1.2).

The significance of gully and riverbank erosion on sediment loads is supported by computer modelling of sediment transport in the Goulburn catchment. Gully erosion and riverbank erosion were identified as the major sources of sediment in the catchment, contributing in excess of 90% of the total sediment load[127]. By comparison, sheet-wash erosion was less than 10% of the total catchment sediment load.

As a result of extensive erosion, some rivers now have large sand 'slugs' moving slowly downstream, reducing environmental values for aquatic fauna. For example, a large sand slug in the Snowy River near Orbost threatens local populations of Australian bass *(Macquaria novemaculeata)*.

Large scale fires in 2003-04 and 2006-07 dramatically increased vulnerability to erosion, leading to in-stream habitat loss, poor water quality and the deposition of large amounts of soil and other materials in stream beds and lakes downstream of the burnt areas.

Barriers preventing the passage of aquatic biota

Infrastructure for management of water resources severs the connectivity of inland waters both longitudinally (upstream–downstream) and laterally (stream–floodplain). Construction of road crossings and weirs has significantly increased the number of barriers to the passage of biota. Other barriers such as levees which reduce the lateral movement of water have effectively isolated rivers from their floodplains, blocking regeneration within these ecosystems and removing habitat, nutrient and organic matter crucial for stream function.

In 1999, the State Fishway Program conducted an inventory of potential barriers to fish movement across the State, and identified up to 2,438 potential barriers, with farm dams and weirs making up the largest proportion[128] (see Part 3.2: Water Resources, Pressures on the Environment). The program also identified a significant number of streamflow monitoring sites, which made up about 30% of the total barriers. The assessment did not record culverts and road crossings but these can also form an effective barrier to fish movement[129].

Recommendation

IW2.3 Remove all redundant in-stream barriers or provide fish passage at all artificial barriers.

Alluvial gold mining

Alluvial gold mining occurred throughout Victoria from 1852 until the late 1980s. Even in the 1980s, extensive lengths of the state's stream network were available for eductor dredging (see Figure IW2.8). Eductor dredges pump material from the stream bed through a sluice box, which captures gold and discharges the residue back to the stream[130]. Combined with gravel extraction, these practices have mobilised vast quantities of sediment, and greatly reduced stream bed and bank stability[131].

Implications

Removal of woody habitat reduces available habitat for fish and other aquatic and terrestrial organisms, and has a significant impact on channel morphology, creating uniform drainage channels, with fewer channel features such as scour holes and bars[132].

Implications include local extinctions and degradation of downstream habitat. In lowland streams with silty or sandy stream beds, woody habitat may form the major stable habitat. Removing these structures affects entire food chains. Increasing uniformity of the river channel through loss of woody habitat or erosion reduces the availability of refugia from high flows during floods, reducing the capacity of biota to recover from these events[133].

Loss of connectivity threatens biodiversity and ecosystem resilience. A significant impact is the direct exclusion of migratory fish (e.g. Murray cod and golden perch) from their spawning grounds in estuaries or headwaters[134]. The lack of connectivity in these rivers also reduces the prospect of re-colonisation when conditions improve.

Macro-invertebrate populations are also affected by the lack of longitudinal connectivity, with about 40% of expected families missing from areas immediately below dams in Victoria[135]. This is attributed to loss of re-colonisation opportunities upstream [136].

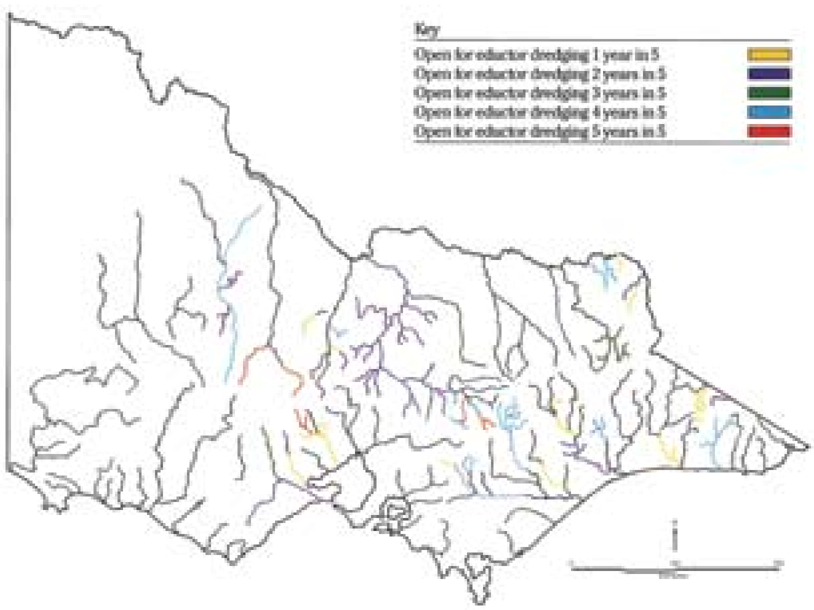
Other implications of loss of connectivity include reduction in diversity and abundance of accessible habitat, fish kills, increased local predation by birds or other fish and reduction in genetic diversity[137].

Ecosystem services provided by in-stream habitat are economically important. Recreational inland fisheries benefit from in-stream habitat in good condition. Erosion of banks can intrude on productive land. Public and private assets such as roads and bridges may also be threatened.

The economic value of unmodified wetlands is often greater than that of wetlands which have been converted for other purposes[138]. For example, the loss of wetlands can reduce the capacity of the land to mitigate floodwaters or stormwater, because wetlands act as water storage points in the landscape and can reduce the speed at which water moves across the land.

Figure IW2.8 Areas available for eductor dredging for gold, 1982 – 1987

Source. Department of Water Resources (1989)



Management responses

Management of in-stream habitat is guided by the Victorian River Health Strategy, and delivered through the Victorian River Health Program (see Introduction). On private land, community organisations such as Landcare have been instrumental in addressing issues such as erosion (see Part 4.2: Land and Biodiversity).

Response Name
Individual projects performed as part of regional river health strategies

Responsible Authority
Department of Sustainability and Environment; catchment management authorities and Melbourne Water

Response type
On-ground works

The Victorian River Health Strategy outlines statewide targets for the protection of in-stream habitat (see Table IW2.2). Since 2002, catchment management authorities and Melbourne Water have worked towards these targets by implementing individual projects guided by regional river health strategies. These targets appear set to be achieved, providing adequate levels of funding are maintained. The extent of degradation of in-stream habitat allows scope for ambitious 'stretch' targets to be set in the future.

Recommendation

IW2.4 More ambitious targets for the rehabilitation of in-stream habitat beyond 2011 should be included in the Victorian River Health Program, given the low proportion of reaches in good condition.

Response Name
Draft Index of Wetland Condition

Responsible Authority
Department of Sustainability and Environment;

Response type
Monitoring tool

The Draft Index of Wetland Condition (IWC) has been under trial since November 2005 (see Box IW2.2). It is currently being finalised by DSE. Given the lack of information on the condition of wetlands across the State, the IWC should be implemented as soon as possible.

Table IW2.2 Victorian River Health Strategy Targets relating to in-stream habitat
Source: DSE (2005)[139]

Target	Achievement
By 2005, an increase in length of river accessible to native fish by an additional 2,000 km	Between 2003 and 2005, fish passage was provided past 33 barriers, allowing access to an additional 2,100 km of river[140]
By 2011, 600 km of rivers where in-stream habitat has been reinstated	Between 2002 and 2005, catchment management authorities and Melbourne Water have re-established 323 km of in-stream habitat[141]
By 2011, 1,000 high-value public infrastructure assets provided with appropriate levels of protection	In progress
An improvement in the status of designated freshwater dependent focal species by 2011	In progress

Response Name
Victoria's Native Vegetation Management – A Framework for Action

Responsible Authority
Department of Sustainability and Environment; and catchment management authorities

Response type
Strategy/policy

The native vegetation framework is the main tool for preventing further loss of vegetation and habitat (see Part 4.2: Land and Biodiversity). To protect wetland habitat on privately owned land, clearing regulations are complemented by other measures, including education programs delivered by catchment management authorities.

The absence of a statewide wetland inventory since 1994 has made it difficult to ascertain recent changes to the extent of wetlands and the impact of management responses such as the native vegetation framework. The specific reporting of wetland vegetation should be included as part of the ongoing development of accounting processes for native vegetation. Individual catchment management authorities are in the process of mapping the extent of wetlands. The improved management of riparian zones is a crucial factor in the protection of wetland vegetation and offers great opportunities for maintaining and improving the values of wetlands and inland waters (see IW3 Riparian vegetation, Implications).

Recommendation

IW2.5 The reporting of wetland vegetation should be included as part of the ongoing development of accounting processes for native vegetation (Net Gain reporting).

Evaluation of responses to in-stream and wetland habitat

The Victorian River Health Program Report Card 2005 reports satisfactory progress towards the targets to reinstate in-stream habitat and protect high-value public assets[142]. Assessing improvement in the status of designated freshwater-dependent focal species, such as native fish populations, requires consistent statewide monitoring, and this is currently being implemented throughout Victoria (see IW5 Aquatic fauna).

River channels are now managed with much greater sensitivity to, and understanding of, the ecological significance of its various components and processes. On ground works are being delivered throughout the State using current best practice. To enable the systematic restoration of in-stream habitat, the Victorian River Health Program would benefit from long-term funding, which currently fluctuates from year to year. In many cases, restoration works involve putting back what was taken away many years ago. The ongoing investment and effort required show the benefits of avoiding damage in the first place.

Inland wetlands have been significantly reduced in extent and, in addition to protection from gross clearing or drainage, they need to be protected from incremental loss and degradation in quality. It is therefore important that proactive management of wetlands is acknowledged as an integral part of habitat management.

For further information

Modification of channels; history of stream management works: Department of Water Resources (1989) An Environmental Handbook

Wetlands information:
http://www.dse.vic.gov.au DSE/nrence.nsf/childdocs/-8946409900BAC6344A256B260015D4AF-BC30FFF2D27FA86DCA25729E000419CD?open

IW3 Riparian Vegetation

Key findings

- Riparian vegetation in good condition supports the resilience of both aquatic and terrestrial ecosystems, allows recovery from disturbance and maintains biodiversity.
- Riparian land is valued for many human uses such as agriculture and recreation, but as a result riparian vegetation has been degraded.
- Uncontrolled stock access to riparian zones continues to be the major pressure on riparian vegetation statewide.
- In 2004, 14% of reach length assessed across Victoria was found to have riparian vegetation in good condition. Nearly half the reaches assessed had poor connectivity of vegetation. Groundcover weeds were widespread in riparian zones, but while shrub and tree weeds were less common, their impact on ecology was greater.
- About 30,000 km of Crown water frontages along rivers in Victoria, and a sizeable proportion are licensed to abutting owners, mainly for grazing. To date, the conservation intent of policy for these frontages has not translated to on-ground conservation outcomes.
- Protection and restoration of riparian vegetation has been promoted through a number of means; including large scale weed-control programs, riparian management agreements, and financial incentive programs.

Description

From an ecological perspective, riparian land is any land that adjoins, regularly influences, or is influenced by a body of water. It includes the land immediately alongside rivers, areas surrounding lakes, and wetlands and floodplains that interact with rivers during floods. The widths of riparian zones vary, and do not correlate with the width or size of the stream[143]. In small, upland streams, the riparian zone can be greater than 100 m in width, and may narrow further downstream, while in floodplain reaches the zone may be much wider[144].

Riparian zones are important as they support the ecological integrity of both aquatic and terrestrial ecosystems, and provide essential ecosystem services[145]. Riparian zones harbour distinctive species pools, so protecting riparian vegetation within terrestrial reserves is an effective means of increasing the number of species protected on a regional basis[146].

Large fallen branches or trunks from riparian vegetation form key woody habitat areas for many fish and invertebrates, and influence the shape of the river substrate (see IW2 In-stream and Wetland Habitat). Riparian vegetation also maintains the condition of aquatic ecosystems by providing bank stability and thereby minimising erosion, filtering sediment and processing nutrients from the catchment (particularly nitrogen), and providing shade which moderates water temperature. Riparian zones therefore help to buffer aquatic ecosystems from modified land use and disturbances within the catchment[147].

The relationship between aquatic ecosystems and riparian zones is reciprocal, as regular flooding is required for recruitment of most riparian species in floodplain ecosystems. Similarly, organic matter from riparian vegetation is a major source of food for in-stream biota, but riparian zones may also benefit from the nutrients and energy that aquatic systems provide[148].

Riparian zones provide a number of other benefits to terrestrial ecosystems. During droughts the proximity of riparian vegetation to water also means it may be the only place where plants have new growth, flowers or are producing seed. In catchments that are largely cleared, riparian vegetation is often the only native vegetation remaining[149]. Degradation of native riparian vegetation is listed as a potentially threatening process under the *Flora and Fauna Guarantee Act 1988*[150].

Riparian zones have always been useful to humans; easy access to water and fertile soil make them inherently useful to agriculture, but they are also important transport corridors, have high recreational values and cultural and spiritual significance. Administrative definitions of riparian land differ from the ecological context, which may change with time. There are currently about 30,000 km of Crown water frontages along rivers in Victoria, which are often of 20 m width, although this varies with location[151]. About 22,000 km is of these frontages are abutted by freehold land, and a sizeable proportion of this length is licensed to adjacent owners, mainly for grazing[152]. The remaining 8000 km of riparian land is in state forest or national parks. A high proportion of lake fringes are also in public ownership; this was estimated as being 80–85% of lake fringes in 1988[153].

Extensive clearing of many catchments and stock access to streams has resulted in the condition of riparian vegetation being moderate to poor across much of the State. Wetland drainage has also caused widespread loss of wetland vegetation. Declining vegetation quality is now the key driver of vegetation loss, rather than broad-scale clearing (See Part 4:2 Land and Biodiversity). Weeds also degrade the quality of riparian vegetation by strangling native plants, out-competing native species and altering ground conditions, preventing the regeneration of native species and reducing biodiversity. Important riparian weeds include willow (Salix spp.), blackberry (Rubus fruticosis aggregate) and phalaris (*Phalaris aquatica)*[154]. Willows were historically planted for aesthetic reasons and, especially from the 1950s,[155] for the control of bank erosion. As recently as the late 1980s, most drainage trusts and river management boards still used willows in erosion control works[156]. Both willow and blackberry are now recognised as weeds of national significance[157].

This section reports on the riparian zones of rivers and streams. The importance of groundwater to baseflow to many rivers in Victoria means groundwater is likely to be similarly important to riparian vegetation. Vegetation is also an essential component of wetlands and its condition will in future be reported through the Index of Wetland Condition.

Objective

Protect and restore continuous corridors of native riparian vegetation for rivers and wetlands, to protect and improve the health of aquatic and terrestrial ecosystems.

State

Indicator IW7 Condition of riparian vegetation of major rivers and tributaries

In 2004, riparian vegetation assessed by the Index of Stream Condition (ISC) was in good condition along 14% of reach length assessed, with 54% in moderate condition and 32% in poor condition[158].

Six basins had 30% or greater of reach length with riparian vegetation in good condition, with the East Gippsland, Snowy, Thomson, and Otway Coast basins being in best condition (see Figure IW3.1). In contrast, the Avoca, Bunyip, Corangamite, Portland Coast and Millicent Coast basins had no reaches with riparian vegetation in good condition, and a further 17 basins had less than 15% of reach length in good condition. In five basins (Corangamite, Portland, Millicent, Hopkins and Barwon), more than 60% of riparian vegetation was in poor condition. The vegetation in poorest condition was generally found in the lowland areas, where extensive clearing has occurred[159]. The 2003 bushfires damaged riparian vegetation in the Upper Murray basin, affecting the condition assessment[160].

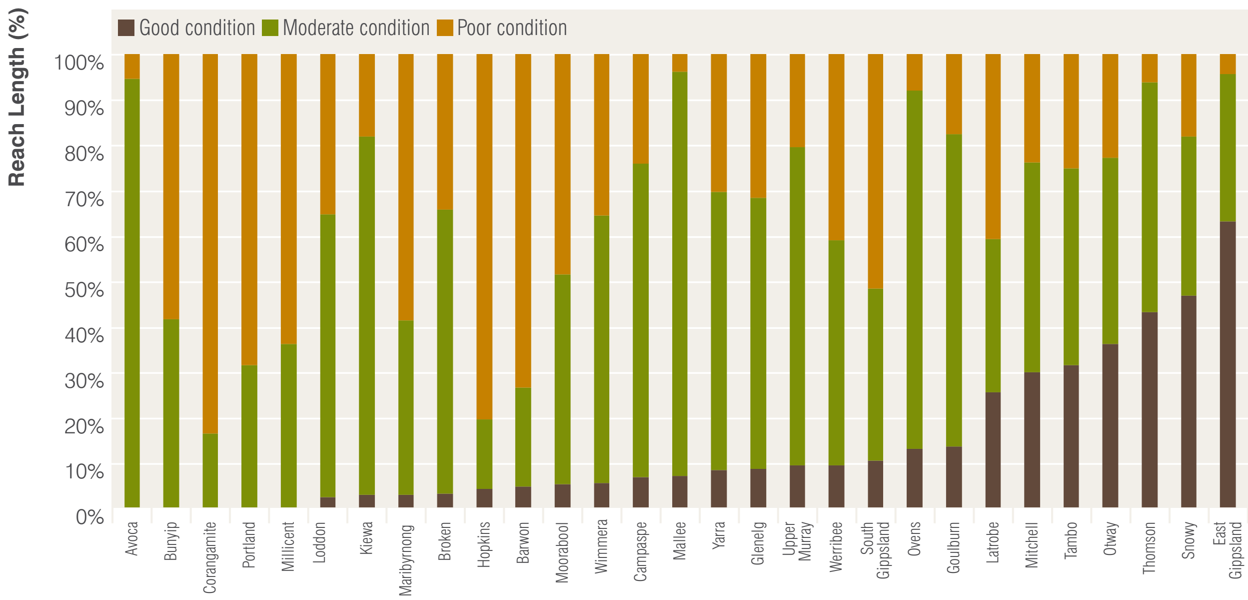
Important aspects of riparian vegetation captured in the ISC are width and connectivity, and the quality, quantity and structure of the vegetation[161]. Included in the assessment of riparian vegetation are estimates of width and longitudinal connectivity, presence of large trees and understorey species, presence of organic litter, weeds and fallen timber, recruitment, and tree canopy[162]. A rating is produced by comparing the measured condition to the ecological vegetation class (EVC) benchmark. 'Good condition' means relatively intact and healthy native vegetation, whereas 'poor condition' signifies little native vegetation remaining.

Longitudinal connectivity

Longitudinal connectivity provides an important guide to the condition of riparian vegetation. Across Victoria, just over one-third (36%) of streamside zones were considered to have riparian vegetation with good longitudinal connectivity. The forested reaches of the upper catchments generally had better longitudinal connectivity than in lowland areas. The basins with best longitudinal connectivity of riparian vegetation were the East Gippsland, Snowy, Tambo, Mitchell and Thomson basins, with the Yarra and Hopkins basins also ranked highly.

Nearly half of all reach length assessed (46%) had riparian vegetation with poor longitudinal connectivity, and 20% was considered to be in moderate condition. The poorest condition reaches were found mostly in basins to the west of the State, particularly the Millicent Coast basin, where land clearing left all reaches with poor connectivity.

