05 INDICATORS, CONDITION AND TRENDS

Section Contents

This chapter assesses the current condition and trends for a range of natural and sustainability issues in the ACT. Assessments are based on 26 indicators across 7 themes selected to address specific environmental issues. These indicators provide evidence on both the status of issues and the effectiveness of environmental management policies and activities.

For each indicator, a graded assessment is provided using a dashboard display containing snapshots of key information including condition, trend and data quality. The dashboards should be read in conjunction with the indicator content provided in each section. The graded assessment criteria are provided below.

Indicator assessment legend

Condition

Good	= Environmental condition is healthy across the ACT, **OR** pressure likely to have negligible impact on environmental condition/human health.
Fair	= Environmental condition is neither positive or negative and may be variable across the ACT, OR pressure likely to have limited impact on environmental condition/human health.
Poor	= Environmental condition is under significant stress, OR pressure likely to have significant impact on environmental condition/ human health.
Unknown	= Data is insufficient to make an assessment of status and trends.
NA	= Assessments of status, trends and data quality are not appropriate for the indicator.

Trend

↑	Improving
↓	Deteriorating
–	Stable
?	Unclear
NA =	Assessments of status, trends and data quality are not appropriate for the indicator.

Data quality

●●● High	= Adequate high-quality evidence and high level of consensus
●●○ Moderate	= Limited evidence or limited consensus
●○○ Low	= Evidence and consensus too low to make an assessment
○○○ NA	= Assessments of status, trends and data quality are not appropriate for the indicator.

Assessment criteria used for indicator dashboards[1]

Data availability, quality and comprehensiveness is a key limitation for indicator assessments. The data quality ratings provided in the indicator dashboards provide a measure of the level of confidence in the condition and trend assessments reported. If adequate high-quality data was available, confidence in the assessment is high. If data was limited, confidence is low. Where data was insufficient to enable an assessment, an unknown rating is applied.

Data availability issues are discussed for each theme reported, highlighting where more information is required to improve environmental knowledge and the capacity to respond to environmental challenges.

Where relevant, the influence of significant climate and other events on data trends are discussed for each indicator. It is important to note that such influences can have a significant impact on environmental condition regardless of management effectiveness.

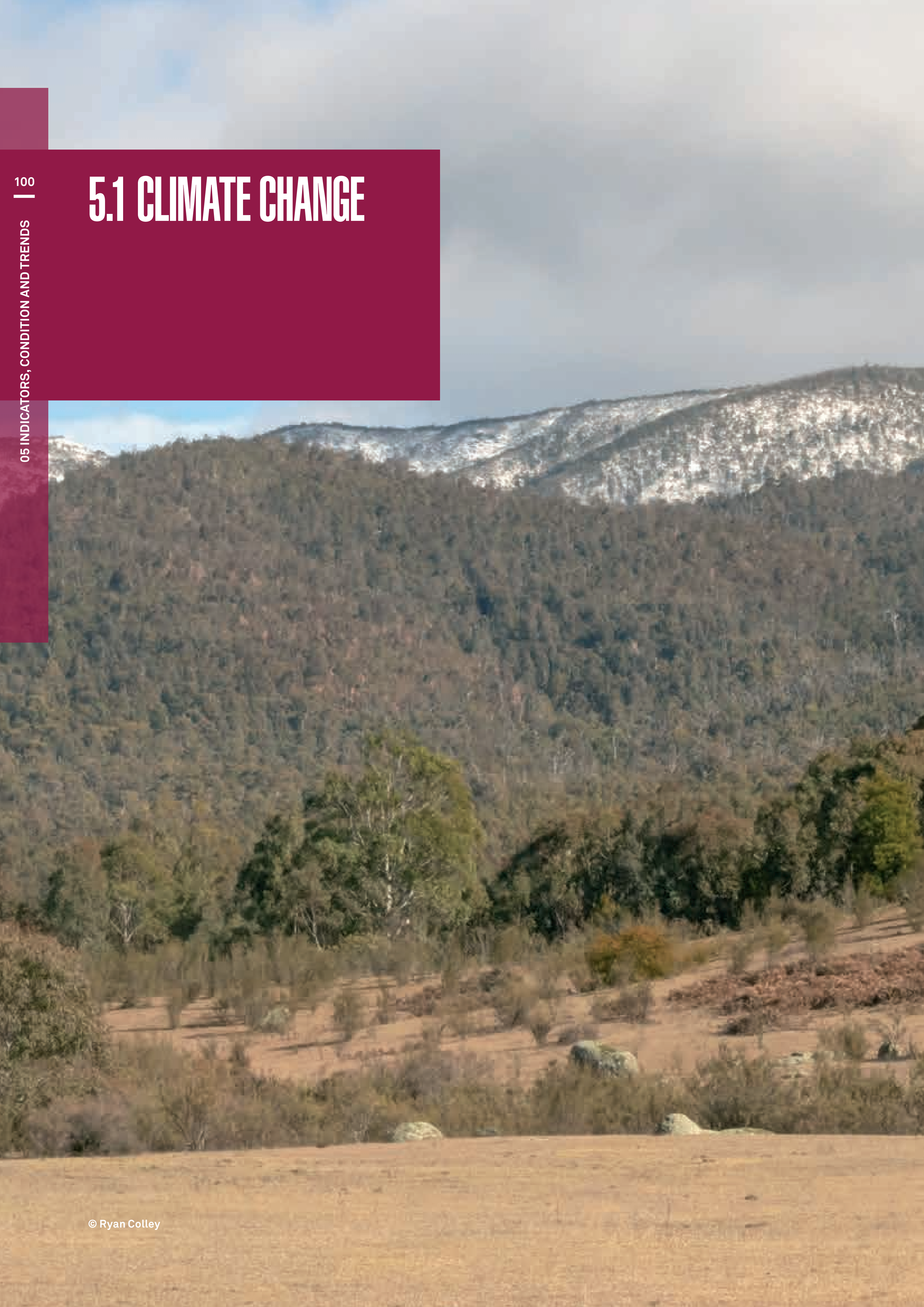
National Environment Protection Measures (NEPM)

The *Commissioner for Sustainability and the Environment Act 1993* requires every State of the Environment report to include an assessment of the ACT's compliance with relevant NEPMs. The NEPMs assessed in this report are:

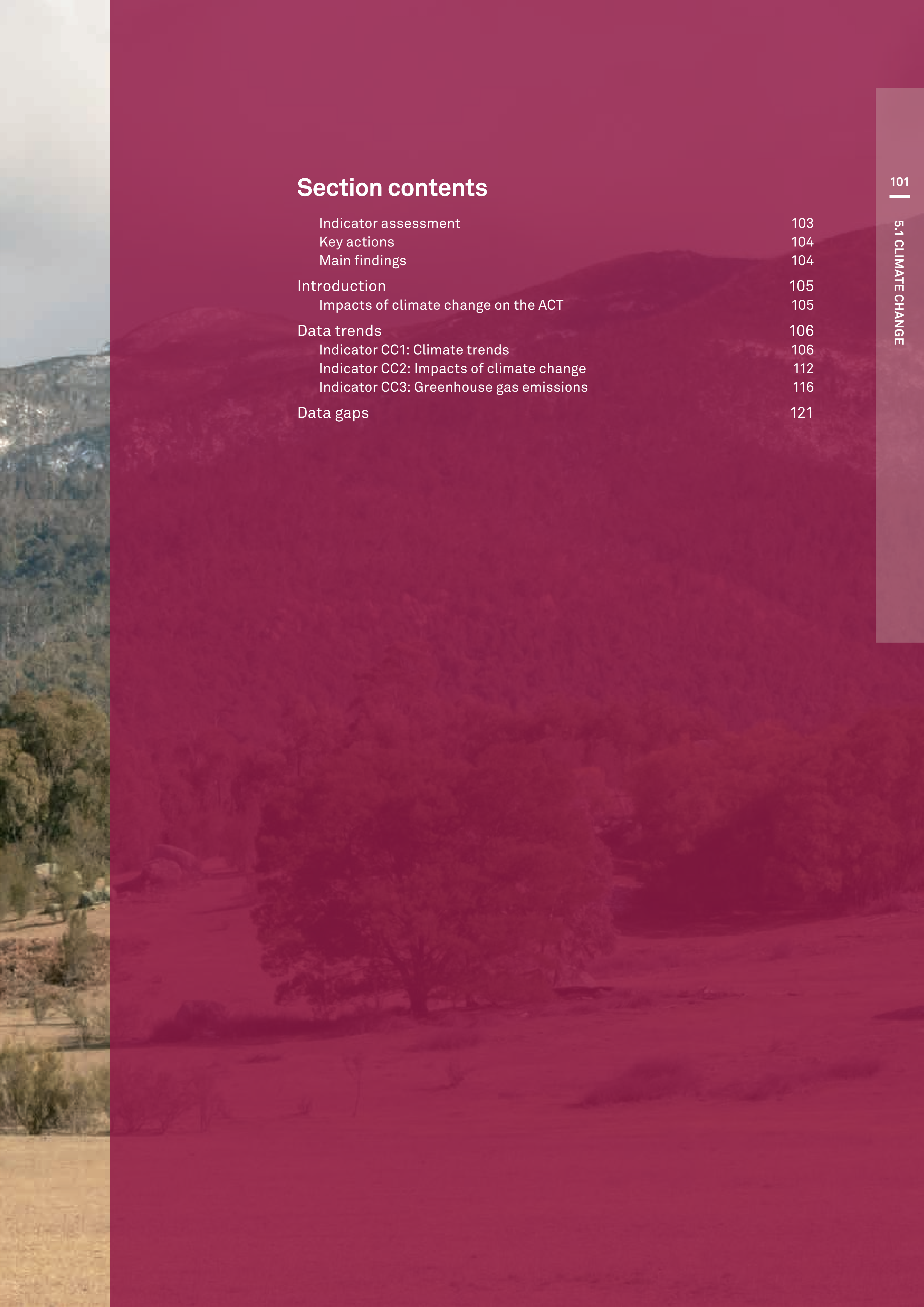
- Movement of Controlled Waste (see section **5.2 Human settlements**)
- Used Packaging Materials (see section **5.2 Human settlements**)
- Ambient Air Quality (see section **5.3 Air**)
- National Pollutant Inventory (see section **5.3 Air**)
- Assessment of Site Contamination (see section **5.4 Land**).

1 Adapted from Commissioner for Environmental Sustainability, 2013, *Victoria: State of the Environment*, The State of Victoria, Melbourne.

5.1 CLIMATE CHANGE



© Ryan Colley



Section contents

Climate change in the ACT

ACT's climate trends

- **1.5°C** increase in mean maximum temperatures since 1926
- **2°C** increase in mean minimum temperatures since 1926
- **2016** was the warmest year on record for mean minimum temperatures
- **2018** was the warmest year on record for daytime temperatures
- **x2** hot days have doubled since 1950
- **5** days above 40°C in January 2019
- most recent years have been drier than average

Projected climate trends

- decrease in rainfall, particularly for spring and winter
- more frequent and prolonged drought
- higher average temperatures and more hot days
- more frequent and severe storms
- increased fire danger

Observed impacts of climate change

- reduced inflows to water storages
- increase in tree dieback and mortality of urban trees
- increase in fire danger
- occurrence of dust storms
- increase in cyanobacterial blooms in Canberra's lakes

ACT's Greenhouse gas emissions

- **17%** decrease in total emissions between 2012–13 and 2017–18
- **24%** decrease in per capita greenhouse gas emissions between 2012–13 and 2017–18
- **0%** projected emissions from electricity generation by 2020
- **13%** increase in transport emissions between 2012–13 and 2017–18
- **62%** of total emissions in 2020 will be from transport

Indicator assessment

Indicator	Status	Condition	Trend	Data quality
CC1: Climate trends	Climate change is having a significant impact on the ACT, with clear evidence of a warming climate and increased occurrence of heat days. Rainfall is variable, but most recent years have been drier than average. Projections suggest a worsening climate with hotter temperatures and decreased rainfall.	Poor	↓	●●● High
CC2: Impacts of climate change	Climate is impacting on the ACT's community, economy and the natural environment. Observed changes include reduced inflows to water storages, increased tree mortality, greater fire danger, and more algal blooms in Canberra's lakes.	Poor	↓	●●○ Moderate
CC3: Greenhouse gas emissions	By 2020, emissions from electricity generation will fall to zero and the ACT will meet the legislated target for total emissions. Transport will contribute over 60% of ACT's emissions after 2020 and will become the main focus for future reductions. However, transport emissions increased by 13% between 2012–13 and 2017–18 and will represent a significant challenge in the future. The phasing out of natural gas will also be important. Per capita greenhouse gas emissions were just over 8 tonnes in 2017–18, a decrease of around 24% from 2012–13.	Good	↑	●●● High

Indicator assessment legend

Condition

Good = Environmental condition is healthy across the ACT, **OR** pressure likely to have negligible impact on environmental condition/human health.

Fair = Environmental condition is neither positive or negative and may be variable across the ACT, OR pressure likely to have limited impact on environmental condition/human health.

Poor = Environmental condition is under significant stress, OR pressure likely to have significant impact on environmental condition/ human health.

Unknown = Data is insufficient to make an assessment of status and trends.

NA = Assessments of status, trends and data quality are not appropriate for the indicator.

Trend

↑ Improving
↓ Deteriorating
– Stable
? Unclear
NA = Assessments of status, trends and data quality are not appropriate for the indicator.

Data quality

●●● **High** = Adequate high-quality evidence and high level of consensus
●●○ **Moderate** = Limited evidence or limited consensus
●○○ **Low** = Evidence and consensus too low to make an assessment
○○○ **NA** = Assessments of status, trends and data quality are not appropriate for the indicator.

Key actions

That the ACT Government:

ACTION 1: investigate and implement measures to reduce transport emissions.

ACTION 2: increase living infrastructure to mitigate the impacts of climate change in urban areas.

ACTION 3: improve knowledge of the impacts of climate change across urban and natural environments to inform strategies on climate adaptation and resilience.

ACTION 4: assess and monitor carbon stocks and investigate opportunities to increase carbon sequestration in natural ecosystems and urban environments.

Main findings

Climate trends

There is clear evidence of a warming climate trend in the ACT.
Annual mean maximum temperatures have risen by over 1.5 °C since records began in 1926.
Minimum temperatures have warmed the most, having risen by around 2 °C since records began in 1926, with 2016 the warmest year on record for mean minimum temperatures.
Since 2013, every year has been among the eleven warmest years on record for daytime temperatures and 2018 was the warmest year on record for daytime temperatures in the ACT.
The number of hot days has doubled since 1950, with 5 days above 40°C in January 2019, and an increase of 4 days per year for temperatures above 35 °C.
Rain is variable in the ACT region, with no long-term trend, although recent years have been drier than average with the exception of 2016.

Projected climate trends

Regional climate modelling suggests the following projections: reduced rainfall, particularly for spring and winter rainfall; more frequent and prolonged drought; average temperatures will continue to increase in all seasons; more frequent and severe storms with flash flooding, violent winds, and thunderstorms; and harsher fire-weather climate.

Impacts of climate change

There are significant climate risks to ACT's community, economy and the natural environment.
Reduced inflows to water storages, with all but 2 years between 2001–02 and 2018–19 below the long-term average.
Increase in tree dieback and mortality of urban trees.
Increase in the average and maximum Fire Danger Index and an increase in the number of days with a very high Fire Danger Rating.
Occurrence of dust storms due to higher temperatures and reduced rainfall.
Increase in cyanobacterial blooms in Canberra's lakes.

Greenhouse gas emissions

In 2017–18, ACT's total greenhouse gas emissions were 3,368 thousand tonnes of CO_2-e (carbon dioxide equivalent).
Total emissions decreased by 17% between 2012–13 and 2017–18 due to the growth in renewable electricity generation.
By 2020, emissions from electricity generation will fall to zero.
With the elimination of electricity emissions, total emissions are projected to decrease to around 1,918 thousand tonnes of CO_2-e, meeting the legislated 2020 target.
Per capita annual greenhouse gas emissions were just over 8 tonnes in 2017–18, a decrease of around 24% from 2012–13 and of 29% compared to 1989–90 levels.
Between 2012–13 and 2017–18, the electricity generation and transport sectors were the dominant source of greenhouse gas emissions in the ACT.
Between 2012–13 and 2017–18 transport emissions increased by 13%; this growth, combined with the decrease in electricity emissions, saw transport contributions rise from 25% to 34% of total emissions.
The stationary gas sector contributed 11% of total emissions in 2017–18 and industrial processes 8%.
As the electricity sector moves towards zero emissions by 2020, transport will contribute 62% of total emissions, nearly double its 2017–18 proportional contribution. Stationary gas and waste will also double in contribution.
Between 2012–13 and 2017–18, greenhouse gas emissions from diesel fuel nearly doubled; as a result, the diesel contribution to total transport emissions rose from 23% to 34% over the same period.
Transport and the phasing out of natural gas will become the main focus for future reductions of greenhouse emissions in the ACT.

INTRODUCTION

This section provides an assessment of climate change in the ACT including current and projected trends in temperature and rainfall, the impacts of climate change on the human and natural environments, and trends in the ACT's greenhouse gas emissions.

The following indicators are assessed:

- CC1: Climate trends
- CC2: Impacts of climate change
- CC3: Greenhouse gas emissions

Climate change is discussed throughout **Chapter 5 Indicators, Condition and Trends** of this report. Information on the impacts of current and future climate change on specific aspects of the environment can be found in each relevant section.

Climate change is the most significant environmental challenge facing governments and communities around the world. In recognition of the need for urgent action, the ACT Government declared a state of climate emergency in May 2019.

Climate change is caused by increases in the amounts of greenhouse gases and aerosols in the Earth's atmosphere. The majority of greenhouse gases come from the burning of fossil fuels, which release carbon dioxide gas to the atmosphere. Climate change is a global challenge with all greenhouse gas emissions, regardless of source and location, contributing to the total atmospheric concentrations which drive local climatic conditions. This means that greenhouse gas emissions from the ACT have an impact on the global environment, not just the local region.

Greenhouse gas emissions are exacerbated by population growth and a range of human activities, including those that drive energy and resource demand and land clearing, which reduce the uptake of carbon dioxide. Consequently, government and community actions are fundamental to reducing emissions including minimising vehicle use, cutting back the consumption of goods, choosing products that are better for the environment, and improving recycling and reuse.

