Chapter 9

Implications of water scarcity for environmental values

9.1 Overview

The best available science and knowledge indicates that the Riverina bioregion is likely to receive less rainfall and surface run-off and increased temperatures under climate change scenarios. This, along with river regulation, will continue to affect flooding regimes and ecological processes across the Riverina floodplain ecosystems. These changes will influence the structure and composition of forests, including river red gum forests and the environmental values they support.

The change in floodplain structure will be predicted. For example, wetlands in the outer floodplains are projected to diminish, including their stands of red gum woodlands. Depending on the co-species present at the time, these landscapes could transform into a range of other ecosystem types including box woodlands and shrublands.

As we move towards an uncertain future, clear management goals will be critical. For example it will be important to focus management on conserving components of the landscape that can be maintained and on managing for change in areas that are undergoing clear ecological transition.

This chapter supports **Step 4** of the analytical framework by assessing the implications of climate variability, climate change and consequent changes in water availability for:

- the ecological attributes of the red gum forests
- the threatened species that are supported by the forests
- each water management unit (WMU) and the associated forests.

The key findings of this chapter include:

- Reduced flooding is a major threat to the environmental values of river red gum forests of the bioregion. Twenty-three listed species are considered to be at moderate to high risk of regional population decline as a result of the predicted impacts of climate change and river regulation on flooding regimes.
- The Millewa forests are likely to transform into a river red gum woodland stand over the long term. However, they are large and heterogeneous and therefore likely to be more resilient to the impacts of climate change compared with other river red gum forests in the Riverina bioregion. They are likely to be a future refuge for threatened species such as superb parrot, barking owl, fishing bat and brush-tailed phascogale.
- The Koondrook-Perricoota and Campbells Island forests are also likely to transform into a river red gum woodland stand over the long term. Around 20 per cent of the river red gum community could transition to a derived scrub on the outer floodplain in the absence of future floods. However, like Millewa, the forests and woodlands provide further habitat security for threatened species.
- The Werai forests are likely to be the most degraded by reduced flooding and water scarcity. Over 40 per cent of the river red gum stand and associated wetlands could be lost within 50 years if current conditions persist. The overall area of functional habitat may not be sufficient to support key threatened species such as the barking owl and white bellied sea-eagle.
- The Murrumbidgee forests are likely to continue to decline with the loss of major wetlands fed by the Murrumbidgee River. Tall red gum forests will contract to areas regularly flooded and with access to subsurface aquifers. Some stands of red gum forests will also be lost on the outer floodplain.
- The Lachlan forests are under severe stress and are likely to continue to decline. Key species, such as the blue-billed duck, freckled duck and superb parrot, may disappear from this forest group over coming decades.
- The Barooga forests (and other State Forests immediately west of Albury) are least likely to change in terms of vegetation type or species composition (fauna and flora) due to relatively high water availability.

Australian Painted Snipe – source Wikipedia

- Wakool and Edward forests are likely to transform into a river red gum woodland stand over the long term with up to 40 per cent of river red gum woodland transitioning from red gum to derived copperburr or grassland in the next 50 years.
- The implication of ecosystem changes for species such as the regent parrot in the western river red gum stands is very unclear. The present range of the superb parrot in this area could decline by more than 99 per cent, unless it is able to respond by moving east.

9.2 Context

Predicting the future effects of climate change on Australia's biodiversity is a major challenge for various reasons:

- Climate change will interact with other stressors that are currently influencing biodiversity.
- Responses to the biophysical changes associated with climate change occur at the level of the individual species as well as whole ecosystems.
- Properties of ecosystems are often non-linear and can be difficult to understand and predict. A change in the average value of a variable, for example temperature, may not be as important ecologically as a change in the variability or extremes of that variable.
- Basic knowledge is generally lacking about limiting factors, genetics, dispersal and interactions among species that comprise Australian communities and ecosystems (Biodiversity and Climate Change Expert Advisory Group, 2009).

Despite this, it is understood that traits that make a species vulnerable to disturbance generally will also predispose that species to risk from rapid climate change (Biodiversity and Climate Change Expert Advisory Group, 2009), and that ecological systems and the biota they support will have to adapt rapidly to cope with climate change (for example, Brereton et al., 1995; Hughes, 2003).

Species most vulnerable will be those with:

- a narrow range of physiological tolerance to:
  - temperature
  - water availability
  - fire
- low genetic variability
- long generation times
- long time to sexual maturity
- specialised requirements for:
  - other species, for example, for a disperser, prey species or pollinator
  - particular habitat that may itself be restricted
- narrow geographic ranges
- poor dispersal strategies (Biodiversity and Climate Change Expert Advisory Group, 2009).

A number of studies in south-eastern Australia provide evidence that ecosystems and species are already responding to climate change. For example, the potential impacts of climate change on Australian vertebrates, including possible changes in competitive regimes, sex ratios and parasite transmission, have been reviewed by Stott (1994). Most recent studies have modelled the impacts of rainfall and temperature changes using BIOCLIM and have generally focused on threatened and vulnerable species (Hughes, 2003). Brereton et al. (1995) examined the impact of five greenhouse climate scenarios (CSIRO, 1992) on the distribution of 42 vertebrate species, most with threatened status, from south-east Australia. Of the 42 species studied, 24 were predicted to lose 90–100 per cent of their bioclimate with a 3°C rise in temperature. Similar general conclusions were reached by Dexter et al. (1995) for 58 species of threatened vertebrates, with more than 80 per cent of species predicted to experience contractions in their core climatic habitat under each of three scenarios used (cited in Hughes, 2003).

For Australia's birds, climate change is leading to changes in distribution of species, migration patterns, local abundance, phenology, community composition, and physiology, morphology and behaviour (Chambers et al., 2005). Examples of species likely to be severely affected by predicted increases in temperature include malleefowl, red-lored whistler and regent parrot (Chambers et al., 2005). Severe drought coupled with overgrazing from stock and rabbits are thought to be responsible for the dramatic decline and range contraction of the eastern subspecies of the thick-billed grasswren (NPWS, 2002). Soil moisture levels are expected to fall as a result of climate change, affecting frogs, skinks and soil invertebrates, thus directly affecting birds via their food supply (Williams et al., 2003).

The potential impact of climate change on Australian invertebrates has received less attention than for vertebrates (Hughes, 2003), although it could have major implications for ecological dynamics and species' capacity to adapt. Beaumont and Hughes (2002) used BIOCLIM to determine the current climatic ranges of 77 butterfly species restricted to Australia. They found that under an extreme scenario (temperature increase of 2.1–3.9°C by 2050), 92 per cent of species bioclimates were predicted to decrease, with 83 per cent declining by at least 50 per cent. Many herbivorous invertebrates are also likely be affected by reductions in plant quality as atmospheric CO_2 increases (Hughes, 2003). Reduced nitrogen content and increased carbon/nitrogen ratios in eucalyptus foliage, for example, have been associated with increased mortality and reduced digestive efficiency in the chrysomelid beetle (*Chrysophtharta flaveola*), consistent with studies for non-Australian insect species (Lawler et al., 1997).

The way ecosystems and species respond to a warming climate is not likely to be linear, but is likely to occur in rapid transformations after a long period of little change. Such rapid transformations usually occur when tipping points or critical thresholds are crossed. Increasing frequency and intensity of extreme climate events have the potential to more readily breach tipping points and thresholds. Most current projections of future climatic conditions are couched in terms of average temperature and rainfall, while researchers assessing impacts on particular systems and species are more likely to be interested in information on the extreme events (Biodiversity and Climate Change Expert Advisory Group, 2009).

Formation of novel ecosystems, abrupt changes in ecosystem structure and functioning, and surprising, counterintuitive outcomes will become more commonplace features of ecosystem responses to climate change in future. Over the next 100 years Australia could well experience changes in ecosystem type and distribution at least as great as those associated with the transition from the last glacial maximum to the present – a period of at least 5,000 years (Biodiversity and Climate Change Expert Advisory Group, 2009).

