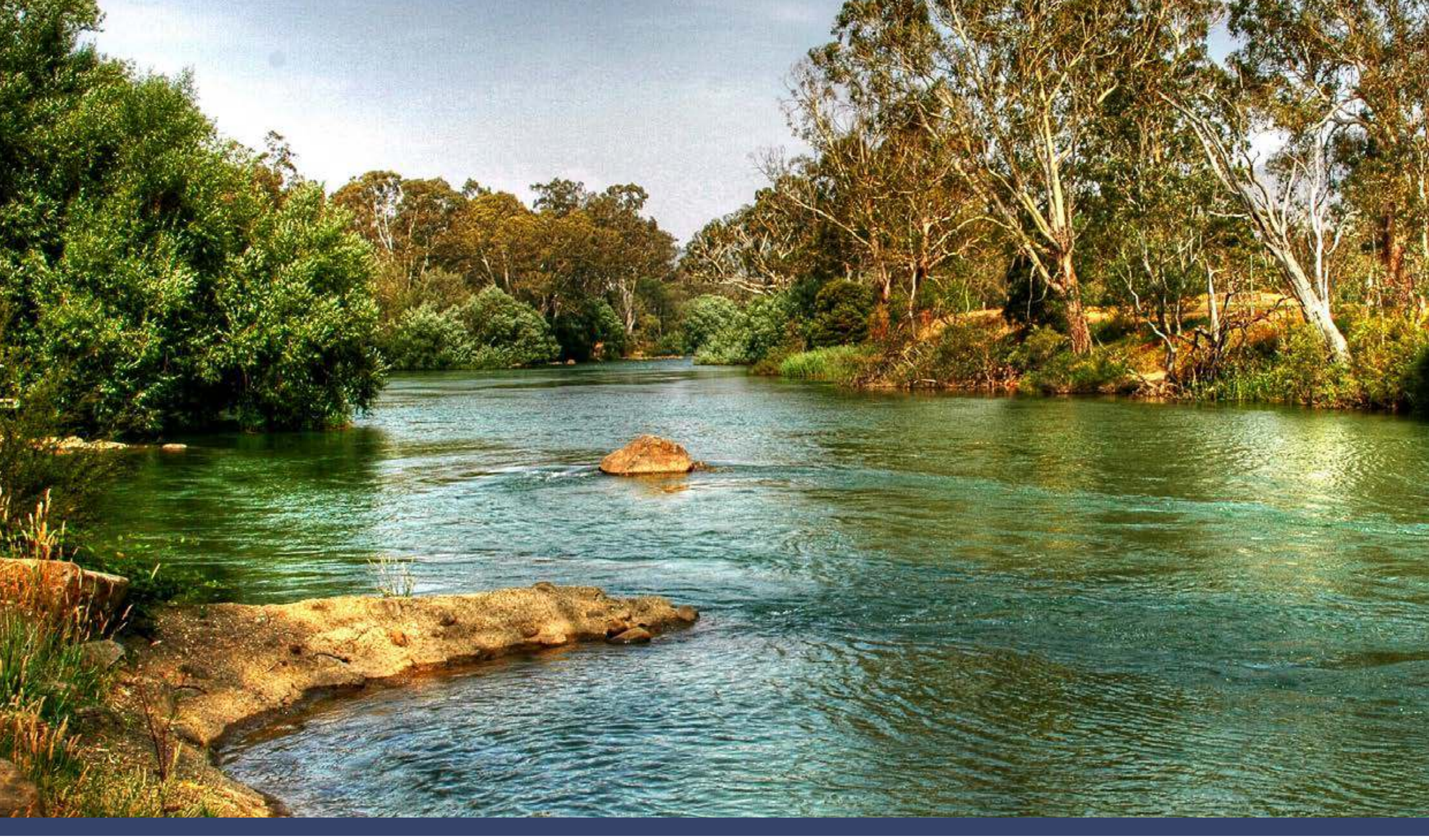


4. Freshwater Ecosystems

Guide to chapter 4

Chapter 4 focuses on freshwater habitats – rivers and streams, wetlands and aquifers – on ecosystems dependent on freshwater, in particular riparian (streamside) and floodplain habitats. Estuarine and coastal ecosystems such as mangroves, salt marshes and seagrass beds also rely on freshwater input, but are covered in chapter 2.

Section 4.1 describes the natural values of Victoria's freshwater ecosystems and the major habitat types and section 4.2 characterises important ecological processes, particularly natural flow regimes. Section 4.3 describes the current state of biodiversity and habitats in freshwater ecosystems. Section 4.4 outlines major threats, in particular disruptions to flow regimes and degradation of freshwater habitats. Finally, sections 4.5 and 4.6 identify gaps and priority reforms for policies and programs in six major areas: environmental flows, riparian habitats, freshwater protected areas, wetlands, groundwater and catchment management.

Topics covered

4.1 Values
- Biodiversity
- Important places
- Habitat types

4.2 Ecological characteristics and processes
- Flow regimes
- Ecotones and diversity
- Riparian vegetation and water quality

4.3 State of freshwater ecosystems
- Threatened biodiversity
- Rivers and streams
- Wetlands
- Riparian vegetation
- Floodplains
- Groundwater-dependent ecosystems

4.4 Major threats
- Changes to natural flow regimes
- Loss and degradation of habitats
- Dysfunction of biological interactions
- Climate change

4.5 Conservation gaps and priorities
- Environmental flows
- Riparian protection and restoration
- Freshwater protected areas
- Wetlands
- Groundwater
- Catchment management

4.6 Future directions

4.7 Sources

4.1 Values

For many of us, water simply flows from a faucet... We have lost a sense of respect for the wild river, for the complex workings of a wetland, for the intricate web of life that water supports. We have been quick to assume rights to use water but slow to recognise obligations to preserve and protect it... In short, we need a water ethical guide to right conduct in the face of complex decisions about natural systems we do not and cannot fully understand.

Sandra Postel, 1992[1]

Much of Victoria's landscape is densely woven with rivers and streams – the greatest concentration of waterways on Australia's mainland. They engender life-sustaining connections from mountain headwaters to coastal estuaries, laterally between waterways, riparian fringes and floodplains, and vertically between surface and subterranean habitats.

Figure 4.1 Victoria's rivers and river basins

Map: VNPA

Variability along these three spatial dimensions and through the fourth dimension of time has generated great diversity and complexity in Victoria's freshwater ecosystems – from cold, rushing mountain streams to warm, slow-moving pools in the drylands, subterranean seepages through rock pores and fractures, and a multitude of wetland types – lakes, floodplain billabongs, shallow freshwater and saline swamps, and alpine peatlands.

For the richness of life they sustain, the refugia they provide in dry times and their contributions to the health and productivity of other ecosystems, Victoria's freshwater ecosystems have immense ecological value. They also have immense utility for humans, which has generated short-sighted exploitation without care for the system as a whole.

4.1.1 Biodiversity

Globally, freshwater ecosystems cover less than 1% of the earth's surface but support 6% of described species.[2] They are often highly productive and provide great habitat diversity because of the ecotones (transition areas between different environments) they create at multiple scales.[3]

Victoria's freshwater habitats are known to support more than 100 waterbird species, 54 freshwater fish, 38 frogs, 40 crayfish and a large uncounted number of other invertebrate species.[4] More than 800 vascular plants are associated with Victoria's wetlands.[5] Some groups of freshwater organisms – crayfish, galaxiid fish and stygofauna (groundwater-inhabiting organisms) – have high levels of endemism in Victoria (Table 4.1, Box 4.1). Many are also increasingly rare, with close to half or more of the state's frogs, freshwater fish and freshwater crayfish threatened.

Aquifer ecosystems, lacking light and low in energy and oxygen, are inhabited by specialised organisms known as stygofauna, which are mostly crustaceans but also include worms, mites, beetles, snails, and millipedes. Compared to surface water environments, groundwater ecosystems are relatively stable and persistent through geological time, and some may be 'living museums', with species from Gondwanan and earlier times.[6] Most Victorian groundwater ecosystems have not been surveyed, so little is known about the stygofauna, but they are likely to have exceptionally high endemicity, with most species confined to one aquifer.[7]

Table 4.1 Status of some freshwater groups[8]

Groups	Indigenous to Victoria	% of Australian species	Endemic to Victoria	Threatened or extinct [(1)]
Fish	54	20%	8 (15%)	31 (57%)
Frogs	38	16%	1 (3%)	15 (39%)
Turtles	3	12%	0	2 (67%)
Crayfish	38	25%	23 (60%)	25 (66%)

[(1)] Based on the Victorian government's advisory lists.

Box 4.1 Crustaceans and fish

South-eastern Australia is a hotspot for endemic crayfish. In Victoria, 40 species have been recorded (38 described) – mostly burrowing and spiny crayfish but also swamp and land crayfish and yabbies. At least 23, possibly 25, are unique to Victoria.[9] Some freshwater habitats have multiple species with tiny ranges. Because of their limited dispersal capacity, small ranges, low rates of reproduction and slow maturation, crayfish are vulnerable to decline. Twenty-six species have been assessed as threatened (in the government's 2009 advisory list), and 12 are listed as threatened under the Flora and Fauna Guarantee Act.

Another 25 shrimps, amphipods and other crustaceans are known to be endemic to Victoria.[10] Six new endemic isopods were recently identified in groundwater-dependent streams, springs and seeps in The Grampians National Park. There are undoubtedly many more endemic crustaceans in groundwater ecosystems, for they dominate stygofaunal communities, and most are unique to single aquifers.

Of Victoria's 54 known freshwater fish species, eight galaxiids are endemic, with many still to be formally described after research showing that what was called the mountain galaxias (*Galaxias olidus*) is really a complex of 15 species.[11] More than half of Victoria's freshwater fish species, including the galaxiid endemics, are considered threatened.[12] Before trout were introduced into Victorian waters, galaxiids were the top fish predators.

4.1.2 Important places

Heritage river areas

Victoria has 18 heritage river areas, which are segments or corridors on public land declared under the Heritage Act for significant recreation, conservation, scenic or cultural heritage values. They total 2000 kilometres, 3% of the length of Victoria's named streams (Figure 4.2).

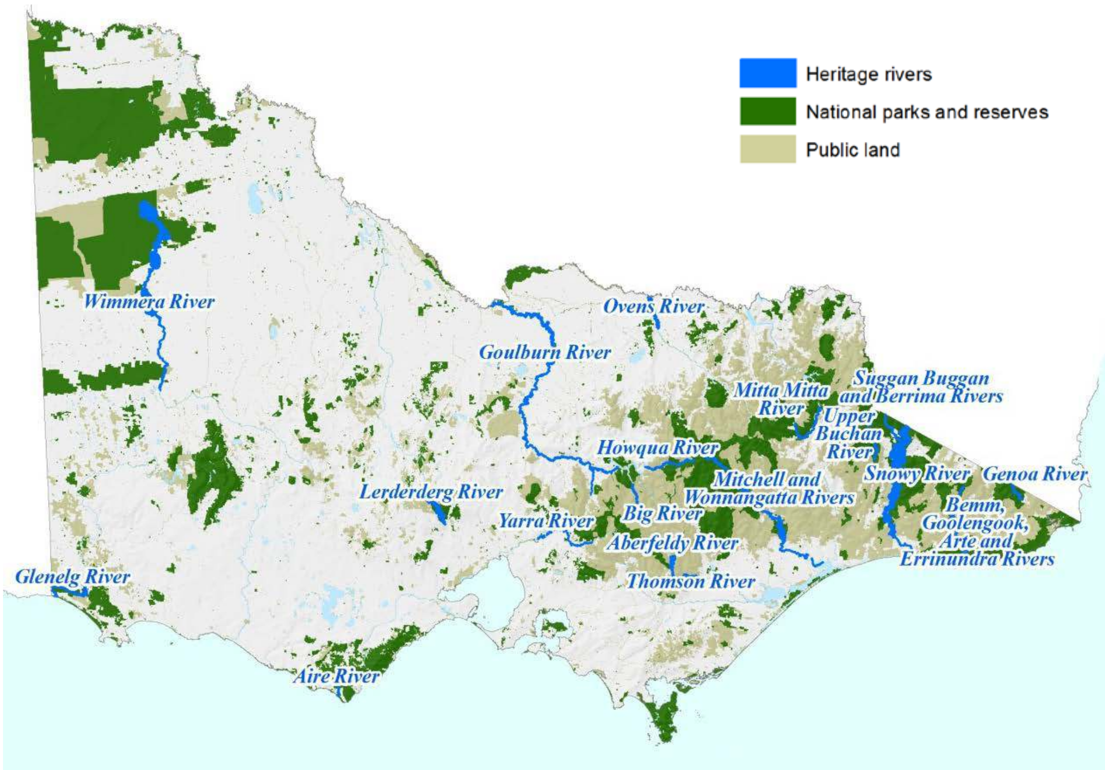
High-value wetlands

Nine freshwater wetland complexes have been recognised as internationally significant, and are listed under the Ramsar Convention (another two Ramsar wetlands are marine-only sites) (Figure 4.3). As the Victorian government recognises, many other wetlands have values likely to also qualify them for Ramsar listing.[13] More than 1300 freshwater wetlands in 29 sites are listed as nationally significant in Australia's Directory of Important Wetlands.[14] Many other wetlands also have very high values not recognised in the directory.