Figure IW3.1 Condition of riparian vegetation, by basin
Source: DSE (2007)[163]



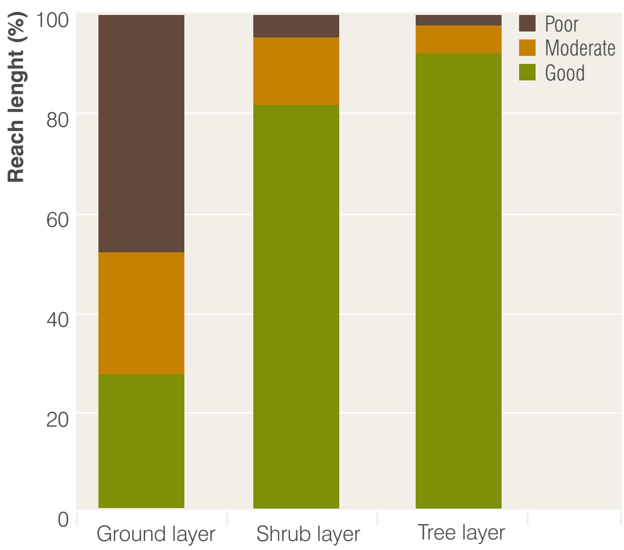
Weeds

Presence of weeds is also an important indicator of the health of riparian vegetation. In 2004, weed cover was assessed in the ground, shrub, and tree layers. Across Victoria, ground layer[ii] vegetation has been more degraded by weeds, such as phalaris (*Phalaris aquatica*), rye grass (*Lolium spp.*) and thistles, than shrub[iii] and tree layer[iv] vegetation (see Figure IW3.2). Statewide, 27% of reaches had a ground layer in good condition (i.e. few weeds), whereas 82% and 92% of reaches were in good condition in terms of shrub layer and tree weeds respectively. However, tree and shrub weeds such as willow and blackberry have a more detrimental impact than groundcover weeds.

Only six basins had more than 50% of reaches assessed with ground-layer riparian vegetation in good condition in terms of weeds, whereas 28 basins had at least 50% of shrub-layer vegetation in good condition, and all basins had at least 50% of tree-layer vegetation in good condition.

The basins with fewest ground-layer weeds were the arid Mallee basin and the forested Mitchell and East Gippsland basins, whereas cleared catchments tended to have more ground-layer weeds. Basins with shrub and tree layers that scored moderate or poor for weeds tended to be central or eastern basins such as the Bunyip, Ovens, Upper Murray and Kiewa, with infestations of blackberry or willow.

Figure IW3.2 Assessment of riparian vegetation in respect of weeds across Victoria, by reach
Source DSE (2008)[164]



The pressures that willow and the aquatic weed arrowhead *(Sagitiaria graminea var. platyphylla)* place on inland waters are described in detail below (see Indicator IW8 and Box IW3.1, respectively).

Pressures

The main pressures on riparian and wetland vegetation are clearing, altered flow regimes, stock access to riparian land, invasive species, wetland drainage, pollution and climate change. Pressures on riparian vegetation reported in other sections are: altered flow regimes (IW1 Flow regimes, Implications); modifications to in-stream habitat (IW2 In-stream and wetland habitat, Implications); water quality (IW4 Water Quality, Implications) and climate change (IW6 Implications of climate change for inland waters, Implications).

Vegetation clearing

Many Victorian settlements were established near inland waters to gain easy access to water and because of the fertile soils on floodplains. This has resulted in extensive removal of riparian vegetation in some areas, such as the agricultural areas of the lower Werribee and Goulburn basins. Damage to riparian vegetation is still occurring in areas associated with residential development and the appeal of water views.

Recreation activities along rivers and in wetlands, such as high-speed boating, have contributed to bank erosion and the loss of habitat for riparian vegetation. Recreational activities have also led to the removal of riparian vegetation to enable access for swimming, boating and fishing.

Stock access to riparian land

Domestic stock, particularly cattle, favour riparian frontages and if uncontrolled prefer to spend much of their time along streambanks and in the water. The pressure that uncontrolled domestic stock grazing places on riparian zones has been well documented, but it persists on both public and private land throughout Victoria, including the Barmah and Gunbower forests[165]. Uncontrolled stock access to riparian zones results in erosion and loss of riparian vegetation. Trampling and grazing of river and wetland banks destabilises banks, as bare soil on streambanks and compacted walking tracks are prone to erosion[166]. Other pressures caused by uncontrolled stock access to streams are the introduction and spread of exotic plants, inhibition of native vegetation, soil compaction, lack of regeneration of native vegetation, loss of the buffering effect of riparian vegetation[167] and the addition of nutrients through dung and urine[168].

Investigations by catchment management authorities indicate that fenced stream frontages were in significantly better condition than those left unfenced, reflecting the impact of stock access[169]. Cattle grazing on the floodplain, which reduces groundcover and increases seed predation by ants[170] has been described as one of the causes of low recruitment of River Red Gums. Restoration work has shown that, even in drought, once riparian areas are fenced, River Red Gum recruitment is possible.

ii In this context, refers to non-woody vegetation
iii Woody shrubs below 5 m
iv Woody vegetation above 5 m in height

Indicator IW8 Extent of willows across Victoria

Watercourses dominated by willows exhibit reductions in numbers and diversity of invertebrates, fish and native plants. Some of the reasons for this include:

- Willows have lower habitat value than native riparian vegetation. Fewer insects results in fewer insectivorous birds and less food for fish
- Willows dry out streams and wetlands by using more water than the native vegetation they replace
- Stands of willow exclude native vegetation below the canopy due to shade and dense roots
- Willows drop all their leaves in autumn, creating a huge quantity of organic material, followed by several months of very little leaf litter. The biota of Victoria's inland waters are adapted to continuous leaf fall
- Roots and foliage trap sediment, build up the ground and divert flows into banks. Eventually watercourses may change course to flow around willows[171].

Most catchments in the higher-rainfall areas have well-established populations of willow. Willows are commonly found in the middle and lower reaches of rivers, particularly those subjected to clearing and channelisation works. Extensive areas of willow in the upper catchment of the Snowy River have recently been removed. The extent and distribution of willow in Victoria has not been fully mapped.

Willows are placing pressure on a number of nationally significant wetland communities in Victoria, including:

- Sedge-rich mountain swamp gum *(Eucalyptus aquatica)* community at Yellingbo, which is the habitat of the nationally endangered helmeted honeyeater *(Lichenostomus melanops cassidix)*
- Alpine bogs and fens of the Bogong High Plains
- Red gum floodplain vegetation on the lower Ovens River[172].

An example of another invasive aquatic weed, Arrowhead, is shown in Box IW3.1.

Box IW3.1 The spread of Arrowhead *(Sagittaria graminea)* in northern Victoria

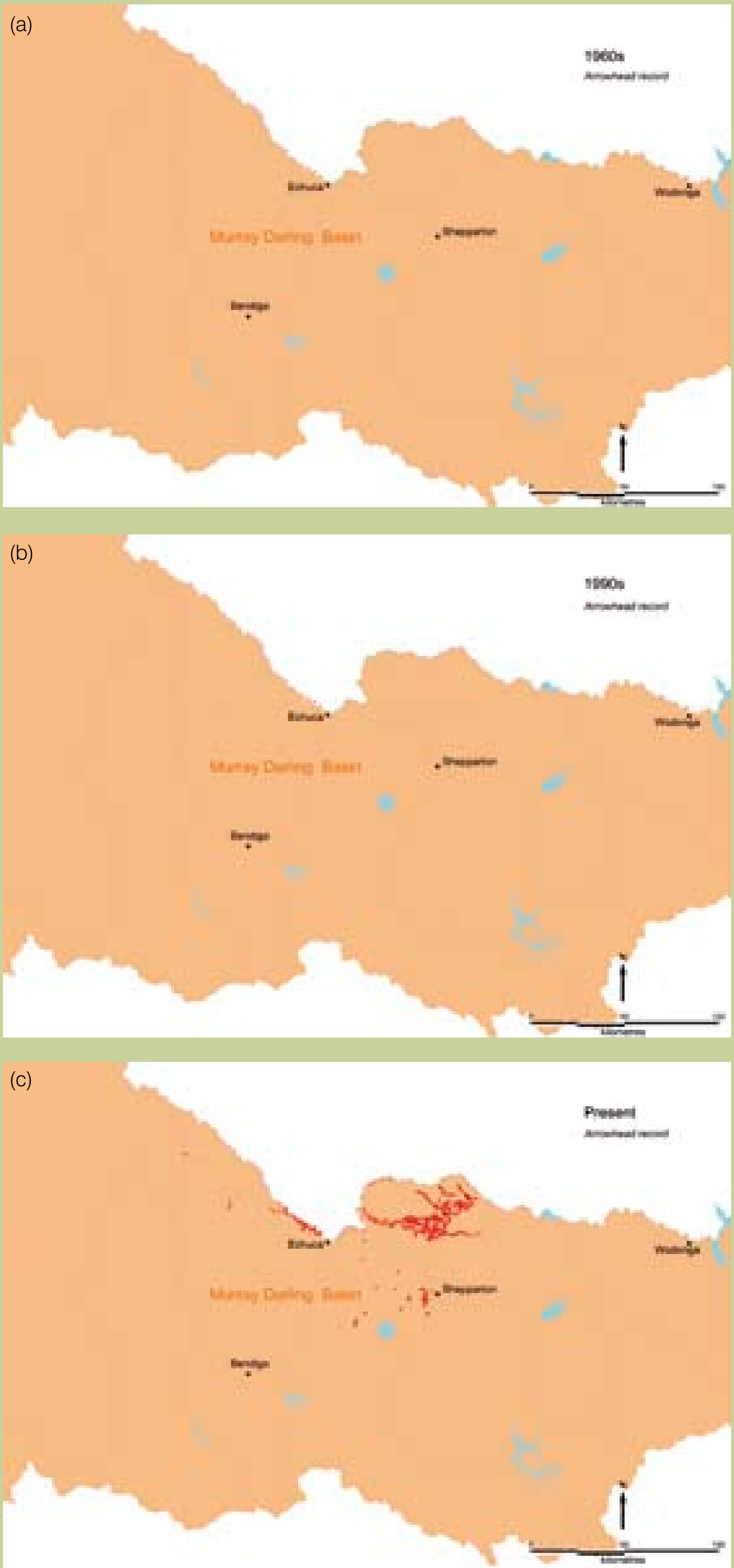
Arrowhead (*Sagittaria graminea*) is an aquatic weed and a serious problem in the waterways of Northern Victoria and southern New South Wales. In shallow waterways and wetlands Arrowhead is an aggressive competitor and dominates the emergent aquatic plant ecosystems. Its vigorous and choking habit restricts the flow of water and threatens native aquatic flora and fauna. The degree of infestation can substantially alter the flow regime of many tributary streams, dramatically threatening biodiversity and stream health of creeks that are already stressed. It is also a serious problem for water authorities and irrigators in these areas with channels and drains becoming more infested each year with this very aggressive and invasive weed[173].

Used as an ornamental in the aquarium trade, Arrowhead was identified in the wild in Victoria in 1962 in the Nine Mile Creek at Wunghnu, north of Shepparton (Figure LB3.8a). By the 1990s it had spread over much of the waterways around the Goulburn River and along the Murray River between Echuca and Tocumwal (Figure LB3.8b). By 2006/07 it had spread to many irrigation channels in the Goulburn-Broken system and had spread downstream of Echuca (Figure LB3.8c).

Arrowhead is a robust organism that is difficult to control. If no management actions were undertaken, it is predicted that all River Murray reaches (Albury to beyond Mildura) will be occupied by Arrowhead in less than 10 years. Modelling suggests that with a control program of spraying three times a year in upstream reaches, sites in reaches below Torrumbarry will not become occupied, and over time the number of sites occupied will decline, indicating the effectiveness of the management strategy[174]. There is potential for a large outbreak in Barmah Forest (and Gunbower Forest). Such an outbreak could be controlled but at high cost[175].

Although declared a noxious weed in other states, the species can be sold and grown in Victoria[176]. One of the aims of the Arrowhead Strategic Plan is that by December 2009 there will be no net expansion of Arrowhead (measured in terms of total occurrences and total area)[177].

Figure IW3.3 (from top to bottom) Distribution of Arrowhead in the Victorian Murray-Darling Basin in the 1960's, 1990's and at present, respectively
Source: Goulburn-Murray Water



Implications

Riparian vegetation in good condition supports the resilience of aquatic and terrestrial ecosystems, allowing recovery from disturbance and maintaining biodiversity. Riparian vegetation provides habitat for platypus, water rats, frogs and waterbirds, as well as the terrestrial adult stages of macro-invertebrates. In some ecosystems, riparian vegetation forms a large proportion of remnant vegetation, so it is locally significant.

An implication of degraded riparian vegetation is that surrounding aquatic and terrestrial ecosystems become vulnerable to disturbances. Intact riparian vegetation is a source of wood for in-stream habitat. The exchange of nutrients and energy from the riparian zone is central to the functioning of river-floodplain systems[178]. Without the ecosystem services that riparian vegetation provides, these ecosystems are less resilent. For example, removal of riparian vegetation can result in severe erosion that fundamentally changes the stream ecosystem and aids invasion by weeds such as willow, threatening the survival of some native species.

The resilience of biodiversity depends on the availability of refugia from disturbances such as flood and drought[179]. Removal of riparian vegetation can reduce the efficacy of drought and flood refugia for in-stream and terrestrial flora and fauna. The availability of refugia is expected to become more important under climate change, as there will be less water available and the frequency of extreme events is likely to increase.

Loss of connectivity or fragmentation of riparian vegetation reduces the capacity of species to disperse through the landscape, and this may be of fundamental importance in maintaining viable populations[180].

Loss of connectivity also reduces the capacity of riparian vegetation to filter catchment inputs. A reduction in the extent and quality of riparian vegetation has implications for the amount of soil and nutrients that moves from cultivated fields into waterways[181]. Riparian soils and in-stream sediments can reduce nitrogen loads to downstream environments through microbial denitrification.

Degraded riparian vegetation reduces the amount of habitat available for insect-eating birds and insect parasites that protect agricultural land and crops from damage. Even losing a small number of birds can allow significantly more below-ground pasture grubs to survive and become adults[182]. Further, a well-managed riparian frontage can add significant market value to a rural property.

Management responses

The importance of riparian land, pressures on its condition and management responses have been stated in a number of studies over the past two decades. Key documents include the *Land Conservation Council's Rivers and Streams Special Investigation (1991)*; The *Victorian Biodiversity Strategy (1997)*; The *Victorian River Health Strategy (2002)* and the Victorian Environment Assessment Council's *River Red Gum Forests Investigation (2007)*.

Improved management of riparian land is complicated by mismatches between administrative and ecological definitions of riparian land, varying land tenure and natural changes in the paths of rivers over time[183]. Riparian Crown Land is dealt with by two Acts: the *Land Act 1958*, and the *Crown Land (Reserves) Act 1978*. The Victorian River Health Strategy provides a framework for managing riparian land in this context, and the Victorian River Health Program (see IW0 Introduction) coordinates programs to improve the condition of riparian vegetation.

Riparian vegetation is also protected under Victoria's Native Vegetation Management – A Framework for Action. Management responses to loss and modification of native vegetation are discussed in more detail in Part 4.2: Land and Biodiversity.

Response Name
Individual projects performed as part of regional river health strategies

Responsible Authority
Department of Sustainability and Environment; catchment management authorities

Response type
various

The Victorian River Health Strategy outlines statewide targets for the improvement of riparian vegetation. Through the implementation of regional river health strategies between 2002 and 2005, catchment management authorities and Melbourne Water have made substantial progress towards these goals (see Table IW3.2).

Recommendation

IW3.1 More ambitious targets for the rehabilitation of riparian vegetation beyond 2011 should be considered for the Victorian River Health Program.

Table IW3.2 Victorian River Health Strategy Targets for Riparian Vegetation
Source: Victorian Government (2006) [184]

Target	Achievement
By 2011, 4,800 km of rivers with an improvement of one rating (using the Index of Stream Condition) in the measurement of riparian condition	Over 2,000 km of existing riparian vegetation fenced, more than 750,000 riparian plants established, and 178 km of bank stabilisation works undertaken
By 2011, 7,000 ha of riparian areas under management agreements	A total of 3,077 landholder agreements established, allowing for the protection of around 6,000 ha of riparian areas through stock exclusion, weed control and revegetation[185]

Response Name
Willow Control Program

Responsible Authority
East Gippsland Catchment Management Authority

Response type
Program

Between 2002 and 2005, almost $1 million was invested to eliminate willow populations along 300 km of the Wonnangatta, Dargo, Deddick and Combienbar Rivers in the upper reaches of the Snowy, Tambo and Mitchell basins[186]. Natural regeneration of native plants was encouraged and, in some cases, supported by plantings of native vegetation on the banks. Follow-up surveys were conducted to confirm the success of the removal program.

Response Name
RiverTender

Responsible Authority
North east CMA, North Central CMA

Response type
market-based instrument

RiverTender provides financial incentives for landholders with river frontage to improve river health and derive benefits for their own property and the community. This scheme, based on principles established through the development of BushTender (see Part 4.2: Land and Biodiversity, LB1) addresses a market failure in relation to ecosystem services provided by healthy rivers. These ecosystem services represent public goods but there has been little financial incentive for landholders to contribute to improved river health.

Individuals or groups of landowners prepare management plans that describe measures to be undertaken, and the funding required to complete the work over five years. Funds are allocated through an auction process to bids that demonstrate the best value.

Pilot tenders in 2006 demonstrated a positive response from the community. The North East Catchment Management Authority let a tender in the Ovens River valley which resulted in management agreements for an additional 800 ha of riparian land, affecting 60 km of river frontage. Another tender let in the North Central CMA resulted in an additional 230 ha of land under management agreements, affecting over 39 km of river frontage.

Response Name
Special Investigation into Rivers and Streams (1991)

Responsible Authority
Land Conservation Council (LCC)

Response type
Public land use planning

The LCC was directed by Government in 1987 to investigate 'the scenic, recreational, cultural and ecological values of rivers and streams in Victoria, and make recommendations on the use of these rivers and how their identified values can be best protected'[187]. These recommendations were subsequently accepted by Government.

A key recommendation was that stream beds and banks be used to conserve native flora and fauna as part of an integrated habitat network across the State, and to maintain and restore indigenous vegetation[188]. The investigation recommended Crown land water frontages be managed firstly for conservation, then for recreation where consistent with conservation, and then for stock grazing provided there was no conflict with conservation or recreational objectives[189]. These recommendations were subsequently endorsed through the Biodiversity Strategy and Victorian River Health Strategy[190].

The LCC Investigation also recommended that special status be conferred to rivers of high environmental and community value. This resulted in the establishment of Heritage Rivers, Essentially Natural Catchments and Representative Rivers. The recognition of the high value of river systems which remain relatively intact, such as the Ovens and the Mitchell, is of enduring importance given persistent requests for additional water storages.

Evaluation of responses to riparian vegetation

The importance of riparian vegetation and pressures on its condition are well documented. Substantial programs to restore riparian vegetation are in place, and the importance of partnerships with adjacent landholders has been recognised[191]. Progress has also been made in formalising management arrangements and responsibilities to provide better long-term protection for riparian areas[192]. Substantial change is still required to transfer the understanding and intention of management documents into on-ground outcomes, as shown by the low proportion of reaches statewide with riparian vegetation in good condition. Significant scope exists for reforming the governance of riparian land, as outlined by a recent review of the management of riparian land in Victoria[193].

Improving connectivity of remnant riparian zones with high ecological values offers opportunities to increase species richness at a regional scale. It is a proactive, strategic approach to increasing the health of inland waters. Victoria is in the fortunate position, compared to other jurisdictions, to have extensive lengths of stream bed and bank under public ownership. This offers greater scope for strategically improving connectivity, and overall improvements in the management of riparian land.