9.3 Implications for ecological attributes of the forests

The NRC has predicted the likely impact of climate change, including altered flooding regimes, on the five key ecological attributes of river red gum forest ecosystems outlined in **Chapter 4**:

- refugia/connectivity
- wetlands
- vegetation mosaics
- hollow-bearing trees
- coarse woody debris.

9.3.1 Refugia and connectivity

The forests provide significant areas of refugia for many species in the bioregion, and are the predominant forest remnants between and across which species are able to move in the landscape, via functional corridors (see **Chapter 4**).

For forests to survive over time it is necessary for young saplings to be recruited to the population of mature trees (eucalypts live for 200–500 years) which over time naturally thin to mature forests of greater inter-tree spacing (Sutherland et al., 2004).

In the absence of rejuvenating floods, the health of the river red gum forests will decline to a point at which the canopy will senesce completely, and the forest will no longer be able to produce seed and propagate. The limit of resilience of these river red gum forests will have been surpassed, resulting in long-term structural and floristic modification and loss of their capacity to support certain species.

If all the trees die without seeding, then in the absence of flooding the stand is likely to assume the structure of a derived community dominated by native tussock grasses and perhaps a few native shrubs, with possible influx of more arid understorey species (for example, chenopods such as copperburr) and weed species. It is not likely that other native canopy species such as black box will assume dominance or transition into these forests unless they are already present in the stand, or unless planting is considered as part of a silvicultural response, as seeds of most eucalypts fall close to the canopy of the parent tree (Binns, D, FNSW, pers. comm., 2009).

Given the above, and in light of assessments of river flows presented in **Chapter 8**, it is likely that climate change will result in some loss of refugia and functional connectivity on the higher floodplains, and that this loss may be amplified if other stressors such as overgrazing and habitat loss persist.

Conversely, the limit of resilience of river red gum forests on inner parts of the floodplains, which require relatively low commence-to-flows, is not likely to be breached in the absence of major disturbance factors. Instead, these areas should persist into the future, and will provide core areas of refugia in the Riverina over the longer term. Increased emphasis on protecting these climatic refugia and providing functional connectivity will be needed (Noss, 2001). SLATS analysis may be effective in the identification of potential refugia (Pennay, 2009).

Stressed river red gum in Niemur State Forest

9.3.2 Wetlands

Projected changes to rainfall and temperature in the lower Murray-Darling Basin will result in decreased surface water flows (Beare and Heaney, 2002), and a reduction in the frequency and size of flooding events. The magnitude of change to flooding frequency, extent and duration for selected forest stands and wetlands is discussed in **Chapter 8**. This will translate to a reduction in the net area of wetland, the duration or persistence of floodwater, and the frequency of wetland replenishment. These factors will impact on wetland fauna species, with less frequent breeding opportunities and possible declines or extinctions of local populations (Kingsford and Norman, 2002). The problem may be compounded by the recent incursion of the native giant rush (*Juncus ingens*) into open water wetlands and wetlands dominated by aquatic macrophytes (Webster, R, pers. comm., 2009).

The extent of wetland loss in the Riverina bioregion is difficult to predict although recent modelling studies in other areas provide clues as to the likely magnitude of the problem. For example, a study of the heavily regulated Macquarie River system and the associated Macquarie Marshes (Johnson, 1998; Australian Greenhouse Office, 2002; Herron et al., 2002) suggests that future decreases in mean annual flow may result in a 20–40 per cent reduction in area of the semi-permanent and ephemeral wetlands of the Macquarie Marshes by the year 2030. Rainfall decline is projected to be more acute in southern NSW than in northern NSW. Green (2003) reports a 30 per cent reduction in snow cover in the Snowy Mountains has been evident over the last 45 years, with reductions in snow cover expected to continue (Hughes, 2003).

Notwithstanding potential loss or reduction in numbers of some species, wetlands of the Riverina bioregion may also be able to support species not historically recorded in the region. Baxter et al. (2001) documented recent observations of the black-necked stork in the Channel Country in north-eastern South Australia, well to the south of its customary range. They suggested that monsoon flooding in Queensland and far-northern South Australia during the summer–autumn of 2001 may explain this unusual occurrence. Recent observations of the magpie goose in this region, a vagrant well outside its usual range, have also been noted (Baxter et al., 2001), with small numbers of this species turning up in the bioregion in the last few years (Webster, R, pers. comm., 2009). As species move parallel to climate gradients (Chambers et al., 2005), particularly from north to south and potentially from arid and semi-arid regions toward more temperate regions, they may well begin to use the river red gum forests.

9.3.3 Vegetation mosaics

The importance of vegetation mosaics in the river red gum forests was summarised in **Chapter 4**. The likely impact of climate change is difficult to predict, but the following is likely:

- incursion of river red gum onto the periphery of the larger, more open wetlands as they contract, with possible invasion of the native giant rush
- transition of the structure of river red gum communities from tall river red gum forests into open river red gum woodlands as ecosystem productivity declines as a result of loss of moisture
- possible senescence and mortality of river red gum and river red gum–black box woodlands on the higher floodplains, replaced by derived shrublands or grasslands, with periodic episodes of river red gum regrowth when flooding occurs, and/or
- maintenance of extent and location of sandplains woodlands dominated by cypress communities.

These points are discussed in more detail below in relation to individual responses of the major forests to climate change. The important consideration in the context of response to climate change is that the structural and floristic heterogeneity of the vegetation mosaic may not change over time, but its spatial configuration will. If the structural complexity of ecotones and vegetation mosaics is retained, even if they shift over time, then this will assist in protecting individual species reliant on ecosystem interfaces, including many woodland birds.

Another important benefit of mosaics is their capacity to buffer against phenological changes which are likely to have a major influence on dynamics of bird populations. Keatley and Hudson (2005) observed changes in flowering dates of 56 species of Australian plants over 22 years; 24 species had mean advancement of 13.6 days; remaining species had mean flowering of 20.8 days later. Greater floristic richness associated with vegetation mosaics provides a wider range of flowering times, and thus improves the capacity of species to persist.

9.3.4 Hollow-bearing trees

The importance of hollow-bearing trees in the river red gum forests is summarised in **Chapter 4**.

The density of hollow-bearing trees required to sustain viable populations of vertebrates is a function of the diversity of competing fauna species at a site, population densities, number of hollows required by each individual over the long term, and the number of hollows with suitable characteristics occurring in each tree. Accurately estimating hollow requirements in a given habitat is currently difficult due to the lack of this baseline information, and attempts at modelling have been limited. However, there is much circumstantial and some experimental evidence to indicate that hollows are a limiting resource, and that recovery of threatened hollow-using fauna would benefit from their greater availability (NSW Scientific Committee, 2007).

Abundance and species richness of hollow-dependent fauna have been correlated with the density of hollow-bearing trees in a wide range of studies (e.g. McIlroy, 1978; Meredith, 1984, Lindenmayer et al., 1991; Traill, 1991; Smith et al., 1994; Eyre and Smith, 1997; Kavanagh and Stanton, 1998; Alexander et al. 2002; Gibbons and Lindenmayer, 2002; Kavanagh and Wheeler, 2004). Evidence that hollows are a limiting resource in eucalypt forests includes fighting for hollow possession within and between species, successive use of the same hollow by different pairs of breeding birds, and progressively greater use of poor-quality hollows as population density increases or hollow availability decreases (Newton, 1994; Gibbons and Lindenmayer, 2002; Heinsohn et al., 2003). In some instances it is the prey species of a threatened predator that is limited by hollow availability. For example, in dry open forest habitats the common ringtail possum (*Pseudocheirus peregrinus*) is dependent on large hollows and only abundant in areas with large trees (Soderquist et al., 1999). As this species is an important prey item of the powerful owl (*Ninox strenua*), loss of hollows indirectly hinders recovery efforts for the predator.