Important bird and biodiversity areas

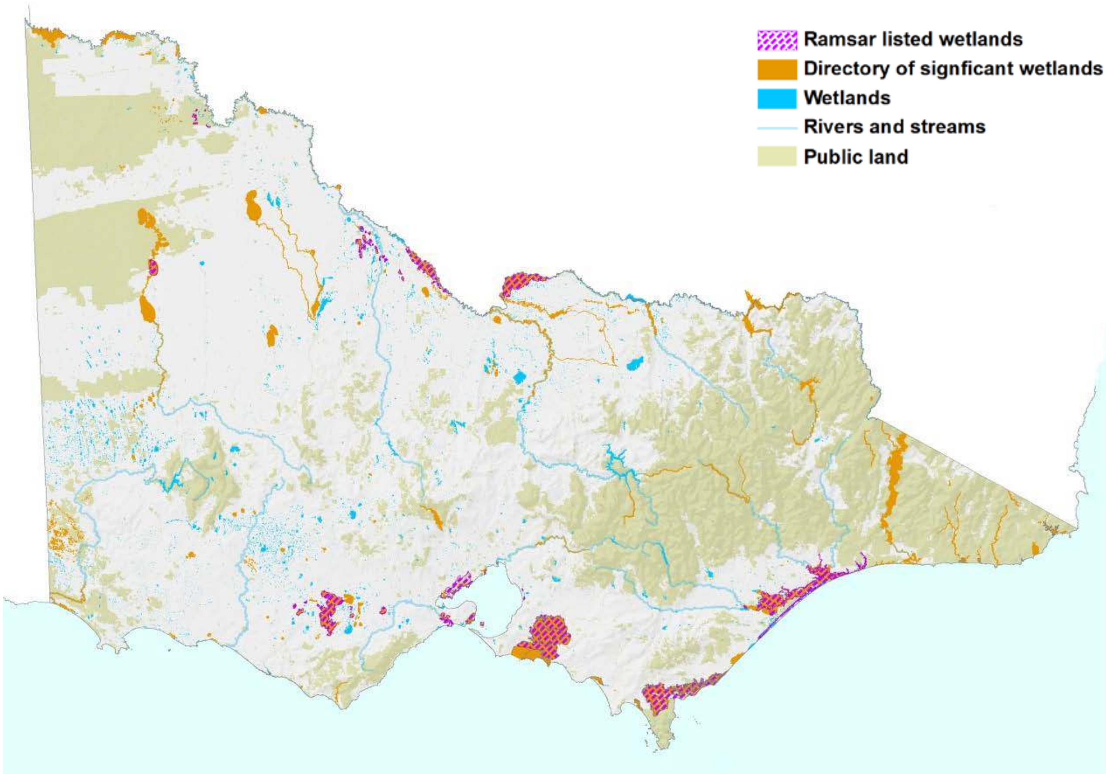
For waterbirds resident in Victoria, the following freshwater or partially freshwater sites have been identified as particularly significant and were designated in 2009 as 'important bird areas' by Birds Australia: Barmah-Millewa, Bellarine wetlands, Carrum wetlands, Devilbend reservoir, Gippsland Lakes, Lake Corangamite complex, Lower Brodribb River, Natimuk-Douglas wetlands, north Victorian wetlands, Port Fairy to Warrnambool, Werribee and Avalon, Western Port, Yambuk (more details in chapters 2 and 3).[15] Some of these wetlands grade from salt water to freshwater, and Lake Corangamite, Natimuk–Douglas and north Victorian wetlands consist of a mix of saline and fresh water lakes. To be designated as important bird areas, wetlands must regularly support threshold numbers of birds when conditions, such as water levels, are suitable.

Figure 4.2 Victoria's heritage rivers



Map: VNPA. Data source: Department of Environment and Primary Industries

Figure 4.3 Wetlands, including of international (Ramsar-listed) and national significance



Map: VNPA. Data source: Department of Environment and Primary Industries

4.1.3 Habitat types

Surface water-dependent ecosystems are those that rely on flowing waters (rivers, streams and springs) or still surface waters (pools, lakes, ponds and swamps).

Rivers and streams

Victoria has 3820 named watercourses extending 56,000 kilometres, as well as many un-named tributaries and distributaries (streams that flow away from a main branch) that bring total stream-length to about 85,000 kilometres.[16] Flows are naturally highly variable from year to year but are now regulated in the majority of rivers by storage, diversion and extraction of water for human uses. Victoria's 70 major water storages are capable of holding more than 12 million megalitres. Annual flows over the eight years from 2003-04 to 2010-2011 averaged 26 million megalitres but ranged from 7 million to 45 million (27 to 175% of the eight year average).[17]

Wetlands

Victoria has an estimated 23,739 natural wetlands, which are 'areas of permanent, periodic or intermittent inundation that hold still or very slow moving water'.[18] They cover about 600,000 hectares (2.6% of Victoria's surface area). There are also some 11,060 artificial wetlands (eg farm dams, reservoirs and sewage treatment ponds) covering 171,000 hectares. As well as providing habitat, wetlands help maintain water quality, by filtering nutrients and sediments, and reduce the impacts of floods, by slowing and holding floodwaters. Because of their high productivity and the incorporation of carbon into sediments, many freshwater wetlands are likely to be significant carbon sinks.[19]

Riparian habitats

As the interface between land and water channel, riparian areas are highly productive and ecologically important links between terrestrial and aquatic ecosystems. Although only a very small proportion of total catchment area, they have a large influence on the healthy functioning of river ecosystems by providing habitat, shading the water, and contributing carbon and nutrients. In largely cleared landscapes, they often contain the only native vegetation. They buffer rivers and streams to some extent from land use impacts – by filtering out sediment, nutrients and pesticides.[20] They are also often sites of high biodiversity – for example, supporting more birds and more species of birds than non-riparian sites.[21] Riparian habitats are valuable as resting, roosting, nesting and hawking sites for insect and fish-eating birds and mammals, as basking and hunting sites for reptiles, as calling and feeding sites for frogs, as shelter sites for insects.[22] They are important as refugia for land animals in dry times and as dispersal corridors. Their productivity means they are also likely to be significant carbon sinks. Victoria is fortunate in having 30,000 kilometres of riparian land in public ownership (crown water frontages, mostly on larger waterways), although state ownership has often not been exercised in the public interest.

Floodplains

The lowlands that border waterways, and which are flooded when water overflows river banks, are also highly productive and ecologically important transition zones (covered mostly in chapter 3).

Groundwater-dependent ecosystems

Ecosystems that depend partially or completely on water from beneath the earth's surface which has undergone physical and chemical changes due to interactions with the aquifer environment are of three types:[23]

- subterranean aquifer and cave ecosystems, often inhabited by specialised invertebrates known as stygofauna
- ecosystems dependent on groundwater coming to the surface, for example perennially flowing rivers and streams, and permanent wetlands in a floodplain
- ecosystems dependent on subsurface groundwater accessible through the roots of trees, for example river red gum forests along the lower River Murray and paperbark swamp forests.

4.2 Ecological characteristics and processes

4.2.1 Flow regimes

'The natural flow regime is of profound importance in the structuring and functioning of riverine ecosystems and shaping the life history strategies of freshwater-dependent biota.'

Yung En Chee, 2010[24]

Flow regimes – the patterns of water flow resulting from interactions of climate, geology, topography and vegetation – are 'the maestro' of riverine ecosystems, orchestrating ecological processes, maintenance of biodiversity and evolutionary change (Figure 4.4).[25] The life history strategies of aquatic species have evolved primarily in response to natural flow regimes.[26]

Influential aspects of flow regimes include the magnitude and seasonal patterns of river flows; the timing of extreme flows; the frequency and duration of floods, droughts and intermittent flows; daily, seasonal and annual flow variability; rates of change in flow events; and interactions between surface water and groundwater.[27]

Flow regimes are influential in the following ecological processes:[28]

- regulation of the hydrological cycle and biogeochemical cycles – storage, transport and transformation of water, minerals and organic matter
- primary production and secondary production – the capture, transformation and flow of energy through food webs
- formation and maintenance of biophysical habitats – flows affect substrates (sand, salt, rock) and structural features (boulders, logs)
- movement – flows are necessary to transport the various life-history stages of many microorganisms, plants and animals, and to recolonise re-wetted habitats
- biological interactions – flows facilitate processes such as seed dispersal, and influence competition, herbivory and predation
- natural disturbance regimes – eg floods and droughts alter ecosystems by creating spaces for colonisation, releasing and distributing resources, and altering the mortality rates of species.

Flow variability – habitat diversity and disturbance

Each component of a natural flow regime – from no flows to floods – facilitates different riverine functions and processes. For example, 'freshes', which substantially increase river height for a short while, improve water quality by flushing stagnant water, create new habitat patches and turn pools to runs, enabling the movement of sediments and organisms. 'Bankfull flows', which completely fill a channel without breaking the banks, maintain channel shape, while 'overbank flows' are vital for floodplain productivity and for organic inputs to rivers.[29]

The variability between seasons and years, ranging from drought to floods, often creates essential ecological disturbance, without which these systems become more uniform, sustaining less variety of life.[30] River headwaters and segments that flow through arid landscapes often dry out or contract to isolated pools. They are tough times for many aquatic species, with high levels of predation, competition and physiological stress, but this variability maintains species diversity by limiting domination by any particular groups of organisms. Organisms in dryland river systems adapted to persist in harsh conditions and prevent displacement by dominant but less tolerant species. In the short-term they suffer localised extinctions, with natural recovery occurring as species recolonise from local refuges or from elsewhere. Conserving habitat diversity requires maintaining the natural variability of interactions of water flow with features such as pools, runs, bars, benches, overhanging banks and anabranches and structural elements such as sediment, pebbles, boulders, tree roots, coarse woody debris and aquatic plants. These interactions produce fine-scale flow patterns such as slackwaters, eddies, transverse flows and velocity gradients.[31] The slackwater habitats created provide refuge from currents, and hatching, rearing and feeding environments for zooplankton and the young of shrimp and fish.

Connections and movements

Maintaining linkages is essentially about making sure that a river is part of the total landscape, that it is not just regarded as a channel running though the land. Maintaining each of the linkages [along a river, between a river and its banks and floodplains and between a river and groundwater sources] is essential to maintaining the ecological health of a river.

Victorian government, 2002[32]

Ecosystem function depends on flows to transport nutrients, organic materials, and organisms into and out of habitat patches. Flows are needed to disperse animals for breeding or to complete a life history stage, access resources or recolonise areas where local extinction has occurred. Waterbirds need particular flood durations and temperatures before breeding, many plant seeds require flooding prior to germination, and some fish need specific flows to migrate or breed. Murray cod, for example, migrate upstream with early spring flows, female tupong migrate downstream to spawning grounds during high flows in late autumn and winter, and broad-finned galaxias need a rise in water level for spawning along stream edges, then another high flow to cover the exposed eggs before hatching.[33]

Waterways facilitate connections at multiple scales – at the landscape scale, enabling seasonal movement of species, and at the local scale, facilitating daily movements and dispersal. Streamside vegetation is also essential for connectivity, for aquatic and terrestrial plants and animals.

Floodplains and flooding[34]

'Pulsed flooding is the major factor influencing biota in these river-floodplain systems...'

James Fitzsimmons and others, 2011

Overbank flooding of rivers is crucial for many vegetation communities and species on floodplains and for maintaining ecological connectivity along and across floodplains, and between rivers and floodplains. It is necessary for much more than meeting the water requirements of plants and animals in flood plains. Overbank flooding is integral to biological processes such as regeneration, dispersal and growth, and to geomorphological processes such as the deposition of silts and the regulation of ground water depth and chemistry.

A recent assessment of flooding requirements for floodplains of the Murray, Goulburn, Ovens and King Rivers in northern Victoria, the first such assessment in Victoria, found at least 110 ecological vegetation classes across 224,000 hectares and 124 rare or threatened plant taxa and 62 threatened vertebrate fauna taxa (excluding fish) depend on flooding.[35] Some examples of different flooding requirements are shown in Table 4.2. For about 30 ecological vegetation classes, the critical interval to maintain healthy ecosystems is one flood event about every two years.

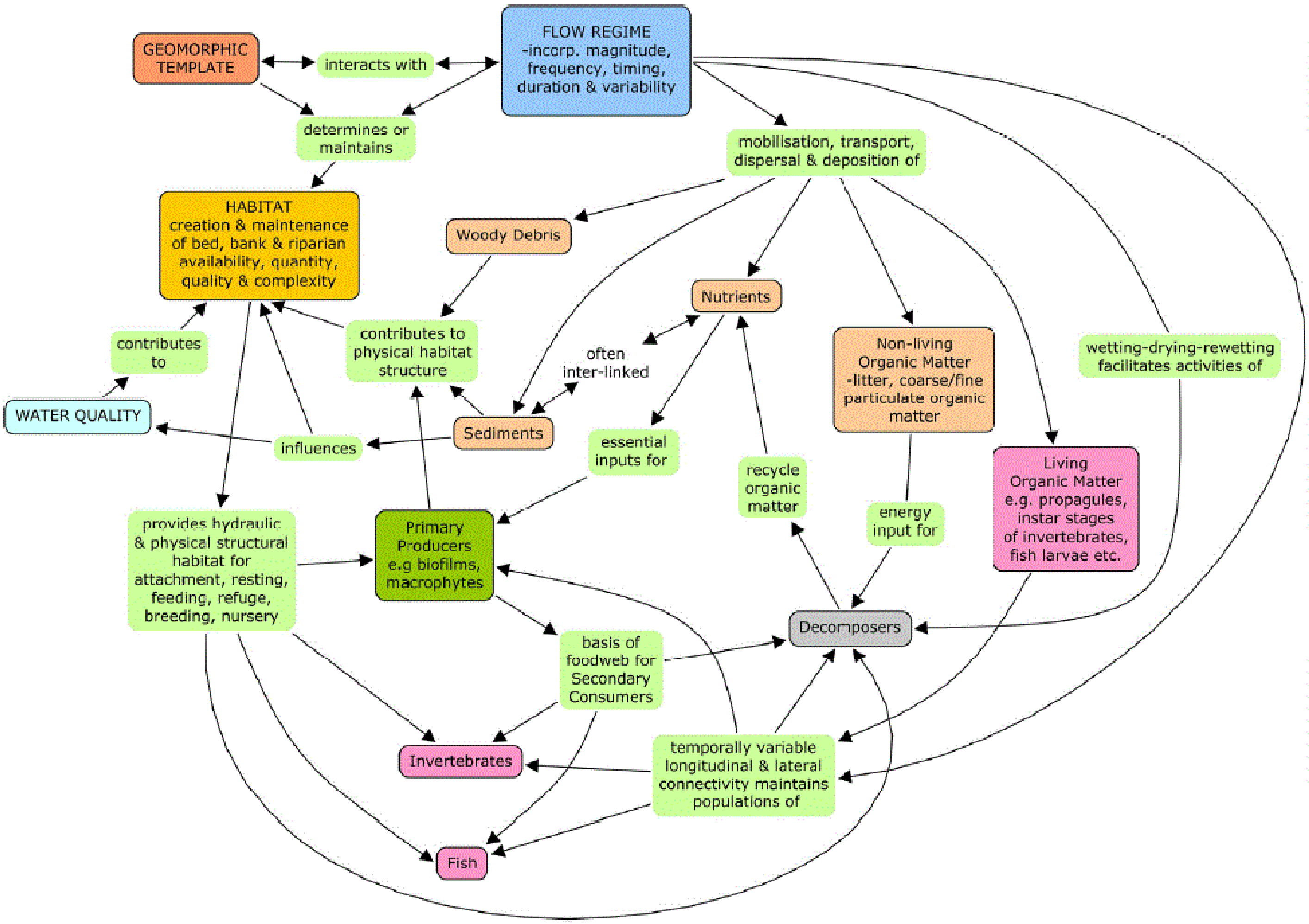
Table 4.2 Examples of flooding requirements for some flood-dependent ecological vegetation classes (EVCs) in the Murray River floodplain[36]

