

Action Statement

Flora and Fauna Guarantee Act 1988

No. 178

Alteration to the natural temperature regimes of rivers and streams

Description

The temperature of the water in streams and rivers is an important factor contributing to habitat quality. The natural water temperature regimes of rivers and streams in Victoria are primarily a function of air temperature - colder in winter, warmer in summer. Under natural conditions, most water bodies have annual temperature variations that reflect these seasonal changes. Water temperatures, however, are usually lower than air temperatures so that even when air temperatures are high, only the surface water of the river or stream is heated. Colder groundwater flows tend to keep the temperature cooler.

All native fish and invertebrate species are adapted to the natural ambient temperature regimes of Victoria's rivers and streams (OWR 1990, Boulton and Brock 1999). All animals associated with freshwater (with the exception of birds and mammals) are cold-blooded, that is, they are unable to control their body temperatures. Therefore, they are highly dependent on ambient temperatures (Hellawell 1986). Plants associated with freshwaters also have no mechanism for temperature control.

Natural water temperatures can either be increased or decreased, depending on the source of the change. Both increases and decreases are included under the term 'Thermal Water Pollution'. A number of factors have been identified that can lead to thermal pollution, including river regulation, heated industrial discharges, the release of power station cooling waters, returning irrigation waters, changes in riparian vegetation, and the inter-basin transfer of water (Pusey *et al.* 1998, Ryan *et al.* 2001).

Decreased water temperature

The main cause of decreased water temperature is the release of water from dams which have offtakes or outlets situated deep in the water. During summer, large, still bodies of water can form layers of different temperatures, a process known as stratification, where a warm layer of water at the top overlays a cold body of water at the bottom. This effect mainly occurs in dams that are deeper than 5m (Ryan *et al.* 2001).

Many impoundments in Victoria utilise outlets located deep in the body of the dam (deeper than 5m) which can release cold water during summer. For example, Lake Hume draws water from over 30m deep in the reservoir, lowering temperatures downstream by about 6°C, while Dartmouth Dam releases water from over 60m deep and reduces water temperature by as much as 15°C (Shafron *et al.* 1990, Koehn *et al.* 1995). Lake Eildon releases water from nearly 50m deep, reducing natural temperatures in the Goulburn River by about 8°C (Mackay and Shafron 1988).

While cold water naturally warms up as it travels downstream, this drop in natural stream temperatures can persist for many kilometres downstream of the dam structure. The effects of changed temperature patterns from Lake Hume can be seen as far as 200 kilometres downstream (Walker 1979). The impacts of cold water released from Dartmouth Dam are noticeable downstream to Tallandoon, over 70 kilometres away (Ryan *et al.* 2001) and releases from Lake Eildon cause impacts for about 100 kilometres downstream to Goulburn Weir (Mackay and Shafron 1988).

Increased water temperature

A lack of bankside vegetation along streams reduces shading and can result in markedly increased water temperatures particularly during summer (Tunbridge 1988, OWR 1990, Mitchell 1990, Hall 1991).

Water temperatures in rivers and streams can also be increased when summer flows are significantly reduced by water diversions for domestic or irrigation (OCE 1988).

Large amounts of excess heat are produced during electricity generation, and the discharged cooling water can have a higher temperature than the stream water into which it is released (Harasymiw 1983, Cadwallader and Backhouse 1983).

While some large dams are stratified over summer, the stratification breaks down over winter and released water may, in fact, be warmer than the natural temperatures downstream (Ryan *et al.* 2001).

Other temperature effects

Simple increases and decreases in water temperature are not the only types of thermal pollution in rivers and streams:

- the seasonal or even daily amplitude of temperature change can either be reduced with cold water releases (Saltveit *et al.* 1994, Grownos 1998) or increased when riparian vegetation is grazed and shade is lost (Quinn *et al.* 1993);
- the natural rapid rise in temperature that occurs in spring can be reduced, or even eliminated (Lugg 1999);
- the peak in summer temperature may be delayed by weeks or months (Acaba *et al.* 2000); and
- the rate of temperature change may be larger than natural, for example when a large volume of water is released suddenly for electricity generation or irrigation (Mackay and Shafron 1998).