Hollow-bearing trees in the river red gum forests provide nesting sites for several mammals and birds such as the brush-tailed phascogale, squirrel glider, inland forest bat, barking owl, regent parrot and superb parrot, and are associated with large, old river red gum trees. Yet the prognosis for retention of hollows in some of these forests is uncertain. The impact of climate change on hollow-bearing trees is difficult to predict. There may be a reduction in the area of the forest that supports hollow-bearing trees as old trees occupying infrequently flooded areas senesce and die. The dead stags may stand in the landscape and provide a resource for some hollow-dependent fauna over the medium term (possibly up to 50 years). However, as the large dead trees eventually rot and fall, these former forests will be devoid of hollows for many decades or centuries given the time taken to grow hollows suitable for refuge and nesting, and may never do so if trees fail to reach maturity after sporadic regeneration events. Even where hollows persist, declining canopy health and thus decreasing levels of nutrients in the foliage, nectar and pollen may preclude some species that normally occupy them.

Given a likely contraction of forests supporting hollow-bearing trees to areas of long-term refugia (as discussed earlier), accelerating the control or eliminating the existing stressors on availability of hollows provides a ‘starting point’ in building resilience in these systems (Biodiversity and Climate Change Expert Advisory Group, 2009). As outlined in Chapter 4 the natural density of hollow-bearing trees in mature and relatively undisturbed river red gum forests is in the range of 6–25 per hectare.

9.3.5 Coarse woody debris

Retention of coarse woody debris on the forest floor is important for ecological function in river red gum forests. It is likely that the major risk to fallen timber with climate change will be wildfire, and fire risk management, which can both renew and degrade environmental values. Changes in fire regimes as a response to climate change are highly likely in the future (Hughes, 2003). Increased temperatures will increase fuel dryness and reduce relative humidity, and this will be exacerbated in those regions where rainfall decreases (Howden et al., 1999).

Beer and Williams (1995) used the Macarthur Forest Fire Danger Index and the CSIRO (1992) used climate scenarios to predict changes in future fire incidence. The Macarthur Index incorporates climatic parameters such as air temperature, relative humidity and days since rain and fuel load to predict fire danger. The models indicate an increase in fire risk over much of Australia. More quantitative modelling by Williams et al. (2001) confirmed this general result, indicating an increase in the number of days of very high and extreme fire danger.

Management of coarse woody debris in the river red gum forests will need to balance ecological function and fire risk. Use of fire itself in periods of low-fire risk may provide an adaptive management response to fuel load build-up, recognising that retention of large fallen logs on the forest floor is important for these forests.

Timber residue after harvesting operation

Koala in Barooga State Forest

9.4 Implications for threatened species

The NRC has assessed the possible of impact on EPBC- and TSC-listed species known to be dependent on the key ecological attributes of the river red gum forests. Impacts of silviculture on hollow-bearing trees and dead fallen timber in river red gum forest are discussed in **Chapter 11**. These more site-specific impacts or stressors are relevant because the ecological function of disturbed forests is more vulnerable to climate change (for example, Noss, 2001; Biodiversity and Climate Change Expert Advisory Group, 2009).

It is recognised that climate change is likely to impact on individual species through other effects including:

- increased temperatures
- changes to rainfall seasonality
- changes in foliage nutrient properties
- impacts on herbivorous animals including invertebrates
- changes in nutrient cycling and soil nitrification
- introduction of novel pests
- changes in fire.

It is beyond the scope of this document to analyse species' responses to these additional effects and limited data is available to support such analyses.

A total of 68 species, species groups or populations listed under the EPBC or TSC Acts are tabulated in **Chapter 4**. **Table 9.1** below outlines the likely impacts to these species from predicted reductions in flooding. The level of impact (high, medium or low) generally reflects the species' reliance on the river red gum forests, and the effect of reduced flows on its habitat. Analysis in this table is drawn largely from species profiles provided by DECCW and available on its website.

Twenty-three listed species are considered to be at moderate to high risk of regional population decline as a result of the likely impacts of climate change and river regulation on flooding regimes. Twenty of these are listed as 'key species' in **Chapter 4**.

Reduced flooding and the increased frequency of high intensity fire are major threats to river red gum fauna, as they lead to contraction of habitat arising from senescence and mortality of forest and woodland, or transition of forest and woodland structures and distribution.

Table 9.1: Likely impact of reduced flows on TSC- and EPBC-listed fauna species in river red gum forests

Scientific name	Common name	Impact of reduced flows	Likely impact	Justification/comments
Ardea alba	Eastern Great Egret	Changes to flood regimes drying out previously damp grassland and wetland areas for foraging and breeding.	**H**	Migratory species that can move large distances to available water sources. Commonly occurs in disturbed environments provided water is present. Feeds in disturbed habitat but reliant on treed wetlands for breeding.
Botaurus poiciloptilus	Australasian Bittern	Reduced flow into wetland habitats, leading to reduction in current habitat health and further loss of suitable habitat.	**H**	Widely distributed but declining over south-eastern Australia. Likely to be listed in the future as endangered in NSW.
Crinia sloanei	Sloane's Froglet	Potential impacts to breeding habitat caused by reduced water quality and availability.	**H**	DECCW lists the following threats that are regionally relevant to this species: 1. Degradation of habitat and water quality through clearing and grazing 2. Changes in water availability, flow and flooding regimes in creeks, rivers, floodplains and wetlands (Cogger, 2000). The only recent records of this species are concentrated in the Murray region – it has disappeared from the northern part of its range.
Litoria raniformis	Southern Bell Frog	Potential impacts on timing of breeding as influenced by flooding and water levels. Impacts also likely on breeding habitat caused by reduced water quality and availability.	**H**	DECCW lists the following threats that are regionally relevant to this species: 1. Lack of appropriate flooding regime, i.e. flooding at the wrong time of the year, infrequent flooding, e.g. once every five or 10 years, waterbodies not lasting long enough for tadpoles to develop. 2. Alteration to natural flooding regimes from irrigation and river regulation, which may either divert water away from previously flooded wetlands or cause some areas to become permanently flooded and no longer receive rising water levels to trigger breeding. 3. Introduction of chemicals (pesticides, defoliants, etc.) either into waterbodies or directly onto animals. 4. Loss of aquatic and/or terrestrial habitat through draining of waterbodies or clearing for agricultural development.
Myotis macropus	Large-footed Myotis	Potential reduction in roosting and nesting habitat due to reduced water table.	**H**	DECCW lists the following threats that are regionally relevant to this species: 1. Reduction in stream water quality affecting food resources 2. Clearing adjacent to foraging areas.
Ninox connivens	Barking Owl	Potential significant reduction in nesting habitat due to reduced water table.	**H**	Found in river red gums in the region. DECCW lists the following threats that are regionally relevant to this species: 1. Clearing and degradation of habitat, mostly through cultivation, intense grazing and the establishment of exotic pastures 2. Inappropriate forest harvesting practices that have changed forest structure and removed old-growth hollow-bearing trees.