Ecological vegetation class	Critical interval (years)	Minimum duration (months)
Alluvial plains semi-arid grassland	25	1.5-6
Aquatic herbland	2	6-12
Billabong wetland aggregate	(variable) 2	>6
Floodplain riparian woodland	7	<1
Grassy riverine forest	4	1-4
Red gum swamp	3	4-9
Riverine chenopod woodland	30-50	<1-3

Biogeochemical cycles and energy transfers

The interaction of the flow regime with river and stream structures is integral to biogeochemical cycling and energy transfers through riverine systems.[37] For example, during low or no flow times, organic matter from riparian areas accumulates and dries on bars, benches and other features protruding from the water. Flow fluctuation subjects them to cycles of wetting and drying, which facilitates physical breakdown and microbial decomposition. Flows distribute this fresh pool of nutrients and carbon throughout the river system for use by microbes, zooplankton, algae, plants and animals. Microbes below streambeds and in stream banks where groundwater and surface water mix (in the 'hyporheic' zone) are also important recyclers, transforming nutrients and carbon washed into streams into food for aquatic invertebrates, in turn consumed by other organisms.[38] It is by such processes that water quality is maintained. After prolonged periods of no overbank flows (eg due to river regulation or drought), flooding can lead to 'blackwater' events and death of fish, crustaceans and other organisms. They occur when large accumulations of organic material are washed into streams and consumed by bacteria, leading to a sudden depletion of dissolved oxygen and increased acidity.[39]

Figure 4.4 A simplified conceptual model of the main hydrological, geomorphical and ecological interactions and processes in riverine ecosystems[40]



Source: Chee (2010)

4.2.2 Groundwater and surface water connectivity

As receptors, storages, and transmitters of water, groundwater systems (aquifers) regulate parts of the hydrological cycle, absorbing runoff and stream flows through river channels as well as the floodplain.[41] This process buffers changes to rates of flow during flooding. When floods recede, aquifers release water back to the stream, sustaining flow rates and again buffering rates of flow and river level changes. This process has implications for riverine life because changes in rates of flow and water levels affect water velocity, shear stress and intensity of scouring disturbance with impacts such as uprooting of seedling and adult plants. Rapid recession of flood flows may strand organisms in floodplain environments that are not suitable for longer-term survival. The mitigation of flood magnitude and rapid flow rate changes constitutes an ecosystem service called 'flood attenuation'.

Groundwater and surface water systems are intimately linked, with groundwater reserves relying on surface recharge and many surface ecosystems relying on groundwater sustenance.[42] A study in the Murray-Darling basin showed that water stress in river red gums was lower between flood events in areas underlain by shallow aquifers, implying groundwater dependency.[43] Because only small changes in the depth to groundwater can substantially reduce water available to vegetation, groundwater-dependent systems are likely to be vulnerable to changes in groundwater flow.

Underground systems are buffered from many environmental changes taking place at the surface and have much higher levels of endemic and relict species (from ancient lineages) than surface environments.[44] But stygofauna are potentially highly vulnerable to changes in groundwater regimes. They are often specialised with long life cycles and low fecundity, some with limited capacity to survive environmental change. Underground groundwater ecosystems are dark with low energy and oxygen availability and low productivity. They have very simple food webs, dominated by detritivores (organisms that feed off dead plants and animals), with microbes rather than plants at the base. To detect population declines requires close monitoring but response times to change can be decades.'[45]

4.2.3 Ecotones and diversity

'Acting in concert, bioclimatic, hydrologic and geomorphic processes create complex mosaics of habitat patches at multiple spatiotemporal scales. In natural settings, the quantity, quality, physical properties and spatial arrangement of habitat types will determine the type and abundance of the biotic community as well as the rates of ecological processes.'

Yung En Chee, 2010[46]

Riverine ecosystems have high ecological value in part because of the diversity of ecotones (transitional habitats) they create – zones of exchange of materials and energy and pathways for movement of organisms (as well as of pollution).[47] At large scales, they provide a range of wet to moist habitats, with gradients extending outward to riparian and floodplain areas and below ground. At smaller scales, ecotones occur where fluctuating flows interact with elevated features such as bars and benches, and at interfaces with groundwater.

One important ecotone known as the hyporheic zone is in the sediments of stream beds and banks where surface water and groundwater mix and water chemistry is altered by microbes. Where the water emerges, it promotes growth of periphyton (bottom organisms attached to plants and other objects), creating hotspots of productivity that sustain microorganisms and invertebrates.[48] Variations in the stream bed, changes in flow direction and features such as riffles, sand and gravel bars generate a mosaic of patches of surface-groundwater exchanges.[49] The hyporheic zone often extends for several kilometres along rivers and also laterally (landward).[50] (Groundwater is also connected to coastal and marine ecosystems.)

4.2.4 Riparian vegetation and water quality

Intact riparian vegetation alongside rivers provides a multitude of benefits – it provides connectivity in the landscape, is highly biodiverse, provides habitat for and protects rare and threatened species, improves water quality (by filtration and shading to keep the water cool), stabilises banks and provides in-stream habitat for fish and invertebrates.

Riverside Rescue, 2011[51]

The typical sign of a degraded stream or river is a narrow strip of fringing vegetation or none at all. A healthy riparian zone is essential to maintain water quality.[52] By stabilising the soil and stream banks and reducing the velocity of overland flow, riparian vegetation limits water and wind erosion. It filters and retains incoming sediments and processes nutrients, limiting their input into streams. Healthy riparian soils are important for microbial conversion of nutrients into forms available for use by plants and animals. When riparian vegetation is lost or degraded, high sediment and nutrient loads lead to turbid water, toxic algal blooms and reduced aquatic biodiversity.

4.2.5 Freshwater refugia

Many freshwater ecosystems are important refugia – places in which organisms can persist when regional environments change – and will become increasingly so as the climate changes. Australian freshwater organisms have evolved in conditions of high natural variability and their life history strategies are frequently oriented around refugia. The richness of refugial strategies in Australian riverine ecosystems is unusually high by global standards because of Australia's long-term climate variability.[53] In dry times and places, sites of permanent wetness – wetlands, springs, groundwater-fed rivers for example – are vital for the persistence of many species. Some surface aquatic animals prevent desiccation (drying out) by migrating into moist areas such as the hyporheic zones of rivers. Water-filled crayfish burrows are refugia for some stream insects.[54] Aquifers have been refugia from increasing surface aridity in Australia over millenia.[55]

4.3 State of freshwater ecosystems

4.3.1 Threatened biodiversity

World-wide, freshwater habitats have the highest proportion of threatened plants and animals, and Victoria seems no different. Close to half or more of the state's frogs, freshwater fish and freshwater crayfish are threatened (Table 4.4). Six wetland communities have been listed as threatened, although this does not reflect the real status of wetland communities, which have not been comprehensively mapped and assessed.

The poor status of native fish in Victoria is a telling indication of the pervasive deterioration of freshwater habitats. In the Murray-Darling system (as a whole), native fish populations are estimated to be at 10% of their pre-European colonisation levels, and most of the fish biomass, 80-90% in some rivers, consists of introduced species.[56] More than half of Victoria's freshwater fish are threatened, including species endemic to the state (Table 4.4). At least three are extinct (although they survive elsewhere) and it is possible that others (particularly galaxiids) have gone extinct before being discovered, due to introduced predatory trout.[57] A similarly high proportion of other freshwater groups are also threatened – about two-thirds of crayfish and turtles and more than a third of frogs. Formal listings of threatened species under the Flora and Fauna Guarantee Act do not reflect the conservation status of freshwater groups, with only about half the species considered threatened (on the Victorian government's advisory lists) formally listed (Table 4.4). Several wetland ecological communities have been listed as threatened under state or national laws (Table 4.3) and more than 85% of the 145 wetland ecological vegetation classes mapped in Victoria are threatened in at least one bioregion.[58]

Table 4.3 Wetland ecological communities listed under state and national laws

Wetland communities listed under the Flora and Fauna Guarantee Act
Alpine bog community
Fen (bog pool) community
Granite foothills spring wetland (north-east Victoria) community
Herb-rich plains grassy wetland (west Gippsland) community
Lowland riverine fish community of the southern Murray-Darling Basin
Montane swamp complex community
Red gum swamp community no. 1
Sedge rich *Eucalyptus camphora* swamp community
Wetland communities listed under the Environment Protection & Biodiversity Conservation Act
Alpine sphagnum bogs and associated fens ecological community (endangered)
River Murray and associated wetlands, floodplains and groundwater systems, from the junction of the Darling River to the sea (critically endangered) (11 kilometres is in Victoria)
Seasonal herbaceous wetlands (freshwater) of the temperate lowland plains (critically endangered)

Table 4.4 Extinct and threatened species in some freshwater groups (government advisory lists and Flora and Fauna Guarantee Act)[59]

Freshwater group	Extinct (regionally)	Critically endangered	Endangered	Vulnerable	Extinct or threatened (Advisory)	% extinct or threatened (Advisory)	Extinct or threatened (FFG Act)[1]
Fish	3	11	6	11	31	57%	19
Frogs	0	8	4	3	15	39%	11
Turtles	0	0	1	1	2	67%	1
Crayfish	0	3	14	8	25	66%	12

Sources: Department of Sustainability and Environment and others listed for Table 4.1. [1] FFG Act is the Flora and Fauna Guarantee Act.

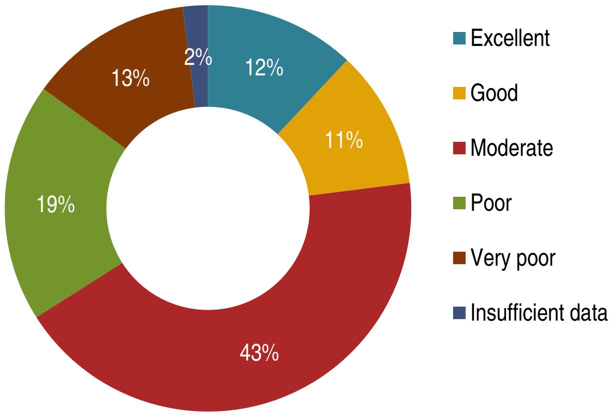
4.3.2 Rivers and streams

The latest Victorian survey of the condition of 29,000 kilometres of rivers and streams (the 2010 index of stream condition, Box 4.2) found that less than one-quarter (23%) of river length was in good or excellent condition and close to one-third (32%) was in poor or very poor condition, with the remainder (43%) in moderate condition (Figure 4.5).[60] The results are similar to those obtained in the 2004 Index, so the 2010 results, obtained at the end of the millennium drought (1997-2009), suggest that rivers and streams in good condition have resilience to severe droughts.[61]

Fourteen of Victoria's 29 basins had less than 10% of their river length in good or excellent condition (Figure 4.6). Most are in the state's mid-west and have been extensively cleared for agriculture. Only three basins, largely within national parks, had at least 70% of their river length in good or excellent condition and another three had at least 50% in this condition.