Whilst many climate change impacts are inevitable given the existing levels of greenhouse gases in the atmosphere, it is vital to reduce emissions to minimise the severity of climate change for the generations to come. The future impacts of climate change will depend on the degree to which we can mitigate greenhouse gas emissions today.

Impacts of climate change on the ACT

Climate change has significant natural, social and economic repercussions for the ACT driven by increased temperatures, decreased rainfall, and the greater risk of extreme weather events and fire. These have severe consequences for ecosystem health and biodiversity, ecosystem services, and human health and wellbeing.

Recent research has found that one-third of the Canberra community have low or very low resilience to climate change and are highly vulnerable to the likely negative impacts.[1] Resilience was generally linked to income levels with low-income community members being the most vulnerable. This was particularly the case for heat where 36% of people live in homes that perform poorly in heatwaves. The study also found that nearly 40% of Canberrans have low resilience to extreme weather events due to lack of preparedness.

Climate change has also been shown to have a significant impact on medical costs and the economy. A study of the Adelaide community's response to hot weather found that for every degree above the threshold of 33ºC, medical costs increased by over 40% and lost work days by nearly 75%.[2]

Advice from the international scientific community is that if we are to avoid the most catastrophic effects of climate change, the increase in average global temperature must not exceed 2 °C above pre-industrial levels.[3] Beyond 2 °C warming there is a risk that the climate system will pass an irreversible tipping point, beyond which the task of stabilising global warming becomes impossible. This would mean an increasingly extreme and unpredictable global climate.

Climate change is a significant challenge that will require the ACT Government and community to adapt to a changing environment and undertake preventative actions to build resilience and minimise impacts on the natural and urban environments.

1 Schirmer, J. and B. Yabsley, 2018, *Living Well with a Changing Climate: Findings of the 2018 ACT Longitudinal Survey on Climate Change*, University of Canberra.
2 Xiang J. et al., 2017, The Economic Burden of Occupational Heat Illnesses in Adelaide, South Australia, 2001–2015, *Occupational and Environmental Medicine*, 74:A37.
3 Environment, Planning and Sustainable Development Directorate (EPSDD), 2019, *ACT Climate Change Strategy 2019–25*, ACT Government, Canberra, found at https://www.environment.act.gov.au/__data/assets/pdf_file/0003/1414641/ACT-Climate-Change-Strategy–2019–2025.pdf/_recache

DATA TRENDS

Indicator CC1: Climate trends

The ACT's climate is determined by atmospheric conditions and sea-surface temperatures. The main drivers of natural climate variability include (but are not limited to) the El Niño–Southern Oscillation (including La Niña cycles), the Indian Ocean Dipole, and the Southern Annular Mode which influence climate across south-eastern Australia. Changes in the frequency and duration of these drivers cause year-to-year variations in temperature and rainfall.

This natural climate variability is now significantly influenced by human-induced climate change. Evidence of global and regional warming caused by greenhouse gas emissions is incontrovertible.[4 5] The data presented in this section shows the impact of climate change on the ACT region.

Eastern Grey Kangaroos. Source: Ryan Colley.

4 United Nations Intergovernmental Panel on Climate Change (IPCC), Pachauri, R.K. et al., eds, 2014, *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, IPCC, Geneva, found at https://www.ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf

5 Bureau Of Meteorology, 2018, *State of the Climate 2018*, Commonwealth of Australia, Canberra, found at http://www.bom.gov.au/state-of-the-climate/

EXPERT COMMENTARY
THE STATE OF CANBERRA'S CLIMATE

Dr Sophie Lewis, Senior Lecturer, School of Science at the University of NSW, Canberra. Dr Lewis is the 2019 ACT Scientist of the Year and is currently serving as a lead author on the Intergovernmental Panel on Climate Change (IPCC) sixth assessment report.

A recent report by the IPCC estimates humans have already caused approximately 1 °C of global warming because of increased greenhouse gas emissions.[6] This warming has already affected our ecosystems and biodiversity, human health and livelihoods in many regions, raised sea levels, and changed the intensity and frequency of heatwaves, droughts and floods.

The impacts of global warming are being felt in the ACT region with annual average temperatures increasing (Figure 1). Extreme events are already becoming more frequent in Australia and the ACT because of climate change.[7] In January 2019, Canberra experienced a total of 5 days above 40 °C.[8] Since 2007, this 40 °C threshold has been reached 16 times, but had not occurred once in the 25-year period between 1973 and 1998.

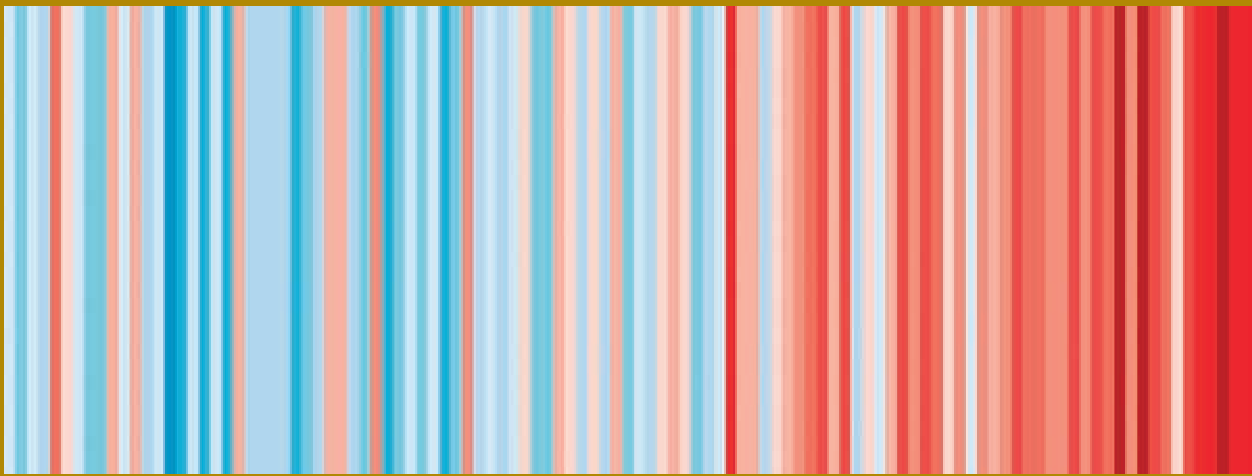


Figure 1:
Canberra's climate stripes, 1910 to 2018.

Each stripe represents the annual average ACT/NSW temperatures. The coolest temperatures are shown in dark blue, the hottest are dark red. Further information is available at https://showyourstripes.info.

The impact of global warming on our weather and climate extremes is clearest for changes in temperatures.[9] Long-term data shows that there has been a doubling in the number of hot days in Canberra since 1950 (Figure 2).[10] The frequency and duration of heatwaves has also increased. In addition, there have been 50% more monthly heat records broken in NSW and ACT compared to cold records. Climate change is also affecting other important weather extremes such as the timing and severity of frost events, heavy rain and wind storms. These extreme events have potentially large repercussions for people and the environment.

6 IPCC, Masson-Delmotte, V. et al., eds, 2018, *Special Report:Global Warming of 1.5 °C*. IPCC, Geneva: 32, found at https://www.ipcc.ch/site/assets/uploads/sites/2/2018/07/SR15_SPM_version_stand_alone_LR.pdf.
7 Bureau Of Meteorology, 2018, *State of the Climate 2018*, Commonwealth of Australia, Canberra, found at http://www.bom.gov.au/state-of-the-climate/
8 Bureau Of Meteorology, 14 March 2019, *Special Climate Statement 68 – Widespread Heatwaves during December 2018 and January 2019*, Commonwealth of Australia, Canberra, found at http://www.bom.gov.au/climate/current/statements/scs68.pdf
9 Perkins-Kirkpatrick, S. E. et al, 2016, Natural Hazards in Australia: Heatwaves, *Climate Change*, 139:101–114, doi:10.1007/s10584–016–1650–0.
10 Steffen, W. et al., 2014, *Heatwaves: Hotter, Longer, More Often*, Climate Council of Australia Ltd, found at https://www.climatecouncil.org.au/uploads/9901f6614a2cac7b2b888f55b4dff9cc.pdf

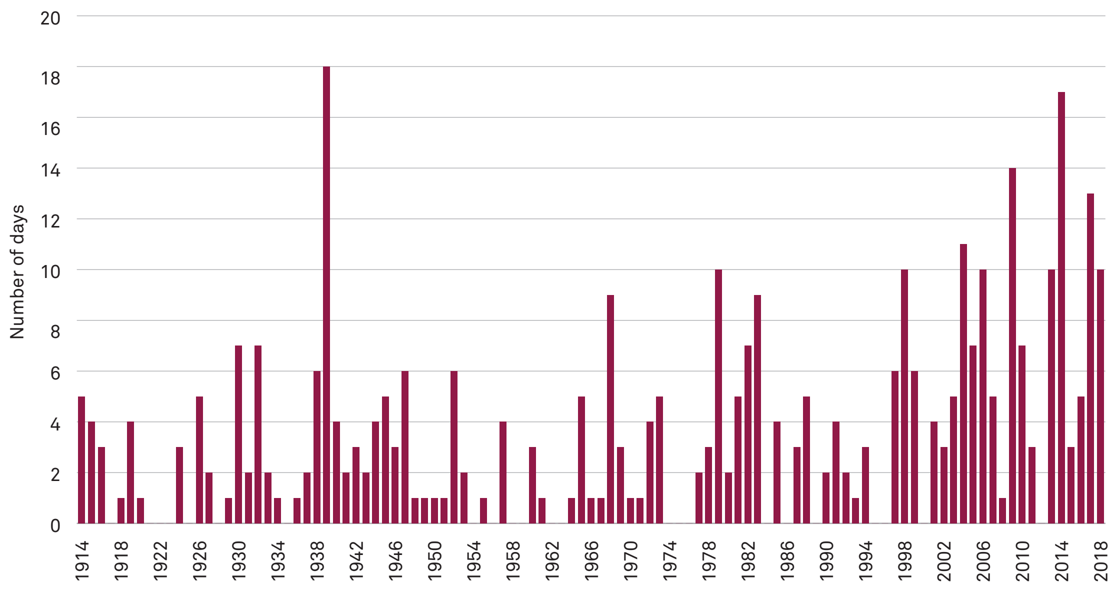


Figure 2:

Annual number of hot days in Canberra (maximum temperature above the long-term 99th percentile value), 1914 to 2018.

Data sourced from: Bureau of Meteorology, Canberra Airport site

Multiple climate extremes can also occur at the same time, leading to impacts much greater than for individual extremes. We experienced this compound extreme effect in 2018, when extreme heat combined with an extended period of low rainfall left 100% of NSW in declared drought conditions.[11] When extreme heat occurs with low rainfall, such as in Queensland in November 2018, bushfire risks can also increase.[12] Measures of annual fire danger have increased substantially for Canberra.[13]

Climate change is a global-scale problem but it is already affecting all Canberrans – and it will continue to do so for decades to come. At current rates, global warming is likely to reach 1.5 °C between 2030 and 2052, and greenhouse gas emissions are projected to result in over 3 °C of global warming this century. Such an increase will result in significant climate risks to people, the economy and the natural environment.

In Canberra, these trends translate into an increase in the frequency, severity and duration of heatwaves, a greater number of heat-related deaths and challenges for local agriculture.[14] Climate models also project a decrease in overall rainfall, particularly during spring, together with greater fire risks.[15]

While Australia's per capita greenhouse gas emissions remain high compared to other developed countries, the ACT has demonstrated it is a global leader in emissions reduction.[16] By setting ambitious targets to achieve zero net greenhouse gas emissions by 2045, Canberra has been rated amongst leading jurisdictions in climate policy in the world.[17] Policies include a 100% renewable electricity target by 2020, transition to zero emissions from vehicles, and a climate adaptation strategy. This strategy includes green (or living) infrastructure as a key tool to reduce the critical impacts of future climate change, such as the role of urban trees in Canberra to reduce the urban heat island effect on hot days (Figure 3).

---

11 Bureau Of Meteorology, 1 November 2018, *Special Climate Statement 66 – An Abnormally Dry Period in Eastern Australia*, Commonwealth of Australia, Canberra, found at http://www.bom.gov.au/climate/current/statements/scs66.pdf

12 Bureau Of Meteorology, 12 December 2018, *Special Climate Statement 67 – An Extreme Heatwave on the Tropical Queensland Coast*, Commonwealth of Australia, Canberra, found at http://www.bom.gov.au/climate/current/statements/scs67.pdf

13 Dowdy, A.J., 2018, Climatological Variability of Fire Weather in Australia, *Journal of Applied Meteorology and Climatology*, 57: 221–234.

14 Herold, N. et al., 2018, Australian Climate Extremes in the 21st Century According to a Regional Climate Model Ensemble: Implications for Health and Agriculture, *Weather Climate Extremes*, 20: 54–68.

15 Clarke, H. et al., 2013, Changes in Australian Fire Weather between 1973 and 2010, *International Journal of Climatology*, 944: 931–944.

16 Australia has the highest per capita carbon dioxide emissions of all countries within the Organisation for Economic Co-operation and Development (OECD).

17 EPSDD, 2019, *ACT Climate Change Strategy 2019–25*, ACT Government, Canberra, found at https://www.environment.act.gov.au/__data/assets/pdf_file/0003/1414641/ACT-Climate-Change-Strategy-2019-2025.pdf/_recache

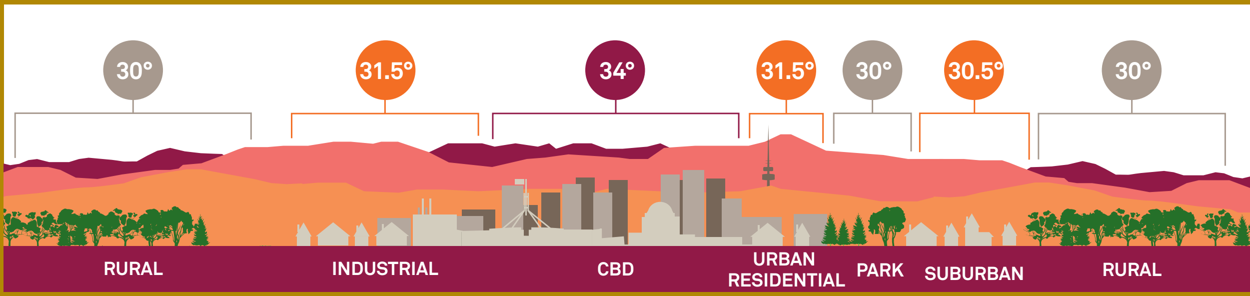


Figure 3:
Urban heat island effect comparing temperatures across different land use and vegetation cover (late afternoon temperature).

Source: Adapted from Commissioner for Sustainability and the Environment, 2017, *Implementation Status Report on ACT Government's Climate Change Policy*, ACT Government, Canberra.

Climate change remains a complex and enduring global problem, with significant impacts at the local level. Figure 4 shows the possible climate warming a child born in Canberra today will experience during their lifetime. It is clear that climate change affects everyone alive today and will do so for many generations to come. Addressing the challenges of climate change requires all of Canberra to continue acting together as global leaders in mitigating and adapting to climate challenge.

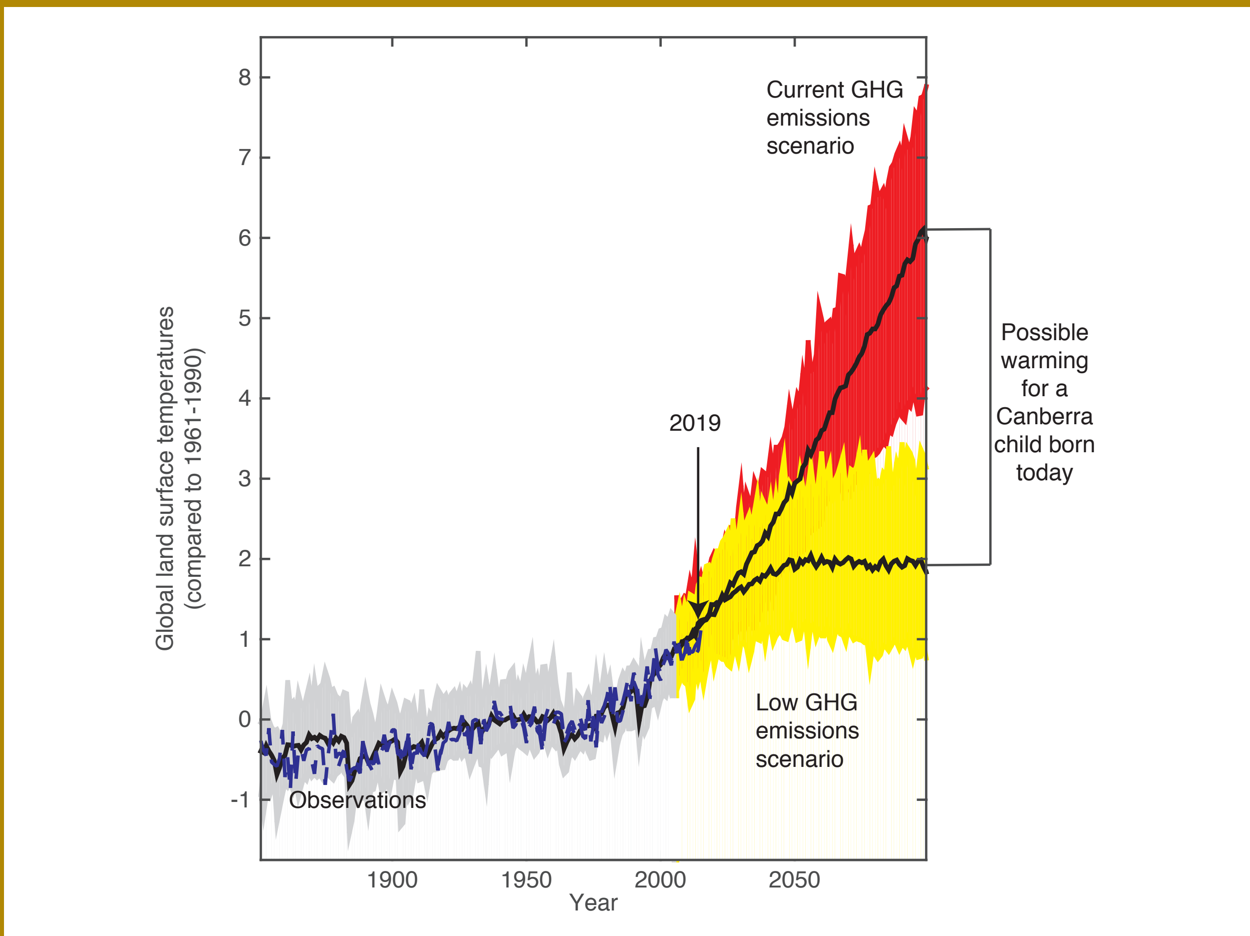


Figure 4:
Projections of future warming under different emissions scenarios that a child born in Canberra today will experience during their lifetime.