Table 9.1: Likely impact of reduced flows on TSC- and EPBC-listed fauna species in river red gum forests continued

Scientific name	Common name	Impact of reduced flows	Likely impact	Justification/comments
Petaurus norfolcensis	Squirrel Glider	Significant impacts through reduction in river red gum (RRG) health, reduced tree hollows and nectar abundance due to reduced water table.	**H**	Prefers mixed species stands with a shrub midstorey. Requires abundant tree hollows for refuge and nest sites. DECCW lists the following threats that are regionally relevant to this species: 1. Loss and fragmentation of habitat 2. Loss of hollow-bearing trees 3. Loss of flowering understorey and midstorey shrubs in forests.
Phascolarctos cinereus	Koala	Potentially significant reduction in foliage quality due to reduced water table.	**H**	Koala has selective feeding habits in terms of foliage selection. Some natural populations along the Murray and translocated population near Narrandera in river red gums.
Polytelis anthopeplus monarchoides	Regent Parrot (eastern subspecies)	Significant impact on long-term reduction in forage and breeding habitat.	**H**	RRG forest is breeding habitat. Species distribution is restricted. Reductions in the current range are predicted as a result of climate change (Chambers et al., 2005). Climate change may constrain the ease of movement of this species between breeding and foraging habitats.
Polytelis swainsonii	Superb Parrot	Long-term reduction in forage and breeding habitat will have a significant impact.	**H**	River red gum forest is breeding habitat. Species distribution is restricted. Climate change will add additional impacts to movement corridors from breeding to foraging habitats.
Rostratula australis	Australian Painted Snipe	Changes to flood regimes impacting on inland wetland water levels.	**H**	The Murray-Darling drainage system appears to have been a key area for this species, as many records of this species come from this region.
Stictonetta naevosa	Freckled Duck	Potential impacts on roost sites due to changes to flood and flow regimes.	**H**	Breeds in large temporary swamps created by floods in the Bulloo and Lake Eyre basins and the Murray-Darling system, particularly along the Paroo and Lachlan rivers, and other rivers within the Riverina. The duck is forced to disperse during extensive inland droughts when wetlands in the Murray River basin provide important habitat. DECCW lists the following threats that are regionally relevant to this species: 1. Draining and clearing of wetland and swamp habitat 2. Changes to natural river flows and flood patterns as a result of dams, weirs and irrigation. Garnett and Crowley (2000) identified that the El Niño Southern Oscillation Index influences the abundance of this species.
Burhinus grallarius	Bush Stone-curlew	Change in flow may reduce condition of understorey for this species	**M**	Widely distributed over NSW and wider mainland Australia. Not limited to, but many records from river red gum forests.
Grus rubicunda	Brolga	Potential local impacts due to loss of foraging and breeding habitat caused by reduced flow and flooding.	**M**	A significant threat is the loss of wetland habitat through clearing and draining for flood mitigation and agriculture.
Grus spp.	Cranes (1 species in bioregion)	Drying of wetlands due to changes in flow regimes.	**M**	Refer to brolga above.
Haliaeetus leucogaster	White-bellied Sea-Eagle	Drying of wetlands will reduce foraging areas and reduced flood flows will impact on quality of breeding habitat.	**M**	Suitable habitat along the major rivers and permanent wetlands.

Table 9.1: Likely impact of reduced flows on TSC- and EPBC-listed fauna species in river red gum forests continued

Scientific name	Common name	Impact of reduced flows	Likely impact	Justification/comments
Lophoictinia isura	Square-tailed Kite	Potential indirect impacts on breeding habitat due to reduction in river red gum health due to flow changes.	M	DECCW lists the following threats that are regionally relevant to this species: 1. Disturbance to or removal of potential nest trees near watercourses 2. Clearing, logging, burning and grazing of habitats resulting in a reduction in nesting and feeding resources.
Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)	Potential indirect impacts on breeding/foraging habitat due to reduction in river red gum health due to flow changes.	M	Western edge of the species distribution utilising higher site quality RRG communities. Marginal habitat as this species occupies mostly upper levels of drier open forests or woodlands dominated by box and ironbark eucalypts, especially mugga ironbark (*Eucalyptus sideroxylon*), white box (*Eucalyptus albens*), grey box (*Eucalyptus microcarpa*), yellow box (*Eucalyptus melliodora*) and forest red gum (*Eucalyptus tereticornis*).
Ninox strenua	Powerful Owl	Potential significant reduction in nesting habitat due to reduced water table.	M	DECCW lists the following threats that are regionally relevant to this species: 1. Historical loss and fragmentation of suitable forest and woodland habitat from land clearing for residential and agricultural development. This loss also affects the populations of arboreal prey species, particularly the greater glider which reduces food availability for the powerful owl. 2. Inappropriate forest-harvesting practices that have changed forest structure and removed old-growth hollow-bearing trees. Loss of hollow-bearing trees reduces the availability of suitable nest sites and prey habitat. 3. Can be extremely sensitive to disturbance around the nest site, particularly during pre-laying, laying and downy chick stages. Disturbance during the breeding period may affect breeding success. Change in flows will result in reduction of tree health and availability of mature hollow-bearing trees, and will affect prey species' habitat condition.
Phascogale tapoatafa	Brush-tailed Phascogale	Significant impacts through reduction in river red gum health, reduced tree hollows and nectar abundance due to reduced water table.	M	Preferentially forages in large rough-barked trees, therefore river red gum is not the preferred food source. Females have exclusive territories of approximately 20–60 ha, while males have overlapping territories of up to 100 ha.
Plegadis falcinellus	Glossy Ibis	Drying of wetlands due to changes in flow regimes.	M	Breeds in the Lowbidgee floodplain.
Oxyura australis	Blue-billed Duck	Impacts to lakes and wetlands in which species resides. Reduction of foraging and breeding habitat due to reduced flow and water quality.	M	Non-breeding areas are present on the Murray River system. Breeding is normally in large permanent freshwater lakes, dams and swamps with dense aquatic vegetation.
Pachycephala inornata	Gilbert's Whistler	Declining state of river red gum, black box and associated shrub layer resulting from a reduction in flows may have an impact.	M	This species requires an intact shrub layer and therefore vegetation clearance would reduce potential habitat for this species. There are only three separate populations remaining in NSW, including the Edward River (McGregor, 2009) and lower Murray Valley forests. Whistlers do not make any regular large-scale movements. The pair holds and defends the territory all year round.
Anatidae	Waterfowl	Drying of wetlands due to changes in flow regimes.	L–M	Potential low to moderate impacts from altered flow regimes on species (excluding those mentioned above).

Table 9.1: Likely impact of reduced flows on TSC- and EPBC-listed fauna species in river red gum forests continued

Scientific name	Common name	Impact of reduced flows	Likely impact	Justification/comments
Pyrrholaemus sagittatus	Speckled Warbler	Unlikely	**L–M**	There has been a decline in population density throughout its range, with the decline exceeding 40 per cent where no vegetation remnants larger than 100 ha survive. Large, relatively undisturbed remnants are required for the species to persist in an area. DECCW lists the following threats that are regionally relevant to this species: 1. Due to the fragmented nature of the populations and their small size the species is susceptible to catastrophic events and localised extinction. 2. Clearance of remnant grassy woodland habitat for paddock management reasons and for firewood. 3. Poor regeneration of grassy woodland habitats. 4. Modification and destruction of ground habitat through removal of litter and fallen timber, introduction of exotic pasture grasses, heavy grazing and compaction by stock and frequent fire. 5. Habitat is lost and further fragmented as land is being cleared for residential and agricultural developments. In particular, nest predation increases significantly, to nest failure rates of over 80 per cent, in isolated fragments.
Accipitridae	Raptors (3 species in bioregion)	Unlikely	**L**	Potential low impacts from altered flow regimes on species (excluding those mentioned above).
Amytornis textilis ssp modestus	Thick-billed Grasswren (eastern subspecies)	Unlikely	**L**	Prefers saltbush and shrubland habitats, and has not been recorded in the Riverina for approximately 90 years.
Anthochaera phrygia	Regent Honeyeater	Unlikely impact as the species in highly nomadic and is not known to be strongly associated with river red gum forests.	**L**	While the species has been recorded in river red gum forests, only three key breeding regions are known, in north-east Victoria (Chiltern-Albury), in NSW at Capertee Valley, and in the Bundarra-Barraba region of NSW. In NSW the distribution is very patchy and mainly confined to the two main breeding areas and surrounding fragmented woodlands.
Apus pacificus	Fork-tailed Swift	Unlikely	**L**	Unlikely to be impacted. Rarely on land.
Ardea ibis	Cattle Egret	Changes to pasture composition and drying of wetland breeding areas due to changes in flood regimes.	**L**	Adaptable migratory species that inhabits a variety of habitats. Potential impacts on breeding due to changes in flow as it utilises wetlands.
Cacatua leadbeateri	Major Mitchell's Cockatoo	Low/medium (locally) impact potential due to reduced availability of local drinking water impacts adjacent to breeding habitat.	**L**	Widely distributed over a broad range of habitat types in NSW and wider south-eastern mainland Australia (Simpson and Day, 2004), and not limited to river red gum forests. More likely in drier woodlands.
Calidris acuminata	Sharp-tailed Sandpiper	Drying of wetlands due to changes in flow regimes.	**L**	The sharp-tailed sandpiper is a summer migrant from Arctic Siberia, being found on wetlands throughout Australia.
Calidris ruficollis	Red-necked Stint	Drying of wetlands due to changes in flow regimes.	**L**	Utilises the margins of lakes and swamps.
Calyptorhynchus lathami	Glossy Black-cockatoo	Low impact potential due to reduced availability of local drinking water.	**L**	Widely distributed over a broad range of habitat types in NSW and wider eastern mainland Australia (Simpson and Day, 2004), and not likely in river red gum forests.
Chalinolobus picatus	Little Pied Bat	Impacts to vegetation health in river red gum sites.	**L**	Occurs in a range of vegetation communities.