The endorsement of the LCC recommendations 17 years ago, however, has not resulted in a shift from the default use of Crown Land water frontages abutting private property for grazing, to a conservation focus. As a result the Land Conservation Council's successor, the Victorian Environment Assessment Council (VEAC), recommended stronger protection for crown land water frontages in its River Red Gum Forests Investigation by phasing out domestic stock grazing from Crown Land water frontages over a five year period[194]. The VEAC Investigation also explored potential exceptions, and incentives for both adjustment and ongoing support for the positive actions of many landholders. The Victorian Government is currently considering VEAC's recommendations.

Improving riparian condition involves all levels of government, private land holders and CMAs. A broad range of responses are either available or being developed, and objective analysis of public and private costs and benefits is necessary to develop cost-effective investment strategies. Activities that are within the duty of care of private landholders and managers as set out in the *Catchment and Land Protection Act 1994* should be funded by the landholder. Activities considered beyond the landholder's duty of care, however, are candidates for support by government incentives.

The partnering approach that has been so far successfully used to improve riparian land management on private land should be developed further. Landholders often have limited financial capacity to undertake works such as fencing, to prevent uncontrolled stock access to streams. Fencing allows regeneration of riparian vegetation, and is therefore essential to the sustenance of riparian zones[195]. Financial incentives are important, and would be assisted in the long tem by the development of markets for ecosystem services.

The immense value of riparian zones to both inland waters and terrestrial ecosystems demands commensurate effort is exerted in managing them. Momentum for improving the management of riparian zones to form an integrated habitat network across the State should be re-established through the forthcoming Land and Biodiversity White Paper, the 2009 renewal of Crown water frontages, and through ongoing engagement with riparian landholders across Victoria.

For further information

River Red Gum Forests Investigation
http://www.veac.vic.gov.au / riverredgumfinal.htm

Review of Management of Riparian Land in Victoria
www.publicland.com.au/pdf/Riparian%20 Report%20Exec%20Summary.pdf

Recommendations

IW3.2 The Victorian Government should consider progressively extending VEAC recommendations on phasing out uncontrolled grazing of domestic stock on Crown land water frontages to the rest of Victoria, beginning with the 2009 licence renewal process

IW3.3 The Victorian Government should update and streamline governance arrangements to facilitate protection and restoration of Crown Land water frontages

IW3.4 The Victorian Government and catchment management authorities should consider regional-scale connectivity of riparian vegetation in the prioritisation of rehabilitation projects, as part of forming an integrated habitat network across the State.

Photo: Jane Tovey

IW4 Water Quality

Key findings

- Land clearing for agriculture and urbanisation and contemporary land use changes have led to major catchment-wide changes, including erosion and salinity, which have significantly affected water quality in inland waters.
- In 2005, water quality objectives for salinity were met at 68% of sites across Victoria, and objectives for total nitrogen, total phosphorus, and turbidity were met at less than half the sites monitored.
- Concentrations of total nitrogen and total phosphorus posed a risk to ecosystem health at about 80% of lowland sites in 2005.
- Increasing trends in total nitrogen were detected at over half the sites across Victoria.
- River regulation, along with increased nutrient inputs and low streamflow, are now recognised as a major cause of cyanobacterial blooms in rivers.
- The degradation of important receiving waters such as Port Phillip Bay, Western Port, Gippsland Lakes and the Murray River is a major driver of water quality improvement programs. Management responses target a range of spatial scales, from regional to the individual.

Description

Water quality is fundamental to the ecosystem services that inland waters provide, such as drinking water, cycling of nutrients, maintenance of biodiversity, and recreational and cultural opportunities[196]. Poor water quality has serious implications for the ecological health of inland waters, biodiversity, and human and livestock health.

As water quality degrades, inland waters can fundamentally change, increasing the cost of water treatment, marginalising agricultural activity and reducing the viability of other economic activities that support community wellbeing. Inland waters have been used as drains for the catchment, degrading the ecosystem services provided by high-quality water.

Water quality is influenced by many other elements of the environment, such as catchment processes and management, flow regimes, riparian vegetation and in-stream habitat. Even in the driest parts of the landscape, most activities affect water quality in some way[197]. Land clearing for agriculture and urbanisation, and contemporary land use change has led to major catchment-wide changes, including erosion and salinity. Widespread application of fertilisers has increased concentrations of nitrogen and phosphorus in waterways. Research undertaken nationally in 2001 showed that phosphorus concentrations in inland waters were three times higher than pre-European estimates, while nitrogen concentrations were estimated to be at least double[198]. Point sources of pollution, such as discharges from agriculture, industry and wastewater treatment plants, have also contributed to elevated concentrations of phosphorus and nitrogen in urban waterways.

In-stream pressures on water quality include stock access to streams, suspension of sediments and release of nutrients, river regulation and extraction of water, and the impact of invasive species such as carp and willow. The impacts of climate change will modify these pressures, as reduced rainfall and higher temperatures change catchment hydrology and in-stream processes.

This section focuses on four key variables: salinity, turbidity, nitrogen and phosphorus. At a national level, these variables are considered to be the most significant river contaminants[199]. Only the water quality of major rivers and tributaries is examined. There are numerous other variables that contribute to water quality, such as pH, pesticides, heavy metals and temperature, which may have particular local or regional significance. Water quality is also affected by interactions between these components—for example; salinity and temperature both affect the saturation concentration of dissolved oxygen.

While some species are salt tolerant, salinity can cause death or damage to a wide range of plants and animals. This in turn reduces habitat availability and a reduction in biodiversity. Species dependent on those directly affected by salinity may be affected too[200].

Turbidity provides a measure of suspended solids in the water. Sediment transport is a natural and important function of inland waters, but excessive quantities of sediment are an ecological threat.

Nitrogen and phosphorus are essential plant nutrients, but when waterbodies become enriched with these nutrients (i.e. eutrophication), excessive algal and other plant growth, toxic algal blooms, and more subtle changes to the species composition of aquatic communities can result[201].

The statutory framework for the protection of Victoria's inland waters is set out in the State Environment Protection Policy (Waters of Victoria) (SEPP WoV) made under the *Environment Protection Act 1970.* The SEPP WoV contains water quality indicators and objectives that protect the beneficial uses and values of inland waters.

Water quality data are collected at over 200 sites through the Victorian Water Quality Network, and monitoring programs implemented by water corporations and the Murray-Darling Basin Commission[202].

Objectives

- Manage the catchment to ensure that land use changes do not place further pressure on inland waters, particularly through control of point sources of pollution and the improved management of riparian zones and wetlands
- Maintain robust ecosystems that provide water purification, nutrient cycling and transport services for environmental and community benefit

State

The following sections describe water quality variables in terms of current status and trends. The status of a water quality variable at a site is expressed in terms of whether the relevant SEPP WoV objective, expressed as a concentration, was attained or not during 2005. Attainment for a given year can be influenced by climatic factors such as rainfall and flow, as well as changes in inputs from the catchment.

Non-attainment of an objective indicates that the ecosystem is at risk. Rather than signifying a "pass" or "fail", this outcome may then trigger an EPA risk-based investigation, in which the level of risk is further evaluated.

Trends that were detected over time-frames ranging from five years to around 30 years[203]. In the following sections trends are reported in terms of change over the length of the time series at each individual site. The methodology used to detect trends takes climatic influences into account[204].

Due to the different data requirements, different numbers of sites were assessed for SEPP WoV attainment and trends in each CMA area.

Indicator IW9 Trends and status of salinity concentrations in rivers

Salinisation is a serious issue for many lowland waterways throughout Victoria and Australia. (see Part 4.2: Land and Biodiversity, LB6 Salinity). SEPP objectives for salinity are generally expressed in terms of electrical conductivity (EC).

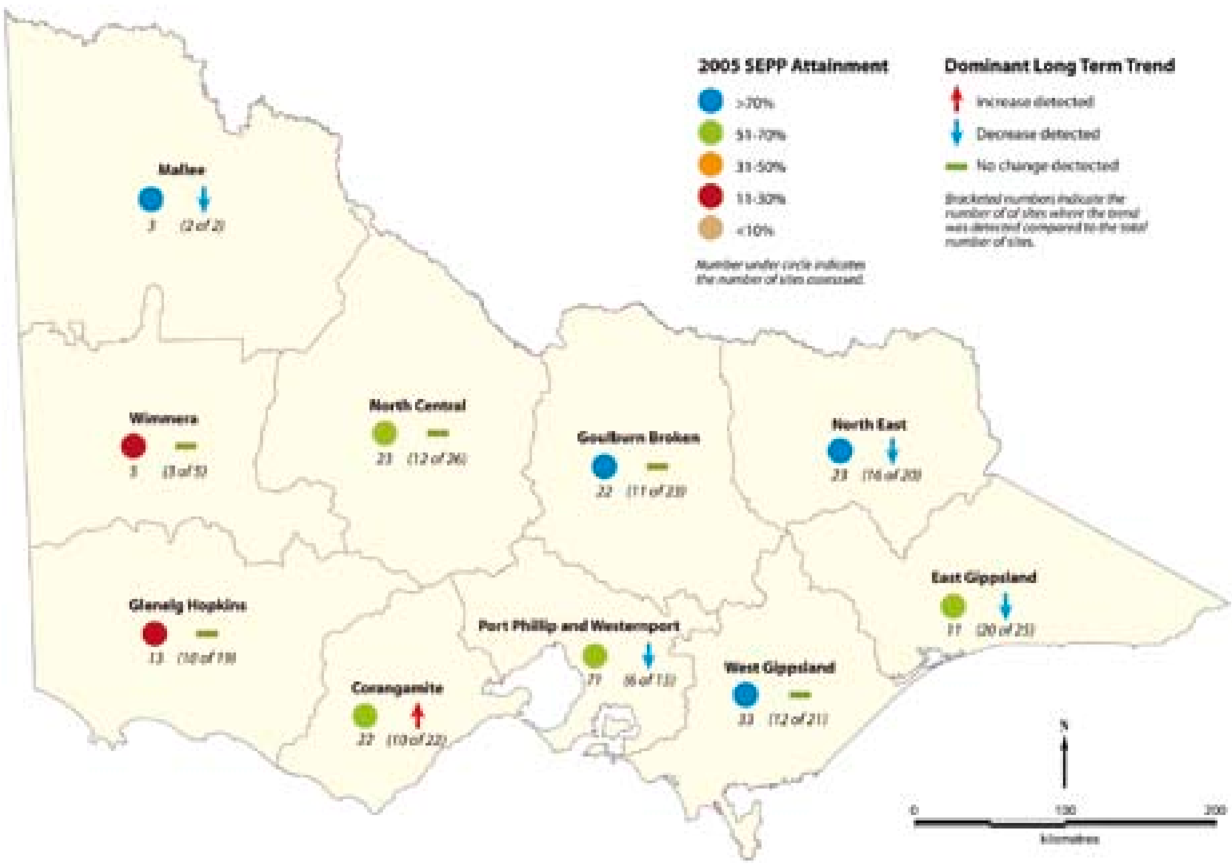
In 2005, EC objectives were achieved at 67% of sites across Victoria, indicating that these sites were not at risk from salinity. EC levels were lower in upland sites (85% of 87 upland sites attained SEPP objectives), compared to lowland sites (55% of 139 sites attained SEPP objectives)[v].

EC objectives were attained at all sites in two CMA areas (North East and Mallee) and high rates of attainment were also recorded in the Goulburn Broken and West Gippsland CMA areas (see Figure IW4.1). Only three sites were assessed in the Mallee CMA area, so it may not be representative of the entire area. In four CMA areas (North Central, Port Phillip, East Gippsland and Corangamite), EC objectives were attained at 50–70% of sites. In the Glenelg Hopkins and Wimmera CMA areas, EC objectives were attained at 23% and 20% of sites respectively.

Increasing EC was detected at 20% of sites, decreases at 42% of sites, and EC remained stable at 38% of sites. Salinity increased mainly in western Victoria, in particular the Wimmera, Glenelg Hopkins and Corangamite CMA areas, the western part of the Port Phillip CMA area and a number of locations in the North Central CMA area[205] (see Figure IW4.1).

EC had decreased at the site in the Mallee CMA area, and at 80% of sites in the North East CMA and East Gippsland CMA areas.

Figure IW4.1 Attainment of conductivity objectives (2005) and dominant long-term trends in conductivity levels for CMA areas
Source: DSE (2007) and SKM (2007)[206]



v Based on counting one objective per site, using 75th percentile objectives or otherwise EC Max

Indicator IW10 Trends and status of turbidity concentrations in rivers

Many inland waters in Victoria are naturally turbid due to high concentrations of suspended sediment[207]. Turbidity is not the same as the colour of water. Some Victoria inland waters appear brown due to the presence of tannins. These highly coloured waters are usually clear, with very low levels of suspended sediments and turbidity[208].

In 2005, turbidity objectives were attained at 43% of sites across Victoria, indicating that these sites were not at risk from turbidity. Levels of attainment of objectives were similar for upland (45% of 95 sites met the objectives) and lowland sites (42% of 141 sites met the objectives)[vi].

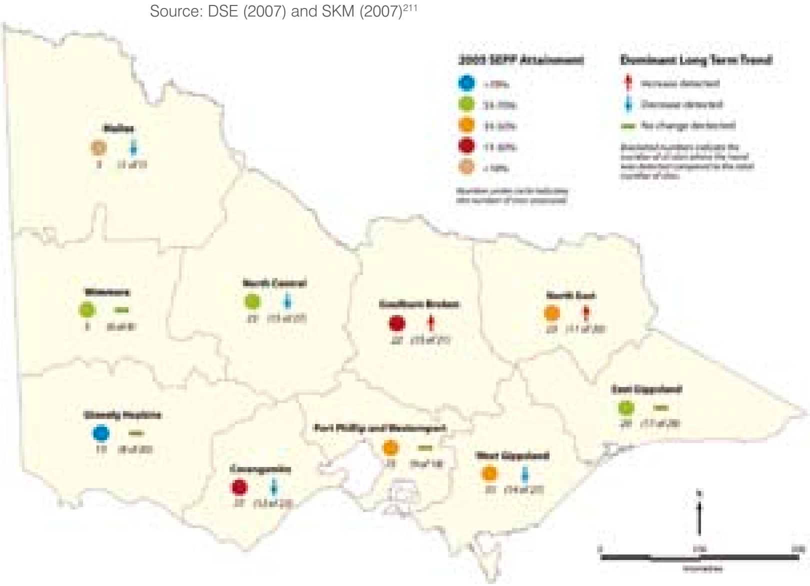
The Glenelg Hopkins and East Gippsland CMA areas had the highest levels of attainment in 2005, with 93% and 70% of all sites assessed attaining turbidity objectives respectively (see Figure IW4.2).

In five CMA areas (Wimmera, North-Central, West Gippsland, Port Phillip and North East), between 39% and 60% of sites attained turbidity objectives in 2005. The lowest levels of attainment were observed in the Corangamite, Goulburn-Broken and Mallee CMA areas, although once again the low number of sites in the Mallee CMA area limits the significance of this result.

Increases in turbidity were detected at 34% of monitoring sites, whereas 30% showed lower levels and 36% remained stable. Increases in turbidity were detected at a majority of sites in the North East CMA area and at over 70% of sites in the Goulburn-Broken CMA area.

Separate studies have shown short-term increases in turbidity in some catchments in the North East CMA Area following the 2003 bushfires[209]. Erosion of sediments is dramatically increased after fire. The large-scale fires that burned across the Victorian high country in 2003-04 greatly increased erosion in these areas, leading to poor water quality and deposition of large amounts of soil and other materials in stream beds and lakes[210]. The bushfires of 2006-07 are expected to produce similar impacts on turbidity in affected basins (see Part 4.2: Land and Biodiversity, LB8 Fire in the Victorian Landscape).

Figure IW4.2 Attainment of turbidity objectives (2005) and dominant long-term trends in turbidity for CMA areas
Source: DSE (2007) and SKM (2007)[211]



Indicator IW11 Trends and status of total phosphorus concentrations in rivers

In 2005, total phosphorus (TP) objectives were attained at 29% of monitoring sites across Victoria, indicating that 71% of sites were potentially at risk from elevated TP levels[vii]. Levels of attainment were higher in upland sites (44% of 84 sites met the objectives) compared to lowland sites (19% of 140 sites met the objectives). Low levels of attainment in the Port Phillip CMA area contributed to the low state total, due to the relatively large number of sites in this region (15% of 71 sites attained TP objectives).

Low levels of attainment were recorded in the North Central, Corangamite, Goulburn and Mallee CMA areas (see Figure IW4.3). East Gippsland had the highest level of attainment (82% of all sites).

Total phosphorus concentrations increased at 20% of sites, decreased at 42% of sites, and remained stable at 38% of sites. Increases in total phosphorus concentrations were detected at over half the sites in four CMA areas: Goulburn-Broken (80% of sites), Glenelg Hopkins (73% of sites), North East (58% of sites) and Port Phillip (56% of sites). The increases were mostly minor, although there were large increases at one site in the Glenelg Hopkins CMA area and another in the North Central CMA area[212]. Large decreases were found at one site in the Corangamite catchment, and a number of smaller decreases were found at sites in the Port Phillip, North Central and West Gippsland CMA areas.

vi Based on counting one objective per site, using 75th percentile objectives or otherwise 50th percentile

vii Based on counting one objective per site, using 75th percentile objectives or otherwise the 50th percentile objective

Indicator IW12 Trends and status of total nitrogen concentrations in rivers

In 2005, 29% of monitoring sites attained total nitrogen (TN) objectives across Victoria, indicating that 71% of sites were potentially at risk from elevated TN levels[viii]. Levels of attainment were higher in upland sites (43% of 83 sites met the objectives) compared to lowland sites (21% of 134 sites met the objectives). Low levels of attainment in the Port Phillip CMA area contributed to the low state total, due to the relatively large number of sites in this region (3% of 80 sites attained TN objectives).

Levels of attainment were also particularly low in the Corangamite CMA area, with only 5% of sites meeting the objective (see Figure IW4.4). In the East Gippsland, West Gippsland North East and Glenelg CMA areas, more than half of all sites attained total nitrogen objectives. Only one site was assessed in the Mallee CMA area and, although this site attained the objective, it may not be representative of water quality in this area.

Increasing total nitrogen concentrations were detected at 52% of sites, decreases were detected at 18% of sites, and concentrations remained stable at 30% of sites.

Increasing total nitrogen concentrations were detected at 70% and 40% of the sites in the Corangamite and Port Phillip CMA areas respectively; both CMAs had low levels of attainment (see Figure IW4.4). Increasing total nitrogen concentrations were detected at more than 50% of sites in the Glenelg Hopkins, North East and Goulburn-Broken CMA areas. Total nitrogen concentrations decreased in the Wimmera CMA area, although only four sites were reported. No data were available for the Mallee CMA area.