The major problem for Victoria's rivers and streams is of over-extraction of water and the imposition of water regimes suited to human consumption and opposed to ecological needs. This is at its worst during dry times when consumptive uses are given even greater priority over environmental health. For example, in 2007–08, the environment received less than 7% of its already inadequate entitlement while irrigators received 30–35% of their much larger entitlements. The volume of environmental entitlements was just 6% of total entitlements but only 1% was delivered for the environment that year.[62]

Figure 4.5 Victorian river condition, 2010[63]



Data source: Department of Environment and Primary Industries

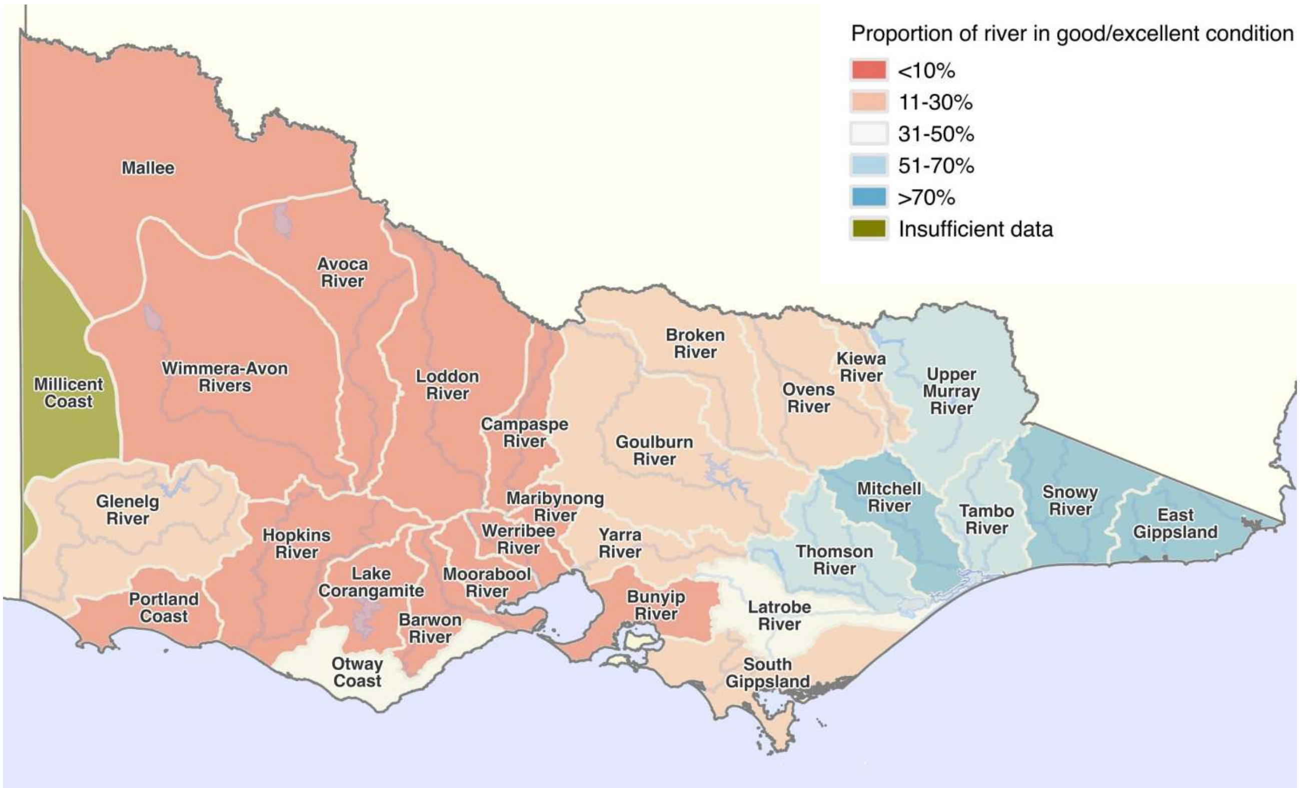
Box 4.2 About the index of stream condition[64]

The index of stream condition is the first statewide measure of river health in Australia. It combines information on 23 indices of five aspects of river health: hydrology, water quality, streamside vegetation, physical form (bed and bank condition and instream habitat) and aquatic life. The point of reference for most of these assessments is 'generally accepted to be what a river would have looked like in its undisturbed or unmodified form'. The condition is evaluated for sections of river 10-30 kilometres in length known as 'reaches'.

Three statewide assessments of river and stream condition have been published to date (in 1999, 2004 and 2013). The latest assessment used remote sensing – LiDAR, which records a three dimensional image, and aerial photography – to assess the streamside zone and physical form. This allows a continuous coverage instead of sampling at random locations.[65] One limitation of LiDAR is that it cannot be used to assess understorey diversity or identify plant species.

There are some concerns about the method used for calculating the Index.[66] When data on particular attributes is lacking, as it is for many reaches, a 'pro rata' score is applied but there is no justification presented for this and it undermines the credibility of the scores. The scores for each attribute are added together, which means that a high score in one indice can mask a low score in another.

Figure 4.6 The proportion of rivers in good to excellent condition in Victoria's river basins, as assessed by the Index of Stream Condition in 2010



Map: VNPA. Data source: Department of Environment and Primary Industries

4.3.3 Wetlands

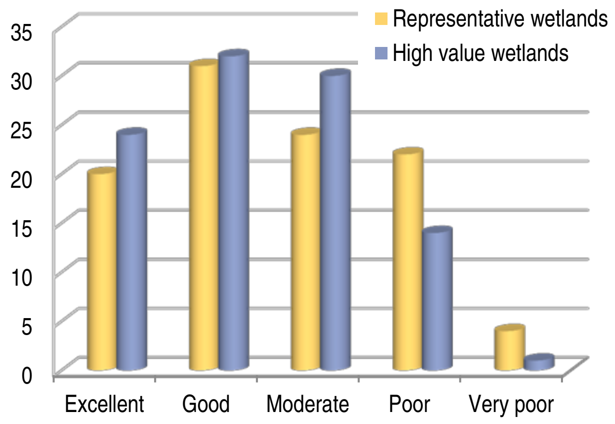
In 1994 it was estimated that about a quarter of Victoria's original wetlands (4000 in number, covering 200,000 hectares) had been destroyed, mainly through drainage (Table 4.7). Many more have been extensively modified and damaged, and their overall extent and condition is thought to be declining. However, there is no more recent information about the overall extent of loss. A 2013 update to the wetland inventory recorded a total of 23,739 natural wetlands covering 604,322 hectares.[67] The increase since 1994 is due to more accurate mapping.

A 2012 index of wetland condition assessment of 587 high-value wetlands (6% of Victoria's non-alpine wetlands) from 2009-10 found that just over half were in good or excellent condition, about a third were in moderate condition and 15% were in poor or very poor condition (Box 4.3).[68] The aspects of wetland health of greatest concern are wetland catchment (42% in poor condition), hydrology (33% in poor condition) and vegetation (47% in poor condition). The poor condition of catchments and wetland vegetation are due to land clearing, changes in flow regimes, grazing, cropping, and weed invasion, exacerbated by the recent drought.

A 2010-11 assessment of an additional 240 wetlands (2% of non-alpine wetlands), selected as representative of Victoria's wetland types, also found that about half were in good or excellent condition but about one quarter were in poor or very poor condition. The aspects of wetland health of greatest concern are similar to those for high-value wetlands: wetland catchment (63% in poor condition), hydrology (25% in poor condition) and vegetation (48% in poor condition).

For both high-value and representative wetlands, condition was generally worse on private land than on public land (Table 4.8). The majority of wetlands (69%) are on private land.[69] But the total area of wetlands is greatest on public land, for they average 54 hectares compared to 13 hectares for wetlands on private land. Only 13% of wetlands, but 55% by area, are in some form of protected area, although not all these are in the national park and conservation system (the tenures recognised by VNPA as securely protected, section 1.4.1).

Figure 4.7 The percentage of representative wetlands (2010-11) and high-value wetlands (2009-10) in good, moderate or poor condition[70]



Source: Index of Wetland Condition

Close to 200,000 hectares of 'significant wetlands and associated buffers' occur on private land (Table 4.6). This includes part of 10 Ramsar wetlands and 93% of the extent of the nationally listed, critically endangered seasonal herbaceous wetland community.[71]

Table 4.5 Significant wetlands on private land[72]

Significant wetland category	Area on private land (hectares)
Ramsar wetlands (with a 250 metre buffer)	48,349
Nationally important wetlands	53,984
Bioregionally significant wetlands	48,652
Important bird areas (with a 250 metre buffer)	47,259
Seasonal herbaceous wetlands (nationally threatened community)	17,078
Total, excluding overlaps between categories	188,126

Source: Trust for Nature

Box 4.3 Index of wetland condition[73]

This assessment combines information on five aspects of wetland health – catchment, physical form, hydrology, soils, water properties and vegetation. All assessments involved an on-site visit to score wetland condition using a standardised method.[74] The first assessment was conducted from 2009-11 and the next one is planned for 2017-18.

Table 4.6 Broad wetland types and losses since European colonisation (1994 data)[75]

Wetland type	Wetlands (number)	Wetlands lost (number)	Wetlands lost (%)	Current area (hectares)	Wetland area lost (hectares)	Wetland area lost (%)
Shallow freshwater	9,140	3,532	28	168,077	95,443	31
Deep freshwater	2,303	349	12	141,126	91,055	37
Saline	1,373	44	3	221,210	14,676	7
Total	12,816	3,925	23	530,413	201,175	26

Source: Department of Sustainability and Environment

Table 4.7 The condition of different aspects of high-value and representative wetlands[76]

Feature	High-value wetlands (%)			Representative wetlands		
	Poor-very poor	Moderate	Good-excellent	Poor-very poor	Moderate	Good-excellent
Catchment	42	9	49	63	9	28
Physical form	2	4	94	5	7	88
Hydrology	33	13	53	25	7	68
Water properties	3	12	85	5	23	72
Soils	10	9	81	20	18	62
Vegetation	47	23	30	48	18	35
Total	14	30	56	26	24	51

Source: Index of wetland condition

4.3.4 Riparian and floodplain habitats

About 500,000 hectares of Victoria is riparian (defined nominally as the area within 60 metres of a named and mapped waterway).[77] As the interface between terrestrial and aquatic ecosystems, riparian zones suffer the impacts of both river regulation and damaging land uses, particularly land clearing and grazing. As a result, most riparian areas in Victoria are degraded.[78] The worst are in the west, including in the Corangamite, Hopkins, Barwon and Moorabool basins, and the best are in the forests of the Otways, the North East and East Gippsland. Despite their often poor condition, riparian areas are highly valuable in rural areas because they often represent a substantial proportion of remnant vegetation.[79] This is due to state ownership of about 60% of the frontage on named waterways and 'the sporadic practice of leaving vegetation along watercourses to protect stream morphology'.[80] However, about 30% of vegetation within a 60 metre zone has been cleared (Table 4.10) and much of it is fragmented and weed-infested.

A 1999 survey found that less than 10% of riparian land was in good to excellent condition, and over 50% was in poor to very poor condition.[81] A 2001 national assessment of river condition found that about half (53%) of the assessed river length in Victoria had substantially or severely modified riparian vegetation.[82]

A 2010 assessment of stream condition, using different methods, found that about one-fifth of streamside vegetation was in excellent condition and about the same proportion was in poor condition (Table 4.9). Major causes of degradation include land clearing, altered flow regimes, stock access and invasive species.[83]

Table 4.8 The proportion of riparian vegetation in excellent or poor condition in 10 regions, 2010[84]

Region	Excellent condition (%)	Poor condition (%)	Reaches assessed (number)
Mallee	1	6	73
North Central	4	13	111
Glenelg Hopkins	8	47	123
Wimmera	10	15	84
Goulburn Broken	14	3	117
Port Phillip	21	31	131
Corangamite	26	30	138
West Gippsland	28	15	114
North East	31	12	139
East Gippsland	47	9	138
Average/total	**21**	**19**	**1168**

Source: Index of stream condition. The other reaches were in moderate condition.

Riparian areas on private lands have been much more damaged than those on public lands. Close to half of riparian land on named waterways (46% based on a 60 metre buffer from the waterway) is on private land and only 44% has native vegetation (Table 4.10).[85] Less than 1% of private riparian land has formal protection, in the form of a conservation covenant, and most of the riparian vegetation on private land (93%) is of ecological vegetation classes not sufficiently represented in protected areas. In contrast, 92% of public riparian land is vegetated and 31% is in some form of protected area (Table 4.10).

Victorian floodplains have suffered widespread and increasing decline due to regulation of river flows preventing pulse flooding. Currently, large overbank flows occur only when water storages are full, and for most of the Murray River floodplain the frequency of small and moderate floods has declined by two-thirds or more compared to the natural flood frequency.[86] As a consequence, growing numbers of river red gums and black boxes are dying or dead, river red gum growth rates have declined and acid sulphate soils have developed due to the drying of once-permanent wetlands.[87] In 2010, an estimated 79% of the area of river red gum, black box and other box communities in 'the living Murray icon sites' was in a stressed condition (moderate to severely degraded condition).[88]

Table 4.9. Riparian land in Victoria – tenure, native vegetation, protected[89]

Category of riparian land	Area (hectares)	% riparian area
Total riparian area[(1)]	509,063	100
Private land	233,519	46
Public land	275,475	54
With native vegetation	356,435	70
Private with native vegetation	102,490	20
Public with native vegetation	253,945	50
Private with under-represented EVCs[(2)]	83,978	16
Public with under-represented EVCs	94,857	19
Private protected by covenant[(3)]	845	0.02
Managed by Parks Victoria	86,003	17

Source: Trust for Nature. Notes: (1) Riparian is defined as a 60 m wide area each side of named waterways. (2) Ecological vegetation class. (3) Protected by a perpetual Trust for Nature covenant.

4.3.5 Groundwater-dependent ecosystems

[There are] critical gaps in our understanding of the condition and prospects for Victoria's groundwater resources.

Victorian Catchment Management Council, 2012[90]

The extent and condition of subterranean groundwater ecosystems are unknown. There has been recent mapping using remote sensing data to identify potential groundwater-dependent ecosystems (as a first-cut prediction) and work is underway to determine the sensitivity of these ecosystems to changes in groundwater quality and quantity.[91] Groundwater resources are increasingly under pressure from extraction and a changing climate, and there is insufficient monitoring to determine whether extraction rates are sustainable.[92] Groundwater comprises about 15% of Victoria's total water use and extraction is increasing.[93] Increased extraction and reduced recharge led to drops in the level of several aquifers from the late 1990s to 2010 but they have risen since wetter conditions in 2011. Long-term declines have continued in Gippsland associated with dewatering of Latrobe Valley coal mines and off-shore oil and gas extraction.[94]

4.4 Major threats

[H]uman settlements have transformed inland waters into a complex and extensive system for harvesting, transporting and controlling the movement of water, with the highest levels of per capita storage in the world.

State of the Environment Victoria 2008[95]

Freshwater ecosystems are the most threatened on earth,[96] a status that probably also applies in Victoria. Most Victorian wetlands have been lost or substantially degraded, and most Victorian rivers have been transformed to service agriculture and human settlements, resulting in the highest per person levels of water storage in the world.[97] About a third of the 41 potentially threatening processes listed under Victoria's Flora and Fauna Guarantee Act affect freshwater ecosystems. The biggest threats are alterations to natural flow regimes, various invasive species, loss and degradation of riparian vegetation and, increasingly, climate change.