Source: Lewis, S.C. et al., 2017, Defining a New Normal for Extremes in a Warming World, *Bulletin of the American Meteorological Society*, 98(6): 1139–1151.

Observed surface temperature

The ACT's annual mean maximum temperatures have risen by over 1.5 °C since records began in 1926 (Figure 5).[18] The frequency and severity of hot temperatures have also increased (see Figure 2). Since 2013, every year has been among the eleven warmest years on record for daytime temperatures and 2018 was the warmest year on record for daytime temperatures in the ACT.

In the ACT, minimum temperatures have warmed the most, with annual mean minimum temperatures having risen by around 2 °C since records began in 1926 (Figure 6). Recent warm years include 2016 which was the warmest year on record for mean minimum temperatures and 2018 which was the tenth warmest year on record.

Other annual temperature trends for the ACT include:

- an increase of 4 days per year for temperatures above 35 °C
- a decrease of 20 days per year for temperatures below 10 °C
- an increase of 20 nights per year for temperatures above 15 °C
- a decrease of 25 nights per year for temperatures below 0 °C
- autumn mean maximum temperatures have risen by just over 1.5 °C since 1926
- the warmest daytime temperatures for autumn were recorded in 2016, with 2018 the second warmest
- autumn mean minimum temperatures have risen by around 1 °C since 1926
- spring mean maximum temperatures have risen by over 1.5 °C since 1926, and
- spring mean minimum temperatures have risen by over 2 °C since 1926.

These results demonstrate a clear warming climate trend in the ACT. The impacts of this warming are discussed in **Indicator CC2: Impacts of climate change**.

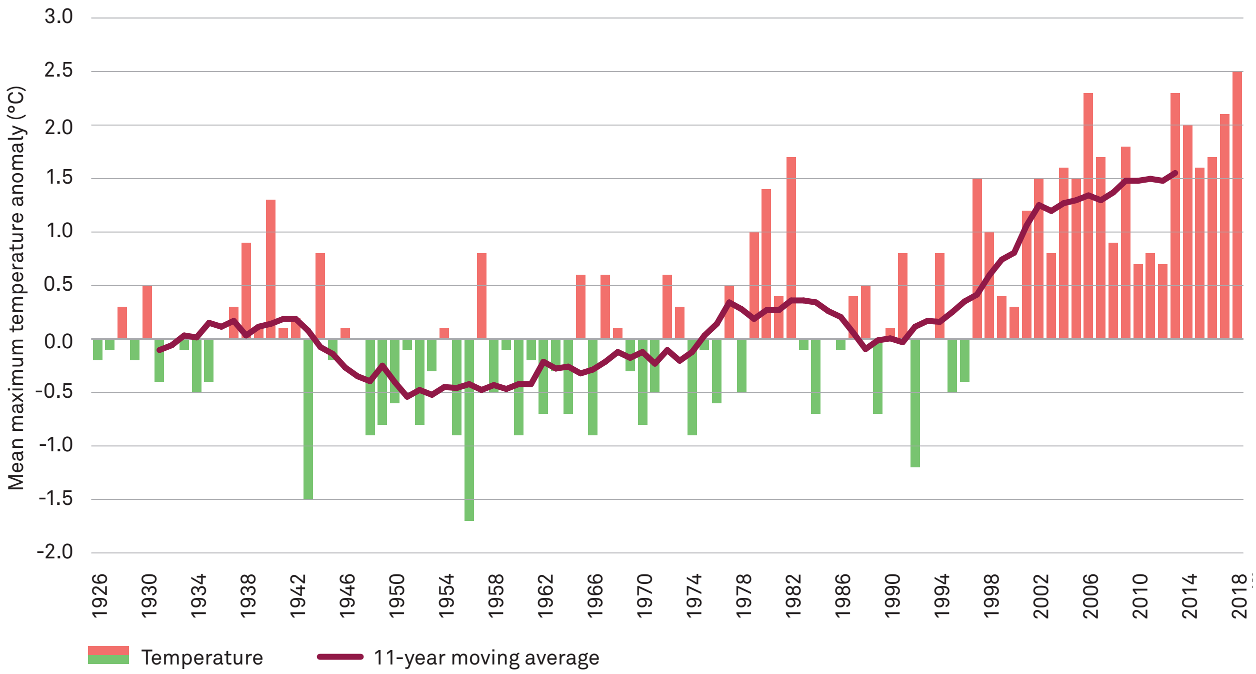


Figure 5:
ACT mean maximum temperature anomaly (as calculated from the 1961 to 1990 average), 1926 to 2018.

Data sourced from: Bureau of Meteorology, Canberra Airport site.

18 Based on Bureau of Meteorology observations at Canberra Airport.

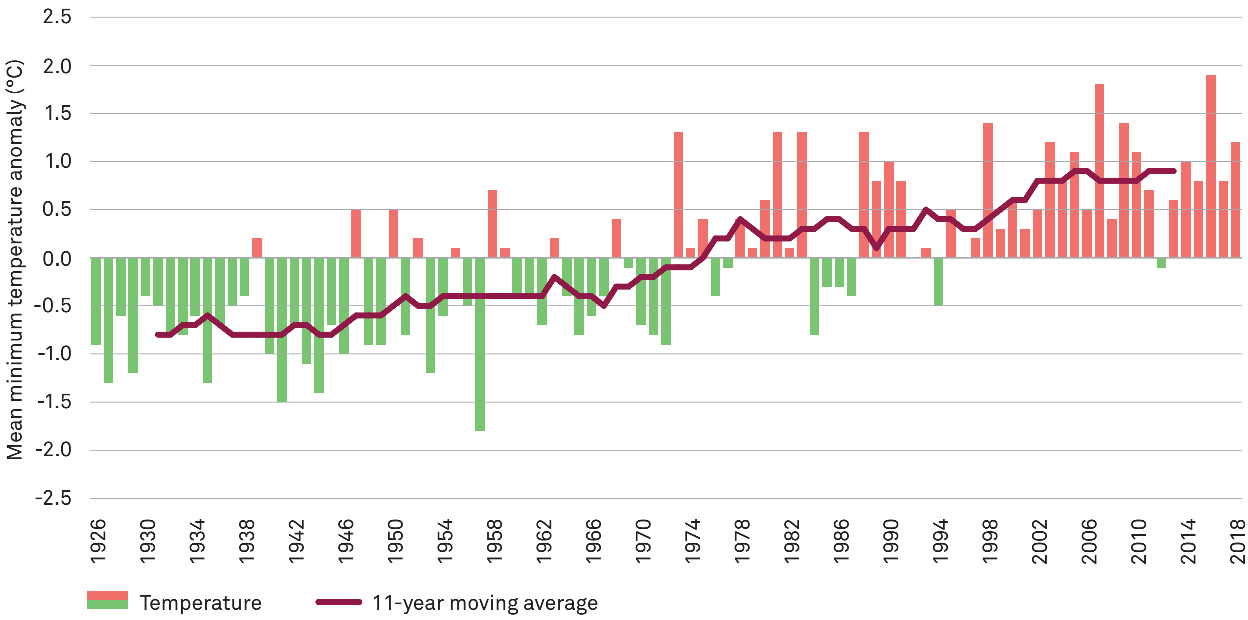


Figure 6:

ACT mean minimum temperature anomaly (as calculated from the 1961 to 1990 average), 1926 to 2018.

Data sourced from: Bureau of Meteorology, Canberra Airport site.

Observed rainfall

There is considerable year-to-year and decadal variability in annual rainfall averaged over the ACT region, with no long-term trend (Figure 7).[19] Over the last two decades, the Millennium Drought drove drier-than-average conditions across the ACT from 2000–2009, before being broken by the two La Niña events of 2010–2011 and 2011–2012. Recent years have been drier than average, except for 2016 which had a strong negative Indian Ocean Dipole in that year which typically results in wetter than average conditions over south-eastern Australia.

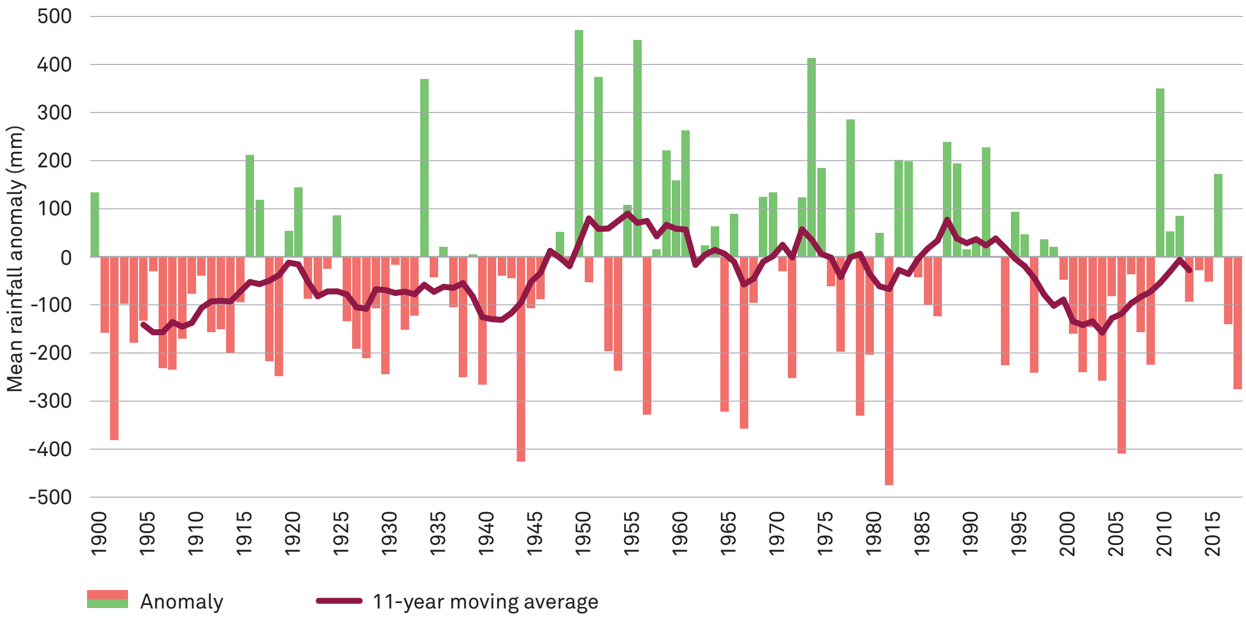


Figure 7:

ACT annual rainfall anomaly (as calculated from the 1961 to 1990 average), 1900 to 2018.

Data sourced from: Bureau of Meteorology, Canberra Airport site.

19 Based on Bureau of Meteorology observations at Canberra Airport.

Projected climate trends

Regional climate modelling has identified the most significant effects of climate change on the ACT.[20] [21] These projections are dependent on the level of global greenhouse gas emissions. Projected impacts include:

- reduced rainfall, particularly for spring and winter rainfall, with more frequent and prolonged drought
- summer and autumn rainfall may remain unchanged
- extreme daily rainfall intensity is projected to increase
- average temperatures will continue to increase in all seasons
- increased extreme temperatures with up to an additional 5 hot days per year by 2030 and 20 more per year by 2070
- temperature increases will mainly be in spring and summer, although the number of hot days will also extend into autumn
- hotter temperatures (day and night), longer and more frequent heatwaves
- harsher fire-weather climate in the future,
- more frequent and severe storms over a longer summer season, with flash flooding, violent winds and thunderstorms
- fewer frosts, and
- increased evapotranspiration.

These projected changes will significantly increase climate pressures on the natural and urban environment.

Indicator CC2: Impacts of climate change

This section assesses the current impacts of climate change on natural ecosystems, biodiversity, the urban environment, and human health and wellbeing. Attributing environmental changes to climate change alone is difficult due to the range of factors that affect the environment. However, data used in this report suggest the following impacts from climate change:

- reductions in rainfall have led to a long-term trend in reduced inflows to water storages, with all but two years below the long-term average between 2001–02 and 2018–19. The total inflows during 2018–19 were the lowest since records began in 1912 (see section **5.2 Human settlements – Water resources**).
- climate change is causing tree dieback (see section **5.5 Biodiversity – Native vegetation extent and condition**).
- increased mortality of urban trees (see **Chapter 4: Urban trees in the ACT – nature in the city**).
- higher temperatures have led to an increase in the average and maximum Fire Danger Index and an increase in the number of days with a very high Fire Danger Rating (see section **5.7 Fire**).
- the occurrence of dust storms due to higher temperatures and reduced rainfall are affecting air quality (see section **5.3 Air**).
- fuel reduction burns undertaken to manage increasing fire danger is also having an impact on air quality (see section **5.3 Air**).
- increase in cyanobacterial blooms in Canberra's lakes, reducing amenity and recreational activities (see section **5.6 Water – Water quality**).

There will be many other impacts which are not captured by data used in this report. This is particularly the case for subtle changes that occur over long periods. For example, it is widely accepted that climate change is having a significant impact on terrestrial and aquatic ecosystems and the biodiversity they support. The repercussions of climate change on human health and wellbeing are also well documented.[22]

It is also difficult to determine climate change impacts at the local level, particularly for the natural environment. This is because the severity of changes depends on a range of factors including landscape types, elevation, and the sensitivity and resilience of ecosystems. This means that the implications of climate change will differ across the ACT with some areas and ecosystem types more affected than others.

Despite this, the broad impacts that climate change has on the ACT region are well known and are shown in the following figures.

20 EPSDD, 2019, *ACT Climate Change Strategy 2019–25*, ACT Government, Canberra, found at https://www.environment.act.gov.au/__data/assets/pdf_file/0003/1414641/ACT-Climate-Change-Strategy-2019-2025.pdf/_recache

21 Webb, L.B. and K. Hennessy, 2015, *Projections for Selected Australian Cities*, CSIRO and Bureau of Meteorology, Australia, found at https://www.climatechangeinaustralia.gov.au/media/ccia/2.1.6/cms_page_media/176/CCIA_Australian_cities_1.pdf

22 Watts, M.A. et.al., 2018, The 2018 Report of the *Lancet* Countdown on Health and Climate Change: Shaping the Health of Nations for Centuries to Come, *The Lancet*, 392(10163): 2479–2514.

Impacts of climate change on the urban environment

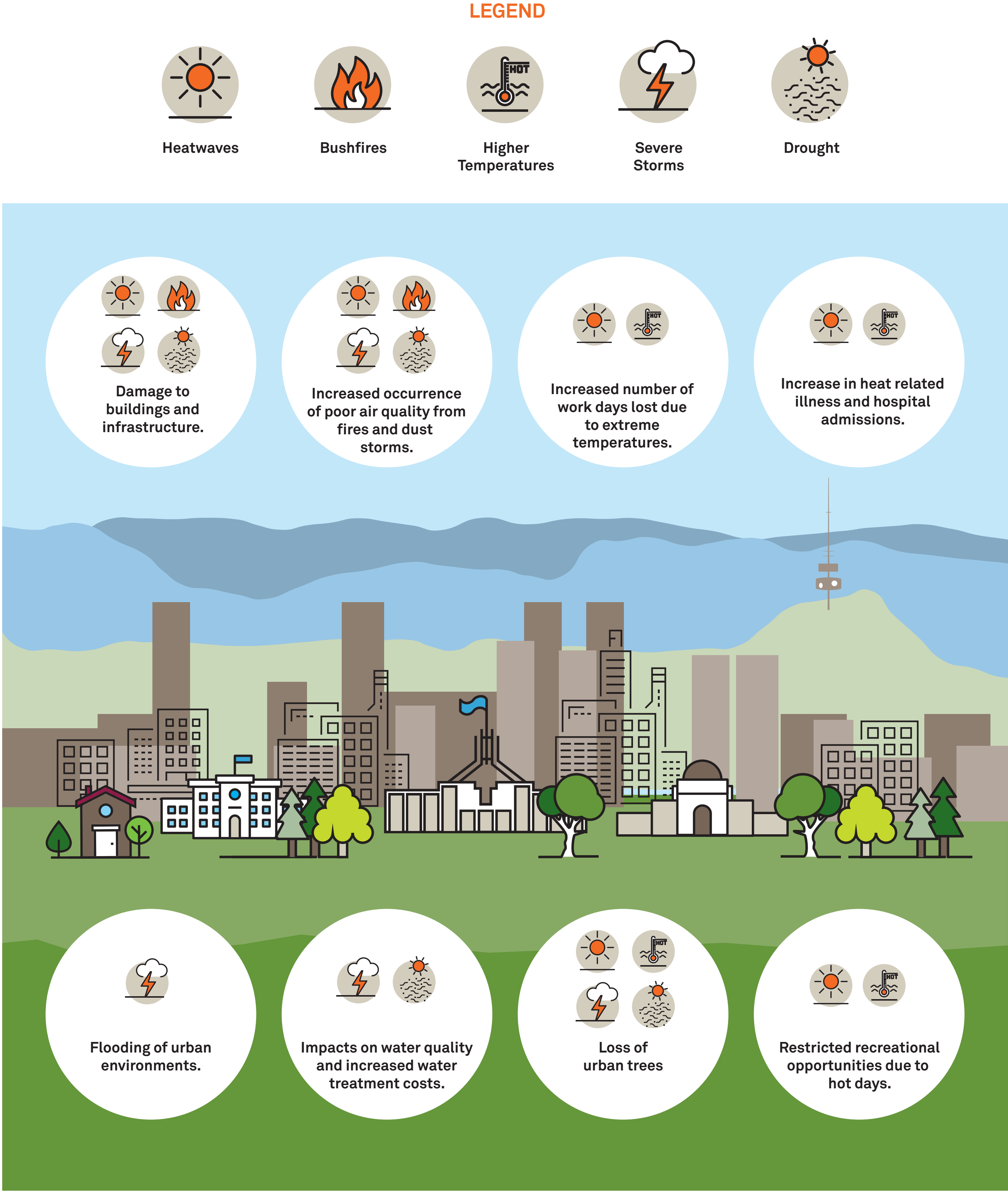


Figure 8:

Impacts of climate change on human health and the urban environment.