Table 9.1: Likely impact of reduced flows on TSC- and EPBC-listed fauna species in river red gum forests continued

Scientific name	Common name	Impact of reduced flows	Likely impact	Justification/comments
Cinclosoma castanotus	Chestnut Quail-thrush	Unlikely	**L**	Prefers semi-arid open woodlands such as Mallee and Mulga (Simpson and Day, 2004), therefore RRG represents marginal habitat at best.
Climacteris picumnus victoriae	Brown Treecreeper (eastern subsp.)	Impacts on RRG forest health.	**L**	Distribution of this subspecies is relatively restricted to Victoria and eastern NSW (Simpson and Day, 2004).
Climactis affinis	White-browed Treecreeper population in the Carrathool LGA south of the Lachlan River and Griffith LGA	Potential reduction in roosting habitat due to reduced water table.	**L**	Marginal habitat as primarily occurs in a range of semi-arid and arid tall shrublands and woodlands across the southern half of Australia although it may also occur in habitats adjacent to those detailed above, including coolibah, river red gum and black box. DECCW lists the following threat as regionally relevant to this species: 1. Past overclearing of habitat resulting in fragmentation of remnants has been the main cause of decline of this population although ongoing decline in habitat quality is currently the major threatening process.
Dasyurus maculatus	Spotted-tailed Quoll	Potential impacts to quality of foraging and breeding habitat.	**L**	Few records in RRG forests along inland rivers (Menkhorst and Knight, 2004). DECCW lists significant threats to the species as being loss, degradation and fragmentation of habitat.
Falco hypoleucos	Grey Falcon	Unlikely	**L**	Occurs in a wide variety woodlands in arid and semi-arid habitats. RRG represents limited marginal habitat at best, given the extent of this species distribution throughout wider arid mainland Australia.
Gallinago hardwickii	Latham's Snipe	Drying of wetlands due to changes in flow regimes, loss of lignum and fringing vegetation.	**L**	Utilises the vegetated margins of lakes and swamps.
Glossopsitta porphyrocephala	Purple-crowned Lorikeet	Potential reduction in foraging habitat (nectar abundance).	**L**	Prefers drier open forests, woodlands and Mallee. Two major threats include loss of nectar-producing eucalypts due to clearing of woodlands, and loss of hollows through tree-clearing.
Grantiella picta	Painted Honeyeater	Unlikely	**L**	Major threats to this species include removal of large, old trees with heavy mistletoe infestations; and degradation of open forest and woodland remnants, including thinning of trees bearing mistletoe.
Hamirostra melanosternon	Black-breasted Buzzard	Unlikely	**L**	Significant threats include the degradation of foraging habitat through tree clearing, and clearing of trees along inland watercourses.
Hirundapus caudacutus	White-throated Needletail	Unlikely	**L**	A migratory species; unlikely to be impacted. Rarely on land.
Hydropogne caspia	Caspian Tern	Drying of wetlands due to changes in flow regimes.	**L**	Nomadic species that utilises large water bodies opportunistically.
Hylacola cauta	Shy Heathwren	Unlikely	**L**	Significant threats include loss of habitat due to clearing, leading to a decline in distribution and abundance; and fragmentation, resulting from clearing or degradation of habitat, leading to a reduction in size of populations and increase the extent to which they are isolated.
*Lasiorhinus krefftii**	Northern Hairy-nosed Wombat	Unlikely	**L**	Unlikely to be present – presumed extinct (in NSW).
Lathamus discolor	Swift Parrot	Unlikely	**L**	River red gum flowering occurs outside the peak period of seasonal occurrence of Swift Parrot in NSW; however, it may feed on lerps in river red gums. Reductions in the current range are predicted as a result of climate change (Chambers et al., 2005).

Table 9.1: Likely impact of reduced flows on TSC- and EPBC-listed fauna species in river red gum forests continued

Scientific name	Common name	Impact of reduced flows	Likely impact	Justification/comments
Leipoa ocellata	Malleefowl	N/A	**L**	Marginal habitat – predominantly inhabit mallee communities, preferring the tall, dense and floristically rich mallee found in higher rainfall (300–450 mm mean annual rainfall) areas. Less frequently found in other eucalypt woodlands (e.g. mixed Inland grey box and yellow gum or bimble box, ironbark-callitris pine, callitris pine, mulga (*Acacia aneura*), and gidgee (*A. cambagei*). Reductions in the current range are predicted as a result of climate change (Chambers et al., 2005).
Melanodryas cucullata cucullata	Hooded Robin (south-eastern form)	Unlikely	**L**	DECCW lists the following threat that is regionally relevant to this species: 1. Clearing of woodlands, resulting in loss and fragmentation of habitat.
Neobatrachus pictus	Painted Burrowing Frog	Impacts on breeding timing due to changes in flood regimes, but not often associated with flooding along major channels.	**L**	This species has been found in only two locations in NSW – 120 km north-west of Mildura on the private land managed for conservation by Australian Wildlife Conservancy, and Scotia Sanctuary, adjacent to the South Australian border and 22 km west of Pooncarie. To date, less than 30 individuals have been found in NSW. DECCW lists the following threats that are regionally relevant to this species: 1. Sand mining and other activities, e.g. cultivation, that disturb the soil in which this species burrows. 2. Altered flooding regimes (timing, frequency and extent of flooding) may prevent the emergence and breeding activities of this species. 3. Soil compaction from machinery and domestic stock. 4. Loss of leaf litter, fallen timber, bark and other groundcover. 5. Pollution of water bodies from farming and industrial chemicals.
Neophema pulchella	Turquoise Parrot	Potential reduction in habitat due to reduced water table.	**L**	Infrequently occurs in river red gums. DECCW lists the following threats that are regionally relevant to this species: 1. Clearing of grassy-woodland and open forest habitat 2. Loss of hollow-bearing trees.
Nyctophilus corbeni	Greater Long-eared Bat (south-eastern form)	Potential reduction in roosting habitat due to reduced water table.	**L**	Marginal habitat – inhabits a variety of vegetation types, including mallee, bulloke (*Allocasuarina leuhmanni*) and box eucalypt dominated communities, but it is distinctly more common in box/ironbark/cypress-pine vegetation that occurs in a north-south belt along the western slopes and plains of NSW and southern Queensland.
Pachycephala rufogularis	Red-lored Whistler	Unlikely	**L**	Found in mallee woodland with a shrub layer, usually of broombush and native pine such as mallee pine (*Callitris verrucosa*), with occasional patches of spinifex and emergent mallee, forming a relatively dispersed canopy. Reductions in the current range are predicted as a result of climate change (Chambers et al., 2005).
Pedionomus torquatus	Plains-wanderer	Unlikely	**L**	Occurs in grassland. Reductions in the current range are predicted as a result of climate change (Chambers et al., 2005).
Petroica rodinogaster	Pink Robin	Unlikely	**L**	On the mainland, the species disperses north and west and into more open habitats in winter. Breeds in rainforest and therefore breeding habitat unlikely to be impacted.