4.4.1 Changes to natural flow regimes

Dams, weirs and water extractions have imposed vastly different flow regimes on Victoria's rivers and are the greatest threat to freshwater ecosystems. There are 70 major dams in Victoria, hundreds of smaller dams and weirs on waterways, and thousands of farm dams on drainage lines or off-stream.[98] The proportion of total flow leaving Victoria's river basins was 56% in 2009-10 and 74% in 2010–11. The flow was less than 10% of natural levels in six basins in 2009-10.[99] Flow patterns have also been disrupted by physical changes to rivers due to dredging, straightening and levee banks, and changes to catchments.

Regulation has reversed normal flow patterns for many Victorian rivers. Under natural conditions, there are typically high winter and spring river flows and low summer and autumn flows. But water is used all year for industrial and domestic purposes, and agricultural users use more during summer, leading to large releases in summer. Changes to flow regimes include loss of flow variability, longer periods of zero or low flow, reduced flood frequencies and magnitudes, reversal of flow seasonality, and loss of no-flow periods.[100] In more than half of Victoria's 29 river basins, fewer than 20% of rivers have healthy flow regimes. In some years, more than three-quarters of the total flow is harvested from a quarter of Victoria's river basins.[101] In such heavily regulated systems, extensive overbank flooding essential for floodplain health occurs only in rare extreme flood events.[102]

The impacts are profound and multi-faceted, resulting in loss or degradation of aquatic, riparian, floodplain, estuarine and groundwater habitats. Almost half (46%) of Victoria's high-value wetlands and a third (32%) of other wetlands recently assessed are threatened by compromised flows, most due to changed flow regimes in their source rivers.[103] Impoundments and loss of natural disturbance due to flow variability have changed the composition of riparian vegetation, and much floodplain vegetation is stressed or dying due to loss of natural flooding regimes. Large areas of mature river red gums in Hattah-Kulkyne National Park downstream from Lake Mournpall have died in recent years due to lack of water. These problems are likely to be exacerbated by climate change, with reduced rainfall and higher evapo-transpiration rates leading to reduced runoff.

The movement of freshwater organisms is greatly impeded by weirs, dams and other constructions. A 1999 inventory identified close to 2500 potential barriers to fish movement – about 40% were farm dams and weirs and 30% were weirs and dams with stream gauges.[104] Large numbers of culverts and road crossings that also impede movement were not counted.

Migration is an essential part of the life cycle of at least 18 native fish species. Golden perch, for example, spawn in the flooded reaches of lowland rivers, use floodplains as nurseries, and then disperse, sometimes for than 2000 kilometres.[105] All aquatic fauna is likely to be affected in various ways – due to reduced availability of accessible habitat, ecosystem changes resulting from exclusion of migratory species, the loss of recolonisation opportunities, fish kills, increased predation and fishing pressure and reduced genetic diversity. A few barriers have a benefit in preventing movement of harmful introduced fish, protecting threatened galaxiids from predatory trout.[106]

Thermal pollution is another consequence of regulated flows, occurring when water discharged from the bottom layer of a dam is substantially colder than the river or stream into which it is released. There are 49 publicly managed dams and an unknown number of privately managed dams in Victoria that are more than five metres deep and discharge water from the bottom layers but the extent to which they cause cold water pollution is unknown due to a lack of temperature monitoring.[107] Most native fish require warm temperatures for spawning, so cold water releases can prevent or slow reproduction. They can reduce growth rates of young animals, reduce overall biological production, and displace temperature-sensitive species.

Box 4.4 Regent parrots need floodplain flooding[108]

The nationally vulnerable eastern subspecies of the regent parrot feeds in mallee vegetation and breeds in hollows in old floodplain eucalypts. Most of them are along the Murray River and highly dependent on riverine flooding. But relatively few breeding sites are amongst the highest priority areas for environmental watering. Only about half of the breeding sites are likely to be inundated by a large flood which, because of river regulation, may occur only once every several decades, far less often than is needed to maintain the trees. Without flooding, the parrot's breeding trees will deteriorate or die, and not be replaced.

Changes to groundwater flows

Because groundwater and surface river flows are interconnected, extraction of groundwater linked to a river system will impact on that river. This is a simple but fundamental fact which water management agencies around the world still struggle with…

Jon Nevill and others, 2010

Exploitation of groundwater has been increasing, often in the absence of a sound understanding of sustainability and needs of groundwater-dependent ecosystems. The physical and functional connections between surface water and groundwater mean that flow changes affecting one are also likely to affect the other.[109]

Loss of groundwater volume reduces habitat for stygofauna and diminishes contributions to river baseflows and wetlands.[110] Most wetlands depend on groundwater to some degree and are vulnerable to changes in groundwater level, because only small drops can substantially reduce the water available to vegetation.[111] A recent wetland assessment found that a quarter of wetlands fed by groundwater had an altered flow regime.[112]

The converse – excessive recharge due to irrigation and replacement of deep-rooted native vegetation with shallow-rooted crops and pasture – is also a problem, leading to dryland salinity. Rising water levels intercept salt and transport it upwards, resulting in stream and land salinisation. Saline groundwater can threaten the biodiversity of surface wetlands and rivers and drive shifts to more salt-tolerant plants and animals.[113]

Groundwater quality is compromised by changes to the natural flow regime and changes in land use (eg removal of native vegetation cover in the catchment, grazing, overuse of fertilisers, erosion of riparian zone) that result in increased sediments, nitrates, phosphates and toxic substances. Fine sediments can clog the top layer of channel sediments, reducing the permeability of the stream bed, hindering exchanges between surface water and groundwater, and reducing the diversity and productivity of this hyporheic zone.[114]

4.4.2 Loss and degradation of habitat

Compromised flow regimes are the major cause of loss and degradation of freshwater habitats, as discussed above. Others are grazing, land clearing and intensive land uses, and removal of woody debris from streams.

Livestock grazing

Grazing severely threatens riparian and floodplain habitats and wetlands, driving vegetation loss, land degradation and poor water quality.[115] In the recent index of wetland condition assessment, it was the most prevalent threat for high-value wetlands, occurring at more than half those surveyed.[116] No catchments in predominantly agricultural regions are in good condition.[117] In the Goulburn Broken catchment, a review of all licensed frontages found that only 10% were in near-natural condition, and more than half were substantially modified.

Cattle trampling and grazing destabilise the banks of wetlands and waterways and promote erosion. Cattle spread weeds, and damage and prevent regeneration of native vegetation. Their preference for particular plants changes the composition, structure and function of riparian and wetland vegetation.[118] Cattle dung and urine are a source of nutrients and, in combination with increased turbidity, they degrade water quality and promote the growth of algae and pathogens, which are a problem for human health as well as biodiversity (Box 4.5).[119] High turbidity can kill fish, reduce growth rates and increase disease.[120] Grazing has led to loss of sensitive habitats, such as sedge rich and herbaceous communities of lowland drainage lines, and changes in abundance and diversity of fish and other animals.[121] A comparison of stream frontages along the Broken-Boosey system in northern Victoria found that grazed frontages had less groundcover, less regeneration, fewer shrubs, more regionally listed weed species and more bare ground than ungrazed frontages.[122]

Box 4.5 Riparian grazing and human health[123]

'Prevention of contamination provides greater surety than removal of contaminants by treatment, so the most effective barrier is protection of source waters to the maximum degree practical.'

Australian Drinking Water Guidelines[124]

The 'Australian drinking water guidelines' state that pathogens are the greatest risk to consumers of drinking water and that preventing contamination is the most effective way to ensure safe drinking water. Yet, Victoria's crown water frontage licences allow landholders to graze and water cattle in waterways, increasing the costs of water treatment and exposing people to disease risks.

Cattle faeces contain pathogens such as *Cryptosporidium*, *Giardia*, *Escherichia coli*, *Salmonella*, *Campylobacter* and *Leptospira* that can be transmitted to humans through water that is ingested or used to grow fruit and vegetables. There are risks with recreation in water downstream of cattle access points. Many pathogens can survive in water or faeces for weeks or months. The cost of water treatment increases as the quality of water decreases, and there are some gaps in the extent or sufficiency of treatment or testing across Victoria. Nutrient inputs from cattle also increase the potential for toxic algal blooms.

Land clearing and intensive land uses

Clearing alters natural patterns of water flow into wetlands, rivers and recharge areas for groundwater. It leads to salinisation and erosion, and increases sediment and nutrient runoff. A study in the granitic Strathbogie Ranges of northeastern Victoria found that 150 years of clearing and agriculture had seriously eroded gullies, streambeds and banks, generating massive 'sand slugs' that blanket pools for kilometres downstream, altering water flows and destroying habitat.[125] Clearing and degradation of vegetation fringing streams and wetlands destroys wildlife habitat and compromises the filtration of sediment and nutrients. Nitrates leached from agricultural fertilisers and from urban and industrial areas pollute groundwater and contribute to eutrophication, stimulating algal blooms and aquatic weeds.[126] Other agricultural or industrial pollutants are heavy metals (mercury, nickel, lead for example) and toxic biocides. There have been numerous cases of contamination killing aquatic species in the short-term, and chronic contamination, which is poorly studied, can compromise reproduction and alter behaviour and metabolism of wildlife.[127]

Physical damage

Damage caused by excavation (dredging, draining), infilling, vehicles and recreation (as well as grazing and land clearing) threaten wetland and riparian areas. More than a third of high-value wetlands assessed in 2009-2011 had had vehicles driving on them, and more than a quarter of high-value wetlands and almost half of the 'representative' wetlands assessed had been excavated.[128]

4.4.3 Dysfunction of biological interactions

Of particular interest is the example of waters in the upper Murray where post c1920 catches of small [trout cod] became rare. … Although changes to habitat were undoubtedly occurring, the upper Murray did not experience the perturbations to flow or temperature regimes generally associated with impairment of the reproduction and recruitment of cod until the 1950s. Some form of negative interaction with introduced fish species, possibly predation, appears the most plausible explanation.

Will Trueman, 2007[129]

Invasive species

Many introduced animals, plants and pathogens threaten freshwater biodiversity, and the extensive modification of freshwater habitats by altered flow regimes, clearing and grazing aids their spread.[130] Climate change is expected to further exacerbate their impacts (see chapter 3).

Introduced fish

Eight exotic fish species have established in Victorian waterways, another is maintained by stocking and two are supplemented by large-scale stocking (Table 4.11).[131] All were introduced for fishing, except gambusia, which was introduced for biological control of mosquitoes (for which it is of little value). Some native fish have been spread beyond their natural range, with unknown impacts. Australia-wide, introduced species (mostly fish) are considered detrimental to more than three-quarters of threatened native fish species.[132] The impacts of invasive fish include domination of habitat and exclusion of native fish, predation of native fish and frogs, damage to aquatic habitats and spread of disease.[133] Carp have become the dominant freshwater fish in many Victorian waterways, displacing native fish, increasing water turbidity and damaging plants. In many sites, they contribute more than 90% of fish biomass (Box 4.6).

Predatory salmonids – brown trout and rainbow trout – impose substantial predation pressure on native fish and frog larvae, and have been implicated in the decline of small native fish, especially galaxiids.[134] Recent work has shown that there are many more galaxiid species in Victoria than previously thought, many endemic with tiny ranges, most threatened by trout. Brown and rainbow trout could have already caused extinctions of 'undiscovered unique lineages, worthy of recognition as species, in small and remote catchments'.[135] Brown trout are also suspected of contributing to declines of trout cod and Macquarie perch.[136]

Table 4.10 Introduced freshwater fish species[137]

Exotic fish species established in inland waterways
Brown trout (*Salmo trutta*)
Rainbow trout (*Oncorhynchus mykiss*)
European carp (*Cyprinus carpio*)
Goldfish (*Carassius auratus*)
Tench (*Tinca tinca*)
Roach (*Rutilus rutilus*)
Redfin perch (*Perca fluviatilis*)
Gambusia (*Gambusia holbrooki*)
Exotic fish species released for stocking
Brown trout (*Salmo trutta*)
Rainbow trout (*Oncorhynchus mykiss*)
Chinook salmon (*Oncorhynchus tschawytscha*)
Native fish introduced beyond their natural range
Freshwater Catfish (*Tandanus tandanus*)
Murray cod (*Maccullochella peelii peelii*)
Trout Cod (*Maccullochella macquariensi*)
Macquarie perch (*Macquaria australasica*)
Golden Perch (*Macquaria ambigua*)
Silver Perch (*Bidyanus bidyanus*)
Australian Bass (*Macquaria novemaculeata*)

Box 4.6 Ecosystem-transforming impacts of carp[138]

Carp are the largest exotic fish in Victoria and superabundant in the Murray-Darling basin. They can achieve densities up to 1000 fish per hectare (three tonnes a hectare). The highly regulated rivers of Victoria provide lots of still water habitats that suit them. Adult carp have no natural predators, and potential native predators of juvenile carp have suffered massive declines.

Carp are ecosystem engineers, changing the characteristics of invaded habitats.[139] Because of the way they feed – sieving the bottom sediment for snails, crustaceans, insect larvae and seeds – they stir up silt, increasing water turbidity. The detrital carbon they eat 'may become "locked" away from the trophic chain for their lifetime (up to 50 years), rather than passing up through a food chain of macroinvertebrates and smaller fish'. Their feeding also destroys aquatic plants, reducing photosynthetic production and changing the composition of invertebrate communities. They outcompete and displace native fish species.

Feral animals

Feral deer, pigs and horses can severely damage wetlands and riparian areas, many of their impacts similar to those of cattle –vegetation damage, decline of particular plant species, erosion and addition of nutrients and pathogens to water.