Status of threat

Alteration to the natural temperature pattern in rivers and streams is listed as a potentially threatening process under the **Flora and Fauna Guarantee Act 1988**.

In its final recommendation the Scientific Advisory Committee (SAC 1992) determined that the alterations to the natural temperature of rivers and streams due to human activities is a potentially threatening process as, in the absence of appropriate management, it:

- poses, or has the potential to pose, a significant threat to the survival of a range of flora and fauna; and
- poses, or has the potential to pose, a significant threat to the survival of two or more taxa; and
- poses, or has the potential to pose, a significant threat to the evolutionary development of two or more taxa.

The process occurs in rivers and streams throughout the State. For cold water pollution, a number of priority areas can be identified.

Ryan *et al.* (2001) identified 49 dams across Victoria with the potential to contribute to cold water pollution in downstream reaches. These were classified into three priority categories: maximum priority (24 dams), medium priority (11 dams) and minimum priority (14 dams), based on the likelihood that the dam would contribute cold water to the effluent stream. This was mainly based on the outlet level in the dam. Maximum priority dams drew water from greater than 10 m depth, and were regularly discharging, medium priority dams drew water from 6-10 m depth or only released water occasionally, and minimum priority dams were either artificially destratified or released water from less than 6 m depth.

The 49 priority dams identified by Ryan *et al.* (2001) were mainly located in three areas: the Bendigo/Ballarat area, west Gippsland, and the north east. However, there were also priority dams located in the Grampians and Otway Ranges. Maximum priority dams were located in all five of these regions.

For increases in temperature due to riparian vegetation degradation or changes to flow regimes, no geographic areas can be identified with higher priority than other regions. According to *Index of Stream Condition* (ISC) data, riparian vegetation is in a degraded state over much of Victoria. No catchment in Victoria had more than 60% of its stream length with streamside zones classified in good or excellent condition (NRE 2002). Only three catchments had over 40% of its stream length with streamside zones in good or excellent condition (East Gippsland, Mitchell and Tambo). However, the majority of good quality riparian vegetation occurs in upper forested areas of most catchments, so lowland agricultural areas should be given high priority.

Management Issues

Impacts on waterways are often the result of a number of threats, so it is often the case that addressing a single threat will not restore the health of the ecosystem. To achieve Victoria's objective of healthy waterways as identified in the Victorian River Health Strategy (NRE 2002),

integrated action and identification of priorities is required. The mechanism for delivering this is the Regional River Health Strategies. These Strategies will describe priorities for threat management at a regional and local level. The catchment management authorities and Melbourne Water will use a risk based approach to assist in identifying priority management actions, as described in Victorian River Health Strategy.

Ecological issues

Alteration to stream temperature regimes has been shown to have serious adverse effects on instream biota (Koehn and O'Connor 1990a) and has been identified as a major cause for the decline of many of Victoria's native freshwater fishes (Koehn and O'Connor 1990a,b, Koehn *et al.* 1995, Ryan *et al.* 2001). These adverse influences arise from a number of direct and indirect effects on flora and fauna.

The physical properties of water can be noticeably changed by temperature. In particular, the level of dissolved oxygen carried in water decreases with increasing temperature. At 30°C, water can carry about half as much dissolved oxygen than at 0°C (Gordon *et al.* 1992).

The toxicity of some chemicals may also depend on water temperature. For example, the chemical phenol becomes less toxic as the temperature increases, but ammonia becomes more toxic (Hellawell 1986).

Each plant or animal species has a specific temperature tolerance level and no species can survive in water temperatures above the lethal critical limit. For example, the lethal critical temperatures for several native fishes are around 27°C to 29°C (Harasymiw 1983, Koehn and O'Connor 1990a). Fish do not survive above these temperatures. This may be a direct impact of the temperature, or may be an indirect effect through the reduction in dissolved oxygen in warmer waters.

While temperature extremes may be lethal to flora and fauna species, most changes to populations are because of sub-lethal effects. As temperature affects all physiological processes of aquatic biota, departures from the normal temperature pattern, particularly sudden or unseasonal changes, could disturb these processes and cause accelerated, or retarded, growth and abnormal timing of life cycles (Hellawell 1986, Tunbridge 1988, OWR 1990, Hall 1991).