Table 9.1: Likely impact of reduced flows on TSC- and EPBC-listed fauna species in river red gum forests

Scientific name	Common name	Impact of reduced flows	Likely impact	Justification/comments
Pomatostomus temporalis temporalis	Grey-crowned Babbler (eastern subspecies)	Unlikely	L	Primarily inhabits open box-gum woodlands on the slopes, and box-cypress-pine and open box woodlands on alluvial plains. DECCW lists the following threats that are regionally relevant to this species: 1. Clearing of woodland remnants 2. Heavy grazing and removal of coarse, woody debris within woodland remnants.
Recurvirostridae, Charadriidae	Shorebirds (Six species in bioregion)	Drying of wetlands due to changes in flow regimes.	L	Potential low impacts from altered flow regimes on species (excluding those mentioned above).
Saccolaimus flaviventris	Yellow-bellied Sheathtail bat	Potential reduction in roosting habitat due to reduced water table.	L	DECCW lists the following threats that are regionally relevant to this species: 1. Foraging habitats are being cleared for residential and agricultural developments, including clearing by residents within rural subdivisions. 2. Loss of hollow-bearing trees; clearing and fragmentation of forest and woodland habitat.
Scolopacidae	Snipe	Drying of wetlands due to changes in flow regimes.	L	Potential low impacts from altered flow regimes on species (excluding those mentioned above).
Stagonopleura guttata	Diamond Firetail	Indirect impacts on groundcover composition (foraging) due to changes to flood regimes.	L	DECCW lists the following threats that are regionally relevant to this species: 1. Clearing and fragmentation of woodland, open forest, grassland and mallee habitat for agriculture and residential development, and firewood collection 2. Modification and destruction of ground and shrub layers within habitat through removal of native plants, litter and fallen timber; introduction of exotic pasture grasses; heavy grazing and compaction by stock; and frequent fire 3. Risk of local extinction due to small, isolated populations.
Tiliqua occipitalis	Western Blue-tongued Lizard	Unlikely	L	Prefers arid and semi-arid sandy habitats; river red gum represents marginal habitat at best. Widely distributed through southern mainland Australia (Cogger, 2000).
Tringa nebularia	Greenshank	Drying of wetlands due to changes in flow regimes.	L	Utilises the margins of lakes and swamps.
Tringa stagnatilis	Marsh Sandpiper	Drying of wetlands due to changes in flow regimes.	L	Utilises the margins of lakes and swamps.
Tyto novaehollandiae	Masked Owl	Potential reduction in nesting habitat due to reduced water table.	L	Usually breeds in moist eucalypt forested gullies, therefore impacts on breeding habitat are unlikely. DECCW lists the following threats that are regionally relevant to this species: 1. Loss of mature hollow-bearing trees and changes to forest and woodland structure, which leads to fewer such trees in the future. 2. Clearing of habitat for grazing, agriculture, forestry or other development.
Vespadelus baverstocki	Inland Forest Bat	Potential reduction in roosting habitat due to reduced water table.	L	DECCW lists the following threats that are regionally relevant to this species: 1. Removal of old hollow trees 2. Predation by feral cats at roost sites 3. Degradation of vegetation and the consequent reduction in arthropod prey diversity and abundance.

9.5 Likely impacts on the environmental values of water management units

9.5.1 Likely impacts on the Millewa forests

Summary

The Millewa forests are likely to be more resilient to adverse impacts of climate change compared with other river red gum forests in the Riverina bioregion, as indicated by recent analyses of condition change (for example, Pennay, 2009). The forest is large and heterogeneous, providing opportunities for species to move and adapt within it.

The forests require relatively low flows (compared with downstream forests) to achieve reasonable levels of flooding, so a large proportion will retain its ecological structure and function. As flows > 25,000 ML/day are unlikely to occur under climate change at the frequency and duration required for sustaining river red gum forest in its current form, it is likely that some tall river red gum forest will transition to river red gum woodland, but with critical habitat such as large hollow trees and coarse woody debris persisting. Up to 5 per cent of river red gum and some wetland may be lost, but most will remain to provide a major refuge for species using river red gum. Together with the Barmah Forest to the south, Millewa is likely to be a future refuge for threatened species such as superb parrot, barking owl, fishing bat and brush-tailed phascogale.

Vegetation distribution response

In presenting the likely ecological response to reduced flows through the Millewa forests, it is assumed that 18,300 ML/day can be delivered to the Barmah-Millewa forest into the future at the frequency and duration required for sustaining river red gum vegetation. This flow is below that required to achieve the interim ecological objectives stated within the Icon Site Management Plan for the Barmah-Millewa forest to 'ensure healthy vegetation in at least 55 per cent of the area of the forest (including virtually all of the giant rush, moira grass, river red gum forest, and some river red gum woodland)' (MDBC, 2006a).

Modelled inundation extents (**Chapter 8**) indicate that only 46 per cent of river red gum very tall forest, 14 per cent of river red gum tall open forest and 3 per cent of river red gum–box woodland will be regularly inundated in Millewa at 18,300 ML/day.[1] The implications of this reduced extent of inundation on changes to vegetation structure and composition within the Millewa forests is difficult to predict in the absence of long-term monitoring data, and is complicated by a poorly understood sub-surface hydrology. However, broad assertions can be made about the distributional and structural response of vegetation communities in Millewa to changed flooding regimes, and likely ecological responses of key species that characterise these communities.

Along with the Albury to Tocumwal cluster of forests, the Millewa forests are arguably more resilient to adverse impacts of climate change as commence-to-flow volumes are generally lower. Thus it is expected that a relatively high proportion of the Millewa forests will retain their broad structure and composition, particularly those forests areas inundated by the 18,300 ML/day flood.

Southern Bell frog

The magnitude and type of change to river red gum forests occupying more elevated parts of the Millewa floodplain, such as areas immediately to the north and south of Moira Lake, are dependent on hydrological behaviour and access to sub-surface water. Change is likely to vary considerably across the extent of forest, with some pockets supported over a longer period by sub-surface aquifer flow while others are not.

It is difficult to quantify the extent of the Millewa forests that are susceptible to complete loss of river red gum forest and woodland through water stress. Given the relative ease of securing environmental flows in this forest it is unlikely that more than 10 per cent of the forests will be lost over the next 50 years unless flow conditions worsen considerably. Those lost are likely to be largely river red gum woodland stands, some of which may continue to support scattered black box or other box species.

It is likely that a proportion of very tall river red gum forest and tall open river red gum forest will assume a structure and vigour of river red gum woodland stands over the long term. Trees will generally survive but regenerating trees may not achieve the size and height of the parent trees. Sedge and herb elements of the understorey are also likely to be replaced by tussock grasses, and possibly native hardy shrubs.

Other vegetation communities in the Millewa forests are likely to respond in different ways to a changed flooding regime. The various wetlands are likely to contract and be replaced by river red gum at their margins, with the exception of those subject to regular flooding. The river red gum–box communities may persist, with box species becoming more dominant over the long term. Areas of derived grassland or scrub may replace dying river red gum forest on the outer floodplain over the long term.

Ecological attributes response

The Millewa forests contain a complex mosaic of integrated flood-dependent communities including:

- Swamps and marshes in the lower, frequently flooded areas where water can pond to a degree.

[1] Only 16 per cent when very tall river red gum forest and tall open river red gum forest are combined.