Weeds

A 2008 government advisory list records 29 invasive plants in aquatic habitats in Victoria, 17 rated as high or very high risk.[140] Just four are listed under the Catchment and Land Protection Act, and therefore have any restrictions over sale or use, or requirements for control. The weed ranked as the highest risk, arrowhead (*Sagittaria graminea*) ,has recently been recognised as a 'weed of national significance' (but is not declared in Victoria). This vigorous weed chokes streams and rivers, restricting water flow, compromising stream health and threatening native plants and animals. Ramsar wetlands at 'immediate risk' include Barmah National Park, Kerang Wetlands and Gunbower Forest.[141] Control is difficult because it can reproduce by seeds and tubers, survives a long time in seed banks and is tolerant to herbicides and mechanical removal. There are no effective herbicides registered for use.

More than 250 environmental weeds are invading riparian vegetation in Victoria.[142] Invasion is facilitated by periodic flooding, grazing, nutrient enrichment, and spread of weeds from agricultural land and via roads.[143] A 2004 survey found that only about one-quarter (27%) of river reaches had a healthy riparian ground layer, most having been invaded by weeds such as Phalaris, Rye Grass and thistles. Although 80-90% of reaches had a healthy shrub and tree layer, woody weeds such as willows and blackberries dominated many sites.[144]

Diseases

The frog-killing chytrid fungus (*Batrachochytrium dendrobatidis*) has probably been a major factor in the rapid decline of several of Victoria's threatened frogs, including the alpine tree frog, growling grass frog, stuttering frog and the endemic baw baw frog.[145] The disease is spread by infected frogs and tadpoles and via water and soil.[146] Introduced plant diseases (myrtle rust and *Phytophthora*) are a threat to riparian and floodplain habitats (see chapter 3).

Fish stocking

Negative impacts of alien salmonids on native aquatic fauna … have been noted for over 140 years. … Despite these impacts, salmonid management is focused largely on providing improved recreational angling opportunities, whereas management of their impacts is almost non-existent.

Jean Jackson and others, 2004[147]

Predatory introduced trout 'have been liberated into almost all waters [of the Murray-Darling Basin] thought to be suitable for them'.[148] And every year, for the benefit of recreational fishers, the Victorian government releases millions of hatchery-bred fish into the environment, including the predatory introduced rainbow trout and brown trout. In 2012, more than 600,000 exotic salmonids were released into 70 lakes or reservoirs, including about 300,000 each of rainbow trout and brown trout and 11,000 chinook salmon.[149] About 2 million native fish of six species were also released in 2011-2012, mostly golden perch and Murray cod.[150]

A 2013 audit of the stocking program by Victoria's auditor general found that the primary industries department was 'not paying sufficient attention to the protection and conservation of ecological processes, habitats and supporting ecosystems in these fisheries'.[151] Environmental risks have not been adequately assessed and the program is focused too narrowly on recreational fishing outcomes (Box 4.7).

Stocking no longer occurs in some streams and dams where threatened species are known to occur.[152] But generally there is a lack of research of the impacts of stocking of both exotic and native fish and a lack of monitoring. There are four main ways by which stocking may affect the ecology of a system (either negatively or positively):[153]

- competition with or predation of native species
- altered genetic composition of wild populations – including erosion of genetic diversity, homogenisation of the gene pool and loss of population structure and locally adapted populations
- unintentional introduction of pathogens or other organisms (the nature of aquaculture practices makes aquaculture facilities prone to the proliferation of disease)
- ecosystem level effects, such as exceeding the carrying capacity of the system and trophic cascades.

The protozoan *Chilodonella cyprinid*, which can infect many native fish species, has spread within Victoria through the stocking of infected trout.[154]

Box 4.7 Fish stocking in the Loddon River basin[155]

In a case study in the Loddon River Basin, Victoria's auditor general noted the high conservation values of the basin, including 20 Ramsar-listed sites and several threatened species. The Loddon is also the site of a river restoration project. Stocking occurs of the following species:

- golden perch and Murray cod in 13 rivers and lakes
- introduced trout in 18 rivers and lakes
- various native species into seven rivers

Despite recreational fishing being popular in the area, with 33 formalised fishing access sites, there is no fishery management plan. Fishing of Murray cod (threatened) and Murray spiny crayfish from all waters and silver perch from lakes and impoundments, and fishing in Ramsar-listed Gunbower Creek are permitted. The audit noted that 'Without a complete and robust assessment of all risk and threats, or an integrated long-term management plan for the basin, fishing activities, stocking programs and public access may result in irreversible impacts to the sustainability of these sites and species.'

4.4.4 Climate change

'As Victoria's growing population is heavily dependent on surface water (and increasingly groundwater) sources, reduced water availability is likely to intensify competition for water resources and exacerbate alteration of natural flow regimes.'

Yung En Chee, 2010

Many predicted aspects of climate change – higher temperatures, lower rainfall, higher evaporation, and reduced soil moisture levels, runoff, streamflow and groundwater recharge – will exacerbate existing pressures on freshwater ecosystems. By 2030, runoff into most waterways is projected to decrease by 5 to 45%, and by 2070, river and stream flow may be reduced by half across much of the state.[156] The extent and frequency of droughts in Victoria may more than double by 2050.[157] During the recent millennium drought, stream flow volumes declined to less than a third of the long-term average, and flow reductions since the mid-1990s have already exceeded climate change projections for 2030.[158]

Warmer waters are detrimental to many aquatic species – temperatures above 22 ˚C are lethal for mayfly larvae, for example, and warming may reduce the growth, reproduction and capacity to tolerate toxins of some fish species.[159] Higher temperatures alter oxygen concentration, respiration, production and decomposition.[160] The heating and expansion of surface layers increases the risk of thermal stratification in stationary water (eg dams, weir pools, billabongs) or very slow flowing river reaches and the frequency of algal blooms. Increased fire risk is likely to also reduce runoff – post-fire regrowth uses more water than mature forests – and reduce water quality.[161] Greater frequency of drought will exacerbate demand on water resources and intensify competition between consumptive and non-consumptive uses of groundwater.

4.5 Conservation gaps and priorities

4.5.1 Environmental flows

The rivers have been worked too hard, and in many places we are just as excessively mining the groundwaters that feed them.

Richard Kingsford, 2007[162]

Although socially and economically challenging, restoring environmental flows is essential if Victoria is to arrest degradation and biodiversity decline in freshwater systems. Because of the extent of over-allocation of water and distortion of flow regimes in Victoria, this will require a much stronger commitment to buy back water entitlements on over-allocated rivers, remove impediments to environmental flows, and return to rivers a greater degree of natural flow variability.

Victoria has established an environmental water reserve but it is highly inadequate for many rivers and aquifers and has low security compared to agricultural and industrial uses (Box 4.8). During the millennium drought (1997–2010), many Victorian catchments experienced very low stream flow, among the lowest on record, but environmental allocations were sacrificed in several areas to augment supplies for agricultural and urban uses.[163] In 2007–08, for example, the environment received less than 7% of its entitlement while irrigators received 30–35%.[164]

Although Victoria's wetlands have suffered grievously from being deprived of natural flows, there has been very limited use of environmental water reserves for wetlands, and only for wetlands on public land.[165]

Victoria's 2013 waterway management strategy proposes to better integrate management of rivers and wetlands, and has a policy to identify priority wetlands in regional waterway strategies 'where environmental water management plans and environmental watering is required to maintain or improve wetland values at risk from altered water regimes'.[166] This is important but the strategy overall fails to specify objectives and actions to drive reforms essential to protect and restore wetland health.

Because it lacks clear objectives and targets, the waterway management strategy is likely to perpetuate current patterns of over-extraction at the expense of the health of freshwater ecosystems. A much greater commitment is needed to restore more-natural flow regimes. Targets for environmental flows should be based on a range of ecological criteria (such as specified in Table 4.12) and achieved by a mix of regulatory measures, market-based instruments and infrastructure improvements. The most cost-effective and efficient way to return water to the environment is by purchasing water from willing sellers.[167]

Box 4.8 Victoria's environmental water reserve

The environmental water reserve was established in 2005 under the Water Act as a share of water set aside to 'preserve the environmental values and health of water ecosystems, including their biodiversity, ecological function and quality of water, and the other uses that depend on environmental condition.'[168] It is managed by the Victorian environmental water holder, an independent statutory body. Environmental water can be in the form of entitlements held in storage and released to a river, rules based water (conditional on other entitlements) or above cap (what's left over after consumptive demand is satisfied).

Implementation of the environmental water reserve has been flawed as it lacks sufficient reliable water to protect environmental values and has been repeatedly qualified by the minister responsible for water giving priority to general consumptive demands during dry times. The Water Act requires the following amendments to enable achievement of the purpose of the environmental water reserve:[169]

- Improve the objective of the environmental water reserve to give surface and groundwater systems enforceable statutory protection. The current objective does not require environmental values and the health of ecosystems to be protected.

- Protect the environmental water reserve from qualification of rights. Critical human water needs and ecological needs should be prioritised over general consumptive rights. Qualification of rights for any elements of the environmental water reserve should require financial compensation or water payback.
- Introduce a legislated cap on the amount of water that can be extracted from Victorian water resources to protect environmental values (Sustainable Diversion Limits in the Murray-Darling Basin go some way to meeting this recommendation).
- Bring forward the first water resource assessment and statutory review to 2014.

Restoring floods for floodplains

[An] efficient and effective watering regime to sustain flood-dependent natural values is achievable.

Paul Peake and others, 2011[170]

Restoration of flooding regimes is essential to the health of floodplain biota, including 110 flood-dependent ecological vegetation classes and almost 200 rare and threatened plants and animals on the Murray River floodplain in northern Victoria.[171] Many rivers are so heavily regulated that only rare extreme flood events result in extensive overbank flows.[172] Recent environmental watering programs have focussed only on the largest floodplain blocks ('icon' sites) and a small set of values such as colonial nesting waterbirds, and the reason for their selection over other sites is often unclear or based on the potential to use small-scale engineering works as an alternative to buying water licences.[173] This latter politically expedient approach is based on the flawed notion that the same, limited water supply can be divided further for multiple uses, and is being used to justify reduced allocation of water to wetlands in the Murray-Darling Basin.[174]

Victoria needs 'a comprehensive, systematic, spatially explicit and publicly transparent inventory of flood dependent natural values' as a basis for allocating water and determining priorities for infrastructure investment to protect floodplains.[175] An assessment of the flood requirements of ecological vegetation classes and threatened taxa has recently been done for the Victorian floodplains of the Murray, Goulburn, Ovens and King Rivers.[176] Identifying all flood-dependent natural values and estimating their water requirements should be a high priority for all Victoria's river basins with flood-dependent biota.

Floodplain watering strategies should be based on the flooding requirements of the entire range of terrestrial and aquatic species, and be focused on maintaining natural values including for the following:[177]

- sites likely to assist the recovery of threatened species
- sites of high species richness
- sites for colonial breeding species
- sites that may be in poor condition at present but would recover with watering and be likely to support significant natural values
- corridors important for movement – from flight paths for the daily movements of Superb Parrots between breeding and feeding areas to corridors for longer-term movements such as in response to changing climate over the course of decades.

To achieve sustainable flooding regimes will require much better information about the flooding needs of floodplain biota.[178] The quantification of benefits of improving flooding regimes should go beyond site-specific values to the broader benefits of ecological connectivity. A conceptual framework is needed by which to compare different values and risks and to aid transparent decision-making on water allocations. Although yet to be fully implemented, the Murray-Darling Basin Authority has made progress by developing a hydrological model to set environmental targets for flooding frequencies.[179]

4.5.2 Riparian protection and restoration

Actions to maintain, improve and augment native vegetation on stream frontages are among the most likely to be highly beneficial for improving ecological connectivity and conserving biodiversity.

Victorian Environmental Assessment Council, 2011[180]

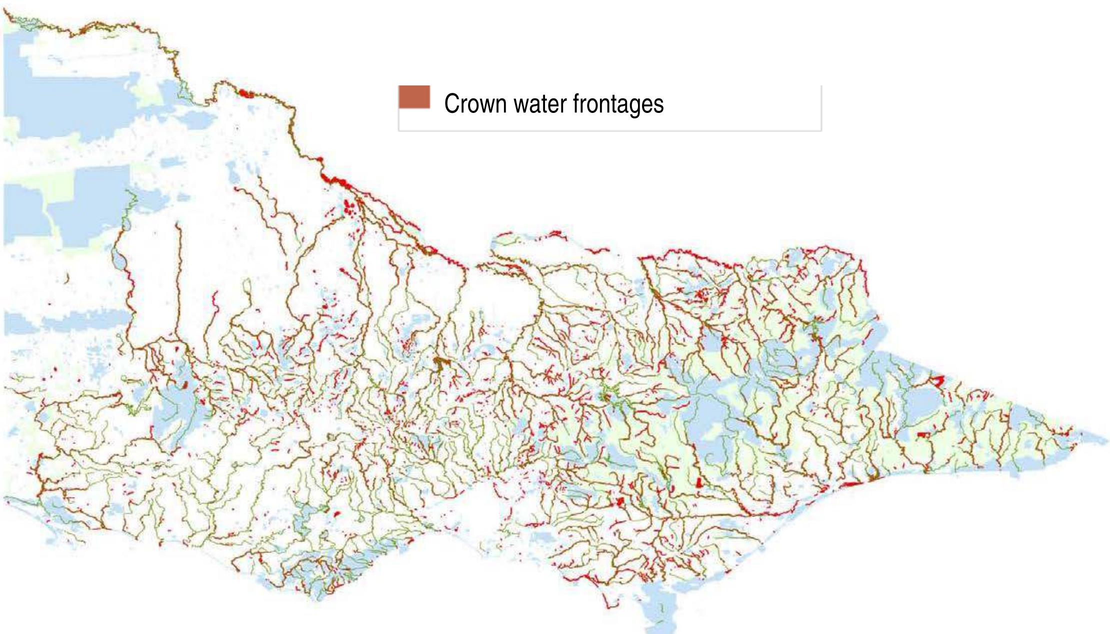
With more than half its riparian area along named waterways in public ownership, Victoria has a great opportunity to address many significant water quality, health and conservation problems by reforming management of the 30,000 kilometres of crown water frontages (Figure 4.7).