One important consideration with regard to native fish is seasonal temperature requirements for particular life cycle processes such as reproduction. Many native fishes spawn in late spring/summer when water temperatures are

normally high. Cold water discharges prevent water reaching temperature levels critical for the spawning of many native fishes (Koehn *et al.* 1995, Lugg 1999, Ryan *et al.* 2001) and the subsequent survival of eggs and larvae (Cadwallader 1978). If spawning does not occur, recruitment is reduced, and a species, over a number of years, may disappear from a stretch of stream altogether (Koehn *et al.* 1995).

The disappearance of Murray Cod from the lower Mitta Mitta River downstream of Dartmouth Dam, has been attributed to cold water releases from the dam. For Murray Cod, suitable spawning temperatures of over 20°C only occurred in three seasons after the dam was constructed in the period 1979 to 1993. There were no suitable summer spawning temperatures between 1985-1993 (Koehn *et al.* 1995).

There is also evidence indicating that temperatures which are substantially different from those associated with normal fish egg development, can lead to unusually high numbers of deformed progeny and/or failure of eggs to hatch (Hall 1991) and that during the breeding season, sharp temperature changes may damage gametes (Harasymiw 1983).

Fish may also suffer numerous adverse effects from alterations to temperature regimes, such as stress, reduced feeding, reduced growth rates, delayed or premature migration, and decreased resistance to disease or predation (Koehn and O'Connor 1990a, Clarkson and Childs 2000).

As with fish, extremes of temperature are also damaging or lethal to invertebrates. Many aquatic macroinvertebrates, such as dragonflies and mayflies, spend their juvenile stages in rivers, then emerge as winged adults to breed. If water temperatures are reduced, the juveniles grow slowly and may not mature to emerge and breed until the late summer months when air temperatures may not suit adults.

With increased water temperature, aquatic macroinvertebrates may grow too quickly and emerge early as very small adults with little breeding potential. When they emerge the air temperatures may not be suitable for breeding.

Egg development in macroinvertebrates may also be affected by water temperature changes. Brittain and Campbell (1991) found that hatching success and development time for eggs of a mayfly genus was correlated with water temperature.

The reduced variety of invertebrates in the Mitta Mitta River down stream of Dartmouth Dam has been partially caused by changed temperature patterns (Doeg 1984, Koehn *et al.* 1995). Some species, which required warm summer conditions, have been completely eliminated due to the release

of cold storage water. Other species, including mayflies, stoneflies, caddisflies and beetles, have become less common. A few previously uncommon species that are better adapted to cold water now dominate the population.

Warm water temperatures can enhance the growth of algae causing algal blooms. These blooms reduce dissolved oxygen levels which can damage fish and invertebrates.

Algae are an important natural component of aquatic ecosystems, but they can cause serious water quality problems when blooms occur. Some algal species produce toxins which affect drinking water supplies, are fatal to cattle and may cause gastroenteric problems and skin irritations in humans.

Wider conservation issues

The release of the Victorian River Health Strategy (NRE 2002) provides a solid basis for improving riparian land and water management, for implementing this Action Statement and meeting the conservation objectives.

The Victorian Government recognises the importance of improving land management in catchment areas for a range of ecological, economic and social reasons. Protection, maintenance and enhancement of the natural resource is seen as a key requirement for economic and social health of the community. A primary goal of catchment management authorities, Melbourne Water the Department of Sustainability and Environment and other bodies such as the Environment Protection Authority is to protect the soil and water resource through targeted activities. It is through such programs that the objectives of this Action Statement will be realised. Management of this threatening process is an integral part of achieving quality catchment management and ecologically sustainable development.

Alterations to the natural temperature regime of rivers and streams occurs for several reasons including:- a lack of shading by riparian vegetation along streams, arising from the overclearing and grazing of riparian vegetation, reductions in streamflow, particularly during Summer, as a consequence of the damming of small streams and tributaries (e.g. farm dams) and water diversion (e.g. pumping from streams for irrigation). These occur statewide mainly in agricultural areas. The degradation of riparian vegetation, and alteration of flow regimes have both been listed as a Potentially Threatening Processes under the **Flora and Fauna Guarantee Act 1988**.