- Rush beds surrounding swamps and marshes, providing nesting and feeding habitat for egrets, spoonbills, ibis, waterfowl and frogs.
- Lakes and billabongs, generally deeper water environments, providing habitat for biota such as fish and macro-invertebrates. These are also important in providing feeding areas for large colonial bird breeding events.
- Localised Moira grass plains which during floods are highly significant as breeding and feeding habitat for colonial breeding waterbirds like egrets, herons, spoonbills and marsh terns.
- River red gum forest of various types depending on inundation, with the lower elevation areas supporting larger and denser river red gum forest.
- Black box woodland in the high, drier zones (MDBC, 2006a).

The relatively large size of the Millewa forests (in combination with the Barmah Forest to the immediate south) and its heterogeneity, as well as the comparatively low flows required to flood large sections of the forest, provide its flora and fauna residents with a reasonable level of long-term security against the impacts of climate change. This is important as they provide habitat for large numbers and a diverse group of fauna, with 54 species of waterbird known to breed (Leslie, 2001), and many arboreal and ground-dwelling fauna (Webster et al., 2003). Amphibia, mammals and fish all benefit from the diversity of habitat, its large size, and frequent flooding. Millewa is arguably the best refuge for many fauna species dependent on river red gums along the Murray, particularly when considered in the context of the adjacent Barmah Forest, which adds to the overall extent of contiguous forest.

Top: Superb parrot. Bottom: Barking owl.

9.5.2 Likely impacts on the Koondrook-Perricoota forests

Summary

Koondrook-Perricoota forests and Campbells Island forests provide further habitat security for ecological communities and individual species associated with river red gum in the Riverina bioregion. The forests will continue to provide habitat for a range of resident communities and species into the future. Modification to vegetation community structure is likely to be significant given recent trends (Pennay, 2009), with much of the river red gum forests likely to transition to lower-productivity river red gum woodland. Critical habitat containing large trees and fallen dead timber is likely to persist across the majority of the forest. Perhaps 20 per cent of the river red gum community is likely to transition to a derived scrub on the outer floodplain in the absence of future floods, but sufficient core habitat is likely to remain to provide a second major refuge for native species, particularly considering its adjacency to the Gunbower forests in Victoria. Species such as barking owl, Gilbert's whistler, and hooded robin should be supported in Koondrook-Perricoota forests under projected flood regimes.

Vegetation distribution response

In presenting the likely ecological response to reduced flows through the Koondrook-Perricoota forests, the minimum regime as modelled under the Works and Measures Program of 2,000 ML/day is selected, delivered into the forest via the Koondrook-Perricoota Forest Flood Enhancement Works. An estimated 34 per cent of the forest would be inundated under this scenario. It is acknowledged that a range of flows would be delivered to the forest through operation of the Enhancement Works. This assessment adopts this event as a base and also considers the range of factors influencing flows to the forests.

The implications of this reduced volume on changes to vegetation structure and composition within Koondrook-Perricoota is difficult to predict in the absence of long-term monitoring data, and is complicated by a poorly understood sub-surface hydrology. However, broad assertions can be made about the distributional and structural response of vegetation communities to changed flooding regimes, and likely ecological responses of key species that characterise these communities.

Located downstream of the Millewa forests, the Koondrook-Perricoota forests are likely to change somewhat more dramatically than Millewa in future, despite the proposed engineering works.

In general terms it is likely that a considerable proportion of the tall and very tall open red gum forests will transition over time to a structure and vigour of typical river red gum woodland stands. Trees will generally survive but regenerating trees may not achieve the size and height of the parent trees. Sedge and herb elements of the understorey are also likely to be replaced by tussock grasses. In the absence of regular flooding the health of the river red gum woodland is likely to continue to decline to a point at which the canopy may senesce completely, with the forest no longer be able to produce seed and propagate. Similar to Millewa, parts of the stand are likely to assume the structure of a derived grassland or chenopod community.

It is difficult to quantify the extent of the Koondrook-Perricoota forests which are susceptible to complete loss of river red gum forest and woodland through water stress. However, it is possible that 20–25 per cent of the river red gum forest may be lost over the next 50 years, possibly more if flow conditions worsen. Those areas lost would most likely be within the woodland communities dominated by river red gum, some of which may continue to support scattered black box or other box species, but some of which may convert to shrubland or grassland.

Other vegetation communities in the Koondrook-Perricoota forests are likely to respond in different ways to a changed flooding regime. The various wetlands are likely to contract and be replaced by river red gum, with the exception of those subject to regular flooding. The river red gum–box communities would likely persist, however, with box species likely to become more dominant over the long term.

Ecological attributes response

The river red gum forest in Koondrook-Perricoota is the second largest in Australia behind Barmah-Millewa, with black box woodlands, inland grey box woodlands, reed beds and less-dominant grassland communities. The region comprises a diverse assemblage of flora and fauna, including species of state, national and international significance, and the wetlands themselves are of international importance. The site has particular significance for breeding colonies of intermediate egret, little egret, eastern great egret and nankeen night heron (MDBC, 2006b).

Most of the ecological values documented for these forests concern vegetation and birds (MDBC, 2006b). These ecological values are threatened by water regulation, weeds, timber harvesting, in-stream barriers to fish and water movement, inappropriate fire regimes, pests and grazing. Water regulation and altered flow regimes present one of the highest risks to ecological function. There has been a 58 per cent reduction in small floods, 77 per cent reduction in medium to large floods and 55 per cent reduction to large floods (URS, 2001, cited in MDBC, 2005), resulting in a decline in forest health (Turner and Kathuria, 2008; Pennay, 2008). Impacts from the altered flow regime include:

- reduced connectivity between wetlands and the river
- reduced fish breeding
- decreased diversity
- loss of wetland types
- reduction in wetland extent
- increased weed invasion (MDBC, 2005).

Similar to Millewa, the Koondrook-Perricoota forests are reasonably large and should offer a reasonable level of resilient habitat for fauna assemblages in the future. Habitat should be retained in the long term for hollow-dependent species such as barking owl, arboreal mammals and various microchiropteran bats. Much of the forest is likely to retain a structure and mosaic which facilitates continued movement of these species. The diversity of permanent wetlands subject to planned environmental flows should also provide refuge for wetland-dependent species such as egret and heron species and the giant banjo frog.

9.5.3 Likely impacts on the Werai forests

Summary

Of the three Ramsar sites, Werai forests are likely to be most degraded by reduced flooding and water scarcity. Over 40 per cent of the river red gum stand and associated wetlands could be lost within 50 years if current conditions persist, or worse if conditions deteriorate. As a result resident species are likely to be forced into a contracting area of core habitat. Most of the black box woodland is likely to persist in the Werai forests, as this does not appear to have declined in the past 20 years relative to river red gum (Pennay, 2009). However, the overall area of functional habitat may not be sufficient to support species with large home ranges such as the barking owl, and may not support the breeding requirements of wetland-dependent fauna such as colonial nesting waterbirds and white-bellied sea-eagle. Breeding success and the continued existence of such species within the southern bioregion may depend on the health and persistence of other functional forests, where change is likely to be less severe.

Vegetation distribution and ecological values response

While no specific hydrologic modelling is available, the potential ecological impact of hydrological change in the Werai forests is likely to be more severe than that in the Millewa and Koondrook-Perricoota forests. Flows of between 3,000 and 13,000 ML/day downstream of Steven's Weir are required for broad-scale inundation of the Werai Forests (GHD, 2009).

If predicted flow reductions (Scenario Cmid, see **Chapter 8**) eventuate, the likely implication for the Werai forests is at least a 50 per cent decline in the distribution of very tall and tall open river red gum forests as they transition to either:

- river red gum woodland (and assume a changed floristic composition in the understorey), or
- derived grassland/chenopod scrub with widespread canopy mortality.

The overall area of river red gum is also likely to decline as the woodland stands on the less frequently watered parts of the forest senesce and die, replaced by a derived grassland/chenopod scrub. The extent of loss of woodland areas might be as much as 40 per cent in the Werai forests over the next 50 years if current flow projections are maintained. Over 90 per cent of river red gum stands these forests are currently unhealthy (GHD, 2009).