Riparian restoration typically requires excluding stock by fencing (and providing off-stream watering), controlling weeds and reintroducing native plants. There is high potential to restore at least some ecological functions of riparian areas, including carbon sequestration, and many benefits are likely to accrue (Box 4.9).[181] The extent of benefits will depend on the attributes of particular riparian areas and the health of the catchment – adjacent land-uses may continue to cause damage or limit recovery – but 'some is better than none'.[182]

To manage crown water frontages in the public interest, for both environmental and public health benefits, stock access needs to be restricted and high-value areas managed for conservation.[183] This requires classifying areas according to conservation criteria, providing incentives for licence holders to fence riparian areas and manage them for conservation, enforcing licence conditions and funding a restoration program.[184]

Similar stewardship measures need to be applied to riparian areas on private land, which account for 46% of riparian area (within 60 metres of a named waterway) and 29% of the extent of riparian areas with native vegetation.[185] The vegetation on privately owned riparian land is mostly of high conservation significance, with more than 90% of it mapped as ecological vegetation classes that are poorly represented in the conservation system. There needs to be more focus on permanently protecting high-value privately owned riparian land by covenants or acquisition for the national park and conservation system.

Figure 4.8 Victoria's crown water frontages



Victoria is unique in still having significant areas of riparian land in public ownership as crown water frontages. They are mostly on larger streams where the riparian land forms a boundary between properties. Most are licensed for agricultural activities by an adjoining landholder but more recently they have also been licensed for conservation purposes. There are currently about 10,000 licenses, issued for five years. Licensees are responsible for managing weeds, pests and fire and for maintaining public access for recreation. Many are being used by landholders without a license for purposes that require licensing. On smaller streams in agricultural landscapes, riparian land is usually in private ownership.

Box 4.9 Benefits of restoring riparian zones[186]

Better ***water quality*** due to:

- more stable soil and stream banks, reducing erosion
- filtering of nutrients and sediments from adjacent areas
- less nutrient input and increased capacity for nutrient processing, therefore reduced input into streams

Improved ***in-stream biodiversity*** due to:

- reduced nutrient and sediment loads in streams
- greater stream shading, which moderates water temperature (10% increase in riparian cover reduces water temperature by about 1 ºC)
- more litter, woody debris and other organic matter in streams, providing more habitat and food sources for aquatic communities (canopy cover of at least 50% is required to provide a reliable supply of leaf litter to support the aquatic food web)

Enhanced ***terrestrial biodiversity*** due to:

- restoration of plant communities unique to riparian areas
- improved condition of vegetation (eg exclusion of stock facilitates natural regeneration)
- increased landscape productivity (riparian areas tend to have larger trees, more regular flowering and reliable plant growth)
- increased foraging, breeding and refugial options for species
- improved habitat for threatened species

Increased ***resilience of ecological communities*** due to:

- re-establishment of dispersal corridors and habitat for species persistence
- restoration of drought refuges
- amelioration of threatening processes

Mitigation of climate change due to:

- a high capacity for carbon storage in riparian vegetation

Box 4.10 Riparian land management, public health and potential legal liabilities

Cattle faeces and urine contain pathogens that can be transmitted to humans, and uncontrolled access of cattle to rivers and streams in Victoria has the potential to introduce these pathogens into untreated or insufficiently treated water sources used by humans. In addition to the overwhelming environmental reasons to restrict stock access, there are strong human health and associated legal reasons to do so.

The Environment Defenders Office (Victoria) has warned that the 'statutory regime around the use of crown water frontages and human health create legal risks for the state government, which are likely to increase as time goes on.'[187] Legal risks include the following:

- The Water Act creates a civil liability for a person who pollutes water, whether authorised or not, and who by that act causes injury to another person.
- The Health Act creates a breach where a person causes a nuisance or knowingly allows a nuisance to exist or emanate from any land owned or occupied by or in the charge or that person.
- The Wrongs Act gives rise to a right to damages where the act or omission of a public authority breaches its duty of care, for example, where it fails to comply with general procedures and applicable standards.
- Injury to a person or their property arising from uncontrolled stock access on riparian land could give rise to an action in common law or statutory negligence or to a claim in public nuisance.

4.5.3 Freshwater protected areas

The need to establish comprehensive and representative freshwater protected areas is urgent … This should be accompanied by effective land and water management that pays more than lip service to the environmental requirements of aquatic ecosystems.

Richard Kingsford and Jon Nevill, 2005[188]

There is just as much need for comprehensive, adequate and representative protection of freshwater ecosystems as there is of terrestrial and marine ecosystems but Australia-wide, only about 2% of named rivers are protected within national parks.[189] Even internationally significant (Ramsar) wetlands are not fully protected – only about half their area in Victoria is in land tenures designated for conservation, and activities like duck hunting are permitted in several sites. Heritage rivers are only protected from the construction of major on-stream dams and not from other alterations to flow regimes.

'Failure to jointly assess freshwater and terrestrial biodiversity results in bias towards terrestrial ecosystems and in effect undervalues the linkages between them.'

Yung En Chee, 2010[190]

The bias is also evident in the lesser protection for many freshwater organisms in protected areas, with fishing permitted in national parks. It is also evident in the configuration of many protected areas (typically square or rectangular) being unrelated to natural drainage characteristics.[191] The bias to terrestrial ecosystems undervalues the linkages between freshwater and terrestrial systems, and the partial protection of wetlands or watercourses means they are highly vulnerable to degrading processes outside park boundaries.[192] The condition of surrounding areas is the primary determinant of wetland condition. While this is acknowledged in the waterway management strategy, it provides no imperative for reform.

There is also a strong bias in the types of wetlands protected, mostly due to the historical conversion of prime agriculture areas to freehold title, leaving little of many freshwater types in public ownership. In the Wimmera – the only bioregion for which there is published information on the extent to which freshwater ecosystems are protected within reserves – the once abundant shallow, less permanent wetlands are poorly represented, probably because their intermittent inundation meant they were more easily converted to agriculture than permanent wetlands.[193]

Nonetheless there are parts of Victoria with large areas of native vegetation and freshwater environments managed as part of 'largely intact ecosystems in extensive parks, reserves or forests'.[194] The protection of highly value, largely intact freshwater ecosystems should be optimised by creating freshwater reference areas under the Reference Areas Act. They provide a unique opportunity to serve as baseline reference areas and should be strictly protected from threats such as fish stocking and recreational fishing.

An essential basis for identifying priority freshwater communities for protection is their systemic classification and description – as has been done for terrestrial vegetation communities. Victoria has broad classifications of types of freshwater environments but these take no account of biological characteristics.[195] There needs to be a state-wide process for classifying freshwater communities and identifying priority areas for conservation investment or action.[196]

Selection of priority sites for freshwater protected areas needs to accommodate the 'unique aspects of freshwater biodiversity, ecology, and system function' – including freshwater-specific biodiversity elements and their strong connectivity.[197] The bioregional classification used for terrestrial ecosystems is 'not effective in representing aquatic ecosystem patterns across Victoria'.[198]

More detailed mapping is needed.[199] Victoria's rivers and streams have been mapped only at a coarse scale, with small streams and tributaries omitted. There is even less information on subsurface ecosystems and linkages with surface ecosystems. Wetlands greater than 1 hectare have been comprehensively mapped and classified into seven categories based on water regimes and salinity. They have also been mapped based on ecological vegetation classes but this mapping is far from comprehensive, with more than two-thirds of wetlands identified by hydrological factors (in four bioregions assessed) not identified in the ecological vegetation class mapping, and only 21% of the area of wetlands covered.[200] The lack of coverage is a serious impediment for wetland conservation planning and the establishment of a comprehensive, adequate and representative reserve system, and conveys a misleading impression of their condition and conservation status. The vegetation classification system has the potential to be a sound basis for planning because it combines hydrology and floristics but it needs to be comprehensive.

The selection of priority areas for protection of freshwater ecosystems should be systematic and based on identified biodiversity and conservation values, such as outlined in Table 4.12.

Table 4.11 Criteria that can be used to assign value in the identification of priority areas for conservation[201]

Criteria	Description of purpose or rationale
Biodiversity Values	
Taxa/community richness	The number of taxa or communities (whichever is relevant) within a planning unit. The greater the richness, the greater the value of the planning unit.
Taxa/community/habitat diversity	The full variety of taxa/communities/habitats (whichever is relevant) within a planning unit. The greater the diversity, the greater the value of the planning unit.
Species aggregations	Site/planning unit regularly hosts and/or supports large numbers of species (particularly migratory species).
Significant population numbers	Site/planning unit supports a significant proportion of the individuals of a native species.
Conservation Values	
Conservation status	The presence-absence or number of taxa, populations, communities or habitat types that are threatened or endangered. The greater the number of such biological entities in the planning unit, the greater the value of planning unit
Rarity, uniqueness, irreplaceability	The rarity, uniqueness, irreplaceability of taxa, populations, communities or habitat types within the focal region. The rarer the biological entities in the planning unit, or the more rare entities within the planning unit, the greater the value of the planning unit
Naturalness/intactness	These terms imply freedom from anthropogenic degradation and disturbances such as urbanisation, clearing, intensive agriculture, grazing, timber harvesting. The greater the degree of naturalness/intactness, the more valuable the planning unit.
Spatial attributes & landscape context	Spatial attributes refers to characteristics such as the size, shape, orientation, spatial configuration and juxtaposition of planning units, which have a bearing on population processes, susceptibility to degradation or disturbance and species persistence. Landscape context is a function of a planning unit's landscape position, and whether it plays a role in providing or supporting ecological processes, particularly for maintaining species populations. Connectivity – does the planning unit provide linkage/movement corridors between refuges (during periods of environmental stress or natural disturbances) or areas important for fulfilling for species life-history requirements (e.g. mating, spawning and nursery grounds)? Buffering – the planning unit may not be important in and of itself, but effectively buffers important areas from adverse influences. Component within a network of areas – the planning unit may not be important in and of itself, but it may have value for being a component in a network with a role in processes such as facilitating recolonisation following local extinction
Representation	Number of examples of the focal biodiversity feature (ie. taxa, communities, habitat type, ecological process) within a single planning unit or network of units. The more under-represented the biodiversity feature, the more valuable the planning unit
Practical considerations	
Physical environment	Lack of contamination: pollution , nutrients
Vulnerability to threatening processes	Risk of future degradation or conversion to production lands, urban development, or for any other purpose that would be detrimental biodiversity within the relevant time frame.

Comprehensive, adequate and representative inclusion of freshwater sites in national parks needs to be complemented by flow regimes that maintain or restore their conservation values. Damaging uses of freshwater areas – such as fishing of declining species – should be prohibited.

It is more than two decades since the last state review of the role of protected areas in freshwater conservation (by the Land Conservation Council in 1991)[202] and much has changed since then to warrant a new investigation of priority areas, and law and policy reforms. The legislation that resulted from the Land Conservation Council investigation, the Heritage Rivers Act, was a major advance at the time (until recently Victoria was the only Australian state with a law specifically for river protection) but it has been poorly implemented and needs revamping.[203] Management plans for heritage rivers have languished and there is insufficient focus on whole-of-catchment managment to protect their values.

In 1991 the Land Conservation Council also recommended the designation of 16 rivers as 'representative rivers' – in recognition of the great variety of Victoria's rivers, exemplified by the contrast between the cold, fast-flowing waters of the deep v-shaped Kiewa River and the warm, slow-moving pools of the lower Wimmera.[204] Rivers designated as representative need not be totally intact or contain outstanding values, but would be the least disturbed of each type (Table 4.13). They would serve as benchmarks for understanding how particular types of rivers function and the restoration potential for others of that type. Designation was intended to permit current uses to continue, require flow regimes to be maintained and motivate selective restoration. This 20 year old recommendation has great merit. The 2002 Victorian River Health Strategy noted the merit of the concept and a new preliminary classification of rivers had been developed but the concept seems to have lapsed.

An emerging priority under climate change is to protect freshwater refugia to facilitate survival of organisms under increasingly adverse conditions.[205] This should include 'evolutionary' refugia – sites that have been protected from dramatic climatic extremes over millennia, such as cave groundwater ecosystems for stygofauna – and 'displaced' refugia – sites such as mountain ranges, deep valleys and areas with steep climatic and environmental gradients, where species might find suitable habitats after displacement from original habitats. High priority should be given to identifying and protecting freshwater refugia.

Table 4.12 Land Conservation Council schedule of representative rivers[206]

Geomorphic unit	Representative rivers (gauge location)
East Victorian dissected uplands	Upper Big River (Glen Valley) Snowy Creek (Granite Flat) Dargo River (Dargo) Buchan River (Mellick Munjie Creek) Nicholson River (Deptford)
East Victorian uplands, dissected plateau	Macalister River (Glencairn)
East Victorian dissected uplands, riverine plains	Thurra River (Point Hicks) Cornella Creek (Colbinabbin)
West Victorian dissected uplands	Avoca River (Avoca)
West Victorian dissected uplands, volcanic plains	Lerderderg River (O'Briens Crossing) McCallum Creek (Carisbrook)
Otway Ranges, dissected plains	Gellibrand River (Carlisle River)
South Gippsland Ranges, riverine plains	Tarra River (Yarram)
Volcanic plains, dissected coastal plains	Kennedy Creek (Kennedy Creek)
Volcanic plains, coastal plains	No representative recommended.
Volcanic plains, west Victorian dissected uplands	Moorabool River (Morrisons)

Note: Representative rivers lie upstream of the nominated stream gauge. No recommendation was made for one category because all streams considered had been substantially modified.