Figure IW4.3 Attainment of total phosphorus objectives (2005) and dominant long-term trends in total phosphorus concentrations for CMA areas
Source: DSE (2007) and SKM (2007)[213]

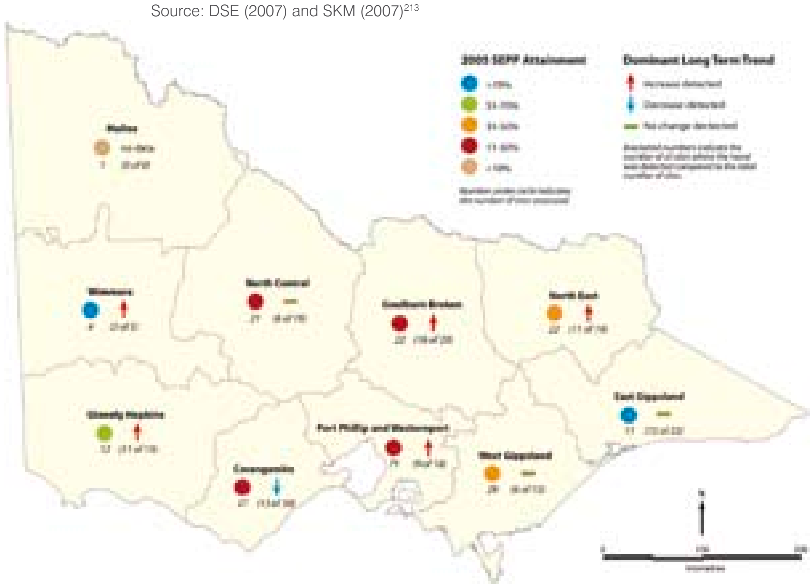
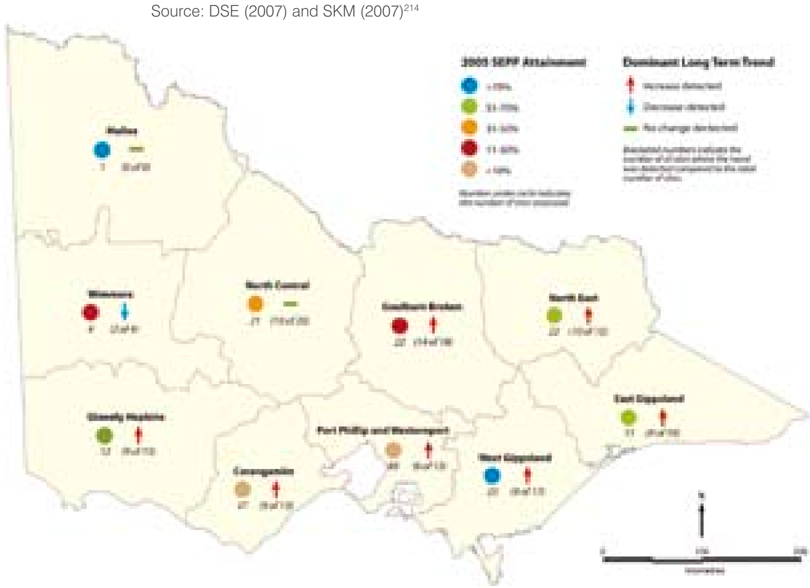


Figure IW4.4 Attainment of total nitrogen objectives (2005) and dominant long-term trends in total nitrogen concentrations for CMA areas
Source: DSE (2007) and SKM (2007)[214]



viii Based on counting one objective per site, using 75th percentile objectives or otherwise the 50th percentile objective

Indicator IW13 Presence of cyanobacterial blooms

Cyanobacteria are naturally present in Victoria's inland waters. Under certain conditions, their populations can explode, causing a potentially toxic bloom. Low river flow has been established as the primary trigger for cyanobacterial blooms, while the amount of nutrients present (in particular, phosphorus) controls the size of the bloom[215]. River regulation has been identified as a root cause of cyanobacterial blooms, as weir pools and low but continuous flows of water effectively convert the river into a series of shallow, thermally-stratified lakes in summer[216].

The number of cyanobacterial blooms recorded has increased dramatically since 1990, although this has been largely due to the improved scrutiny of water bodies[217]. While data have historically been collected by individual agencies such as water authorities (see Table IW4.1), they are now regularly reported on a statewide basis (see Figure IW4.5). These blooms, which are above health alert levels, are reported by water authorities and local waterway managers.

Pressures

All activities in the catchment can affect water quality in some way. Sources of pollutants are generally divided into two broad categories: point sources (e.g. from a pipe) and diffuse sources (from many points throughout the catchment). Pollutants can also be stored in, and released from, the sediments of a water body.

Understanding the pathways by which these pollutants move from their source to inland waters, the transformations they undergo and their eventual fate within inland waters, are important steps to managing water quality.

Some parts of the catchment have much stronger links to pollutant loads than others[220]. Computer modelling of sediment transport in selected catchments of the Murray-Darling Basin concluded that 75% of the suspended sediment load is produced by only 20% of the total contributing area[221]. The effectiveness of water quality management can be improved by prioritising intervention in areas with strong links to pollutant loads.

Table IW4.1 Number and type of waterbodies observed as having cyanobacteria blooms in Victoria, 1993 to 1999
Source: Atech Group Pty Ltd (2000)[218]

Year	Number and type of waterbodies affected by recorded blooms				
	Town Water Supply	Irrigation Water Supply Storages	Recreational Water Bodies	Other (domestic and stock, ornamental, industrial, wastewater)	Total
1993-94	7	27	21	3	58
1994-95	9	15	29	2	55
1995-96	4	25	19	1	49
1996-97	18	40	41	2	101
1997-98	16	36	25	6	83
1998-99	21	29	32	10	92

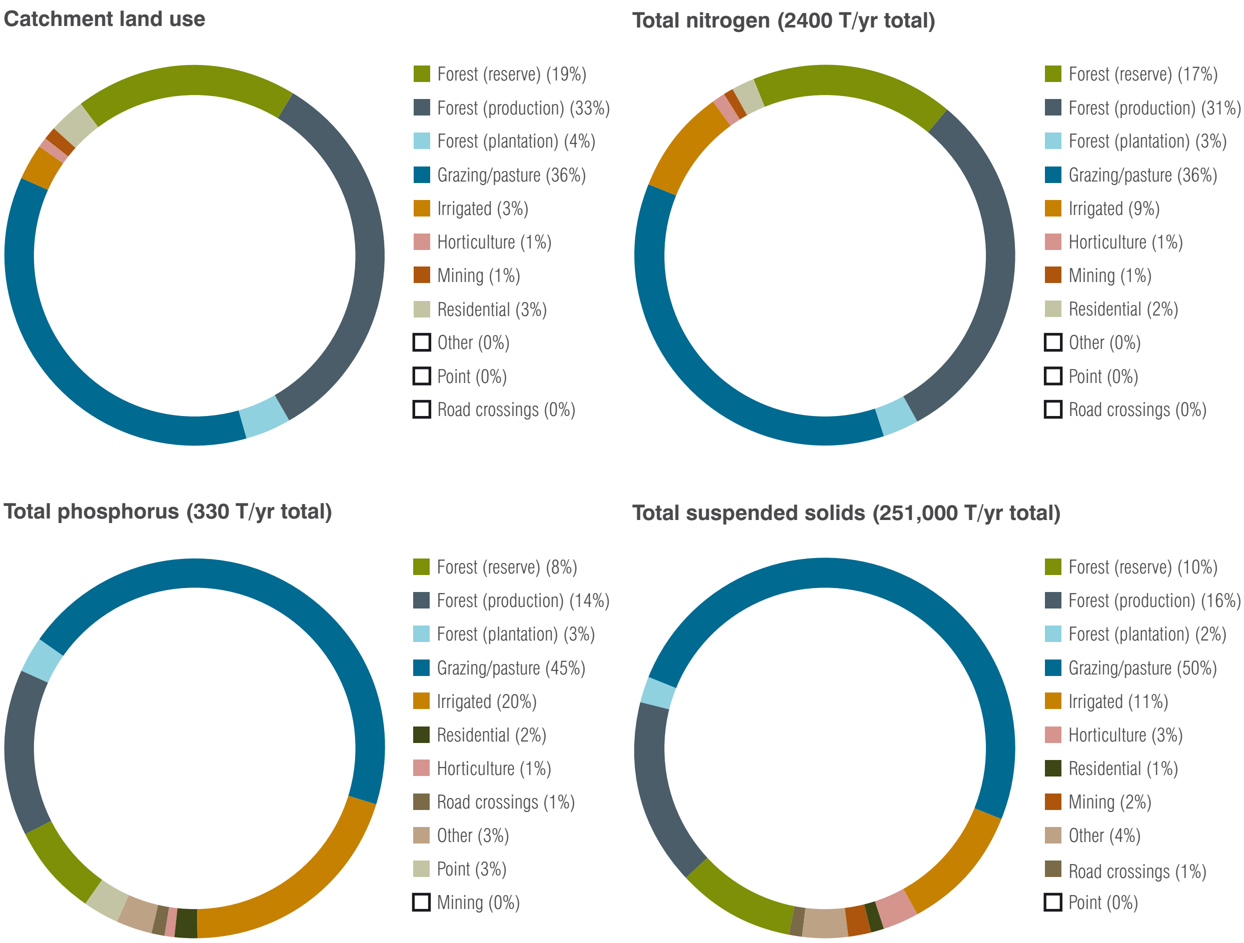
Figure IW4.5 Victorian basins affected by cyanobacterial blooms, March to September 2007
Source: DSE (2007)[219]

The pressure that pollutants place on water quality is also determined by the timing of their discharge to the waterway. Infrequent, major flow events may contribute almost the entire annual pollutant load, and thus place most pressure on the water quality of receiving waterways. Under other circumstances, for example during low flow periods, the concentration of pollutants is of most concern, and therefore processes that increase pollutant concentrations during this time place the greatest pressure on water quality.

Pressures on water quality are also reported in IW1 Flow regimes, IW3 Riparian vegetation, IW5 Aquatic fauna and IW6 Implications of climate change on inland waters.

In terms of sources of contaminants, one of the best-studied regions in Victoria is the catchment of the Gippsland Lakes, which has been investigated as part of improving water quality in the Lakes (see Figure IW4.6). Intensive land uses (e.g. irrigation and horticulture) generally contribute greater amounts of nutrients and sediment per unit area, but extensive land uses (e.g. grazing/pasture, forestry) dominate the contribution to total loads. As land uses intensify, total nutrient and sediment loads are likely to increase unless management is improved.

Figure IW4.6 Modelled estimates of nutrient and sediment sources in catchments of Gippsland lakes
Source: Gippsland Lakes Future Directions Taskforce (2006)[222]



Salinisation

Land use changes, such as the replacement of deep-rooted, native vegetation with shallow-rooted crops and pastures and irrigated agriculture, result in stored sub-surface salts being mobilised by rising groundwater. This process has resulted in the dramatic expansion of land and water salinisation (see Part 4.2 Land and Biodiversity, LB6 Salinity).

Salinisation presents a direct threat to groundwater-dependent wetlands where irrigation and land clearing have raised saline watertables, where saline irrigation tailwaters have been disposed into wetlands, or where estuaries have been artificially opened to the sea. Salinity may also be caused by evaporation in surface waters[223].

The rainfall deficits and higher temperatures experienced over the past 11 years have contrasting effects on salinity. Low rainfall reduces the rate of recharge of saline groundwater levels, and hence reduces the discharge of saline groundwater to surface waters. On the other hand, higher evaporation rates concentrate the salt already in surface waters. Salinisation will remain a latent threat as groundwater levels will rise again with heavy rainfall or flooding events.

Indicator IW14 Use of artificial fertilisers

Fertiliser is a key input for many of Victoria's agricultural enterprises (e.g. beef, dairy and sheep), as it has a strong influence on pasture production and profitability (see Part 4.2: Land and Biodiversity).

In 2000-01, approximately one million tonnes of phosphorus, nitrogen and potassium fertilisers were applied across Victoria. Soil nitrogen levels have also increased through the cultivation of pasture and grain legume crops, which are able to bilogically fix atmospheric nitrogen. Leaching of excess nitrogen through the soil profile is the most widespread cause of soil acidification.

Based on analysis of fertiliser use using the Australian Stocks and Flows Framework, it was estimated that a threefold increase in the application of artificial fertilisers has occurred since the 1960s which reflects the intensification of agricultural practices over this period[224].

Urbanisation

The Melbourne region is the most urbanised part of Victoria, and it is where the water quality impacts of urbanisation are most obvious. A computer model of the Port Phillip catchment shows that urban areas make up less than 25% of the catchment, yet contribute around 50% of the catchment's nitrogen loads[225] to Port Phillip Bay. Metropolitan Melbourne occupies 210,000 ha; its urbanised area has doubled between 1971 and 2004 (see Part 4.2: Land and Biodiversity, Contemporary land use change). Further urban growth is predicted to increase nitrogen loads to Port Phillip Bay by up to 260 tonnes a year by 2030[226].

Urban stormwater is the most significant source of pollution to Melbourne's rivers, creeks and wetlands[227]. Stormwater contains elevated levels of sediment, nitrogen and phosphorus, as well as other contaminants such as metals, hydrocarbons and pathogens. The expansion of urban, industrial and rural residential areas has led to an increase in paved areas, producing higher velocities and volumes in runoff water, which increases the risk of channel erosion. Rapid, direct transport of these pollutants by the drainage system amplifies the pressure placed on receiving waters. Point sources of pollution in urban areas include outlets from sewage treatment plants, intensive animal industries, irrigation and stormwater.

Wastewater treatments plants are generally a major point source of pollution but in Melbourne the major treatment plants discharge to Port Phillip Bay and Bass Strait, rather than to inland waters (see Part 3.2: Water Resources; Part 4.4: Coasts, Estuaries and the Sea). In recent years, increased recycling has reduced the volume of wastewater discharged directly to rivers (see Part 3.2: Water Resources).

Internal loading

Most of the phosphorus and nitrogen found in rivers, storages and estuaries is located in the bottom sediments eroded from the surrounding landscape since catchments were cleared[228]. Nutrients released from the sediment can accumulate in the overlying water column when the water column is stratified and particularly when the bottom waters become anoxic. These processes are more common under low-flow conditions, and in deep water such as reservoirs. The combination of increased erosion and the construction of large impoundments have increased the scale of this pressure.

Bushfires

The pressures that bushfires exert on water quality, such as increases in turbidity, sediment and nutrients and decreases in dissolved oxygen, are most intense in the short term. A post-fire flood in the Ovens River in 2003 produced a sediment slug that increased turbidity enormously in (70,000 NTU,[ix] compared with a normal level of less than 10 NTU) and suspended solids (33,000 mg per litre compared with less than 6 mg per litre). Dissolved oxygen concentrations declined to 0.1 mg per litre, which is approximately 10% of the concentration at which fish deaths occur[229]. The loss of water quality in this event was temporary as the sediment slug moved quickly downstream. Up to 100% of fish populations in the upper reaches of the Ovens River may have been killed by post-fire sediment[230]. Three years after the fires, river health, measured in terms of the condition of macro-invertebrate communities, had not fully recovered at a number of sites[231]. Nutrient and sediment loads received by storages and estuaries may be significantly higher than normal following bushfires, contributing to long term water quality problems and confounding achievement of regional water quality targets.

Fire suppressant chemicals that enter waterways can cause fish kills and affect nutrient concentrations. As more sunlight reaches waterways following the destruction of riparian vegetation, this causes in-stream temperature ranges to fluctuate, affecting in-stream biota and dissolved oxygen levels.

Recommendation

IW4.1 Government and catchment management authorities should continue to promote and encourage the uptake of current best practice land use management to minimise diffuse water quality pollution throughout Victoria.

Implications

The implications of poor water quality are likely to be greatest in lowland rivers and wetlands, water storages and weirs. These areas are particularly susceptible as they are the receiving environments for substantial catchment outflows where there are multiple point sources or diffuse sources of nutrients. They are also often sites where flow velocities are low and residence times are high, providing the opportunity for nutrient-rich sediments to accumulate[232].

Important coastal environments such as Gippsland Lakes, Port Phillip Bay and Western Port have been degraded by pollutants in catchment inflows (see Part 4.4: Coasts, Estuaries and the Sea). The water quality of the River Murray also degrades downstream, which has implications for the health of the Coorong in South Australia and Adelaide's drinking water supply. Without intervention, reduced flows and increased salinity will result in Adelaide's main water supply failing World Health Organisation levels two days in five within 20 years[233].

Biodiversity

Turbidity reduces light and consequently the ability of aquatic plants to photosynthesise and makes it more difficult for animals to live within the waterway, particularly those that are visual predators. At very high levels, suspended sediment can clog and damage fish gills and the filter-feeding apparatus of animals such as mussels.

Sediment contaminated with heavy metals, nutrients and toxic organic compounds may cause a loss of biodiversity through the direct impact of toxicants or indirectly through cyanobacterial blooms. Large-scale sediment deposition can bury entire reaches, replace diverse river habitats with uniform sand beds (sand slugs, and create shallow flow areas that are subject to greater temperature extremes and the risk of invasion by aquatic weeds.

ix Nephelometric Turbidity Units

Salinity can have a range of lethal and non-lethal effects[234] leading to reduced biodiversity and habitat availability. Most freshwater organisms can tolerate a certain level of salinity, with some organisms found in freshwater known to thrive in more saline environments[235]. Some freshwater fish and crustaceans are even diadromous, moving between freshwater, estuarine and even marine environments. Studies into the sensitivity of frogs showed that wetland salinity did not appear to limit their occupancy below 3,000 EC[x], after which it declined rapidly. No amphibians were detected where salinity exceeded 6,000 EC[236]. Salinisation of wetlands regularly causes salinity in excess of these levels, indicating that frog populations would be severely affected[237]. The effects of salinisation on riparian vegetation include lower species-richness of native herbs and shrubs, and less cover of native species, compared to freshwater wetlands[238]. Four of 11 Ramsar-listed wetland areas were at risk of salinity and shallow groundwater in 2000 under the worst-case scenario assessed by the National Land and Water Resources Audit (2001), and up to eight would be at risk by 2050, although this assessment may not incorporate climate change projections[239]. Few studies have examined the effects of salinised rivers or wetlands on biodiversity or ecosystem services[240]. The implications for salinity on inland waters are also discussed in Part 4.2: Land and Biodiversity, LB6 Salinity.

One of the major impacts of high levels of nutrients on inland waters is the over-growth of algae and in-stream vegetation. This greatly increases the risk of algal blooms capable of killing fish, damaging water supplies and preventing recreation. Biodiversity can be adversely affected as wetlands and waterways become dominated by algae and weeds that thrive in high-nutrient conditions, replacing the more diverse, indigenous species adapted to low-nutrient conditions. Death and decomposition of excessive in-stream growth can reduce oxygen levels to the detriment of aquatic biota.

Following the immediate impacts of bushfires, loss of vegetation can lead to an ongoing, large influx of eroded sediment and organic matter entering waterways and reducing water quality. As the organic matter decomposes, it can raise nutrient concentrations and lower dissolved oxygen concentrations, affecting fish, insect larvae, aquatic mammals and waterbirds. It can also increase algal growth and reduce drinking water quality[241].

Lower quality water for consumption

In a water supply context, water quality is of vital importance and has its own regulatory framework and monitoring programs. The data presented in previous indicators are not relevant to consumptive uses. Due to Victoria's reliance on surface water sources, however, surface water quality does have implications for consumptive uses.

Loss of water quality in surface water sources can have significant economic implications, particularly for communities that rely on rivers and streams to provide domestic water. For example, it is estimated that water treatment in the Murray-Darling Basin will cost the community an additional $7m per year by 2050[242].

Higher salinity accelerates corrosion and can damage infrastructure, such as roads and bridges[243]. It also affects soil, plant and livestock health and can therefore reduce agricultural productivity.

Cyanobacterial blooms create pungent smells and make waterways unappealing for recreational activities[244]. Waterways affected by blooms are unsuitable for agriculture use and many stock deaths have been reported[245]. Large blooms in reservoirs can cause major difficulties for drinking water supply, as they block filters and produce tastes and odours that are difficult to treat.[246] Some species of cyanobacteria can produce toxins that are dangerous to animals and humans if they are consumed or possibly even touched[247].