Source: Commissioner for Sustainability and the Environment

Notes: Adapted from, Commissioner for Environmental Sustainability, 2012, *Foundation Paper One: Climate Change Victoria: the Science, Our People, and Our State of Play*, Commissioner for Environmental Sustainability, Melbourne.

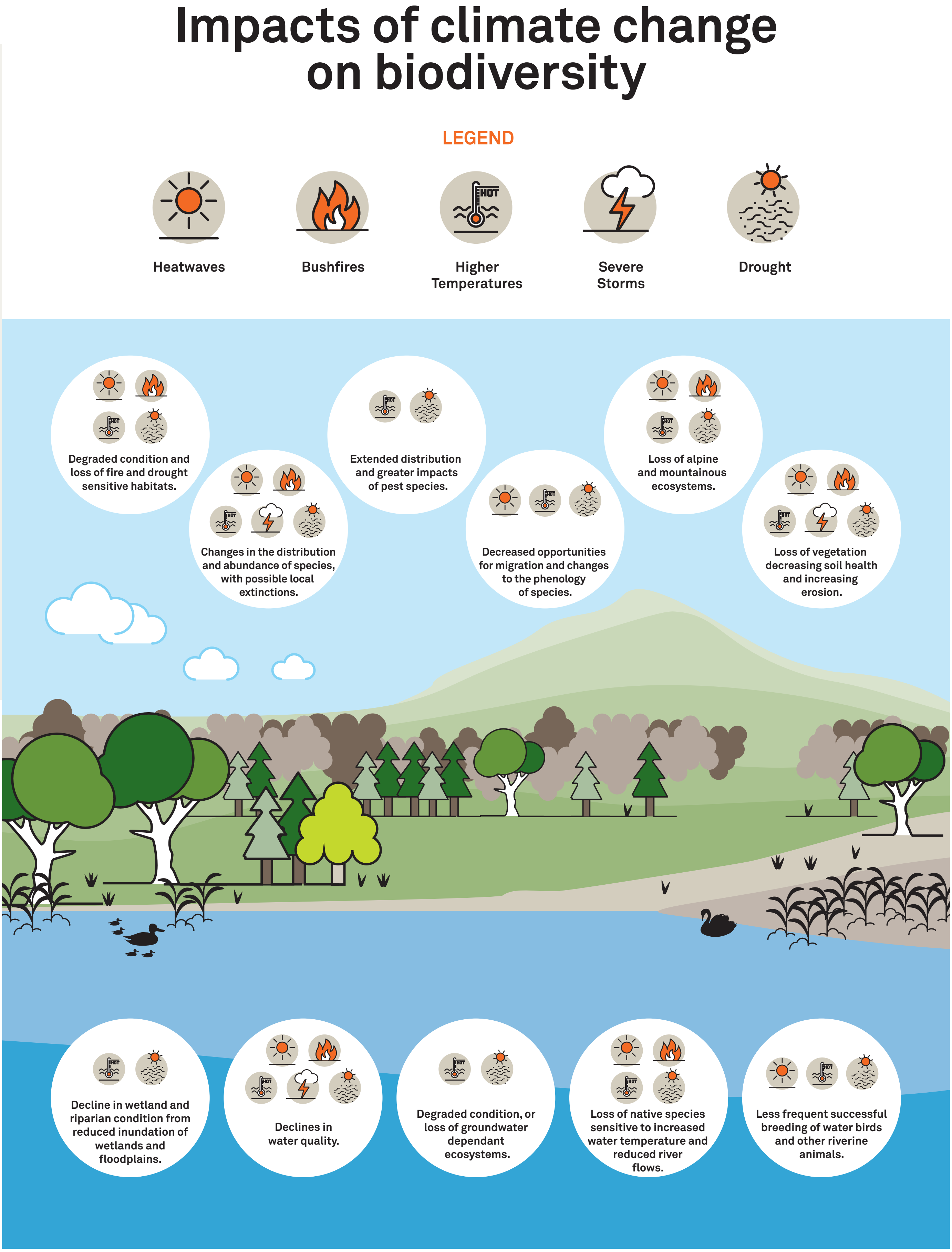


Figure 9:

Impacts of climate change on biodiversity and ecosystem health.

Source: Commissioner for Sustainability and the Environment

Notes: Adapted from, Commissioner for Environmental Sustainability, 2012, *Foundation Paper One: Climate Change Victoria: the Science, Our People, and Our State of Play*, Commissioner for Environmental Sustainability, Melbourne.

Impacts of climate change on primary production

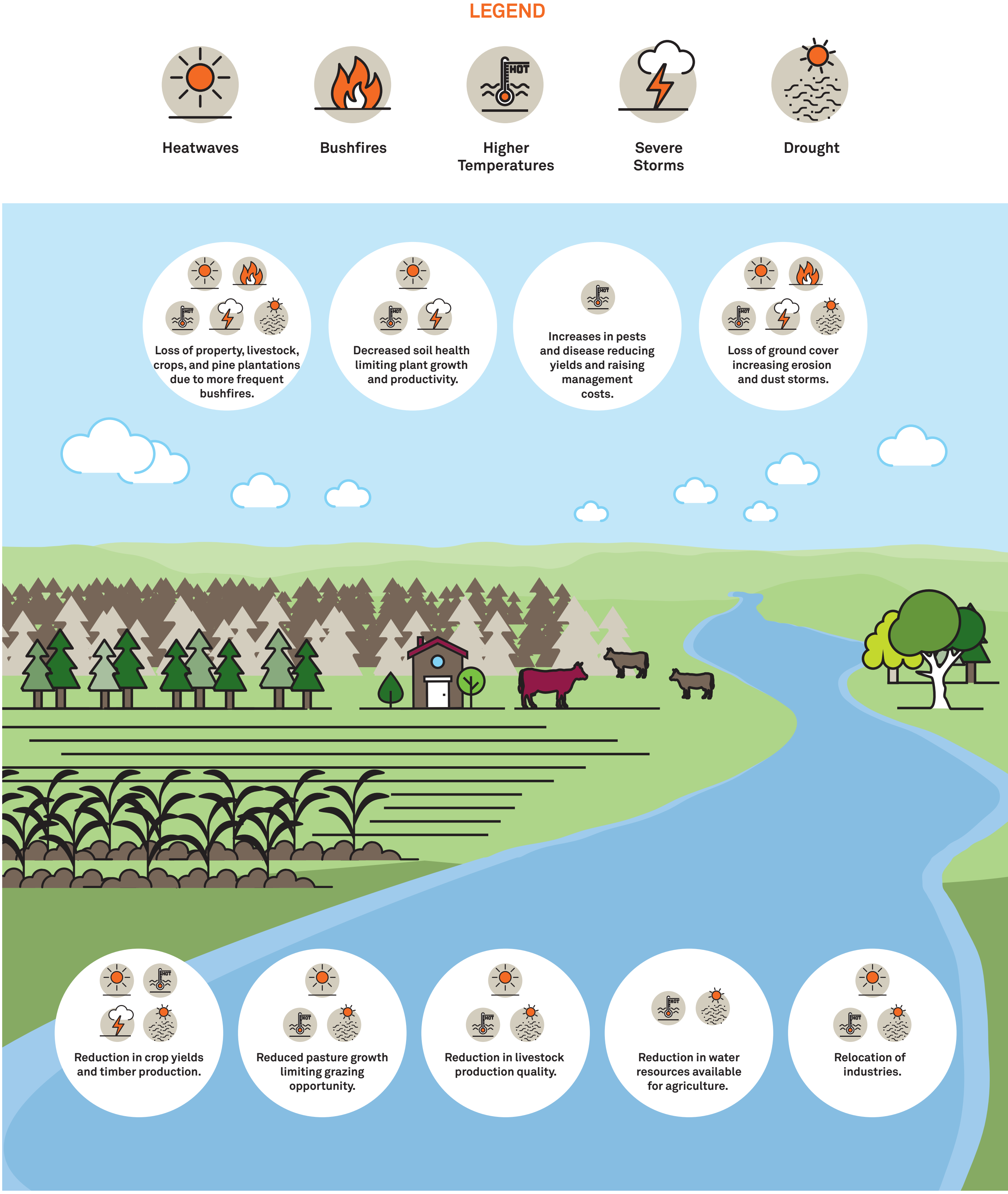


Figure 10:
Impacts of climate change on primary production.

Source: Commissioner for Sustainability and the Environment

Notes: Adapted from, Commissioner for Environmental Sustainability, 2012, *Foundation Paper One: Climate Change Victoria: the Science, Our People, and Our State of Play*, Commissioner for Environmental Sustainability, Melbourne.

Indicator CC3: Greenhouse gas emissions

Greenhouse gas emissions from human activity have increased since the pre-industrial era, mainly through the combustion of fossil fuels and widespread land clearing, with emissions now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the past 800,000 years. The high atmospheric concentrations of these gases have been the dominant cause of the observed changes to climate conditions since the mid–20th century.

Global efforts through the United Nations Framework Convention on Climate Change, including the Paris Agreement, aim to keep the global average temperature increase to well below 2 °C and to pursue efforts to keep warming to below 1.5 °C. Achieving this target will require a significant cut in global greenhouse gas emissions. This is dependent on both regional and local actions to reduce emissions. Whilst the ACT's emissions are only a fraction of that produced globally, the effect of cumulative reductions from local actions across the world will make substantial contributions to minimising the severity of climate change in the future.

The ACT Government has legislated greenhouse gas emissions reduction targets under the *Climate Change and Greenhouse Gas Reduction Act 2010*. The legislated targets are for percentage reductions from 1990 levels and include:

- 40% reduction by 2020[23]
- 50% to 60% reduction by 2025
- 65% to 75% reduction by 2030
- 90% to 95% reduction by 2040, and
- net zero emissions by 2045.

Greenhouse gas types and sources

The majority of greenhouse gas emissions come from energy, transport and industry. Those emitted by human activities and measured in the ACT are:

- carbon dioxide from burning fossil fuels (coal, natural gas and oil), solid waste, trees and wood products, and also as a result of certain chemical reactions (such as the manufacture of cement).
- methane emitted during the production and transport of coal, natural gas and oil, livestock and other agricultural practices, and from organic waste decay in municipal solid-waste landfills.
- nitrous oxide from the combustion of fossil fuels and solid waste, and also from agricultural and industrial activities, and
- fluorinated gases, including hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride and nitrogen trifluoride, which are synthetic gases that are emitted from a variety of industrial processes.

The combined effect of all greenhouse gases is expressed as the amount of warming that would be caused by an equivalent amount of carbon dioxide (CO_2-e). It is important to note that each greenhouse gas has a different warming effect on the atmosphere. For example, 1 tonne of methane is expressed as 21 tonnes of CO_2-e because over the span of 100 years methane will trap 21 times more heat than carbon dioxide. This means that small amounts of some gasses have a potent effect on our climate.

23 The 2020 target is consistent with the IPCC's recommendations and the most ambitious target in Australia.

Trends in the ACT's greenhouse gas emissions

Total emissions

In 2017–18, the ACT's total greenhouse gas emissions were 3,368 thousand tonnes of CO_2-e (Figure 11). This was a 17% decrease on 2012–13 levels, but 5% higher than the 1989–90 levels that are used as the basis for the ACT's emission reduction targets. Decreases in total emissions are the result of the growth in the ACT's total renewable electricity generation, increasing from 20% of electricity supply in 2015–16 to nearly 50% in 2017–18 (see section **5.2 Human settlements – Energy**).

By 2020, ACT's renewable electricity is forecast to meet 100% of demand; as a result, greenhouse gas emissions from electricity generation will fall to zero. With the elimination of electricity emissions, the ACT's total emissions are projected to decrease to around 1,918 thousand tonnes of CO_2-e. This means that total greenhouse gas emissions for the ACT are expected to meet the legislated 2020 target – a 40% reduction on 1990 levels.

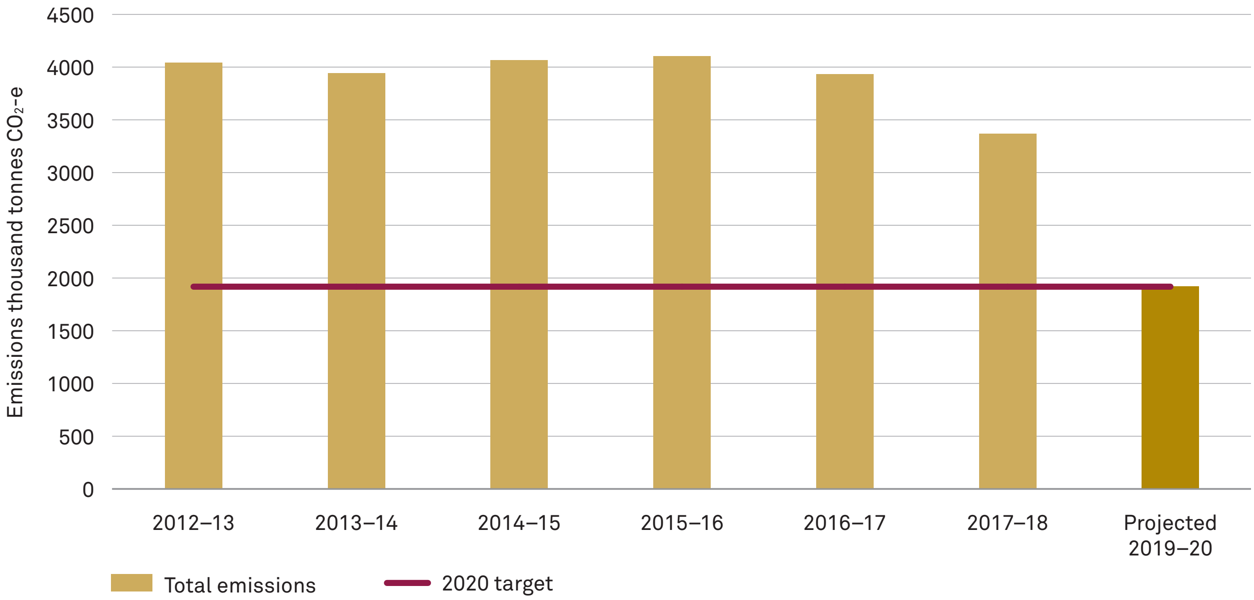


Figure 11:
Total ACT greenhouse gas emissions (CO_2-e) 2012–13 to 2017–18 and projected emissions 2019–20.

Data sourced from: Environment, Planning and Sustainable Development Directorate
Note: Includes net CO_2-e from land use, land-use change and forestry

Per capita emissions

The annual per capita greenhouse gas emissions for the ACT was just over 8 tonnes in 2017–18 (Figure 12). Per capita emissions decreased by around 24% between 2012–13 and 2017–18, and by 29% compared to 1989–90 levels. This decrease has been important to offset annual population growth in the ACT (see section **5.2 Human settlements – Population**).

Per capita emissions will drop significantly with the projected elimination of electricity emissions by 2020.

However, beyond 2020 further decreases in per capita emissions will depend on reductions in other sectors such as transport (see *Emissions by source* below)

The *Climate Change and Greenhouse Gas Reduction Act 2010* introduced a legislated requirement for the ACT's per capita emissions to peak in 2013 (compared to 1990 levels). This target has been met and per capita emissions have decreased since 2012–13.

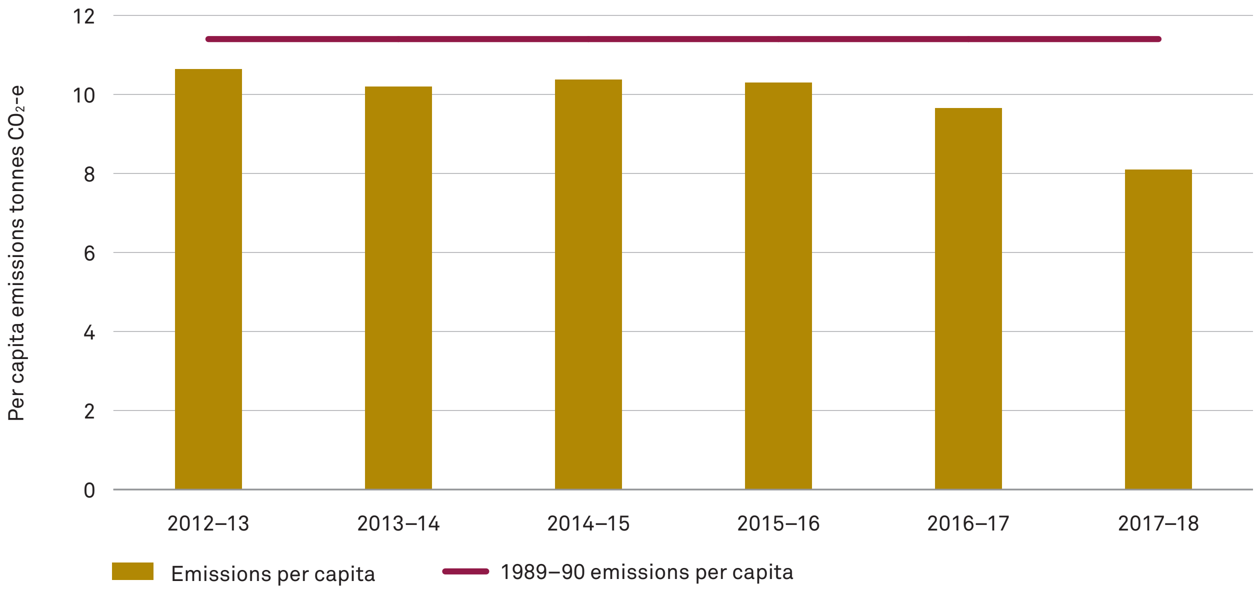


Figure 12:
ACT annual per capita greenhouse gas emissions (CO_2-e) 2012–13 to 2017–18.

Data sourced from: Environment, Planning and Sustainable Development Directorate
Note: Includes net CO_2-e from land use, land-use change and forestry

Emissions by source

Between 2012–13 and 2017–18, the electricity generation and transport sectors were the dominant source of greenhouse gas emissions in the ACT (Figure 13). Electricity accounted for 57% (2,295 thousand tonnes CO_2-e) of total emissions in 2012–13, decreasing to 44% (1,468 thousand tonnes CO_2-e) in 2017–18 as the share of renewable energy increased. With the ACT's renewable electricity forecast to meet 100% of demand, the electricity sector will not contribute to the ACT's emissions after 2020. Further reductions in emissions beyond 2020 will therefore focus on other sectors such as transport, industry, gas and waste.