The forecast magnitude of change in the Werai forests raises questions about the capacity of some species to persist, particularly those with large home ranges such as forest owls and raptors, and wetland-dependent species such as little pied cormorant. Of the three Ramsar sites, Werai is most susceptible to major ecological change and local species extinction.

Despite the unfavourable outlook for the Werai forests it is important to consider that the contraction of the river red gum ecosystem does not necessarily mean that rejuvenation in future is not possible if long-term flooding regimes are restored. The geomorphic characteristics of these and other areas, to which river red gum stands have adapted over thousands of years, are not themselves likely to shift in response to climate change. Because river red gum seeds are sometimes carried significant distances by floodwaters, severely stressed and dead stands of river red gum could conceivably recover following a major flood, as a result of deposition of seed from elsewhere on the floodplain and subsequent regeneration. However, the ecological function of such a stand is likely to be compromised as large hollow trees are replaced by regenerating saplings of lower habitat value, and given persistence of favourable conditions, stands might not assume an adequate level of functional habitat until 200–500 years (for example, Sutherland et al., 2004).

9.5.4 Likely impacts on the Murrumbidgee wetlands

Summary

The Murrumbidgee wetland areas have declined appreciably over the past 50 years, largely as a result of clearing and draining for irrigation, with consequent decline in waterbird numbers in the catchment. This trend is likely to continue with climate change as central-west NSW experiences drier, hotter conditions. Important wetland species such as Australasian bittern, blue-billed duck, freckled duck and southern bell frog are likely to decline further as breeding habitat contracts.

Vegetation distribution and ecological attributes response

While no specific hydrologic modelling is available, the Murrumbidgee system is forecast to receive less floodwater, with negative implications for the Mid-Murrumbidgee and the Lowbidgee Floodplain Wetlands. As with other river red gum communities, the vegetation response to lower flows is likely to be a contraction of tall red gum forests to regularly flooded zones and sub-surface aquifers, and loss of some stands on the outer floodplain. Ultimately black box may not survive because the flow regime to these parts of the floodplain has changed so much from when they were recruited (Kingsford and Thomas, 2001). These are likely to transition into native grasslands.

There is also likely to be continued loss of the extent of the major wetlands fed by the Murrumbidgee. Kingsford and Thomas (2001) used satellite imagery (Landsat MSS) for the period 1975 to 1998 to determine the extent of wetland loss in the Lowbidgee Wetlands, and bird counts to record losses in bird numbers from previous bird censes. The research found that to 2001, around 58 per cent of the floodplain wetlands had been lost, much of the damage occurring between 1975 and 1998. Of those remaining at the time, 44 per cent were degraded, with the floodplain vegetation having little chance of returning to health. The authors observed that flood-dependent aquatic vegetation at the margin of wetlands exhibited reduced health and poor canopy growth. Aquatic macrophytes were unlikely to establish except during extreme events. Even within core areas of the wetlands, reduced health with poor canopy growth was observed, apart from along the floodways where macrophytes such as cumbungi were well established in response to increased flows. Correspondingly lignum was observed to be in poor health in floodways because of increased flooding.

Waterbird numbers were observed by Kingsford and Thomas (2001) to have collapsed by more than 80 per cent since 1983. Maher (1990) considered that the Lower Murrumbidgee floodplain was of national importance for nine species of waterbird (including Australasian bittern and freckled duck). For the six species for which data were available, Kinsgford and Thomas (2001) provided evidence that numbers of all six had declined, particularly after 1995, and that most other individual waterbird species had declined in numbers over an

Wetlands in Wilbriggie State Forest on the Murrumbidgee River

18-year period. Kingsford and Thomas (2001) also suggest that invertebrates, fish, frogs (including the nationally significant southern bell frog) and water plants which the birds feed on are in decline because of reduced habitat area, and that long-term reduction in breeding is expected.

Other studies have also shown a general decline in the condition of the Murrumbidgee River forests and their wetlands and floodplain (for example, Jansen and Robertson, 2005; Hillman et al., 2000). This is supported by SLATS data presented by Pennay (2009), which shows that open wetland areas such as Coononcoocabil Lagoon and Yaradda Lagoon have declined in the past 20 years mainly through clearing for cropping and irrigation.

9.5.5 Impacts on the Lachlan wetlands

Summary

The Lachlan River feeds the Booligal Wetlands and Great Cumbung Swamp. Similar to the Lowbidgee Wetlands on the Murrumbidgee to the south, these wetlands are under severe stress as a result of river regulation and climate change, with flood events, breeding populations of waterbirds and canopy cover in decline (Pennay, 2009). Wetland fauna such as blue-billed duck and freckled duck may not be supported by these wetlands in the future. The associated river red gum stands of the Lachlan River are known to support superb parrot and other key species. If the condition of the Lachlan deteriorates further, such species may also disappear from the Lachlan over coming decades.

Vegetation distribution and ecological values response

The major implication for reduced flows into the Booligal Wetlands and Great Cumbung Swamp relates to amphibian habitat and waterbird breeding habitat. The Great Cumbung Swamp comprises one of the largest reed beds in south-eastern Australia and provides important habitat for waterbirds, amphibians and other fauna (Inland Rivers Network, 2007).

River regulation of these systems has resulted in an increase in the number of trees exhibiting signs of stress in the Booligal Wetlands (Armstrong et al., 2009; Pennay, 2009). Without periodic flooding (as frequent as one in three years for optimal growth), the health of river red gums will decline and continued drought will result in loss of seed production, recruitment and crown cover. These changes will have flow-on effects through the ecosystem, with implications for the food chain and thus function of the system. In the absence of a healthy tree crown there will be insufficient leaf fall to form a detritus layer, which flows onto the abundance of detritus-dependent flora and fauna, affecting the food supply of higher organisms such as fish and waterbirds. Quantifying the impact is not possible.

The breeding cue for many of the waterbirds and migratory shorebirds recorded in Booligal Swamp is flooding (Scott, 1997) so that loss of species from these systems (such as the blue-billed duck and freckled duck) may be anticipated in the absence of periodic flooding events. Without substantial change to water allocation and flooding, there will be continual demise in the health of water-dependent vegetation communities, irregular instances of breeding in waterbirds and declines in amphibian species. Terrestrial vegetation dominated by grasses and shrubs are likely to encroach into former wetlands and riparian sites.

Tree marked for retention in Superb Parrot habitat

9.5.6 Impacts on other forests and riparian zones

The relatively reliable floodwater received in Barooga and other State Forests immediately west of Albury, and its relatively high annual rainfall, suggests that this system is least likely to change in terms of vegetation type or species composition (fauna and flora). Tall river red gum forest and river red gum–yellow box woodland stands should maintain their level of productivity and regeneration potential, and should continue to support key ecological values. These small forests provide a refuge for several fauna species known to rely on river red gum along the Murray, including powerful and barking owls, koala, brush-tailed phascogale and squirrel glider.

In contrast, the Wakool and Edward forests are relatively low in an over-allocated catchment and are thus susceptible to low water allocations, as water is fed downstream for irrigation and domestic supply, or is absorbed upstream for irrigation or environment. They also receive a low annual rainfall. The vegetation response in the Wakool and Edward forests is likely to be considerable, with most of the very tall and tall open river red gum forest assuming a structure and productivity of open river red gum woodland over the long term, and up to 40 per cent of river red gum woodland transitioning from red gum to derived copperburr or grassland in the next 50 years.

The major icon species of the lower Murray is the regent parrot which is reliant on hollow-bearing trees within river red gum forests. The implication of a changing ecology in the western river red gum stands for species such as the regent parrot is unclear. Chambers et al. (2005) predict that under certain climate change scenarios the present range of the species could decline by more than 99 per cent, unless it is able to respond by moving east. Based on Pennay (2009) and the likely predicted flows in the lower Murray, available habitat within the regent parrot's current range are likely to be reduced over the long term.

Dead habitat tree in Booligal State Forest