Sediment deposition following fires has significant implications for water supply to towns depending on river water. Treatment plants struggle to process the additional sediment load and water supplies may be interrupted while additional filtration is applied. Where existing stored supplies are limited, additional water may need to be trucked in to supplement supplies and dilute the sediment to a treatable concentration. The treatment of water from rivers affected by post-fire sediments requires ongoing management because sediment deposited on the river bed is re-suspended each time flow increases.

Reduced opportunities for recreational and cultural activities

Cultural services are affected by keeping people from swimming, boating, and otherwise enjoying inland waters affected by potentially toxic cyanobacterial blooms. These blooms also impose costs on recreational and tourism operations.

Climate change

Implications of climate change on water quality are discussed in IW6 Impacts of Climate Change on Inland Waters.

Infrastructure

There are also implications for water resource management. Water supply dams can lose capacity due to sediment deposition, which requires costly treatment. Sediment build-up can exacerbate flooding where channels have become shallower and outlets blocked. This increases flood magnitude and frequency, increasing the risk of damage to buildings, roads, bridges, pipes, farmland and other infrastructure.

x Electrical conductivity (EC) is measured as microsiemens (μS) per cm at 25°C.

Management responses

Reducing catchment-based pollution and ensuring that land use changes do not place further pressure on inland waters is a fundamental objective of water quality management. A broad range of measures are currently implemented across a range of agencies and organisations to manage water quality in Victoria, reflecting the diversity of both sources and solutions to water quality problems. Responses that improve other aspects of the condition of inland waters (see preceding sections on riparian vegetation, bank stability and flow regimes) and the land (see 4.1 Land and Biodiversity, Management responses sections) are also likely to improve water quality.

Response Name
State Environment Protection Policy (Waters of Victoria)

Responsible Agency
Environment Protection Authority

Response Type
Policy

The State Environment Protection Policy (Waters of Victoria) (SEPP WoV) sets out the statutory framework for the protection of Victoria's waters. The water quality objectives prescribed in the SEPP (WoV) have been used in the planning and guidance of other programs. For example, the Victorian River Health Program expresses its water quality targets in terms of SEPP (WoV) objectives, and they are widely used by catchment management authorities.

Across Victoria, there are 35 attainment programs associated with the SEPP (WoV). These are mainly implemented by catchment management authorities and water authorities. Attainment programs have been implemented to varying levels. The Environment Protection Authority is reviewing the implementation of the SEPP framework and the potential impact of climate change on reference site condition. Recent advances in water quality condition assessment should be investigated, including ecosystem function indicators and risk-based approaches.

Recommendation

IW4.2 State Environment Protection Policy (Waters of Victoria) should be reviewed to ensure consistency with best scientific practice in the context of a changing climate.

Response Name
Gippsland Lakes Future Directions Action Plan (2002)

Responsible Agency
Department of Sustainability and Environment

Response type
Management Plan

The Gippsland Lakes have suffered from frequent cyanobacterial blooms. Over the years an evolving series of plans to improve water quality in the Gippsland Lakes has been produced, culminating in the Gippsland Water Quality Action Plan (2005).

A centrepiece of these plans has been a target to reduce nutrient loads by 40% by 2022[248], established in the Gippsland Lakes Future Directions Action Plan (2002). Substantial investment, of $12.8 million between 2002 and 2006, and $6 million from 2006 to 2009 has been committed to achieving this target. However, modelling indicates that, if current management practices are implemented, only a 12-20% reduction in nutrient loads will result[249]. Along with ongoing implementation of management practices, research is being conducted to improve management practices so the original target is achieved.

A separate target of a 40% reduction in nutrient loads from the Macalister irrigation district was also established in 2002, due to the importance of irrigation to total nutrient loads (see Figure IW4.6). This target has been met four out of the past five years, with lower streamflow contributing to this reduction. Overall, the uncertainty of both modelled load estimates and the measurement of actual loads, combined with unusual climatic conditions which have resulted in droughts, floods and bushfires, have to some extent confounded accurate measurement of progress[250].

Response Name
Victorian Planning Provisions Clause 56

Responsible Agency
Department of Sustainability and Environment

Response Type
Planning scheme

Clause 56 is the Residential Subdivisions component of the Victoria Planning Provisions (VPP) which provides the basis for all local council planning schemes in Victoria[251].

The provisions of Clause 56, which apply specifically to new residential developments, include objectives for integrated water management, mandated performance objectives for urban stormwater management, and improved site management standards. The current focus of the Clause 56 implementation is the stormwater management objectives, although water shortages are also driving interest in integrated water management.

A major challenge in the implementation of Clause 56 is industry capacity[252]. Successful implementation of urban stormwater management measures requires understanding and technical capacity across a broad range of disciplines and organisations. Insufficient knowledge and skills across the sector could ultimately lead to ineffective systems, undermining the credibility and stakeholder acceptance of new techniques.

Industry capacity is being addressed through the Clearwater capacity building program. Initiatives of Clearwater include an officer to help local councils implement Clause 56, as well as a website and training seminars. While Clause 56 applies statewide, Clearwater is currently limited to the Melbourne region.

Clause 56 provisions do not mandate stormwater quality objectives for non-residential development or renovations. Therefore there is scope for broadening the range of developments to which stormwater quality objectives apply and extending capacity building programs into regional Victoria. Clause 56 might also be used to promote integrated water management practices.

Recommendations

IW4.3 Further degradation of urban waterways should be reduced by applying similar integrated water management provisions to non-residential urban subdivisions as currently apply to residential subdivisions under Clause 56 of the Victoria Planning Provisions with continuation and expansion of capacity building programs for council and development industry practitioners.

IW4.4 The review of water quality management objectives based on reductions in contaminant export compared to a base case (e.g. stormwater management objectives for residential development) should factor in continued intensification of urban and rural land uses. Continued research and innovation to improve and develop management practices should be encouraged.

Response Name
Waterwatch in Victoria

Responsible Agency
Waterwatch

Response Type
Community Engagement and water quality monitoring

Waterwatch is a national, community-based water quality monitoring network that has been operating in Victoria for 15 years[253]. Waterwatch is based on a network of regional and local coordinators, hosted by various catchment management authorities, water authorities and local government[254]. In 2004, Waterwatch employed 45 people in Victoria[255].

An ongoing challenge for Waterwatch has been improving the quality of data captured so that it can be used to inform management decisions. This has been addressed through an ongoing process to improve data quality control and assurance and emphasise the quality of the data set in terms of completeness and representativeness, as opposed to sample accuracy.

Over time, Waterwatch has evolved into a diverse program that provides community education, collects water quality data and builds social capital. It is an important link between a range of regional and local organisations, including catchment management authorities, water authorities, local government, private business, the scientific community and the education sector. Opportunities for integrating Waterwatch with other community and government monitoring programs should be pursued.

Evaluation of responses to water quality

Water quality management requires regional-scale management, but like water consumption, it is also one aspect of inland waters that is within the means of each individual to influence. Current management responses address both ends of this spectrum.

In addition to the statewide framework provided by the SEPP, the Victorian Nutrient Management Plan (1995) was an important step in the establishment of regional-scale water quality management. This plan required each CMA region to produce a nutrient management plan.

Environmental degradation of major receiving waters such as Gippsland Lakes, Port Phillip Bay and the River Murray has been a major driver of catchment water quality improvement programs. The Port Phillip Bay Environmental Management Plan (2002) recommended a 1000 t reduction in nitrogen loads to Port Phillip Bay. Half of this reduction was to be achieved through improvements to the Western Treatment Plant at Werribee, and the other 500 t by reducing nitrogen loads from the catchment. Melbourne Water's Waterways Water Quality Strategy (2008) has committed significant funding to improve water quality in the Port Phillip and Westernport catchments, with an estimated $92 million to be invested from 2008 to 2013. Monitoring which will determine progress towards the catchment target is still in process. Increasing urbanisation will continue to increase nutrient loads to Port Phillip Bay, highlighting the need for continuous improvements to management practices and the control of urban planning and development.

In addition to the water quality variables presented in this section, a vast range of industrial and agricultural chemicals end up in waterways. Some of these—for example the herbicide atrazine—can be toxic at very low concentrations (see IW5 Aquatic Fauna, Implications), while other contaminants persist in the environment and accumulate in aquatic biota. Detection of these chemicals in itself poses a challenge. Establishing toxic effects on biota, especially when there may be synergistic or cumulative impacts, is difficult and the subject of current research. Support should be given to research aimed at understanding the levels of these toxicants in rivers and creeks, contributing land uses and impacts on aquatic ecosystems.

Long term datasets of known quality are a vital resource for both scientists and natural resource managers. In the context of drought and climate change, with inland waters varying beyond their usual range of fluctuation, continuity of observations is critical[256].

For further information

Waterwatch Victoria
http://www.vic.waterwatch.org.au/

Water Quality attainment and trend reports
http://www.vicwaterdata.net/

National River Contaminants Program
http://products.lwa.gov.au/products/pk071328

IW5 Aquatic Fauna

Key findings

- Extraction of water, regulation of flow regimes and alteration of habitat are major pressures on aquatic fauna and a primary cause of decreasing native fish populations. Declining water availability over the past 11 years is also affecting the fauna of inland waters.
- Many species are now considered threatened, including 21 freshwater and estuarine fish species, 11 frog species and 29 species of waterbirds.
- Macro-invertebrate communities were found to be in good condition across almost half of the reach length assessed as part of the 2004 Index of Stream Condition.
- The total index of abundance for waterbirds in eastern Australia has shown a declining trend over past decades, with 2007 having the second-lowest abundance on record.
- Implications of the decline in the native aquatic fauna of inland waters include the reduced survival and diversity of species, and reduced ecosystem function and ecosystem services.
- Providing environmental flows, and maintaining and improving the quality and connectivity of in-stream habitat and riparian vegetation that supports aquatic fauna through their life history is essential to maintaining the conservation status of threatened species.

Description

Freshwater fauna contributes significantly to Victoria's biodiversity. Victoria's freshwater systems support two species of freshwater mammals (the platypus (*Ornithorhynchus anatinus*) and water rat (*Hydromys chrysogaster*) over 100 species of waterbirds, 33 species of amphibians, 46 species of freshwater fish and an undetermined number of invertebrate species (see Part 4.2: Land and Biodiversity, LB3 Threatened species and pest plants and animals)[257]. High levels of endemism have been identified but uncertainty remains over the current and reference distributions of many of Victoria's aquatic fauna.

Aquatic fauna have intrinsic value and are integral components of inland waters. The other issues covered in this part of the Report—flow regimes, water quality, in-stream and wetland habitat, riparian vegetation and climate change—can impose major pressures on aquatic fauna. Other pressures include introduced species and recreational fishing. Commercial fishing for native fish species, including Murray cod (*Macquaria australasica*), golden perch and silver perch, is now banned in Victoria's inland waters except for some estuaries. Because of their sensitivity to a range of pressures, the condition of aquatic faunal communities, in particular macro-invertabrates, are used as measures or 'bio-indicators' of the condition of a freshwater system and sometimes of the health of its surrounding catchment[258].

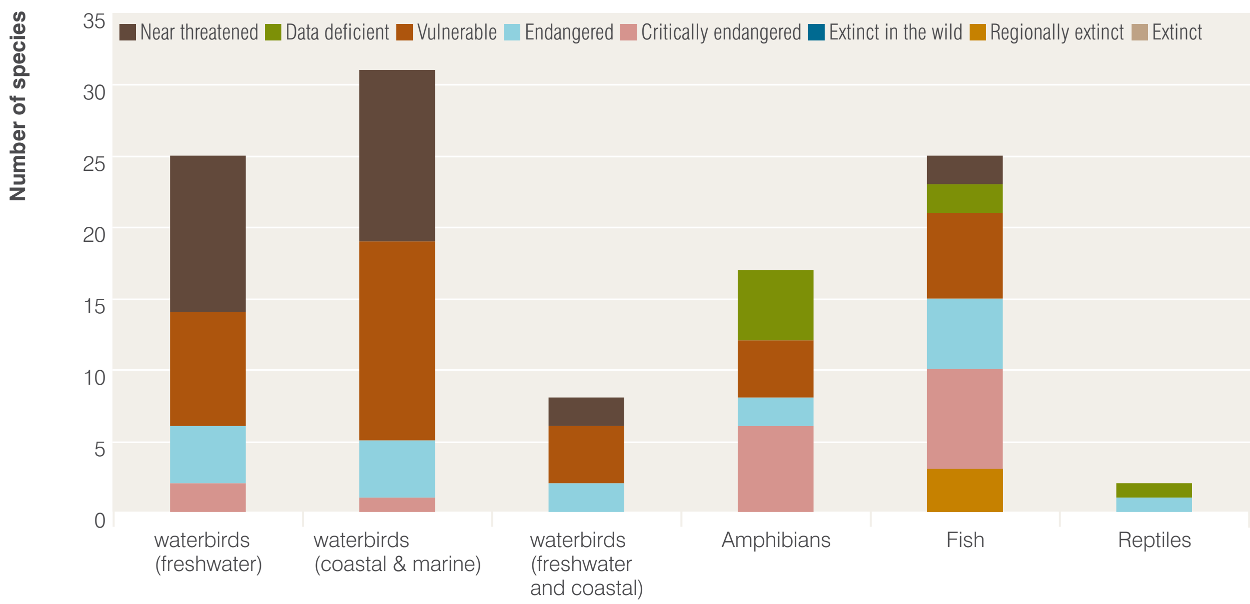
The impact of these pressures is reflected in the number of inland water-dependent species considered threatened under the *Flora and Fauna Guarantee Act 1988*, which includes 21 freshwater and estuarine fish species, 11 frog species and 29 waterbird species.

This section reports the status of aquatic fauna reliant on inland waters. Many species of fish and waterbirds range from freshwater to estuarine and marine habitats, however, and so can't be excluded from this section. Estuarine, coastal and marine fauna are further reported in Part 4.4: Coasts, Estuaries and the Sea. The overall status of biodiversity including threatened species is reported in Part 4.2: Land and Biodiversity.

Objectives

- Improve the conservation status of Victoria's aquatic fauna
- Limit the introduction of new exotic species, and ensure no new exotic species reach pest status
- To protect and improve the habitat of the aquatic fauna of inland waters
- To strengthen the resilience of aquatic fauna to current pressures including climate change

Figure IW5.1 Conservation status of native vertebrate aquatic fauna of inland waters listed in the Advisory list of threatened vertebrate fauna in Victoria – 2007[xi]
Source: DSE (2007)[259]



xi Estuarine fish were also included in this list. All amphibians on the Advisory list are included. Of the reptiles listed, only the two turtle species were considered "aquatic fauna"

State

Indicator IW15 Conservation status of aquatic vertebrate and macro-invertebrate fauna

Many species of aquatic vertebrate fauna are considered threatened under the *Flora and Fauna Guarantee Act 1988.* Further information on the relative conservation status of vertebrate species is provided by the Advisory list of threatened vertebrate fauna in Victoria – 2007[xii] (Advisory list) (see Figure IW5.1).

A total of 21 freshwater and estuarine fish species are listed as threatened under the *Act*. Three species of native fish (Agassiz's chanda perch (*Ambassis agassizii*), freshwater herring (*Potamalosa richmondia*) and southern purple spotted gudgeon (*Mogurnda adspersa*)) are considered regionally extinct under the Advisory list[260]. Seven species are considered critically endangered, including trout cod (*Maccullochella macquariensis*) and silver perch (*Bidyanus bidyanus*)[261]. Five species are considered endangered, including freshwater catfish (*Tandanus tandanus*), Macquarie perch and Murray cod (*Maccullochella peelii peelii*)[262]. A further six species are considered vulnerable, two species are 'near-threatened' or likely to become threatened in future, and there are insufficient data to classify another two species[263].

Frog populations throughout Victoria have declined and 11 out of a total 33 species are considered threatened under the Act[264]. The conservation status of the 17 amphibian species listed in the Advisory list is summarised in Figure IW5.2.

Two species of turtle are considered threatened under the Act; the Broad Shelled Turtle (*Chelodina expansa*) is considered endangered, and the status of Murray River Turtle (*Emydura macquarii*) is considered data deficient.

Twenty-nine species of waterbirds, out of a total of around 100 species, are considered threatened under the Act[265]. Of these, 11 species generally inhabit freshwater systems, 13 species prefer coastal or marine environments[2], and five species may be found in both freshwater and coastal environments[xiii]. The conservation status of the 63 waterbird species listed in the Advisory list is summarised in Figure IW5.2.

Freshwater macro-invertebrates are a diverse group of insects, crustaceans and molluscs that include snails, yabbies, water boatmen, dragonflies, stoneflies and worms. The number of macro-invertebrate species in Victorian freshwater systems is unknown but is estimated to greatly exceed the diversity of vertebrate fauna[267]. In 1997, out of over 100 known species, 14 insects and 19 crustacean species were identified as threatened in Victoria[268].

Platypus is not listed as a threatened species at present[269]. They are common across their range, which extends from tropical Queensland to southern Tasmania[270]. A breeding population exists as close to Melbourne at the mouth of the Plenty River, 15 km from the city[271]. Platypus is protected by law.

The water rat is also distributed widely across eastern Australia, as well as Papua New Guinea and a number of adjacent islands[272]. It occupies a wide variety of habitats and can persist in urban areas[273]. The water rat is not considered threatened[274].

Indicator IW16 Observed versus predicted presence of native fish species

There is general consensus that many native freshwater fish have a reduced distribution and abundance when compared with distribution and abundance prior to European settlement[275]. In the Murray-Darling Basin, it is estimated that fish communities are approximately 10% of previous levels and are in danger of further decline[276].

Historically, few records for fish have been entered into the *Atlas of Victorian Wildlife*, which is the main repository on information on the status and distribution of animal species (see Part 4.2: Land and Biodiversity, Indicator LB21). Information on the condition of native fish communities across Victoria is now collected through the Sustainable Rivers Audit (SRA) which is used for the Murray-Darling Basin. Data for observed versus predicted presence of native fish species are currently available only for the northern basins. The assessment of southern basins will be completed in 2008. Observed data for these basins were collected for the SRA between 2004 and 2006. The predicted species were those believed to have been present in each basin under pre-settlement conditions[277] based on expert knowledge, museum collections and historical data.

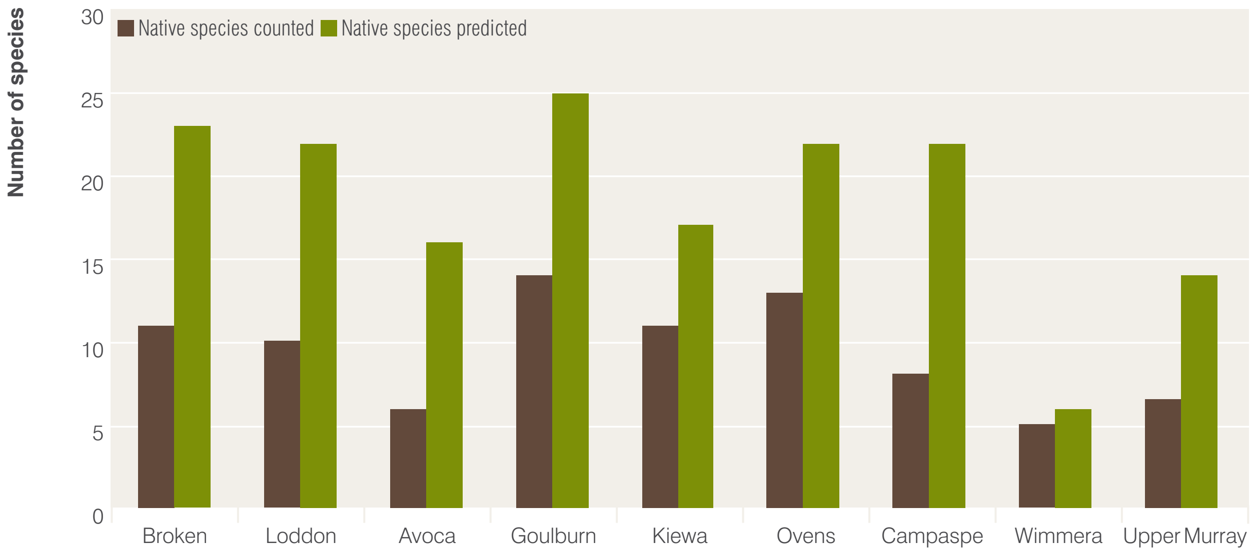
With the exception of basins in the Wimmera (5 species observed to 6 predicted), Goulburn (14 species observed to 25 predicted) and Kiewa (11 species observed of 16 species predicted), only half or less than half of the number of native species predicted to be present were observed (see Figure IW5.2). While the presence of fish in sample locations will vary, the survey results demonstrated consistently lower numbers of native species captured compared to those predicted under reference conditions. This provides a strong indication that native fish species diversity, and hence community integrity, is poor in these areas.

xii The Advisory list can include species not listed under the Flora and Fauna Guarantee Act

xiii Marine species are included here as coastal wetlands are among the areas of wetland considered.