Previous Management Action

- Catchment Management Authorities have been established under the **Catchment and Land Management Act 1994**, replacing the Catchment and Land Protection Boards (Catchment Management Structures Working Party 1997). The role of the catchment management authorities is to ensure the sustainable development of natural resource based industries, the protection of land and water resources and the conservation of natural and cultural heritage. This gives the catchment management authorities a central role in the management of water temperature regimes.
- The importance of thermal pollution has been recognised in the Victorian River Health Strategy (NRE 2002). The Strategy requires the development of community driven regional River Health Strategies within the context of Regional Catchment Strategies. Each regional River Health Strategy will provide for the protection of high value areas, the maintenance of ecologically healthy rivers and the achievement of overall regional improvement by setting river health objectives, priorities and targets.
- The EPA has identified temperature as one of the factors to be considered in the discharge of wastewaters and the release of flows from water storages in the State Environment Protection Policy (Waters of Victoria).
- A Thermal Pollution Workshop was held in Albury in June, 2000. This was a national workshop convened by the Inland Rivers Network and the World Wildlife Fund for Nature (sponsored by a number of organisations including the Murray-Darling Basin Commission, NSW Fisheries, NSW Land and Water Conservation, the Victorian Department of Sustainability and Environment (formerly the Department of Natural Resources and Environment), Queensland Department of Natural Resources and Mines, the Natural Heritage Trust and Environment Australia). A set of recommendations was developed from the workshop (IRN 2001).
- Rivers likely to be at risk from thermal water pollution based on the characteristics and operational regime of dams have been identified and assigned priorities (Ryan *et al.* 2001). These data will be an invaluable tool in setting priority management actions for addressing the Potentially Threatening Process.
- The Code of Forest Practice for Timber Production 1996 provides for the protection of riparian zones in both State and private forests through management of buffer and filter strips along the waterways. Undisturbed riparian

vegetation will reduce temperature variations in timber harvesting areas.

- Numerous programs exist with objectives to protect, restore or rehabilitate riparian vegetation, including:
 - Forest Management Plans;
 - Draft Heritage River Management Plans;
 - Inland Fisheries Management Plans, eg Goulburn-Eildon, Bendigo Region;
 - Local Conservation Strategies (e.g. Cardinia Shire Sites of Significance Program);
 - Proclamation and management of areas under the National Parks Act and management of conservation reserves in accordance with Land Conservation Council and Environment Conservation Council recommendations;
 - Special Area Plans under the CALP Act;
 - Victoria's Landcare Program;
 - Corridors of Green;
 - Tree planting programs;
 - Tree Victoria Action Plan;
 - Property Management Planning Program.
- Streamflow Management Plans, Bulk Entitlement Conversions, Stressed Rivers Rehabilitation Plans and Groundwater Management Plans are being developed to manage water diversions from rivers and streams. These processes provide opportunities to allocate water for environmental purposes, one of which would be to reduce changes to natural water temperature regimes, particularly over the hotter summer months.

Major Conservation Objectives

Long term objectives:

1. To reduce the extent of changes to natural temperature regimes of Victorian rivers and streams to levels which do not compromise the viability of indigenous stream biota;
2. To reverse declines in the conservation status of many individual species or ecological communities that have been adversely affected by changes to natural temperature regimes of Victorian rivers and streams.

Short term objectives:

1. To improve knowledge of the impact of temperature changes on aquatic ecosystems;

2. To manage temperature releases from impoundments to acceptable levels in waterways with maximum priority dams identified by Ryan *et al.* (2001);
3. To manage temperature releases from impoundments to acceptable levels in waterways supporting populations of susceptible threatened taxa and communities;
4. To manage water diversions from rivers and streams over the summer period so that water temperatures are not significantly altered in priority catchments;
5. To protect and restore riparian vegetation in priority catchments;
6. To increase awareness amongst land and water managers and the community of the threat posed by thermal pollution to biodiversity, and the most effective management responses.

Intended Management Action

The intended management actions listed below are further elaborated in the Department of Sustainability and Environment's Priority Actions Information System. Detailed information about the actions and locations, including priorities, is held in this system and will be provided annually to land managers and other authorities.