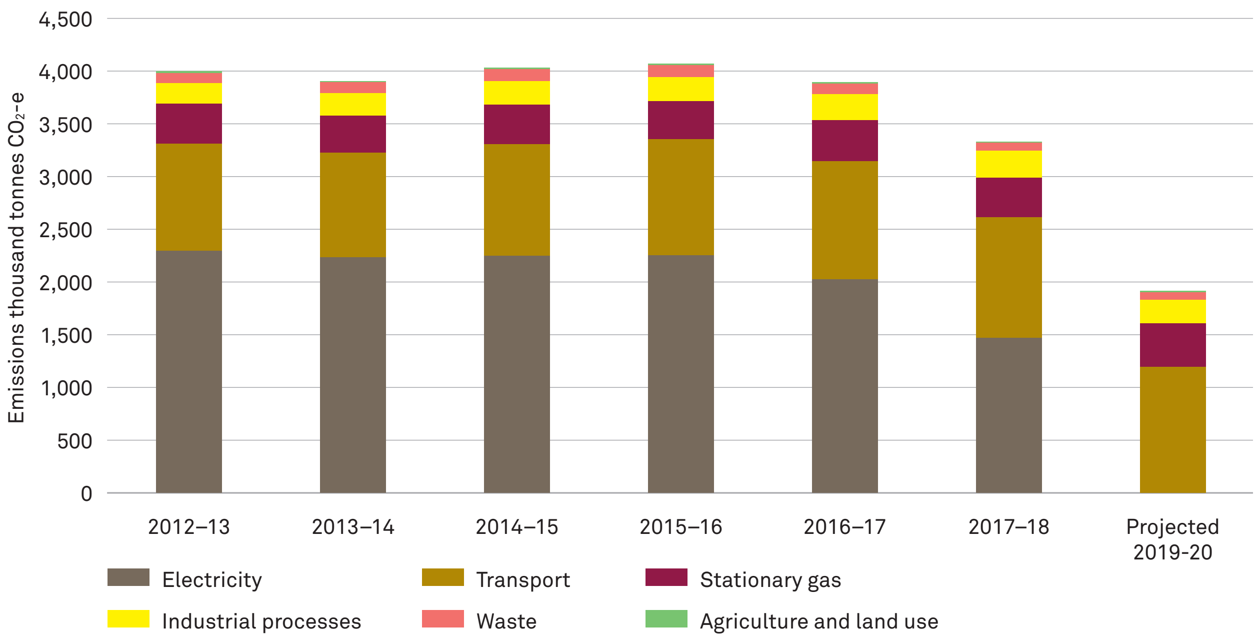


Figure 13:
ACT greenhouse gas emissions (CO_2-e) by source, 2012–13 to 2017–18.

Data sourced from: Environment, Planning and Sustainable Development Directorate
Notes: Agriculture and land use includes net CO_2-e from land use, land-use change and forestry

PROJECTED CHANGES IN EMISSION SOURCES

Transport and natural gas will account for a larger portion of the ACT's carbon footprint as the electricity sector moves towards zero emissions by 2020. Between 2017–18 and 2020, electricity will have declined to 0% of the ACT's total emissions, while transport will account for 62% (Figure 14). Stationary gas and waste will also double in contribution to annual emissions. Transport and the phasing out of natural gas will become the main focus for future reductions of greenhouse gas emissions in the ACT.[24]

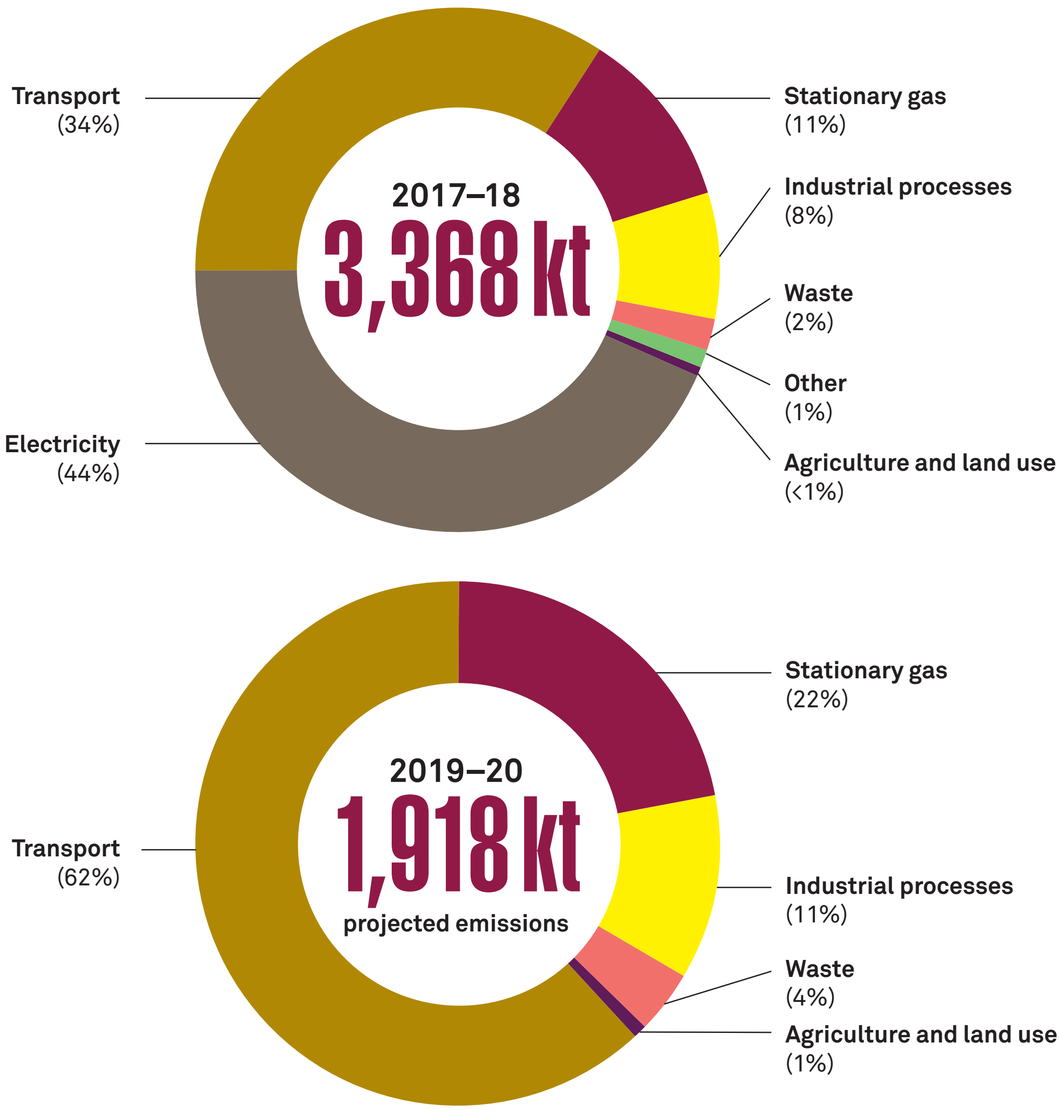


Figure 14:
Total and sector greenhouse gas emissions in the ACT for 2017–18 and projected emissions for 2019–20.

Data sourced from: Environment, Planning and Sustainable Development Directorate

Note: Total includes net CO_2-e from land use, land-use change and forestry

24 EPSDD, 2019, *ACT Climate Change Strategy 2019–25*, ACT Government, Canberra, found at https://www.environment.act.gov.au/__data/assets/pdf_file/0003/1414641/ACT-Climate-Change-Strategy-2019-2025.pdf/_recache

Changes in the emissions of non-electricity sectors are shown in Figure 15. Unlike the electricity sector, transport emissions are growing, both in terms of actual emissions and their proportional contribution to total emissions. Between 2012–13 and 2017–18, transport emissions increased from 1,017 thousand tonnes CO_2-e to 1,147 thousand tonnes, an increase of 13%. This growth, combined with the decrease in electricity emissions, led to transport contributions increasing from 25% to 34% of total emissions in the ACT. This proportion is projected to increase to 62% in 2020.

The stationary gas sector contributed 11% of total emissions in 2017–18, with annual emissions fluctuating from year to year and no overall trend evident.[25] Industrial processes only contributed around 8% of total ACT emissions in 2017–18; however, emissions from this sector have increased by 31% since 2012–13. The waste sector contributed around 2% of total emissions in 2017–18, and is also highly variable due to the annual variation in waste produced (see section **5.2 Human settlements – Waste**). ACT's agriculture sector contributed less than 1% of total emissions in 2017–18.

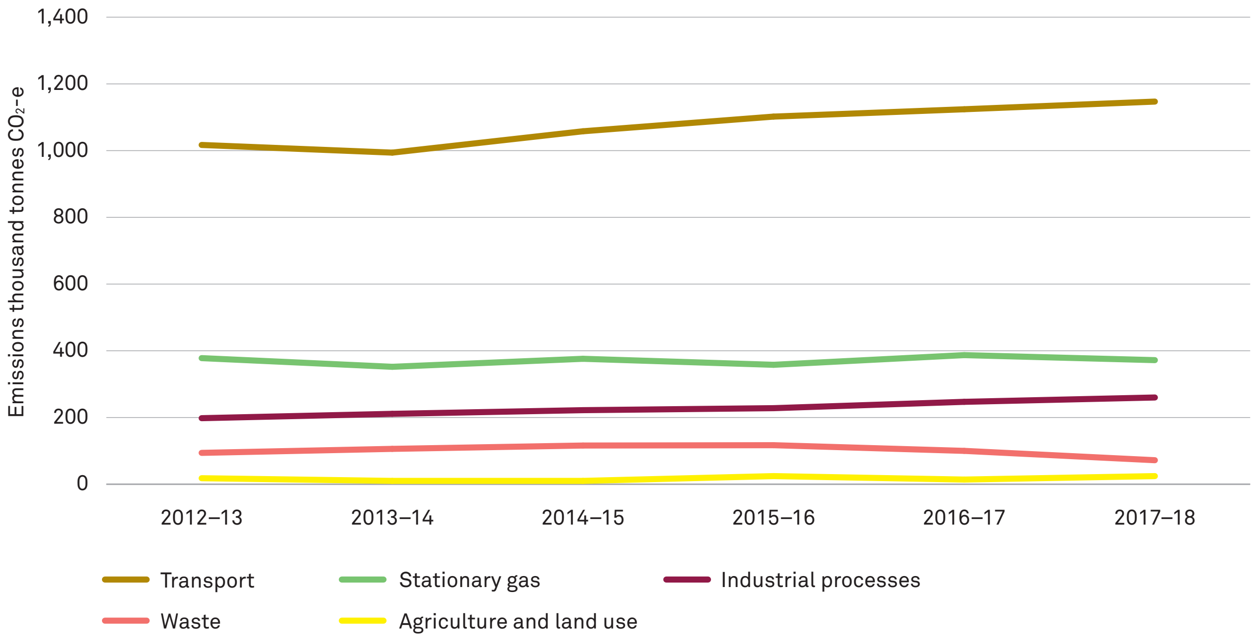


Figure 15:
Main non-electricity sector sources of greenhouse gas emissions (CO_2-e) in the ACT, 2012–13 to 2017–18.

Data sourced from: Environment, Planning and Sustainable Development Directorate

Transport emissions and fuel type

With transport set to contribute 62% of total emissions by 2020, the current growth in ACT's transport emissions has important consequences for ongoing greenhouse gas reductions in the future. Rising transport emissions are the result of growth in the number and use of vehicles in the ACT, including a rise in diesel-powered vehicles (see section **5.2 Human settlements – Transport**).

Diesel-powered passenger vehicles have increased threefold in the ACT, from 4% of total passenger vehicles in 2010 to 12% in 2019.[26] Diesel engines are higher in greenhouse gas emissions than equivalent petrol-fuelled cars.[27] Studies have also shown that the greenhouse gas emissions from diesel cars, utes and vans in Australia have risen sharply since 2011, effectively cancelling out the cut in pollution from new renewable energy replacing some coal plants.[28] The large increase in diesel vehicles is also a concern for air quality given their higher emissions of nitrogen

25 The fluctuating trend is most likely related to changes in annual gas usage due to weather conditions.
26 Passenger vehicles account for 84% of vehicles and 82% of vehicle kilometres travelled in the ACT. Light commercial vehicles, which have a substantial proportion of diesel-powered engines, account for 10% of vehicles and 13% of kilometres travelled (see section **5.2 Human settlements – Transport**).
27 Transport & Environment, 2018, *CO_2 Emissions from Cars: The Facts*, European Federation for Transport and Environment AISBL, Brussels, found at https://www.transportenvironment.org/sites/te/files/publications/2018_04_CO2_emissions_cars_The_facts_report_final_0_0.pdf
28 Morton, A., 2 November 2019, 'Greenhouse Gas Emissions from Diesel Vehicles Cancelled Out Cuts from Renewable Energy', *The Guardian*, found at https://www.theguardian.com/environment/2019/nov/02/greenhouse-gas-emissions-from-diesel-vehicles-cancelled-out-cuts-from-renewable-energy, accessed November 2019.

oxides and much higher emissions of particulate matter (see section **5.3 Air**).

Between 2012–13 and 2017–18, the greenhouse gas emissions from diesel fuel nearly doubled from 230 thousand tonnes CO_2-e to 395 thousand tonnes, driving up the proportional contribution of diesel to total transport emissions from 23% to 34% over the same period (Figure 16). These figures suggest that diesel-powered vehicles are contributing disproportionally higher greenhouse gas emissions compared to petrol vehicles.

To achieve cuts in transport emissions, there will need to be a decrease in the number and use of vehicles in the ACT, especially diesel-powered vehicles. There will also need to be a significant increase in the number of electric vehicles, which combined with the use of renewable energy for charging, will further reduce ACT's greenhouse gas emissions.[29]

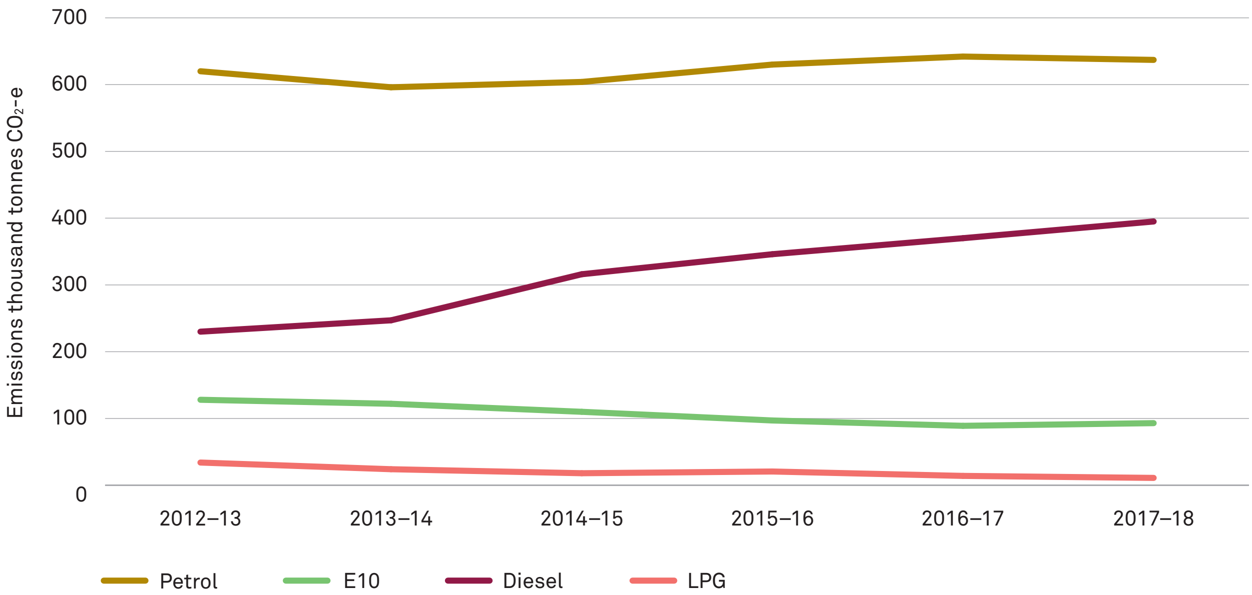


Figure 16:
Main sources of transport greenhouse gas emissions (CO_2-e) in the ACT by fuel type, 2012–13 to 2017–18.

Data sourced from: Environment, Planning and Sustainable Development Directorate

Notes: Petrol includes fuels classified as auto gasoline; E10 is regular unleaded petrol blended with 10% ethanol; diesel includes fuels classified as automotive diesel oil.

DATA GAPS

- More comprehensive data is required on the impacts of climate change on natural ecosystems, the urban environment and human health to improve knowledge, adaptation and resilience.
- To inform future greenhouse gas emission reductions, there will need to be improved data on transport emissions, particularly on the specific contributions of commercial and private transport sectors by fuel types.
- More detailed information is required on the ACT's carbon stocks including by location and vegetation community type, as well as changes over time due to fire and other disturbances such as drought. The ability of natural ecosystems, particularly forests, to sequester carbon is vital for the mitigation of climate change.