Figure IW5.2 Observed and predicted numbers of native fish species in Victoria's northern basins.

Source: MDBC (2007)[278] Note: the Upper Murray basin shown here combines the SRA's Upper Murray and Mitta Mitta basins



Indicator IW17 Abundance of native fish compared to introduced fish

From 2004 to 2007, 23 out of 29 basins in Victoria were assessed for the abundance of native fish species. Two metrics are reported here: numbers of individual fish per species (abundance) and estimated biomass of each species. Estimates of biomass suggest the relative size of each species.

Information on the condition of native fish communities across Victoria is collected by both Department of Sustainability and Environment and Department of Primary Industries, and through the MDBC Sustainable Rivers Audit.

Overall, the surveys reported a greater abundance in numbers of native fish (71%) than introduced fish in Victoria's rivers and streams.

Basins south of the Divide contain species that require a marine life-phase, whereas these species are largely absent north of the Divide[279].

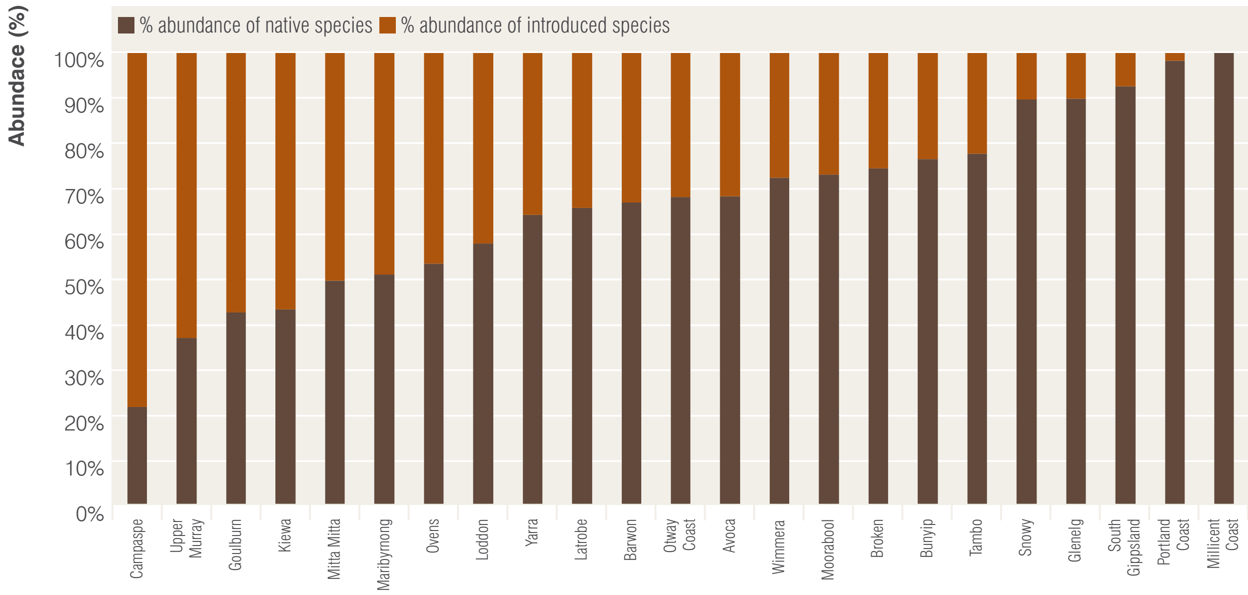
Since European settlement, several exotic species of fish have adversely affected native fish populations. They include rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*), which favour cool upland streams and lakes, and were stocked for recreational purposes[280]. Most trout are now only stocked in 'closed systems' for recreational fishing. Carp, oriental weatherloach (*Misgurnus anguillicaudatus*), gambusia, goldfish (*Carassius auratus*) and redfin perch (*Perca fluviatilus*) are other significant exotic species that prefer slow-flowing or still water[281].

In northern basins, just over half (52%) of the fish captured were native. Abundance of native fish was lowest in the Campaspe basin, where only 21% of all fish captured were native (see Figure IW5.3). Native fish accounted for no more than than half the fish captured in the Upper Murray (37%), Goulburn (42%), Kiewa (43%) and Mitta Mitta (50%) basins. In these basins, cleared land, modified hydrology associated with major water storages and deliberate introduction of non-native fish species for recreational fishing may have favoured introduced fish. In 2007, oriental weatherloach was recorded in the Goulburn River for the first time[282], having spread a considerable distance along the River Murray. The Broken basin had the greatest abundance of native fish in northern basins, with 74% of fish captured being native.

The most common fish species in the Loddon and Avoca basins were a complex of native galaxiid species (Galaxia spp.). Flathead gudgeon (Philypnodon grandiceps) were most common in the Wimmera basin and southern pygmy perch (*Nannoperca australis*) were most common in the Broken basin. Introduced gambusia, otherwise known as the mosquito fish, was the most common species in the Campaspe, Kiewa and Ovens basins, with brown trout the most common species in the Upper Murray and Goulburn basins.

Native fish accounted for less than 40% of the overall fish biomass in each of the northern basins. In six out of 10 basins, native fish accounted for between 4% and 11% of total fish biomass. These were: Upper Murray (MDBC); Mitta Mitta (MDBC); Avoca; Kiewa; Campaspe and Wimmera basins. The Loddon (21%), Ovens (23%), Goulburn (35%) and Broken (37%) basins had relatively higher proportions of native fish in the total fish biomass. These results reflect the abundance of introduced species, but it should be noted that species such as carp, rainbow trout and brown trout are larger than most native fish. For example, in the Avoca basin, introduced fish sampled were on average 50 times larger than native fish[284].

Figure IW5.3 Relative abundance of native fish versus introduced fish in each basin
Source: DSE (2007)[283]

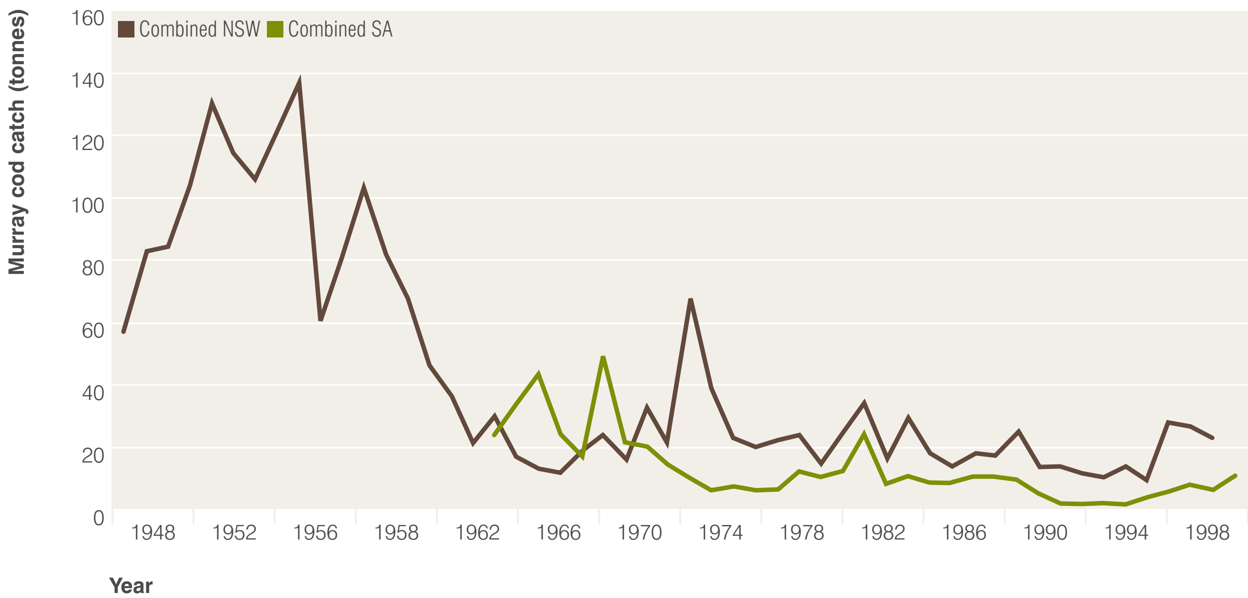


Restocking programs (see IW5 Aquatic fauna, Management responses) contribute significant numbers of juvenile fish, but the contribution of restocking to overall fish populations has not been ascertained.

Historical and anecdotal records indicate that the now endangered Murray cod was once abundant throughout the Campaspe and other basins which make up the larger Murray-Darling Basin[285]. Commercial catch data for Murray cod from NSW and South Australia are believed to reflect the Victorian situation and indicate a dramatic decline in harvest between the 1950s and the 1980s (see Figure IW5.4)[286].

Commercial fishing for native fish species, including Murray cod, golden perch and silver perch, is now banned in Victoria's inland waters except for some estuaries. Over recent years, according to surveys conducted by DPI Victoria, there has been increased angler reporting of Murray Cod numbers, however there are no baseline data available that clearly show if the Murray cod population has further declined over the last 10 years, or started to recover.

Figure IW5.4 Catches of Murray cod by the NSW and South Australian commercial fisheries
Source: DEH (2001)[287]



In contrast, native fish accounted for 82% of fish caught in the southern basins, and in each basin at least half the fish captured were native. The three basins with the lowest abundance of native species were the Maribyrnong (51%), Yarra (64%) and Latrobe (66%). In the Snowy, Glenelg, South Gippsland, Portland Coast and Millicent Coast fbasins, 90% or more of fish captured were native. The Millicent Coast basin, in Victoria's far west, was the only basin in which all the fish captured were native, but the sample size was small (92 fish). However, not all species captured were indigenous to the area, with a small number of translocated carp gudgeon (*Hypseleotris* spp.) identified, whose normal range is the Murray-Darling system.

The short-finned eel (*Anguilla australis*) was the most common native species present in the Barwon and Moorabool basins. Eels were abundant in western Victoria and were important species in several lake systems. Canals and weirs were used by indigenous people to trap eels in the Lake Condah and Toolondo lakes[288]. An estimated 50,000 eels died in Lake Modewarre and another 5,000 in Lake Bolac between October 2004 and January 2006[289]. It is thought that drought played a major role in these deaths[290].

The most abundant species in individual basins were Australian smelt (*Retropinna semoni*), in the Tambo and Snowy basins, and southern pygmy perch in the Glenelg and Portland Coast basins yelloweye mullet (*Aldrichetta forsteri*) in the South Gippsland basin, and common Galaxias (*Galaxias maculatus*) in the Bunyip basin. The most common species captured in the Millicent basin was the native Yarra pygmy perch (*Nannoperca obscura*), at 86% of all individual fish caught. The proportion of biomass contributed by native fish in southern basins was not available.

Recommendation

IW5.1 The Victorian Government should undertake regular, long-term, native fish population surveys across Victoria.

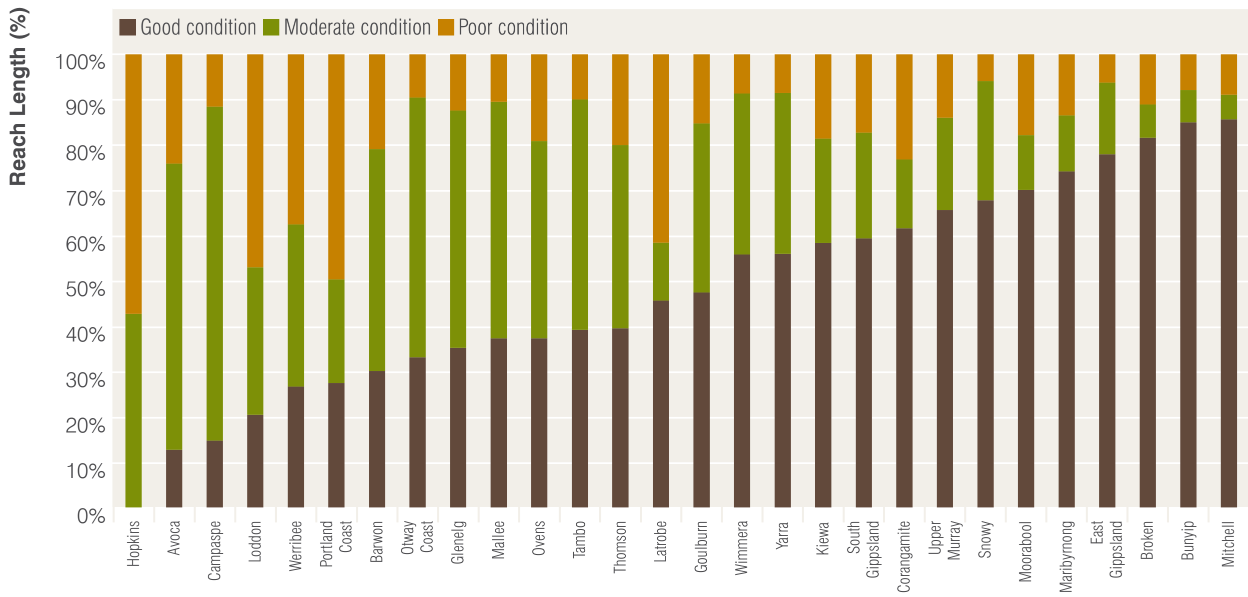
Indicator IW18 – The condition of macro-invertebrate communities of major rivers and tributaries

Aquatic macro-invertebrates are routinely used as indicators of the condition of freshwater systems. They are relatively sedentary, they spend at least part of their life in aquatic ecosystems and are critical to their functioning, and their response to pollution and human disturbances is relatively well understood[291]. Where land use change and habitat modification has been extensive, macro-invertebrate communities show the greatest evidence of impairment[292].

Macro-invertebrate communities were in good condition across 49% of the stream reaches assessed[xiv]. Of the remainder, 32% were in moderate condition and 19% in poor condition. Over half of the river length assessed for macro-invertebrate condition in Victoria (covering 7,138 km and 506 reaches), has been modified. Those areas with significant habitat modification, flow regulation and poor water quality have the macro-invertebrate communities in poorest condition.

Samples can be taken only where water is present, so sites dry at the time of sampling were not included in the condition assessment presented above. As the dry sites are often in poor condition, this may have skewed the results to show better condition than actually existed. Drying and isolated pools are included in the assessment, which may explain some of the lower scores of some basins. Sampling protocols have been amended to capture better data on dry sites[293].

Figure IW5.5 Condition of macro-invertebrate communities of major rivers and tributaries
Source: DSE (2007)[296]



xiv Macro-invertebrate data were available for less than 50% of all ISC reaches. A further 10% of reaches with scores were not physically measured, but extrapolated from nearby reaches after meeting certain criteria.

Changes in macro-invertebrate scores in reference condition sites between 1998 (pre-drought) and 2004 (drought-affected) were identified by the EPA[294]. Notwithstanding the constraints described above, the number of edge habitat sites meeting EPA objectives at reference sites statewide decreased between 1998 and 2004. Macro-invertebrate condition for riffle habitat sites, on the other hand, tended to increase at reference sites statewide over the same period. Low flow conditions in riffle habitat, allowing increased macrophyte and algal growth, were to the advantage of some taxa. For both riffle and edge habitat, little change was noted in the upland forests, with drought having the greatest effect on the lowland forests and cleared hill regions. Since this assessment, there have been four more years of low streamflow, with potentially greater impacts on macro-invertebrate communities.

The macro-invertebrate assessments were not always representative of the basin as a whole. For example, the majority of sites assessed in the highly modified Bunyip basin were clustered by chance in the forested upper parts of the basin, resulting in a condition assessment not representative of the more developed parts of the basin[295]. Random site selection is an important element of monitoring program design but it can lead to uneven coverage of sites across a basin.

Macro-invertebrate communities in the Mitchell, East Gippsland and Broken basins were considered in best condition, indicating that a significant number of their rivers and streams are likely to be close to reference condition (see Figure IW5.5). The Mitchell and East Gippsland basins are generally forested and sparsely populated. Although sections of their lower floodplain reaches have been cleared, a narrow band of vegetation remains along many streams, providing significant habitat for macro-invertebrates in comparison to other more extensively cleared basins. Macro-invertebrate condition is also good in unmodified upland streams.

Of the 28 basins surveyed, the Hopkins, Avoca, Campaspe and Loddon basins demonstrated the poorest macro-invertebrate condition. For example, in the Hopkins basin, 43% of reaches were in moderate condition and 57% in poor condition, indicating that a significant proportion of rivers and streams in the basin fall well short of reference condition. All of these basins are highly modified, with water extraction occurring for irrigation and other consumptive purposes, little to no vegetation in the riparian zones of several rivers and significant clearing of land for agriculture and rural settlements. Large woody debris, an important habitat feature for macro-invertebrates, was sparse in many reaches of these basins (see IW2 In-stream and wetland habitat).

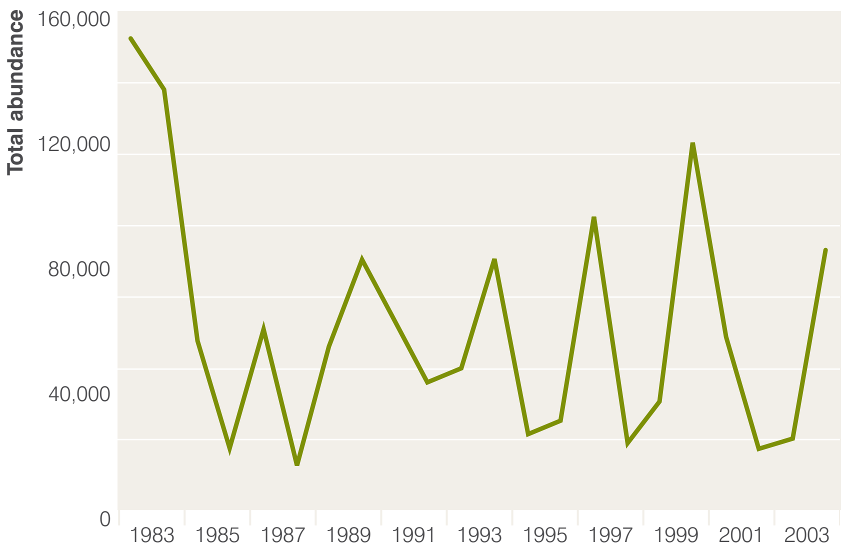
Indicator IW19 the abundance of waterbirds in Victoria

Victorian inland waters provide critical habitat for indigenous and migratory waterbirds. Waterbird communities depend on a range of aquatic organisms for food and can provide an indication of changes to inland water biodiversity, as well as ecosystem health. The abundance (see Figure IW5.6) and distribution of species is indicative of the condition of individual species as well as waterbird species collectively[297].