4.5.4 Wetlands

[In] terms of the legal protection they receive, Victorian wetlands are still stuck in the past. Falling between a patchwork of partially applicable state and federal measures, wetlands are the forgotten piece of Victoria's environmental puzzle, covered by a plethora of rules and regulators but not effectively protected by any of them.

Environment Defenders Office (Victoria), 2012[207]

More than 95% of Victoria's wetland losses have occurred on private lands and 80% of remaining wetlands are on private lands, yet protection for these wetlands under Victoria's planning framework is inconsistent, usually non-specific, and often non-existent.[208] Wetlands on private land include part of 10 Ramsar-listed wetlands and 3600 nationally important wetlands.[209] Protection relies on particular shires or councils applying appropriate zones and overlays in their planning schemes and rigorously assessing development or land use proposals. There are wide-ranging exemptions, and decision-makers have broad discretion. Even when permits are required, decision-makers tend to impose conditions rather than refuse applications.[210] Overall, councils have been reluctant to use the few environmental protection measures in Victoria's planning laws to protect wetlands.[211]

There is need to amend planning schemes to ensure that high-value wetlands are identified – for example, by requiring that high-value wetlands identified by catchment management authorities are identified as such in planning schemes – and given much stronger protection. This could be achieved by a new 'wetlands overlay' for planning schemes that prohibits development that would destroy or degrade high-value wetlands. High-value wetlands to be strictly protected would include all Ramsar sites.

Another legislative gap is in the definition of waterway in the Water Act, which may not encompass several types of wetlands on private land.[212] This should be fixed.

The Flora and Fauna Guarantee Act could provide protection to wetlands that are habitat for threatened species. The Secretary of the Department of Environment and Primary Industries has the power to make 'critical habitat determinations' and the environment minister can issue 'interim conservation orders' to conserve critical habitat that takes precedence over permits, licences, or planning schemes but only one critical habitat determination has ever been made and not a single interim conservation order has been issued.[213]

Victoria needs an overarching strategy to set out goals, targets and measures for wetland protection. (Victoria is the only Australian state without a dedicated wetlands policy or strategy.) The Victorian waterway management strategy has a chapter on wetlands but will not drive comprehensive reform. There are many bodies with some responsibility for wetland management in Victoria – catchment management authorities (six of which have a wetlands strategy), the Victorian Catchment Management Council, various state government agencies, and shires and councils. But none has a clear mandate. A state-wide strategy for wetlands would help coordinate these agencies and assign clear responsibilities.

Wetland conservation is also dependent on restoring more-natural flow regimes, addressed above, and addressing major threats such as damage by cattle and vehicles, pollution and invasion by weeds, fish and feral animals.

4.5.5 Groundwater

'The Department of Sustainability and Environment and water corporations do not know whether groundwater use is sustainable.'

Victorian auditor general, 2010[214]

There is growing pressure on groundwater reserves in Victoria. Entitlements and use have been rising, particularly when the availability of surface water declined during the millennium drought. In 2010, Victoria's auditor general found that there were insufficient groundwater data and monitoring to ascertain the extent of groundwater reserves and whether extraction rates were sustainable.[215] In 2012, Victoria's Catchment Management Committee concluded there was insufficient information to establish a state-wide verdict on groundwater levels, with 'critical gaps in our understanding of the condition and prospects for Victoria's groundwater resources.'[216]

About 43% of Victoria's 62 groundwater management units have inadequate or limited coverage by observation bores, and about 55% of management units have key bores at risk of failure.[217] There is also insufficient licencing, metering and compliance monitoring to be clear about who is extracting groundwater and how much. Many groundwater users do not have meters to measure extraction, and some extract water without licences. The auditor general highlighted particular concern about lack of metering of domestic and stock use, with the estimated use for these users increasing from 44,000 megalitres (9% of total extractions) in 2006–07 to 51,000 megalitres (11%) one year later. There is also no state-wide information on trends in groundwater salinity.[218]

There is need for research to ascertain the extent of reserves and sustainable extraction limits and ensure that these limits are applied. These limits need to take into account the dependence of many riverine, wetland and floodplain ecosystems on groundwater input. A recent mapping exercise by the government has identified the extent of potential linkages (as a first cut prediction)[219] but there is need for more information about the groundwater needs of surface and subterranean ecosystems and the ecology of stygofauna as the essential basis for sustainable management. There has been no research on the water requirements of stygofauna.[220]

The Water Act requires that environmental water requirements be considered in determining the sustainable yields of groundwater systems but there is no accepted definition of groundwater-dependent ecosystems and no consistent method for assessing their requirements, which means there are no specific provisions for their protection or maintenance.[221] However, some policy progress is evident in the 2011 'western region sustainable water strategy', which requires consideration of groundwater-dependent ecosystems.[222]

4.5.6 Catchment management

The processes that can be used to assess the condition of the state's land and water resources and the effectiveness of land protection measures are either absent or insufficient.

Victorian Catchment Management Council, 2012[223]

Effective management of freshwater ecosystems requires effective catchment management. All land use activities can potentially impact freshwater habitats and 'therefore matter'.[224] Catchment damage in Victoria has been most widespread and intense in areas used for agricultural production, natural resource extraction and urban development, on private land. With about two-thirds of the state in private tenure, from which about 80% of native vegetation has been cleared, whole-of-catchment management requires effective partnerships between private landholders and local, regional and state institutions, backed up by effective laws, institutional arrangements and incentives programs.

Essential to these partnerships and for achievement of catchment goals is for government agencies themselves to exemplify best practice land management and to comply with catchment management strategies and strive to meet condition targets. Many activities carried out on crown land by government agencies can either foster or mitigate land degradation – logging in state forests, weed and pest management and fire management for example. State laws and policies should be improved where necessary to achieve catchment condition targets – to prevent damaging grazing along rivers, unsustainable firewood collection and the establishment of new weeds. Under the Catchment and Land Protection Act, catchment management authorities have catchment-wide responsibilities across all land tenures, yet have no influence on how some of the most important biodiversity assets – many forests, rivers and wetlands – are managed to meet catchment targets. To be effective, catchment management strategies have to guide all activities in Victoria whether by private or public land managers.

The latest five-yearly report on catchment condition by the Victorian Catchment Management Council criticises the lack of evaluation and monitoring of the condition and management of land and water resources.[225] There is a lack of clarity about the objectives of management, about what is required to achieve healthy catchments and the priorities for investment. Although the Catchment and Land Protection Act has an objective to maintain and enhance long-term land productivity, explicit biophysical targets are lacking. The waterway management strategy also lacks clearly defined ecologically based objectives and targets for waterway health and clear actions to achieve them. Catchment management strategies need to be based on a more sophisticated ecosystem-based model that accounts for ecological processes, with clear targets and indicators and informed by long-term monitoring programs. As the Catchment Management Council stresses, there should be standard approaches to monitoring, evaluation and review, and a system of sharing information across sectors, organisations and communities involved in land and water management.

4.6 Future directions

More than any other issue, freshwater management in Victoria exposes the short-sightedness of exploitation without care for the health of the system. Dead and dying river red gums, desiccating wetlands, rivers dominated by exotic fish and regular toxic algal blooms are some of the more lamentable symptoms of chronically overworking Victoria's rivers.

The density and diversity of Victoria's waterways and wetlands and the multiple ecotones (transition zones) they create support a rich biodiversity, including many endemic crayfish and fish and ecological communities. Victoria's groundwater systems are likely to harbour a wealth of endemic stygofauna yet to be comprehensively surveyed. Hundreds of wetlands are recognised as internationally or nationally significant, and many support internationally significant numbers of birds.

But a great many rivers, wetlands, riparian zones and floodplains are suffering the effects of flow regulation that reverses natural seasonal patterns, suppresses floods essential for floodplain health, leaves too little water for essential ecological functions and imposes barriers to natural migrations and dispersals. Close to half or more of Victoria's native fish, frog and crayfish species are threatened. A quarter of wetlands have been destroyed and many others have been degraded. Freshwater ecosystems are also damaged by catchment activities such as land clearing, grazing in riparian zones, introduction of invasive species and nutrient enrichment. Victoria's highly stressed freshwater systems lack resilience to cope with the drier future and reduced water availability predicted by climate science

More than any other issue, freshwater highlights the need for whole-of-system planning and management, for freshwater systems are hyper-connected – from headwaters to estuaries, rivers to floodplains and surface waterbodies to below-ground aquifers. Restoring river and wetland health should be at the top of the state's priorities – not only for ecological reasons. This is needed also for economic and human health and for ecosystem services such as water purification. To achieve it will require improving natural flow regimes and connectivity, freshwater protected areas, restoration and management of degraded habitats, and whole-of-catchment management.[226]

The national park and conservation system has been mostly focused around terrestrial values, with freshwater features often incidentally and partially encompassed. Just as for terrestrial areas, a comprehensive, adequate and representative system of freshwater protected areas should be a core conservation strategy.

In recognition of the essential ecological and health services provided by riparian zones, Victoria should seize the opportunity provided by its 30,000 kilometres publicly owned network of crown water frontages to improve water quality and restore riparian habitats. The poor and declining status of many wetlands points to an urgent need to bolster laws and planning processes, particularly for the 80% of Victoria's wetlands on private land.

Sympathetic ecosystem-based management at the catchment scale is an essential complement to protection and restoration of freshwater ecosystems. Reducing pressures in riparian and floodplain areas – by managing invasive species, reducing grazing impacts, preventing clearing and supporting low impact agriculture – will facilitate natural recovery.

Following is a summary of reforms recommended as high priorities over the next decade to make substantial progress on the protection and restoration of Victoria's freshwater ecosystems.

Environmental flows

F1 Establish sustainable environmental flow targets based on ecological criteria for surface water and groundwater systems.[227]

F2 Purchase water entitlements in a staged program aiming to reliably achieve sustainable environmental flow targets.

F3 In over-allocated rivers, accord high security and reliability to environmental water and use it to improve natural flow variability, including natural flood frequencies and high and low flows.

F4 Remove legal and other barriers to environmental watering of wetlands on private land.

F5 Establish a program to strategically remove barriers, such as artificial structures, that prevent environmental water from reaching high conservation value floodplains and downstream areas.

F6 Undertake a systematic assessment of the condition of Victorian aquifers, including identification of linkages between groundwater and surface water, and establish base-level data for ongoing monitoring and to inform management.

F7 Develop watering strategies to protect and recover flood-dependent natural values on floodplains, with priority sites including those with threatened taxa, high species richness, colonial breeding sites or corridors important for movement of biota, and sites in poor condition with the potential to recover significant natural values.

Riparian protection

More details are in the VNPA *Riverside Rescue* report.[228]

F8 Establish a 'special offer' assistance program to crown water frontage licence holders to fence boundaries, set up off-river watering and improve management for environmental outcomes.

F9 Establish a 'waterway guardians' program to offer incentives to landholders with significant conservation assets on private land adjacent to crown water frontages or with privately owned frontages with high conservation values to manage these areas for conservation.

F10 Strategically add riparian areas that meet conservation criteria (for biodiversity values, connectivity and management integrity) to the national park and conservation system and manage them accordingly.

F11 For areas in moderate to good condition, but not suitable for addition to the national park and conservation system, issue a conservation licence that specifies minimum management actions, such as fencing, stock removal or grazing regimes and weed control.

F12 Enforce Victoria's laws to prevent unauthorised activities on riparian public land. Cancel licences where there is evidence of no improvement or action to improve conditions.

F13 Cancel riparian grazing licences where there is evidence of significant damage or no improvement or lack of action to improve conditions.

F14 Provide funding of $20 million per year for four years to accelerate the implementation of good management and assist landholders to take positive steps to repair, restore and protect riparian lands.

Freshwater protected areas

F15 Develop a state-wide process for classifying freshwater communities (akin to terrestrial vegetation communities) and systematically identify high priority areas for protection by applying criteria for assigning biodiversity and conservation value (such as in Table 4.12).

F16 Systematically identify freshwater refugia likely to facilitate survival of organisms under threat from climate change and provide them with a high level of protection.

F17 Create freshwater reference areas under the Reference Areas Act to optimise protection of freshwater ecosystems which are highly intact and have high biodiversity.

F18 Review and revamp the Heritage Rivers Act, including by extending it to wetlands, improving its capacity to prevent damaging land use changes, and requiring monitoring.

F19 Protect the 16 'representative rivers' recommended by the Land Conservation Council in 1991 by amending the Heritage Rivers Act or by protecting them in the national park and conservation system.

Wetlands

F20 Develop a Victorian wetlands strategy that sets policy goals, targets and reporting regimes.

F21 Require land use planning schemes to contain wetland overlays to prohibit destruction or modification of high-value wetlands, as identified by catchment management authorities and including all Ramsar sites.

F22 Use the Flora and Fauna Guarantee Act to protect high-value wetlands that provide habitat for threatened species by declaring them as critical habitat and, where they are under imminent threat, by issuing 'interim conservation orders'.

F23 Protect all Ramsar wetland sites on public land within the national park estate.

F24 Amend the Water Act to include all wetlands on private land in the definition of 'waterway'.

Catchment management

Chapter 3 provides considerably more detail on land use recommendations.

F25 Strengthen catchment management strategies, including by adopting an ecosystem-based approach, identifying clear targets and indicators, developing a long-term monitoring program and clearly linking catchment management to the health of marine and coastal environments and the Murray River.

F26 Strengthen links between catchment management strategies and land-use planning.

F27 Revise and strengthen the Victorian waterway management strategy to define clear indicators and targets for regional river health and restoration.

F28 Recognise the important role played by streams and their environs in landscape connectivity and as carbon sinks by incorporating them into broader connectivity, restoration and carbon sequestration programs.

F29 Minimise land use impacts on rivers and streams by removing grazing from sensitive areas, promoting low impact agriculture and controlling weeds and feral animals. Complement these measures with education to promote improved management practices.

F30 Ensure that public land managers lead the way in complying with regional catchment strategies and their catchment condition targets developed by catchment management authorities.

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