29 ACT Government, 2019, *ACT Climate Change Strategy 2019–25*, ACT Government, Canberra

5.2 HUMAN SETTLEMENTS

© Ryan Colley

Section contents

Human settlements in the ACT

ACT's ecological footprint 2017–18

9x total footprint 9 times the size of the ACT

11% decrease in total footprint since 2009–10

24% decrease in per capita footprint since 2003–04

70% of footprint from household consumption

Electricity

100% projected renewable electricity generation by 2020

12% decrease in per capita use between 2010–11 and 2017–18

Waste 2015–16 to 2018–19

1 to 1.2 million tonnes produced annually

2 to 2.6 tonnes per capita

70% to 80% resource recovery

Transport

82% of all road transport from passenger vehicles

78% of trips taken are by car

1% of passenger vehicles are hybrid and electric cars

12% increase in diesel vehicles between 2010 and 2019

travel to work:

- **80%** car
- **8%** public transport
- **5%** cycling
- **3%** walking

Water

inflows to reservoirs below average for all but 2 years since 2001–02

2018–19 inflows the lowest since records began

37% decrease in per capita water use between 2001–02 and 2017–18

Indicator assessment

Indicator	Status	Condition	Trend	Data quality
HS1: ACT's ecological footprint	The ACT's ecological footprint is over 9 times the size of the land area of the ACT showing that current resource use is unsustainable. Although the ecological footprint is decreasing over time, particularly with the growth in renewable electricity, significant further cuts are required. Households are responsible for 70% of the ACT's footprint; consequently, decreases in community resource consumption will greatly reduce both the ecological and carbon footprints for the ACT.	Poor	↑	●●● High
HS2: Energy consumption and generation	Due to lack of data, this assessment is limited to electricity consumption and generation. ACT's electricity consumption has remained stable, despite population growth, reflecting an ongoing decline in per capita usage. The share of renewable electricity generation has increased significantly and is forecast to reach 100% in 2020.	Good electricity only	↑ electricity only	●●● High: electricity ●○○ **Low:** all other fuels
HS3: Solid waste generation and management	The lack of comprehensive and consistent waste data, and high annual variations in waste produced, makes it difficult to assess the status of waste in the ACT. There are no apparent trends indicating long-term changes in the total amount of waste generated, recovered or landfilled. However, the annual resource recovery rate is generally good at around 70% to 75% of the total waste generated, although this has not improved over the last 10 years. Municipal solid waste accounts for the highest proportion of waste sent to landfill and its generation appears to be stable despite the annual population increase in the ACT.	Fair	–	●●○ **Moderate**
HS4: Transport	The ACT community maintains a high dependence on cars for transport with the number of registered vehicles and their usage increasing. Cars are used for around 80% of all trips undertaken including commuting to work. Public transport, cycling and walking only represent 16% of all travel to work, although public transport use has increased over recent years. Car use contributes to air pollution and greenhouse gases, and has significantly increased road congestion in the ACT. Only 1% of vehicles in the ACT are electric or hybrid.	Poor	–	●●● High
HS5: Water resources	ACT's water resources continue to be affected by a long-term period of mostly dry conditions. In 2018–19, total inflows to the ACT's 4 drinking supply reservoirs was 32 gigalitres, the lowest since records began in 1912, and 86% below the long-term average. At the end of June 2019, the ACT's 4 reservoirs were holding just 57% of the total ACT storage capacity. Over the past 10 years, only 12–17% of the total wastewater produced is recycled in the ACT.	Poor	↓	●●● High
HS6: Water consumption	The ACT and Queanbeyan's total water consumption has remained fairly consistent since 2012–13 at around 50,000 megalitres annually despite population growth. Between 2001–02 and 2017–18, residential per capita water use dropped from 124 kilolitres per year to 78 kilolitres litres per year, a decrease of around 37%. Residential supply is responsible for most of the water use in the ACT, accounting for around 60% of the total supplied annually.	Good	–	High

Indicator assessment legend

Condition

- **Good** = Environmental condition is healthy across the ACT, **OR** pressure likely to have negligible impact on environmental condition/human health.
- **Fair** = Environmental condition is neither positive or negative and may be variable across the ACT, OR pressure likely to have limited impact on environmental condition/human health.
- **Poor** = Environmental condition is under significant stress, OR pressure likely to have significant impact on environmental condition/ human health.
- **Unknown** = Data is insufficient to make an assessment of status and trends.
- **NA** = Assessments of status, trends and data quality are not appropriate for the indicator.

Trend

- ↑ Improving
- ↓ Deteriorating
- – Stable
- ? Unclear
- **NA =** Assessments of status, trends and data quality are not appropriate for the indicator.

Data quality

- ●●● **High** = Adequate high-quality evidence and high level of consensus
- ●●○ **Moderate** = Limited evidence or limited consensus
- ●○○ **Low** = Evidence and consensus too low to make an assessment
- ○○○ **NA** = Assessments of status, trends and data quality are not appropriate for the indicator.

Key actions

That the ACT Government:

ACTION 1: promote and support sustainable household consumption to further decrease the ACT's ecological footprint.

ACTION 2: encourage the development and uptake of distributed energy storage and microgrid technology in domestic, commercial and government buildings and infrastructure to ensure energy supply is sufficient to meet the likely increased demands of the ACT's growing population and periods of high usage due to climate change.

ACTION 3: develop strategies to move toward a circular economy to improve waste recovery rates and reduce resource consumption and waste to landfill.

ACTION 4: develop strategies to improve the uptake of public transport and active travel, including increasing cycling participation across gender and age groups.

ACTION 5: provide incentives to encourage the purchase of electric and hybrid vehicles, and reduce the purchase of diesel powered vehicles.

ACTION 6: identify opportunities to develop water–sensitive urban design across new and existing urban areas. This urban design should incorporate integrated water cycle management to enable the capture and use of stormwater, and create habitat for ACT's biodiversity.

ACTION 7: increase wastewater recycling and use across the ACT for non-potable water needs.

Main findings

Population

In 2018, the ACT's population was approximately 423,000.

In the 10-year period between 2008 and 2018 the population grew by approximately 72,000 people, an average annual increase 1.7% per year.

Districts with the highest population include Belconnen (24%), Tuggeranong (21%), Central Canberra (20%) and Gungahlin (18%).

Gungahlin experienced the highest population growth, accounting for over 50% of total growth over the decade to 2016. Belconnen and North Canberra both grew by around 11,000 people over the same period.

The ACT's population is projected to increase to around 589,000 people by 2041.

Population growth will increase current pressures on the ACT's environment.

Footprint

In 2017–18, the total ecological footprint for the ACT was around 2.12 million hectares. This is over nine times the size of the ACT and shows that current resource use is unsustainable.

The ACT's ecological footprint has consequences for areas of Australia and overseas that provide the resources, goods and services consumed by the ACT community.

Since 2009–10, the total ACT ecological footprint has decreased by nearly 11%.

In 2017–18, the per capita footprint was 5.24 hectares, a decrease of nearly a quarter since 2003–04. The ACT's per capita ecological footprint is now equivalent to that for the average Australian.

Since 2009–10, the total carbon footprint decreased by over 20% and the per capita carbon footprint by 34%. The per capita ACT carbon footprint is now 11% lower than that of Australia.

Household final consumption of goods and services is responsible for 70% of the ACT's ecological footprint.

ACT's ecological footprint is dominated by land disturbance from the pasture required for animal products. However, in per capita terms, the area of land disturbance from pasture requirements decreased by 23% between 2003–04 and 2017–18.

Land disturbance from emissions declined by one-third between 2003–04 and 2017–18 reflecting the ACT's growing renewable electricity supply.

Impacts from food expenditure accounted for 50% of the ACT's total ecological footprint in 2017–18.

Expenditure on mobility accounted for 25% of the total carbon footprint in 2017–18 compared to 19% in 2003–04. Transport will likely become the highest contributor to the ACT's carbon footprint in the future.

Energy

Data on the ACT's energy use is not sufficient to enable a comprehensive assessment of the ACT's energy generation and consumption. This includes a lack of data on energy consumption for fuel types other than electricity, and the consumption of energy by sector.
Electricity demand in the ACT is stable, despite population growth.
Electricity consumption per capita decreased by 12% between 2010–11 and 2017–18.
The ACT's total renewable electricity generation increased significantly between 2015–16 and 2017–18, rising from 20% to nearly 50% of electricity generated.
Predicted renewable electricity generation for the period 2018–19 to 2020–21 shows that the ACT is forecast to reach 100% in 2020.
The ACT will be the first jurisdiction in Australia and the eighth jurisdiction globally, to procure renewable generation equivalent to 100% of its consumption.
Wind farms supply the majority of the ACT's renewable electricity.
Wind farm generation significantly increased from 7% in 2016–17 to over 50% in 2018–19, and will supply over 70% of total renewable electricity in 2019–20 and 2020–21.
Rooftop solar photovoltaic generation continues to be installed in the ACT and has increased its share of renewable electricity generation in recent years.
The only renewable electricity generated in the ACT comes from solar farm and rooftop solar generation.

Waste

Waste data currently excludes waste exported outside the ACT. This means that the data reported understates the actual volume of waste sent to landfill.
Total waste generation, waste to landfill and resources recovered are highly variable in the ACT with changes mostly occurring in response to specific activity from the construction and demolition sector (including the Mr Fluffy program) as well as increases in garden waste.
The annual total waste generated in the ACT between 2009–10 and 2018–19 ranged from 816,000 to 1.2 million tonnes, with no consistent trend over time.
Between 2009–10 and 2018–19, annual landfill per capita ranged from 0.5 to 1.1 tonnes per person, resources recovered from 1.2 to 2 tonnes per person, and total waste between 2 and 2.6 tonnes per person with no consistent trend over time.
Resource recovery is generally much higher than waste sent to landfill, with most years recording a resource recovery rate of 70% or higher.
Annual resource recovery in the ACT has plateaued to around 70% to 75% of the total waste generated or 0.55 tonnes per person (excluding the Mr Fluffy program).
Waste from the Mr Fluffy program accounted for 40% (202,000 tonnes) of the total waste sent to landfill in 2016–17. This declined to 5% (12,000 tonnes) in 2018–19 with the majority of the program completed.
Excluding the Mr Fluffy program, between 2016–17 and 2018–19, municipal solid waste accounted for the highest proportion of the annual total waste sent to landfill (between 39% and 49%), closely followed by commercial and industrial waste (between 35% and 47%). Construction and demolition waste varied widely over the period, from 25% of the total waste sent to landfill in 2016–17, to only 6% and 9% in the following years.
Total municipal solid waste generation appears to be stable despite the annual population increase in the ACT. This may indicate improved recycling behaviours and/or changes in the consumption of goods and services leading to a decline in waste per person.
During the reporting period, ACT was found to comply with the National Environment Protection Measures related to waste management (includes the Movement of Controlled Waste between States and Territories, and Used Packaging Materials).

Transport

Private vehicle use

The ACT community is highly dependent on cars which are used for 78% of all trips undertaken. Public transport is only used for 4% of trips and cycling only 2%.
Although the most common purpose for car travel was work related, cars are the main transport choice for a range of daily activities.
Cars were used for over 80% of travel to work with most commuting undertaken with the driver as the sole vehicle occupant. Public transport was used for only 8% of travel to work, cycling 5% and walking 3%. There was little change in travel-to-work transport modes between 2011 and 2016.
The number of registered vehicles in the ACT has grown from around 253,000 vehicles in 2010 to 304,000 in 2018, an increase of 20%. Passenger vehicles were responsible for 84% of total vehicle registrations and light commercial vehicles 10%.
Vehicle usage is increasing in the ACT. In 2018, ACT's registered vehicles travelled nearly 3,900 million kilometres, with passenger vehicles responsible for 82% of the total kilometres travelled. The next most common category was light commercial vehicles accounting for 13% of kilometres travelled.

Private vehicle use (continued)

Between 2002 and 2017, daily commute times increased by 65% in the ACT, the highest of any Australian city. The ACT's mean daily commute time in 2017 was 52 minutes, which means that the ACT's commute times are approaching those recorded in other Australian cities.
In 2019, 86% of registered passenger vehicles were fuelled by petrol making it the dominant fuel type in the ACT.
Diesel fuelled 12% of vehicles in 2019, a threefold increase since 2010. The large increase in diesel vehicles is of concern given their increased impact on air pollution, especially particulate matter emissions.
Hybrid and electric cars only make up 1% of the total passenger vehicles in the ACT but, in terms of vehicle numbers, have increased from around 150 in 2010 to nearly 2,900 in 2019. The ACT, along with South Australia, have the highest number of electric car purchases in Australia, with 21 electric cars per 10,000 vehicles sold.

Public transport and active travel

Public transport use has been increasing in recent years, growing from 17.6 million boardings annually (45 boardings per capita) in 2014–15 to 20.1 million (48 per capita) in 2018–19.
The 2018–19 figures include nearly 878,000 light rail boardings in just over two months between its commencement on 20 April 2019 and 30 June 2019.
Cycling is highly variable across the ACT with the Civic area having a significantly higher uptake of cycling, likely due to a flatter terrain and shorter distances to work and study centres.
Between 2011 and 2019, cycling participation in the ACT was higher than the national average. Despite this, there are wide variations in year-to-year cycling participation and a statistically significant decline in ACT's weekly cycling participation between 2017 and 2019.
In 2019, the ACT had some 3,100 km of shared paths and some 600 km of on-road cycling facilities. Given the high level of cycling infrastructure in the ACT, there is much scope for improving cycling participation, including across gender and age groups.

Water resources and consumption

Water resources

During 2018–19, total inflow to the ACT's four reservoirs was 32 gigalitres, the lowest since records began in 1912, and 86% below the long-term average.
ACT's water resources are being affected by a long-term period of mostly dry conditions.
Water availability has declined significantly in the ACT with mean storage volumes around 40% below the long-term average for the past 20 years.
Between 2001–02 and 2018–19, total inflows to the ACT's four reservoirs were below the long-term average for all but two years.
At the end of June 2019, the ACT's four reservoirs were holding just 57% (157 gigalitres) of the total ACT storage capacity. This is despite the enlargement of the Cotter Dam in 2013 which increased the ACT's water storage by 72 gigalitres.
Without the increase to the Cotter Dam, the combined ACT storages would have dropped to around 30% of their total capacity – similar to levels during the Millennium Drought.
Between 2009–10 and 2018–19, there was little variation in the ACT's wastewater recycling with volumes remaining around 4,000 megalitres to 4,500 megalitres, representing around 12% to 17% of the ACT's total wastewater produced.
The majority of the ACT's treated wastewater is discharged into the Molonglo River providing environmental flows, protecting riverine ecosystems and providing for downstream use.

Potable water consumption

The ACT and Queanbeyan's total water consumption has remained fairly consistent since 2012–13 at around 50,000 megalitres annually, despite increases in the population serviced.
Water usage in 2017–18 was 54,000 megalitres, the highest volume over the past 10 years. This increase has been driven by hotter and drier weather conditions and is not necessarily indicative of an increasing trend in water usage.
Between 2001–02 and 2017–18, residential per capita water use dropped from 124 kilolitres per year to 78 kilolitres per year, a decrease of around 37%.
The ACT uses over 90% of the water supplied, with Queanbeyan using around 8%.
Residential supply accounts for around 60% of the total water supplied annually, this has remained consistent since 2008–09.
Most gains in water use efficiency can be made at the household level.

INTRODUCTION

This section provides an assessment of the pressures on the environment from human settlement activities in the ACT. The following indicators are assessed:

- HS1: ACT's ecological footprint
- HS2: Energy consumption and generation
- HS3: Solid waste generation and management
- HS4: Transport
- HS5: Water resources
- HS6: Water consumption

A range of human settlement activities impact on the environment. The use of energy (including transport energy) and water, as well as the consumption of goods and services, place pressure on the environment through demands on resources and waste generation.

Population is a key driver of environmental pressure from human settlement activities. As the population increases, so does the demand for energy and resources, the amount of waste generated, and the need for land development for infrastructure, housing, and energy production.

Consequently, everyday decisions made by the community are critical to reducing human settlement pressures on the environment. For example, minimising vehicle use, increasing water and energy efficiency in the home, reducing the consumption of goods, choosing products that are better for the environment, and improving recycling and reuse.

The consumption of fuels and the generation of waste are also the major source of air pollution and greenhouse gas emissions in the ACT. Information on air quality can be found in section **5.3 Air**, and information on and greenhouse gas emissions can be found in section **5.1 Climate Change**.

DATA TRENDS

ACT's population

This section discusses changes in the ACT's population. For information on population density and the impacts of population growth on the ACT's land use, see section **5.4 Land**.

Whilst population growth is a critical driver and indicator of environmental pressure and change, this report does not include a condition assessment of population change. However, it is important to include population data to understand changes in many of the indicators used for this report.

Environmental pressures are exacerbated by a growing population as it increases the demand for energy, transport, resources such as water, and a range of goods and services. This leads to land use change for food production, housing and other infrastructure, and more waste going back into the environment. Such changes can lead to direct impacts on the environment through the loss of vegetation and biodiversity, increased water extraction and degradation of water quality, increased air pollution and greenhouse gas emissions, and increased land and water impacts from waste.

Although a growing population generally results in increases in environmental pressures, this can be minimised by improving sustainability through energy and resource use efficiencies, and by reducing waste through improved recycling and reuse.

Population growth in the ACT

In 2018, the ACT's population was approximately 423,000 (Figure 1). The ACT has experienced strong and sustained population growth – in the 10-year period between 2008 and 2018 the population grew by approximately 72,000 people, an average annual increase of 7,200 or 1.7% per year. The average annual increase over the 10-year period was variable, driven by a combination of factors including natural increase, retention of people of a diversity of ages, and immigration from overseas and interstate.

The ACT's 2016 population share by district is shown in Figure 2. Districts with the highest population include Belconnen (24%), Tuggeranong (21%), Central Canberra (20%) and Gungahlin (18%).

Areas of the ACT experiencing the highest population growth include Gungahlin which accounted for over 50% (around 39,000 people) of the total growth over the decade to 2016, and Belconnen and North Canberra which both grew by around 11,000 people over the decade. Other growth areas included Molonglo and South Canberra with both adding around 4,000 people, and Woden Valley increasing by 2,800 people. Tuggeranong recorded a population decline of nearly 2,000 people over the 10-year period.

The ACT's population is projected to increase to around 589,000 people by 2041. This will increase pressures on the ACT's environment and will require effective sustainability and land use measures to minimise the impacts of such growth.

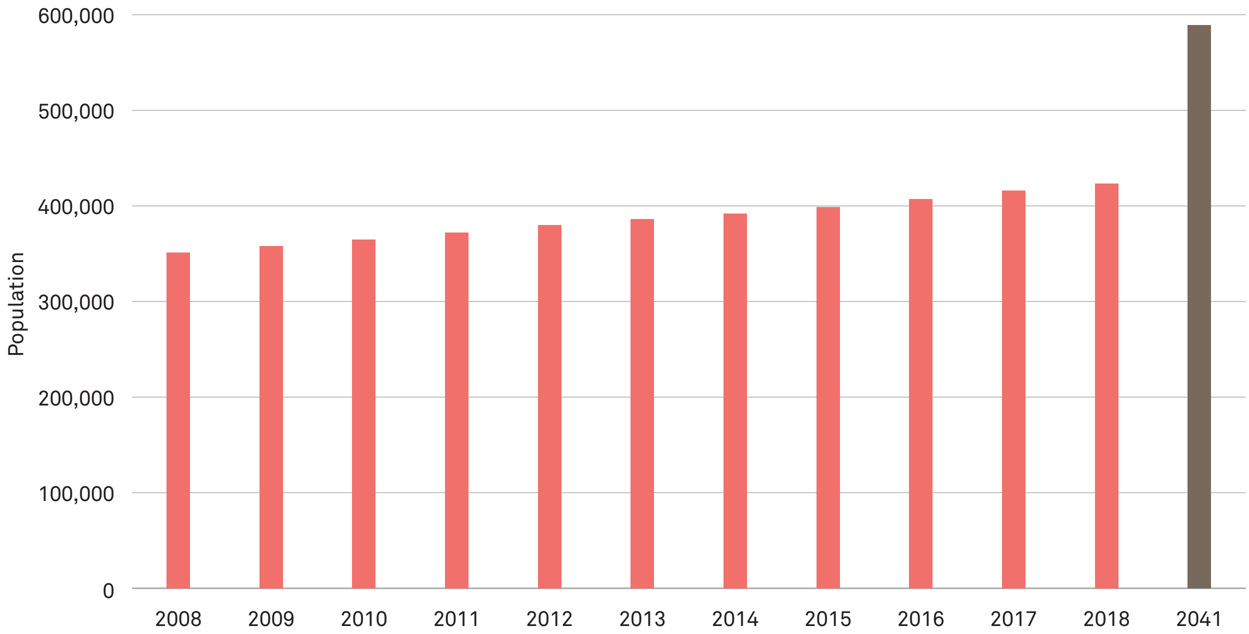


Figure 1:
ACT estimated resident population 2008–2018 (as at 31 December) and projected population in 2041.