Annual aerial surveys conducted across eastern Australia from 1983 to 2004 have provided information on the trends and abundance of up to 50 waterbird species, including several threatened species[298]. The index of abundance for waterbirds in eastern Australia has shown a declining trend over past decades, with 2007 having the second lowest abundance on record. The declining abundance coincides with declining habitat availability, which is currently the lowest in 25 years.

The southern-most survey bands (bands 1-3) traverse Victoria and also extend from the Coorong in South Australia across to the NSW south coast. The abundance of waterbirds in these bands shows wide variability rather than an obvious declining trend (see Figure IW5.6). This may reflect the concentration of waterbirds close to available water, as habitat further afield in central NSW and southern Queensland has been severely reduced.

Figure IW5.6 Abundance of waterbirds observed by the Eastern Australian Annual Waterbird Count, in bands 1-3.
Source: Kingsford, R.T & Porter, J.L (2005)[299]



A Victorian survey, the Summer Waterfowl count, has monitored 300 wetlands across Victoria since 1987 (see Figure IW5.7). Survey results show a declining trend in game duck numbers due to the decreasing availability of wetland habitat. A total of 91,210 game ducks were counted in 2007, compared to 182,487 in 2006 and just 41% of the long-term average of 219,465[300].

Pressures

Alteration of habitat is a major pressure for aquatic fauna and a primary cause of decreasing native fish populations[302]. A number of pressures on aquatic fauna are listed as potentially threatening processes under the *Flora and Fauna Guarantee Act 1988*. Processes relevant to freshwater systems are listed below.

Flow regimes

Flow regimes and the pressure they place on freshwater systems are discussed in IW1 Flow regimes, with implications for Aquatic Fauna discussed in IW1 Flow regimes, Implications.

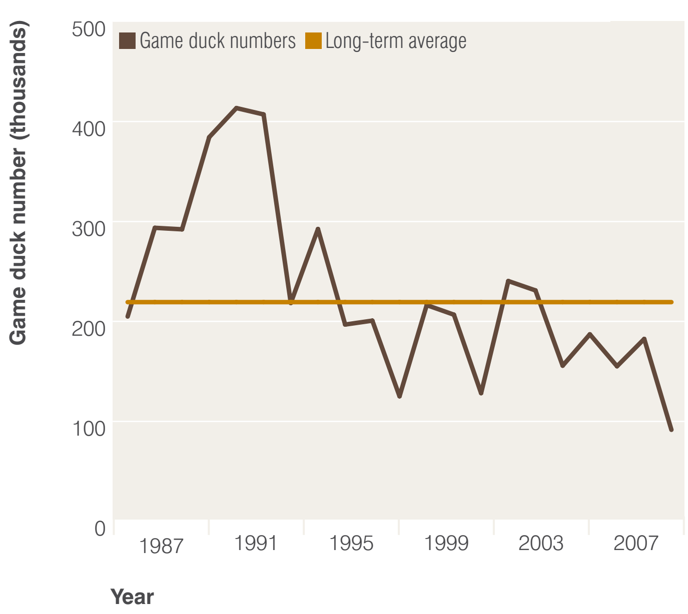
Degradation of in-stream habitat

In-stream habitat and the pressure that its degradation places on freshwater systems are discussed in IW2 In-stream and wetland habitat, with implications for Aquatic Fauna discussed in IW2 In-stream and wetland habitat, Implications. Removal of wood debris from Victorian streams, and prevention of passage of aquatic biota as a result of the presence of in-stream structures are both listed as potentially threatening processes under the *Act*.

Degraded riparian vegetation

Riparian vegetation and the pressures that its degradation places on freshwater systems are discussed in IW3 Riparian vegetation, with implications for Aquatic Fauna discussed in IW3 Riparian vegetation, Implications.

Figure IW5.7 Number of game birds counted by the Summer Waterfowl Count, 1987 to 2007
Source: DSE (2007)[301]



Degraded water quality

Sediment input into rivers and streams due to human activities is listed as a potentially threatening Process under the *Act,* as are two other forms of water pollution:

- Input of toxic substances into Victorian rivers and streams. Herbicides, for example, have been implicated in a number of fish kills, and emerging scientific evidence points to their role in the decline in amphibian populations.[303]
- Alteration to the natural temperature regimes of rivers and streams. Water released from dams, including water released to generate hydro-electricity, may be significantly colder than the surface water, particularly during summer[304]. This form of pollution is pronounced downstream of the Hume, Eildon, Thomson and Dartmouth Dams, and a further 49 dams may be implicated[305].

Introduced species

Introduction of live fish into waters outside their natural range within a Victorian river catchment after 1770 is listed as a potentially threatening process under the Act. Introduced species and translocated native species place pressure on native aquatic fauna through predation, competition, aggressive behaviour, disease and habitat modification. Humans have played a major role in the dispersal of exotic freshwater species in Victoria[306] for recreational fishing, ornamental purposes and biological control, while translocation of native species has been used for aquaculture and to enhance recreational fishing.

Recreational fishing and hunting

Recreational fishing and hunting exert a small but localised pressure on aquatic fauna through removal of fish and waterbirds, bank erosion and associated trampling of riparian and aquatic vegetation. Over the past 13 years, the duck hunting season has been cancelled due to low bird numbers or breeding activity in 1995, 2003, 2007 and 2008.

Climate change

Many of Victoria's freshwater systems are sensitive to climate variations[307] and climate change will be a major pressure on aquatic fauna over the next few decades[308] (see IW6 Impacts of Climate Change on Inland Waters for more detail).

Disease

Infection of amphibians with chytrid fungus, resulting in chytridiomycosis is listed as a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) and the *Flora and Fauna Guarantee Act*. This fungus is known to affect the critically endangered spotted tree frog[309].

Implications

Ecosystems are generally very dynamic, but recent research indicates that, if certain tolerance thresholds are exceeded for some species, their resilience will be lost and ecosystems may change irreversibly[310]. If keystone species such as Murray cod are lost, this regime change can prove even more dramatic as cascading changes in ecosystem structure and function take effect. Generally, the presence of a number of freshwater species with similar ecosystem functions but different responses to catchment modification may enhance the resilience of ecosystems[311]. A diversity of ecological responses to threats and pressures helps to insure ecosystems against the disturbances produced by climate change.

Reduced survival and diversity of species

In those systems affected by river regulation, fewer fish are able to breed, fewer fish survive to adulthood and, eventually, fewer fish species survive[312]. For example, the highly-regulated Campaspe River supports significantly fewer native fish species than the less-regulated Broken River. The most-regulated upper sections of the Campaspe River support far fewer species and much lower abundances of fish larvae because river regulation has reduced habitat availability and quality[313]. Furthermore, modification of seasonal patterns of flow eliminates natural triggers for migration and spawning in native fish and affects the survival of juvenile fish.

Reduced flooding and increased river regulation has led to reduced waterbird breeding. Where river regulation and diversions upstream have caused a significant long-term decline in river flows, waterbird abundance and diversity has declined significantly over the corresponding period[314].

Removal of large woody habitat in northern Victoria has added to the fragmentation and reduction in Murray cod populations. Reduction of in-stream woody habitat has created large stretches of waterways in Victoria unsuitable for Murray cod. Its poor conservation status is largely attributed to this factor[315]. Murray cod are highly territorial, and prefer submerged wood habitat for spawning and shelter. Up to 80% of these fish are found within a metre of a snag. Furthermore, Murray cod, and freshwater blackfish, are known to lay adhesive eggs on or in logs[316]. Sedimentation, along with trout and redfin predation, has also been an important contributor to the decline of fish species such as the Macquarie perch (*Macquaria australasica*) in Victoria[317].

The implications of degraded water quality on aquatic fauna are presented in IW4 Water Quality, Implications.

The major implication of cold water releases from dams is the direct loss of species such as Murray cod, trout cod, Macquarie perch, golden perch (*Macquaria Ambigua*) and silver perch from affected reaches[318]. Following the construction of the Dartmouth Dam in 1980, populations of trout cod, Macquarie perch and Murray cod were lost from the Mitta Mitta River, due to cold water releases inhibiting spawning and favouring the introduced brown trout[319].

Poor water quality can result in mass deaths of fish and other aquatic fauna. Three major incidents involving large Murray cod in Victoria were reported between 2002 and 2004. One of these events, on Broken Creek in November 2002, resulted in the death of over 179 adult Murray cod[320] and another event in the Goulburn River in January 2004 resulted in the death of several thousand fish[321]. Suggested causes included low dissolved oxygen, high levels of suspended sediment, and sudden changes in temperature and herbicide inputs[322].

In 2006–07, seven fish death incidents were reported in north-western Victoria, with all but two incidents involving less than 50 fish[323]. Likely causes included high temperatures, low dissolved oxygen and low flow.

Poor water quality can also have major impacts on populations of aquatic fauna. Large, mature fish take a long time to replace. It was estimated that a replacement program with an 80% chance of restoring the Murray cod lost in either the Broken Creek or Goulburn River fish kills would cost approximately $1.5 million and take about 30 years[324].

While much smaller than the trout species, the aggressive gambusia has been implicated in the decline of at least nine of species of fish and the decline of more than 10 frog species in Australia[325]. Gambusia chase and fin-nip fish much larger than themselves prey on the eggs of native fish and frogs and larval native fish and significantly reduce growth rates of small native fish[326].

The impacts of carp on native fish communities are not clear but their high abundance in many streams and lakes indicates they are probably competing with native fish for food and space[327]. Their feeding behaviour is a concern because it may alter zooplankton levels, increase turbidity and bank instability, and even increase the risk of algal blooms[328].

The distribution and abundance of native galaxiid species in south-eastern Australia, such as mountain galaxias (*Galaxias olidus*) and barred galaxias (*Galaxias brevipinnis*), have been seriously reduced wherever brown trout and rainbow trout have been introduced[329]. These large predatory fish are also thought to impact on a number of threatened frog species such as the spotted tree frog (*Litoria spenceri*)[330]. The spotted tree frog has also been adversely affected by sedimentation[331].

Toxicological studies have shown the high sensitivity of frogs to a wide range of contaminants present in the surrounding environment, due to their semi-permeable skin[332]. At exposure to low concentrations of contaminants, normal patterns of growth can be altered[333], resulting in abnormalities of the limbs. Trace amounts (0.1 parts per billion) of the herbicide atrazine, Australia's second most commonly used agricultural pesticide, have been found to cause male frogs to grow ovaries[334]. Simazine, a related herbicide, was found to have similar effects.

Reduced ecosystem function and ecosystem services

Loss of aquatic fauna can have cascading effects on the conditions of inland waters. For example, research has shown that depletion of freshwater macro-invertebrate diversity due to predation by brown trout can influence nutrient spiralling[xv] and decrease water quality. Predation by this introduced species on algal grazers such as freshwater molluscs has been shown to increase the risk of algal blooms downstream[335].

Climate change will have serious repercussions for aquatic fauna and ecosystem services. Primarily, climate change will affect aquatic fauna through changes to rainfall and flow regimes, altering the availability and quality of their habitat. Climate change will also impact aquatic fauna by altering the nature and intensity of the existing pressures. For many aquatic species already vulnerable, the risk of local and broader extinctions will increase and northern species, such as spangled grunter (*Leiopotherapon unicolor*) and an introduced cichlid fish, tilapia, may be able to move south. One tilapia species has established a population in the warm water storages of the Hazelwood power station near Morwell[336].

Extinction of aquatic fauna due to climate change will impair the ability of inland waters to provide ecosystem function and reduce ecosystem stability and recovery potential in a rapidly changing environment. As a consequence, capacity to generate ecosystem services will be reduced[337].

Recommendation

IW5.2 The Victorian Government, in conjunction with other State and Commonweatlh Governments, improve knowledge and information regarding resilience and thresholds for species, communities and ecosystems in respect of water quality, reduced flow and invasive species.

Management responses

Aquatic fauna face numerous pressures, as reported throughout this section. Management responses must maintain and improve habitat which supports ecological communities as well as cater for species-specific needs. Some of the management responses of most benefit to aquatic fauna are improvements to in-stream habitat, riparian vegetation, water quality and consistent provision of worthwhile environmental flows, described in the preceding sections.

The Murray-Darling Basin Council's Native Fish Strategy (2003–2013) outlines responses to major pressures to fish populations in the Murray-Darling Basin. The *Flora and Fauna Guarantee Act 1988* is failing to meet its stated objectives and is in need of review (see Part 4.2: Land and Biodiversity, LB3, Management Responses). The *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) is also reported in Part 4.2: Land and Biodiversity, LB3, Management Responses.

Response Name
Guidelines for Assessing Translocations of Live Aquatic Organisms in Victoria

Responsible Authority
Department of Primary Industries, Department of Sustainability and Environment

Response type
Guidelines

These guidelines provide a framework for the assessment of proposals to translocate live aquatic organisms within and into Victoria, which require approval under the *Victorian Fisheries Act 1995*[338]. Translocation is the deliberate, human-assisted movement of aquatic organisms using associated transport media[339]. The scope of these guidelines includes the stocking of introduced species such as trout for recreational fishing, as well as the stocking of native fish for both recreational fishing and conservation. Standard protocols have been developed for the most common types of translocation.

Accidental movement of aquatic organisms is dealt with by other legislative and administrative arrangements.

Recommendation

IW5.3 The Victorian Government should develop a State action plan for exotic aquatic species.

Response Name
Native Fish Restocking Program

Responsible Authority
Department of Primary Industries

Response type
Recovery program

Native fish populations have been augmented by stocking of fingerlings since 1988[340], and this currently occurs under the *Guidelines for Assessing Translocations of Live Aquatic Organisms in Victoria* (see Table IW5.1). The purpose of stocking is to support recreational fishing and maintain native fish populations. However, stocking of trout cod, which is considered critically endangered under the Advisory list is specifically for conservation[341]. Murray cod, golden perch, silver perch and trout cod are stocked into inland waters north of the Divide. Australian bass, which is native to coastal streams south of the Divide and east of Wilson's Promontory, are stocked into selected lakes in this region.

While restocking programs contribute significant numbers of juvenile fish, the proportion of overall fish populations resulting from restocking has not been ascertained. Large, mature fish lost through poor water quality events are not easily replaced by restocking programs, despite the large numbers of fingerlings stocked (see IW5 Aquatic Fauna, Implications).

xv Spiralling is the nutrient cycling process superimposed on the downstream movement of waters

Table IW5.1 Number and species of native fish stocked to inland waters since 2000
Source: DPI (2008)[342]

Year	Murray cod	Golden perch	Australian bass	Silver perch	Trout cod
2000	137,008	400,000	10,200	5,000	22,430
2001	242,250	376,220	10,000	10,000	51,700
2002	332,425	566,000	22,450	20,000	30,000
2003	185,950	296,500	79,350	15,000	44,260
2004	243,979	620,725	10,000	15,000	30,000
2005	194,500	725,000	10,000	20,000	24,900
2006	281,850	298,270	0	10,000	10,400
2007	119,895	544,090	0	5,000	0

Recommendation

IW5.4 The Victorian Government should incorporate all native fish stocking into population rehabilitation plans.

Evaluation of responses to aquatic fauna

In addition to the measures described above and in previous sections, there are many other management responses to pressures on aquatic fauna.

Through the *Murray-Darling Basin Council's* Native Fish Strategy (2003–2013), fish passage is also being improved along the main stem of the River Murray, which should help support fish populations in Victorian tributaries. In 2001, the Murray-Darling Basin Commission initiated a program to improve fish passage from the sea to the Hume Dam, a distance of over 2,000 km. Fourteen fishways have been constructed and monitoring suggests that they are passing large numbers of fish (>50,000 fish over 40 days) with a high diversity of species (13 species) and a wide range of sizes (40 mm to 1,000 mm long)[343].

Environmental water has been vital in maintaining minimum standards of water quality to support aquatic fauna in recent years. The Lake Eildon water quality reserve has been used several times to improve Murray cod habitat in Broken Creek, and water was also released to maintain habitat for the Murray hardyhead *(Craterocephalus fluviatilis)* in spring 2007. Controversy surrounding the second release (despite the relatively small volume of water (1.6 GL) required) demonstrates the pressures that are brought to bear on environmental water managers.

Under the *Flora and Fauna Guarantee Act*, action statements have been developed for some threatened species, including nine fish species, four amphibian species and a number of waterbird species. Recovery plans have also been developed for some species of fish. Development and implementation of these recovery plans and action statements to allow long-term restoration and management of these populations would assist the conservation of these species. Long-term, statewide surveys of populations, such as the State Waterfowl count and the fish surveys described in Section 6.4 are important management tools that deserve ongoing funding.

For further information

Fishes of the Murray-Darling Basin
http://publication.mdbc.gov.au/index.php

Recommendations

IW5.5 Recovery plans for threatened species should be implemented systematically, for the long-term benefit of the species

Photo: Geoffrey Browne

IW6 Impacts of Climate Change on Inland Waters

Key findings

- By 2030, streamflow may vary from no change or slight increases in East Gippsland to 25-40% decreases in river systems in western and north-western Victoria. By 2070, streamflow may decrease by up to 50% across much of the State.
- A rise in temperature of 1°C in the Murray-Darling Basin reduces the annual climatological inflow by 15%, even if rainfall does not change.
- By 2020, a 10-40% reduction in snow cover is likely with potentially significant consequences for alpine and downstream inland waters in Victoria. Under a medium climate change scenario, frequency of significant floods in the Barmah forest will be once in 17 years. River red gums require significant flooding every five to 10 years, which means that without intervention, these trees are unlikely to survive.
- Forest regrowth following more frequent bushfires will be associated with heavy uptake of water by the young trees at the same time as predicted reductions in rainfall. This will have a significant impact on streamflow.
- The current degraded state of many inland waters increases the challenge of mitigating the environmental impacts of climate change.
- In the northern region, most of the water allocated to the environment is in the components of flow that will be most impacted by climate change; and thus potentially may no longer be able to meet the intended environmental objectives.

Description

Current projections indicate that Victoria's future climate is likely to be warmer and, for most of the State, drier than during the second half of the twentieth century[344] (see Part 4.1: Atmosphere, Climate Change).

With lower water availability across most of Victoria, streamflow and recharge of groundwater are likely to decrease and soil moisture will reduce.

Victoria is heavily dependent on surface water availability, with 84% of water harvested for consumption in 2006–07 coming from surface water sources. The decade of low streamflow has highlighted the vulnerability of domestic and rural supply systems to prolonged reductions in its availability.

Lower streamflow increases the impact of consumption on flow regimes, which are already degraded in many rivers (see IW1 Flow regimes). With climate change, competition for water resources is likely to increase, and the decisions made to determine how Victoria's water is allocated, and the level of environmental degradation that may result, will be a major consideration as the costs associated with maintaining healthy inland waters rise.

The implications of climate change for specific ecological communities are not well understood. The effects are expected to be varied and complex, but generalisations are possible. Inland waters are already degraded, and are under ongoing pressure from human activities. Climate change is an additional pressure on Victoria's degraded inland waters.

The impact of climate change will depend on the rate at which it occurs, and the extent to which the frequency of extreme events changes. If the magnitude or rate of climate change is outside the range of past variations and exceeds the capacity for species to migrate or adapt, the vulnerability of inland waters will increase[345].