Planning and Co-ordination

1. Ensure that strategies to manage alterations to natural temperature regimes are a key component of each regional river health strategy, developed under the Victorian River Health Strategy (NRE 2002) and that appropriate cost-sharing arrangements are agreed to by stakeholders.

Responsibility: Catchment Management Authorities, Melbourne Water

2. Ensure that all stakeholders are engaged in developing strategies to address issues associated with changed water temperature and that environmental, economic and social factors are all considered in decision-making.

Responsibility: DSE (Catchment and Water Services, Biodiversity & Natural Resources Division, Regions), DPI (Fisheries Victoria), Catchment Management Authorities, Water Authorities

3. Ensure that all authorities with land or water management responsibilities include, as part of their normal business plans or strategies, objectives and targets to minimise alterations to natural temperature regimes in waterways.

Responsibility: DSE (Catchment and Water Services, Biodiversity & Natural Resources Division, Regions), DPI (Fisheries Victoria), Catchment Management Authorities, Water Authorities

4. Review the operation procedures, release strategies and operation constraints of all dams listed as maximum and medium research priority by Ryan *et al.* (2001). This review should identify strategies to minimise current impacts, undertake a triple bottom line assessment of strategies and identify funding arrangements. The review must take into account existing uses such as water supply and salmonid fisheries.

Responsibility: Water Authorities

5. Implement the management actions outlined in the Action Statement for the Potentially Threatening Process “Degradation of native riparian vegetation along Victorian rivers and streams” that would benefit temperature regimes in rivers and streams.

Responsibility: DSE (Biodiversity & Natural Resources Division)

6. Implement the management actions outlined in the Action Statement for the Potentially Threatening Process “Alteration to the natural flow regimes of rivers and streams” that would benefit temperature regimes in rivers and streams.

Responsibility: DSE (Biodiversity & Natural Resources Division)

Production of guidelines, legislation

7. Establish guidelines for the acceptable deviations of temperature from natural.

Responsibility: EPA

Research

8. Undertake, as funding becomes available, technical research in priority areas:
 - investigate the thermal tolerances of priority species likely to be affected by thermal pollution, particularly sub lethal effects on different life stages (such as eggs or juveniles);
 - investigate the relationship between releases and the downstream extent of cold water pollution for all maximum and medium priority dams;
 - review temperature monitoring technology to determine the best cost effective methods for monitoring temperature changes;
 - conduct hydrodynamic assessment of maximum and medium priority dams to determine if stratification is likely. This includes modelling of within dam stratification as well as downstream heat flux calculations;
 - review operational changes that can be implemented to prevent or reduce the impact of stratification in dams (such as multi-level offtake towers, variable level intake structures, the use or the installation of siphons over dam

walls, air bubble curtains, impellers) to determine cost benefit relationships;

- undertake scientifically based test/pilot case(s) to demonstrate the benefits of mitigating thermal pollution, and to monitor the recovery of biota and ecological processes.

Responsibility: DSE (Catchment and Water Services, Biodiversity & Natural Resources Division), Catchment Management Authorities, Water Authorities

9. Undertake, where appropriate, economic research into the cost effectiveness of different control measures, and into the possible application of incentives and other economic instruments which may contribute to solutions.

Responsibility: DSE (Catchment and Water Services)

Resource assessment and monitoring

10. Develop and implement a monitoring strategy for all maximum and medium priority dams. The strategy should measure the longitudinal extent of temperature changes associated with dam releases in priority rivers at risk from thermal pollution.

Responsibility: DSE (Catchment and Water Services), Water Authorities

11. Establish priorities and protocols for biological monitoring of the effects of thermal pollution.

Responsibility: DSE (Biodiversity & Natural Resources Division)

12. Develop appropriate performance indicators for this threatening process to assist land and water management authorities in environmental audit and condition of catchment requirements.

Responsibility: DSE (Catchment and Water Services, Biodiversity & Natural Resources Division)

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Further information can be obtained from Department of Sustainability and Environment Customer Service Centre on 136 186.

Flora and Fauna Guarantee Action Statements are available from the Department of Sustainability and Environment website: <http://www.dse.vic.gov.au>

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