Data sourced from: Australian Bureau of Statistics[1] and Environment, Planning and Sustainable Development Directorate.

1 Australian Bureau of Statistics (ABS), 2019, 3101.0 Australian Demographic Statistics, March 2019, ABS,Canberra

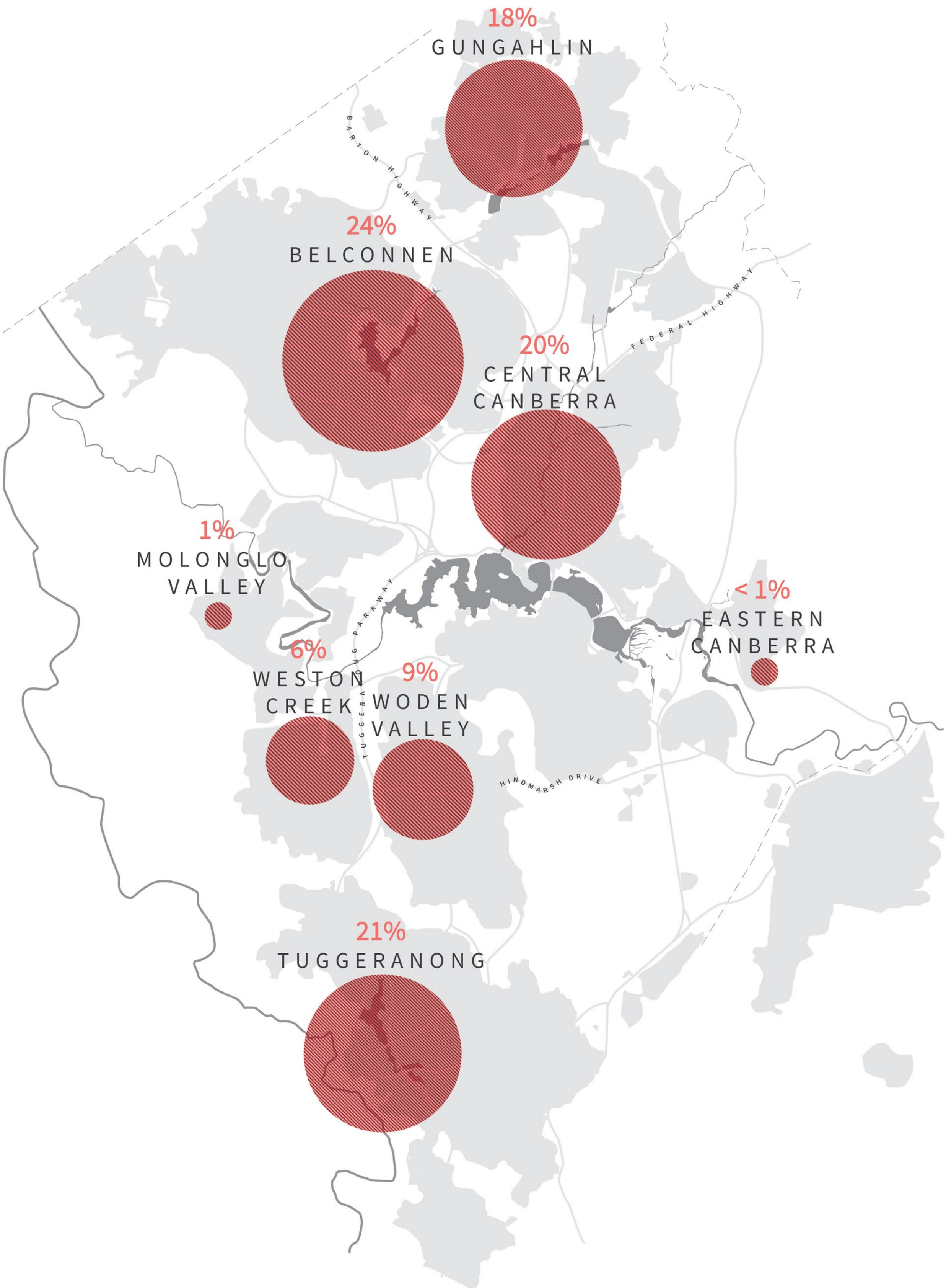


Figure 2:
ACT 2016 – population share by district

Source: Environment, Planning and Sustainable Development Directorate, 2018, *Planning Strategy 2018*, ACT Government, Canberra.

Indicator HS1: ACT's ecological footprint

Estimates of the ACT's ecological footprint have been provided for the four previous ACT State of the Environment reports. An ecological footprint assesses impacts in terms of the Australian land area (in hectares) needed to support a population. This comprises the land for agriculture, forestry, built environments and water required to provide a range of resources, and all goods and services. A footprint also includes a general estimate for the land deemed to be disturbed by the greenhouse gas emissions arising from the population's resource use and consumption of goods and services.

Changes in the ecological footprint are an overall measure of the effect our daily activities and resource consumption have on the environment. While the size of the total footprint is influenced by increasing population and changes to industry, individual behaviours can also affect sustainability. Actions to minimise resource use and waste can help to reduce the ACT's ecological footprint.

The ecological footprint used for this report uses a land disturbance approach. This is a different assessment from the footprints reported in previous ACT State of the Environment reports. It is based on areas of land use which are weighted by disturbance factors to account for how transformed each land type is from a pristine state. In addition, the calculation of an emissions land component is included. The emissions land component converts the total greenhouse gas emissions to a disturbed land area and is calculated from a full carbon footprint.

The change in methodology means that results from the current ecological footprint assessment cannot be compared with previous reporting periods. However, the new methodology has been applied to previous years' data to provide an assessment of changes to the ACT's footprint over time.

The ACT's environmental footprint has been calculated for 2003–04, 2009–10, 2015–16 and 2017–18. For the carbon footprint, the amount of greenhouse gas stored in the ACT's ecosystems is included in all calculations.

ACT's total ecological footprint

In 2017–18, the total ecological footprint for the ACT was around 2.19 million hectares, Figure 3). This is over nine times the size of the ACT and means that at current consumption levels, we need an area nine times the size of the ACT to provide the resources, goods and services we use, and to regulate our pollution. It is clear that our current resource use is unsustainable, placing enormous stress on the earth's natural ecosystems. It is also evident that the ACT's ecological footprint has consequences for areas of Australia and overseas that provide the wide range of resources, goods and services consumed by the ACT community.

The ACT total footprint peaked in 2009–10 at just under 2.45 million hectares. Since then, the footprint has decreased by nearly 11% despite population growth of over 16% over the same period. This is due to the significant decrease in ACT's per capita footprint which has fallen by nearly a quarter from 6.9 hectares per person in 2003–04 to 5.24 hectares in 2017–18 (Figure 4). The decrease means that ACT's per capita footprint is now equivalent to that for Australia, having been higher for 2003–04, 2009–10 and 2015–16.

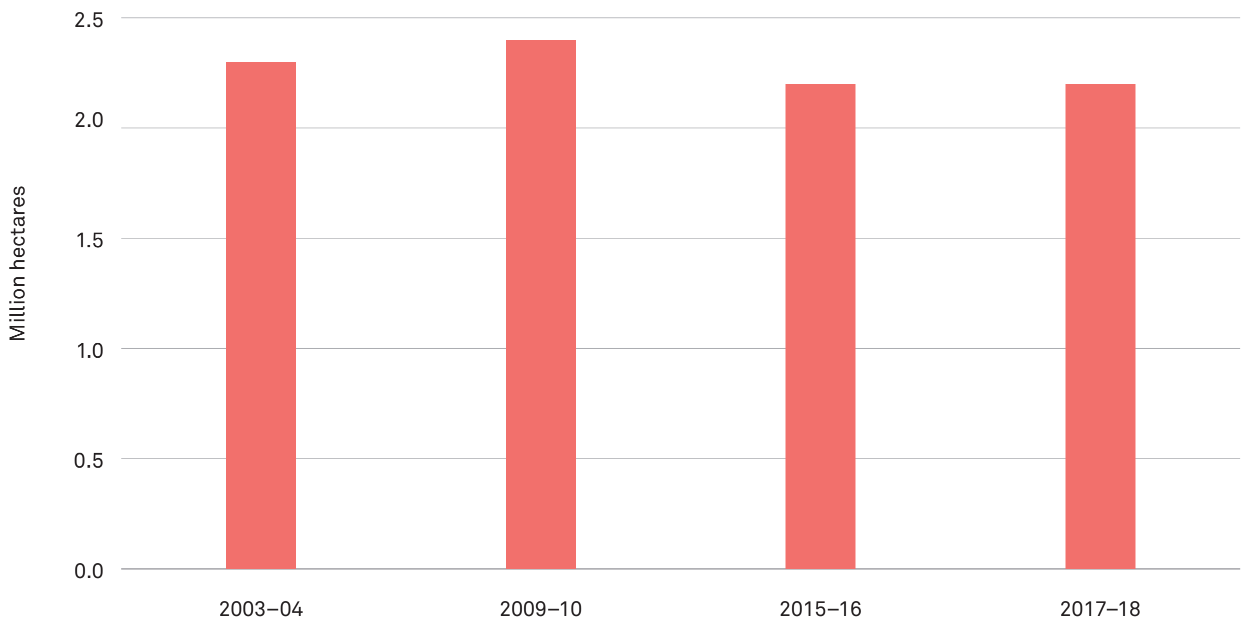


Figure 3:
ACT total ecological footprint (disturbance), 2003–04 to 2017–18.

Source: Commissioner for Sustainability and the Environment

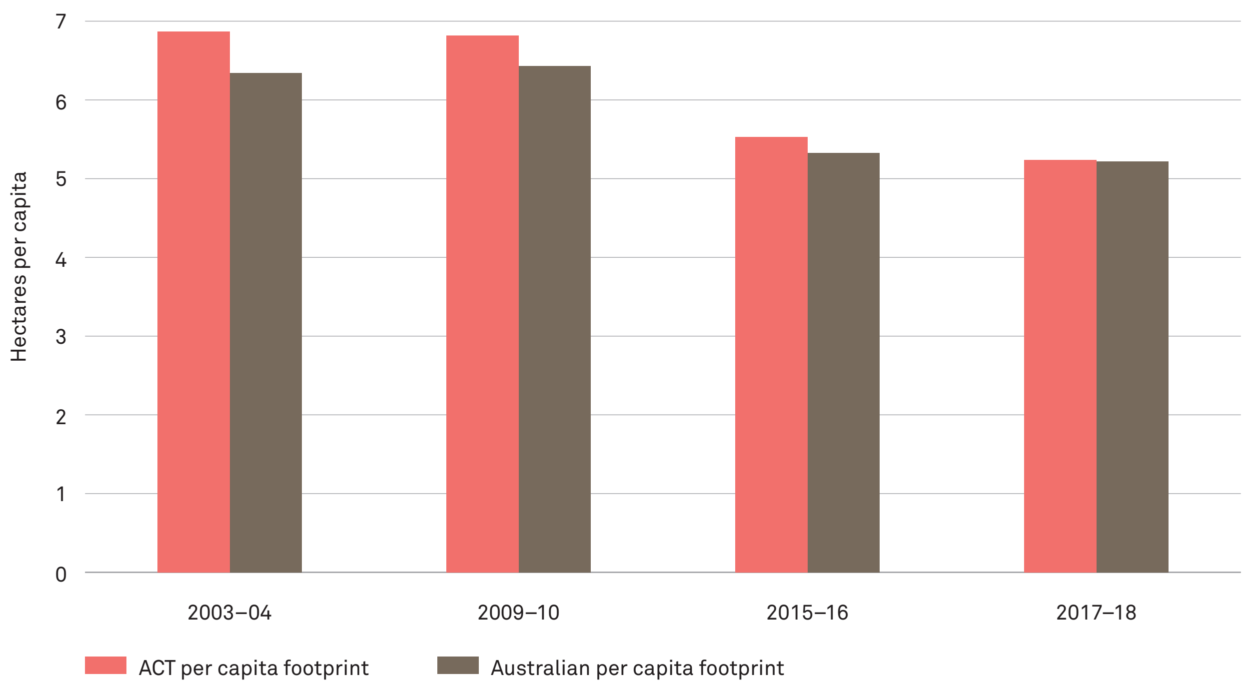


Figure 4:
ACT and Australian per capita ecological footprint (disturbance), 2003–04 to 2017–18.

Source: Commissioner for Sustainability and the Environment

ACT's carbon footprint

The total carbon footprint of the ACT population was approximately 5.93 million tonnes carbon dioxide equivalent (CO_2-e) in 2017–18 (Figure 5). This is a decrease of over 20% from a peak of 7.45 million tonnes CO_2-e in 2009–10. This decrease has occurred despite continued population growth in the ACT over the period, and is a result of a significant decrease in the per capita carbon footprint. The per capita carbon footprint for the ACT fell from 21.5 tonnes CO_2-e in 2003–04 to 14.2 in 2017–18, a reduction of around 34% (Figure 6). The per capita ACT carbon footprint was 7.5% higher than the per capita Australian footprint in 2003–04, but is now 11% lower than that of Australia.

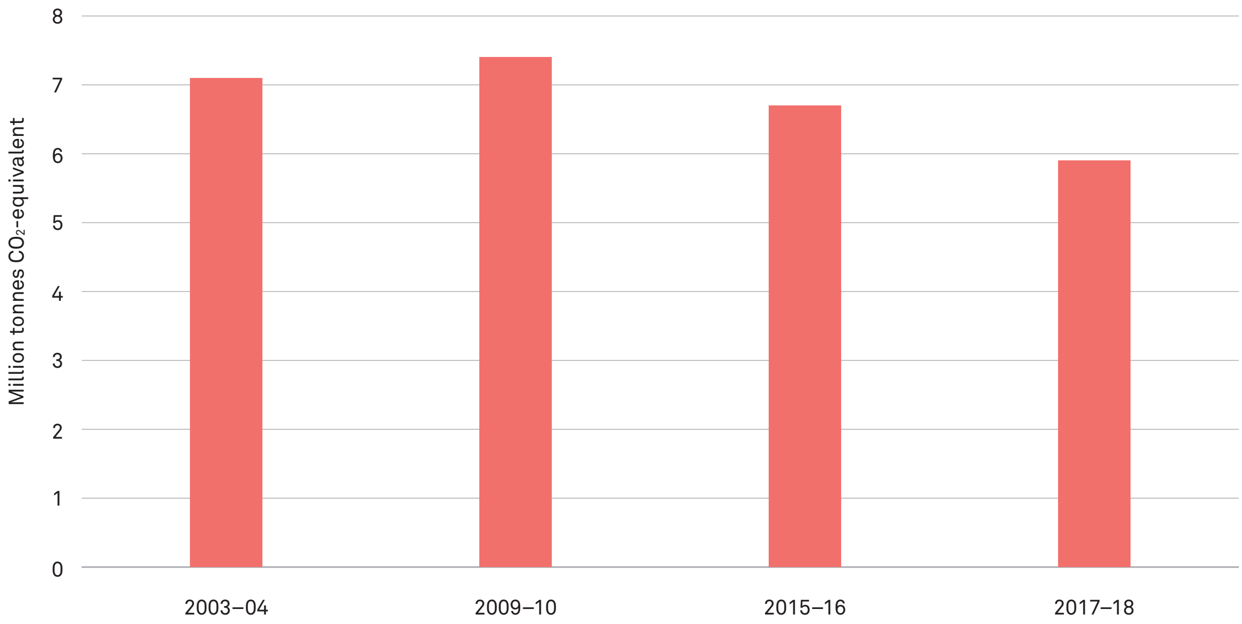


Figure 5:
ACT total carbon footprint (disturbance), 2003–04 to 2017–18.
Source: Commissioner for Sustainability and the Environment

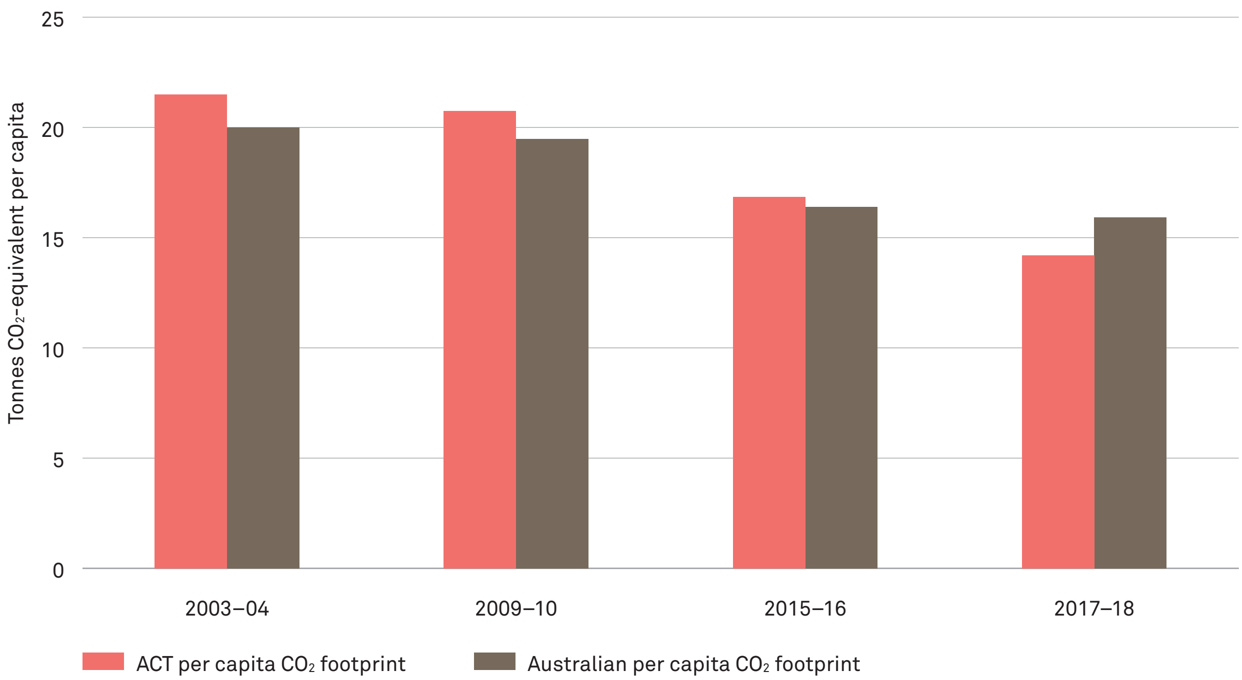


Figure 6:
ACT and Australian per capita carbon footprint (disturbance), 2003–04 to 2017–18.
Source: Commissioner for Sustainability and the Environment

Components of the ACT's ecological footprint

Household final consumption[2] is responsible for most (around 70%) of the ACT's ecological footprint for all years assessed (Figure 7). This shows the importance of changing community behaviour to minimise resource consumption and waste. Education and awareness-raising on sustainable consumption is imperative to reduce components of both the ecological and carbon footprints for the ACT.