Climate change will also exacerbate other pressures which may cumulatively reduce water availability such as the loss of connectivity of rivers, forests regenerating after bushfires, the legacy of historic groundwater extraction, and increased interception of catchment runoff due to forestry activities, farm dams and salt interception schemes.

The purpose of this section is to identify the impacts of climate change for Victorian inland waters.

Objectives

- Improve decision support systems to mitigate the impacts of climate change on inland waters
- Identify, protect and restore inland waters and, in particular, drought refugia crucial for supporting biodiversity and ecosystem resilience
- Improve the management of rivers and wetlands during drought
- Manage catchments and riparian zones to minimise the risk of extreme events such as bushfires and flooding to inland waters

State

The current state of Victoria's climate and projections for climate change are examined in detail in Part 4.1: Atmosphere, Climate Change.

Pressures

The key pressures arising from climate change for inland waters are described in Part 4.1: Atmosphere. In summary, these include: uncertain changes in rainfall but drier conditions are more likely for most of the State; significant rises in average annual temperature, especially for overnight minimums; greater frequency of extreme weather events such as severe storms and floods; greater frequency and intensity of forest fires; sea level rise; and diminished snow cover and duration.

The impact of these pressures on inland waters is closely linked to the impact of these pressures on catchments, which are discussed in Part 4.2: Land and Biodiversity.

Implications

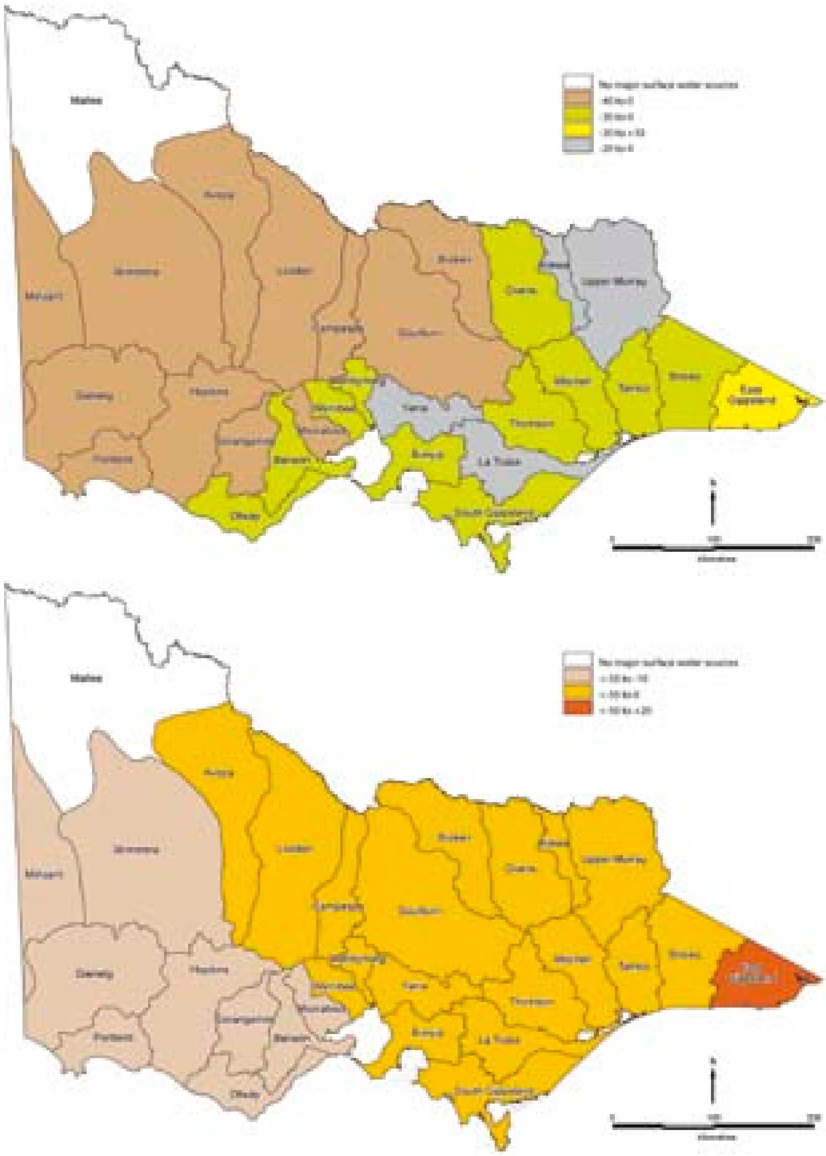
Reduced water availability

The major implication of climate change for inland waters is the likelihood of reduced water availability across most of Victoria. Based on historical data, runoff into rivers decreases by approximately two to three per cent for every one per cent decrease in rainfall[346]. By 2030, streamflow may vary from no change or slight increases in East Gippsland to 25% to 40% decreases in river systems in western and north-western Victoria (see Figure IW6.1)[347]. By 2070, streamflow may decrease by up to 50%. However, the evidence to date suggests that climate change is progressing more strongly than that described in the highest scenario used by the Intergovernmental Panel on Climate Change[348]. In rivers where flow is not regulated by dams and weirs, reduction in flow is likely to be greater during winter, when rainfall decreases are predicted to be larger[349]. Less rainfall and higher evaporation will also reduce groundwater recharge, resulting in lower watertables.

Victoria has already experienced a decade of low streamflow (see Part 3.2: Water Resources) which, in many rivers, particularly in the northern and central areas, has generally been greater than in the 'high' climate change scenario for 2030[350]. It is not clear whether the reduction in streamflows over the past decade is due to climate change, but climate change has been implicated in the step changes to streamflow recorded over the past four decades in south-western Western Australia. Many of the weather systems that bring rain to south west Western Australia also bring rain to Victoria, although the reduction in rainfall there was likely to be caused by different mechanisms to those reducing rainfall in Victoria [351].

Temperatures are likely to increase under climate change. There is evidence that rising temperatures have had a strong impact on the water resources of southern Australia[353]. Historical data from the period 1950 to 2006 show that a rise of 1°C in the Murray-Darling Basin leads to an approximate 15% reduction in the annual climatological inflow, even if rainfall does not change[354].

Figure IW6.1 Predicted change in annual runoff for Victoria's river basins in 2030 (top) and 2070 (bottom)
Source: Victorian Government (2007)[352]



Evaporative losses in storages, which are already considerable, will also increase (see Part 3.2: Water Resources). Reduced rainfall and lower soil moisture caused by higher rates of evaporation will increase the demand for irrigation water[355]. These factors are all likely to increase competition for available water. Seasonal and intermittent waterbodies will dry out more rapidly, which may affect the resilience of ecosystems.

Flow regimes

During years of low streamflow, the flow to support environmental function in many rivers reduces disproportionately, due to competition with water consumption. For example, a 35% reduction in the total flow in the Upper Murray basin in 2004–05, compared to annual average flows, resulted in a 76% decrease in the volume of water available for the environment (see Part 3.21 Water Resources). Under climate change, the reduction in flow available to support environmental function will therefore be proportionately less than that shown in Figure IW6.1, unless there are changes to water allocations. The condition of flow regimes, which is already poor across many basins in Victoria, will therefore decline even further.

The effects on components of the flow regime are also important. The *Northern Region Sustainable Water Strategy* discussion paper provides examples of the impacts of climate change on the high and cease-to-flow components of flow regimes in northern rivers. Flood frequency reduces with higher climate change scenarios. Even under a medium climate change scenario, with current patterns of water consumption, the gap between significant floods in the Barmah forest will be at least 17 years. Red Red Gum forests require significant flooding every five to ten years[356], which means these trees are unlikely to survive[357]. With tens of thousands of hectares of forests and wetlands already at risk of being lost, the River Red Gum forests face a bleak future without decisive intervention. Species such as egrets, herons, spoonbills, and Murray cod also depend on the flooding of floodplains and riverine wetlands for suitable breeding habitat, and their continued survival will also be affected by the reduced frequency of flooding[358].

Reduced water availability also increases the length of cease-to-flow events. The Loddon River has ceased to flow for longer than two months only twice in the past 114 years–in 2004 and 2005[359]. If the inflow patterns of the past decade are applied to the 114-year historic record, there are about 20 cease-to-flow events longer than two months[360]. This change could lead to the disappearance of the regionally important river blackfish[361].

The environmental water reserve, which is the environment's right to water, consists of several different components within the allocation framework. In the northern region, only a very small percentage of the environmental water reserve has high reliability, and most of the water allocated to the environment is in the components of flow that will be most impacted by climate change. The environmental water reserve can be qualified for consumptive use by ministerial discretion to meet critical human need. In 2006/2007 there were 40 temporary reductions in the environmental water reserve across the State to maintain water supplies for human consumption. With increased competition for water resources into the future, the allocation system must be sufficiently robust to deal with water scarcity, and give equal status to the environment's right to water.

Across Victoria, flow regimes are most altered from their natural condition in summer, and the most altered component during this time is low flow (see IW1 Flow regimes). Under climate change, further reductions in low-flow levels may occur due to reduced groundwater recharge or the effects of consumption discussed above. Changes to the catchment, such as the channelisation of streams and wetlands and urbanisation, are likely to enhance this tendency, as they result in water moving more quickly through the catchment. The implications of degraded flow regimes are explained in IW1 Flow regimes, Implications. During the decade to 2005/06, autumn rains generally failed, decreasing by 61%[362]. If this proves to be a feature of rainfall patterns under climate change, then it is likely the low flow period in summer will lengthen, increasing the stress on streams.

Furthermore, higher temperatures since the 1950s have reduced the snow season in the Australian Alps, leading to more precipitation falling as rain rather than snow, and earlier melting of snow on the ground[363]. By 2020, a 10-40% reduction in snow cover is likely[364], resulting in earlier peak autumn and winter flows, and possibly higher peak flows[365].

The predicted increase in the frequency of bushfires may result in short-term increases in streamflow[366], followed by longer-term reductions. Once regenerating forest reaches a phase of rapid growth, which may take 10 to 15 years[367], it uses more water than mature forest. It is estimated that regrowth of vegetation following the 2003 alpine fires will reduce flows to the River Murray by up to 700 GL a year or 10% of mean annual flow[368]. The maximum reduction in flow is expected to occur 20 to 25 years after the fire[369], with impacts continuing for another 80 to 100 years after that time[370].

Reduced groundwater recharge has the potential to decrease low-flow levels in streams, and lower water levels in wetlands. As a result, patterns of wetland inundation may change, and seasonal wetlands may become ephemeral. On the other hand, reduced levels of groundwater recharge may assist the control of salinisation. Lower groundwater levels may stress riparian and wetland vegetation that is dependent on groundwater.

Rising sea levels may increase inundation of coastal wetlands and floodplains, and the length of estuarine reaches of rivers will increase.

Biodiversity

Inland waters and their biodiversity have been degraded and subject to numerous pressures. Climate change will exacerbate the impacts of many of these pressures on biodiversity.

The frequency of disturbances to inland waters, such as droughts and bushfires, are likely to become more frequent. While aquatic communities are adapted to these natural disturbances, they depend on having adequate refugia, and time between disturbances, in which to recover.

Refuges can be provided by intact riparian vegetation, as well as pools in rivers. When flow returns, or following a bushfire, populations can disperse and re-colonise the rejuvenated landscape. Due to the fragmentation and degradation of inland waters however, many of these refuges are damaged or inaccessible. Populations fragmented by barriers, such as the river blackfish in the Loddon River, or those with low mobility, such as freshwater mussels and crayfish, may be particularly affected by the increasing lack of suitable habitat during droughts.

Following the 2003 alpine fires, 30% of sites monitored in an EPA study of fire-affected areas in eastern Victoria showed declines in stream health after the fires, as measured by macro-invertebrates rather than by an Index of Stream Condition assessment. In most cases the streams recovered to pre-fire levels of health within three years. The recovery of native fish populations may be more affected by fragmentation due to barriers and predation by rainbow and brown trout, and therefore may be slower.

As noted in IW5 Aquatic Fauna, Implications, a loss of resilience among key species can irreversibly alter an ecosystem's structure and function[371].

Local extinction of freshwater fauna species due to climate change impacts will not only impair the ability of freshwater ecosystems to provide ecosystem functions but, by reducing biodiversity, will also threaten system stability and recovery potential in the rapidly changing environment.

Recommendations

IW6.1 The Victorian Government should consider listing climate change as a threatening process under the *Flora and Fauna Guarantee Act 1988.*

IW6.2 Identify drought refugia and ensure adequate protection and improvement of sites during drought.

IW6.3 Provision of adequate EWRs for all rivers should receive priority over the provision of drought refugia.

Water quality

Climate change will modify existing pressures on water quality. Victoria has experienced higher temperatures over past decades leading to higher water temperature. Temperature is a controlling variable for the distribution of many species of aquatic fauna, and will have implications for the distributions of sensitive species. Changing temperature regimes will interact with other pressures, such as the fragmentation of populations, to dictate species' distributions. These implications may be mixed in the sense that the distribution of invasive species like trout, as well as those of native species, may be limited.

Higher temperatures reduce the capacity of water bodies to store dissolved oxygen, and may increase the tendency to thermal stratification in stationary water bodies such as dams and weir pools. Combined with lower inflow rates and higher rates of plant respiration, this may increase the frequency of low dissolved oxygen concentrations. Over the 2007/2008 summer for example, there were several occasions where water had to be released along Broken Creek to increase dissolved oxygen concentrations and avert Murray Cod deaths[372]. Smaller volumes of water present under low flow conditions are also susceptible to larger variations in water temperature, in particular from high summer temperatures. Water bodies under pressure from high nutrient levels or modified flow regimes, such as weir pools, will be particularly susceptible. As a result algal blooms are likely to increase in frequency[373].

Reduced levels of groundwater recharge may assist the control of salinisation[374] but, higher rates of evaporation may lead to high concentrations of salts and other pollutants in surface waters.

The occurrence of fire events is likely to increase. These can lead to both short and long term effects on stream health and water quality, including sedimentation and algal blooms, due to nutrients bound to the sediment[375].

Climate change may also result in acidification of inland waters, through the exposure of acid sulfate soils to oxygen[376]. In an undisturbed state, below the water table or covered by surface water, acid sulfate soils are benign and not acidic. Exposure to oxygen can occur through drying of surface water, lowering of groundwater tables through lack of recharge, excessive extraction or dewatering processes, or excavation. This triggers chemical and micro-biological reactions that generate significant amounts of sulfuric acid, which can be extremely damaging to the environment. Acidification of wetlands due to excessive groundwater extraction and reduced recharge has occurred along the Swan Coastal Plain near Perth, Western Australia[377].

Recommendations

IW6.4 Identify areas most at risk of in-stream habitat loss or degradation due to climate change impacts and incorporate these into regional river health strategies.

IW6.5 Increase the knowledge and understanding of the impacts of climate change on the environmental values of inland waters; including risks posed by acidification.

Management responses

Climate change presents a major challenge to water resources planning because it will reduce water availability. The current degraded state of many inland waters increases the challenge of mitigating the environmental impacts of climate change. Developing the knowledge and tools to analyse and plan proactively, given the risks and uncertainty associated with a changing climate, is a high priority of water sector responses to climate change.

Management responses to climate change are also reported in Part 4.1: Atmosphere, Climate Change.

Response Name

Estimation of water availability, Murray-Darling Basin Sustainable Yields Project

Responsible Authority

CSIRO

Response type

Model

The CSIRO has been contracted by the National Water Commission to report on current and future water availability in the Murray-Darling Basin. This contract, which was initiated in 2006 for completion in 2008, is the largest in CSIRO's history[378]. A computer model of the Murray-Darling Basin's water resources has been developed that simulates surface water and groundwater flows and extractions within the basin's catchments and the interactions between the catchments.

The model simulates multiple climate scenarios: the historical record, the past 10 years, a range (dry, medium and wet) of possible climates by 2030, and takes account of the influences of forestry, farm dams and groundwater extraction[379]. In all, over 600 permutations have been simulated[380]. This information can be used to assess the basin-wide impacts of management decisions in any one part of the basin, with greater confidence and rigour than previously possible.

Current and future water availability for the 18 regions of the Murray-Darling Basin has been finalised. Assessments of the environmental requirements of inland waters are not directly addressed in these reports. While decisions about sustainable yields, and who gets the water, should be informed by the best available science, they also require community input and political deliberation.

Response Name
South Eastern Australian Climate Initiative

Responsible Authority
Murray-Darling Basin Commission, in collaboration with Department of Sustainability and Environment, The Australian Greenhouse Office (within the Department of the Environment and Water Resources), Australia's Managing Climate Variability program, CSIRO and Bureau of Meteorology.

Response type
Research program

The South Eastern Australian Climate Initiative (SEACI) is a $7 million, three-year program to investigate causes and impacts of climate change and climate variability across south-eastern Australia[381]. The initiative commenced in 2006 and the research has three main themes[382]:

- Assess the current level of knowledge about climate variability and its drivers over south-eastern Australia
- High-resolution climate projections and impacts to determine the extent to which climate in south-eastern Australia are likely to change under enhanced greenhouse conditions (changes in average climate, inter-annual variability and extreme events, and associated impacts on streamflows)

Investigate whether reliable climate forecasts with a lead time of three to 12 months can be applied to south-eastern Australia, and if they can be applied to crop forecasts and streamflows.

Evaluation of responses to the impacts of climate change on inland waters

Inland waters are an integral part of the landscape, and as the climate changes, may become even more important as refugia and links between different bio-regions. It is therefore important that the commitment to restore river condition stated in *Our Water Our Future* is maintained.

Understanding of the impact of climate change on the water sector is developing rapidly, and is being assimilated into long-term planning. This is illustrative of how quickly water resource planning is changing (see Part 3.2: Water Resources, Management Responses). The assumptions used in these strategies recognise that climate change may result in 'step changes' to streamflow. As pointed out in IW1 Flow Regimes, Implications, the return of environmental entitlements in the Northern region are dependent on 'normal' rainfall and implementation of entitlements for the Central region have been delayed until water storages recover[383]. This policy appears inconsistent with current projections for climate change and appears to undermine the purpose of the environmental water reserve.

Pressures outlined in earlier sections reduce the capacity of inland waters to resist and recover from events such as drought which are likely to become more common as the climate changes. Management responses such as the improvement of riparian vegetation and connectivity of habitat proactively minimise the impacts of drought[384]. Thus, management responses outlined in earlier sections may also play important roles in adapting to a changing climate.

The implications of climate change for specific ecological communities are not well understood, nor are potential changes in distribution of key aquatic fauna. As a first step, catchment management authorities have identified drought refuges as a feature of drought response plans[385]. These refuges could be given high priority in the allocation of environmental water.

Difficult decisions will need to be made in future as the availability of water declines. Under severe climate change, further trade-off of environmental assets may be considered. If this occurs, acknowledgement must be given to the implicit trade-offs that have already occurred through the development and modification of inland waters.

The decisions are ultimately social and therefore political choices. The processes by which these are made can and must be improved. Decision making must be evidence based, transparent, equitable and grounded in the understanding that healthy communities ultimately depend on a healthy environment. The greater the 'water literacy' and climate awareness of the broader community, the greater the prospect of the difficult long-term decisions that the government needs to make being more widely understood and accepted by the community.

For further information

Sustainable Yields Project reports
http://www.csiro.au/partnerships/MDBSY.html

Northern Region Sustainable Water Strategy Discussion Paper
http://www.ourwater.vic.gov.au/programs/sws/northern/strategy

Risks to the Shared Water Resources of the Murray Darling Basin
http://www.clw.csiro.au/forms/pubslist/Default.aspx?au=van%20dijk,%20a&an=Albert%20Van%20Dijk


Photo: Courtesy of DSE