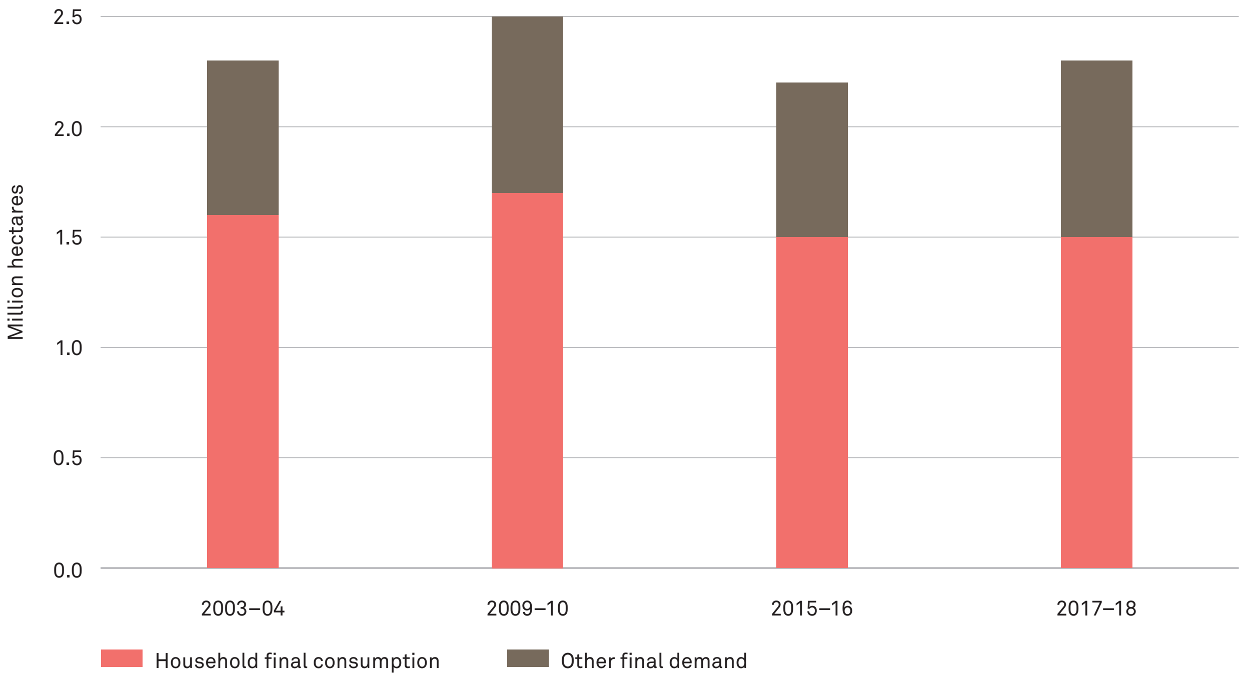


Figure 7:
Final demand contributions to the ACT ecological footprint (disturbance), 2003–04 to 2017–18.

Source: Commissioner for Sustainability and the Environment

Notes: Household final consumption consists of goods and services households buy directly to support their day-to-day lives; Other final demand comprises private and government final consumption, private and government gross fixed capital formation, changes in inventories (stocks), and exports.

ACT's ecological footprint is dominated by land disturbance as a result of the large land area required for pasture to produce products such as meat, milk and fibre (Figure 8). The pasture required to meet the ACT's demand for such products accounted for around 70% of the per capita footprint for each year assessed. However, the area of land disturbance from pasture requirements has decreased by around 23% from 4.8 hectares per capita in 2003–04, to 3.7 hectares in 2017–18.

The next highest component of the ACT's footprint was emissions land which was responsible for around 20% of the land disturbance for each year assessed. The per capita area of disturbance from emissions land has also significantly declined in the ACT, from 1.5 hectares per capita in 2003–04 to around one hectare in 2017–18, a decrease of around one-third. The falling contribution from emissions land reflects the ACT's growing renewable electricity supply.

Other components have a relatively small contribution to the per capita land disturbance footprint and show little change over time. These include disturbances from dry cropland (around 4% of the per capita footprint for all assessed years), forestry (around 2%) and the built environment (around 1%). Results for the built environment again reflects just how little of the ACT's per capita ecological footprint is contained within the ACT.

2 Household final consumption consists of goods and services households buy directly to support their day-to-day lives.

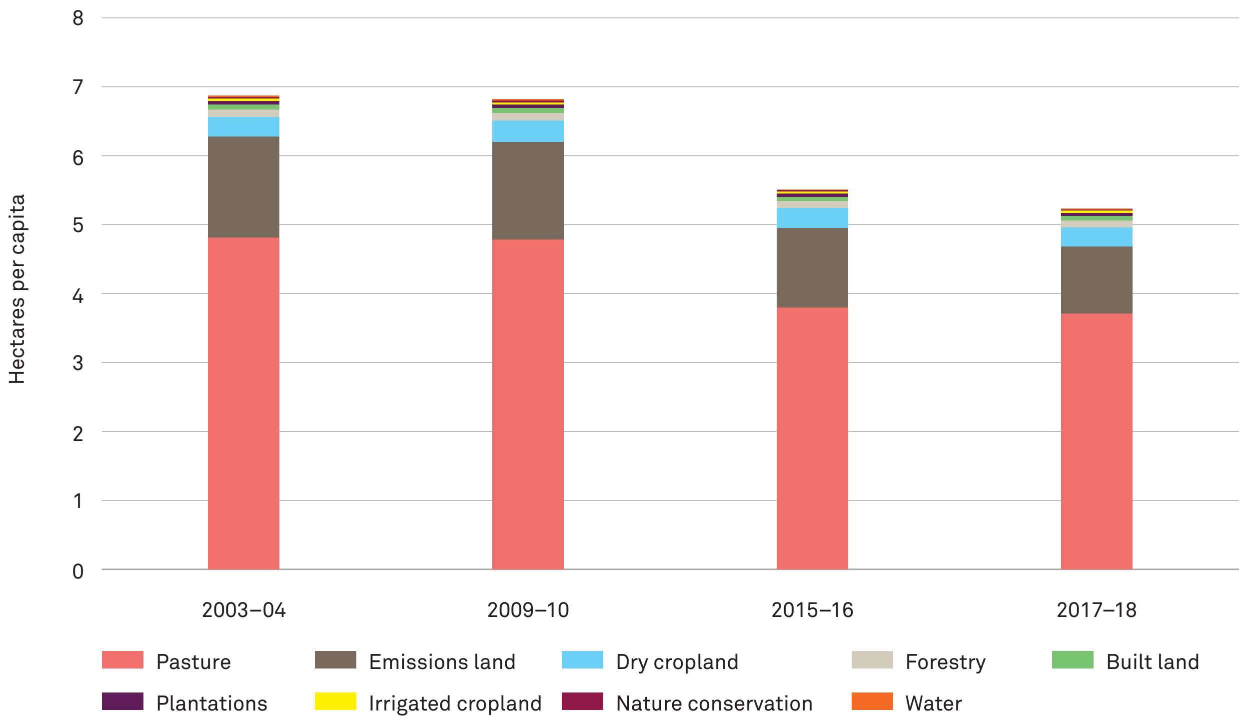


Figure 8:
ACT ecological footprint (disturbance) components per capita, 2003–04 to 2017–18.
Source: Commissioner for Sustainability and the Environment

ACT's ecological footprint by expenditure

Ecological footprint calculations can also be considered by consumption category. This can help guide community action and government policy aimed at reducing the ACT's footprint. The consumption categories are food, shelter, energy use, mobility, goods, services and other. All flow-on impacts are included within each category. For example, the land required to grow wheat and the energy used to harvest the wheat is all included within the food category. The services category covers a large number of services, including telecommunications, finance, medicine, entertainment and government.

The provision of food dominates most ecological footprints due to the extensive land required for the average diet. Food expenditure accounted for around 50% of the ACT's total footprint for all years assessed with no evident trend (Figure 9). Selecting more locally-produced and alternative sources of protein with lower footprints could substantially reduce the overall footprint of the ACT.

Services was the next highest contributor to the footprint at around 20% for all years assessed, again with no clear trend.

Goods decreased from 269,000 hectares (11% of the total footprint) in 2009–10, to around 186,000 hectares (8% of the total footprint) in 2017–18. The contribution from goods is falling as expenditure patterns shift further towards services.

Energy use has also decreased from 6% to 4% of the total footprint reflecting the growth in renewable energy.

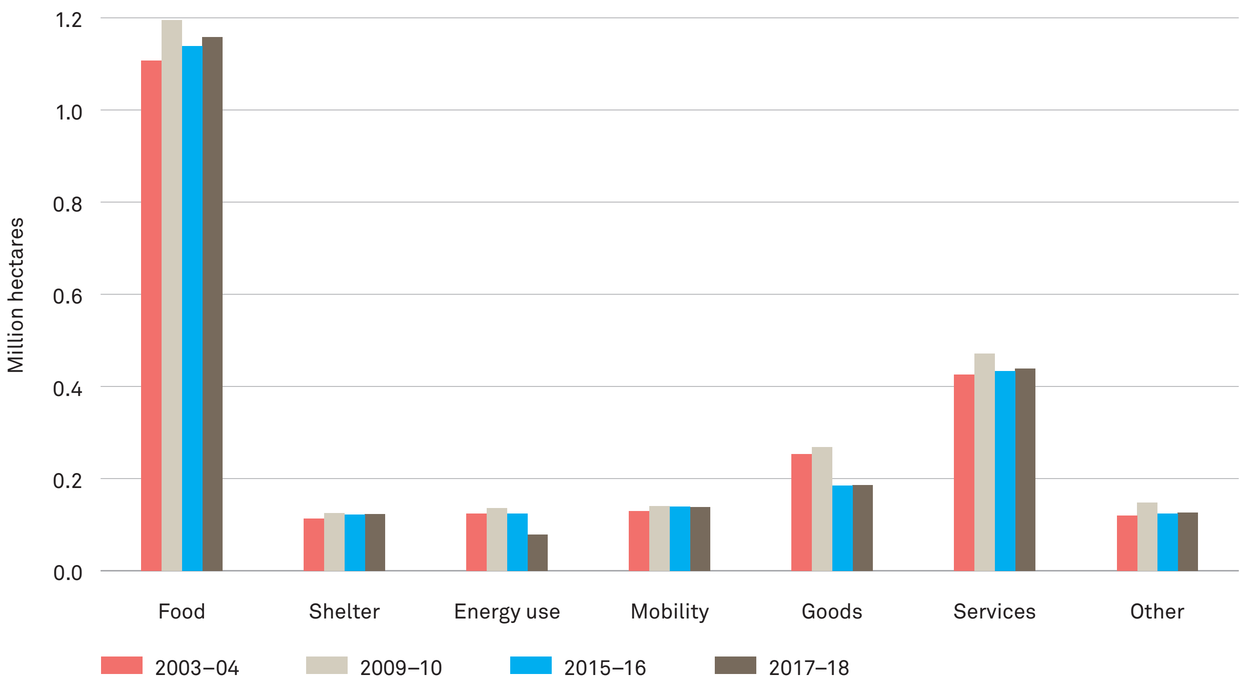


Figure 9:
ACT total environmental footprint by expenditure group, 2003–04 to 2017–18.

Source: Commissioner for Sustainability and the Environment

For carbon footprints, the expenditure groups have a much more even contribution with services, mobility and food all making substantial contributions to the ACT's carbon footprint.

There has been a notable decrease in the carbon footprint from energy due to the increase of renewable electricity in the ACT. The energy footprint fell from around 1.75 million tonnes CO_2-e (23% of the total carbon footprint) in 2009–10, to around 900,000 tonnes CO_2-e (15%) in 2017–18 (Figure 10).

In 2017–18, mobility was responsible for 25% of the total carbon footprint, rising from 19% in 2002–03. However, in terms of total tonnes CO_2-e there has been little change in mobility since 2009–10 with the change in percentage contribution mainly due a decreasing energy footprint.

Other changes in the carbon footprint include a 168,000 tonnes CO_2-e (10%) decrease from services between 2009–10 and 2017–18, and a 120,000 tonnes CO_2-e (14%) decrease from goods over the same period.

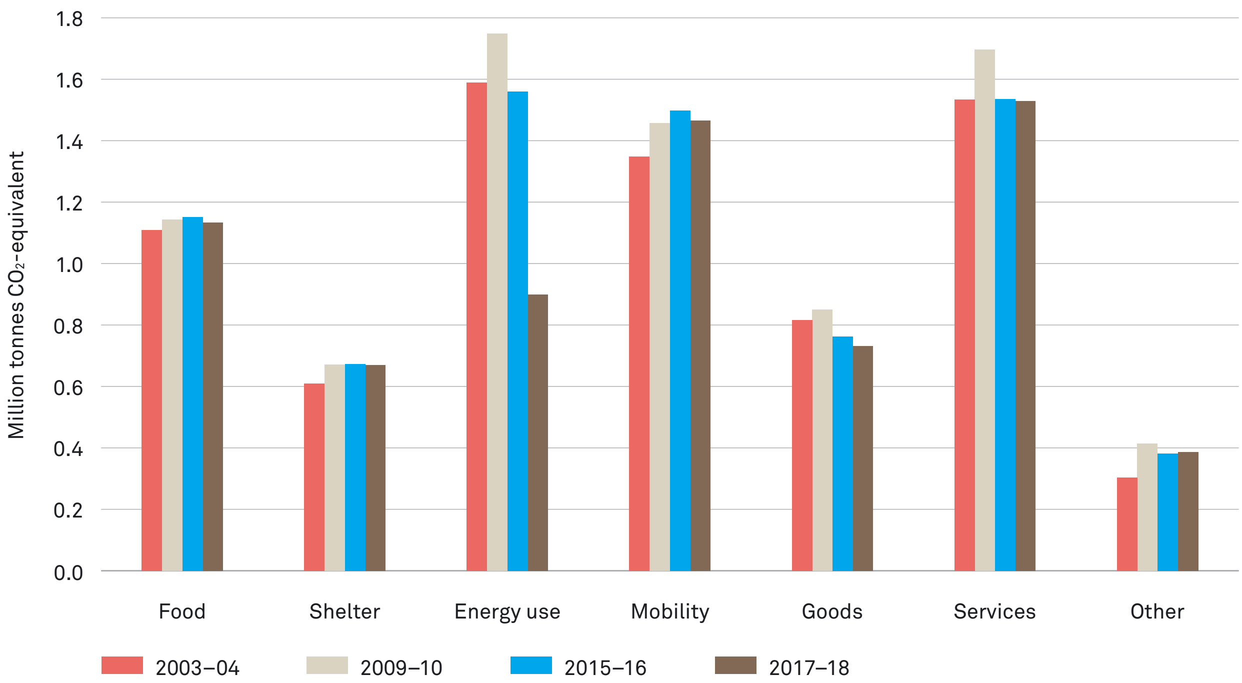


Figure 10:
ACT total carbon footprint by expenditure group, 2003–04 to 2017–18.
Source: Commissioner for Sustainability and the Environment

Drivers of change

The main drivers for changes in the ACT ecological footprint include:

- a very slow rate of increase in household final consumption since 2008
- a decrease in median household income leading to a plateauing of expenditure increases
- a decline in expenditure on components with higher footprint intensities
- increases in housing costs contributing to reduced expenditure
- increases in the services component of ACT household expenditure (health and education in particular)
- relatively small increases in household greenhouse gas emissions
- increase in renewable electricity reducing the energy footprint
- household consumption contributes most to the ACT's total footprint
- private car emissions are now one of the ACT's biggest carbon footprint components and are likely to increase with the growth in private vehicle use and commuting times, and
- air travel was only responsible for around 3.5% of the total 2017–18 carbon footprint, but is growing.

Indicator HS2: Energy consumption and generation

This indicator assesses ACT's energy use. For greenhouse gas emissions and air pollution resulting from energy generation and use, see sections **5.1 Climate change** and **5.3 Air**.

Energy is central to everyday life for both social and economic activity. The level of energy use is determined by a range of factors including population and economic activity. Another significant driver of energy use is climate through increased demand for heating and cooling. Consequently, climate change will increase energy demand in the future with more frequent hot days and heatwave periods although this may be partially offset by a reduction in colder temperatures (see section **5.1 Climate change**).

The environmental impacts of energy use are determined by the type of generation. Non-renewable energy based on fossil fuels (including transport fuels) make significant contributions to greenhouse gas emissions and air pollution. They also impact on the environment through land use changes (both resource extraction and infrastructure requirements) that cause habitat loss and degradation of land and water, and can require high levels of water consumption. Renewable energy such as solar, wind and hydro-electricity have substantially lower environmental impacts, particularly for greenhouse gas emissions and air pollution, but can still impact on the environment through land use change and the use of hazardous material for construction and maintenance. Hydro-electricity also affects aquatic health due to the alteration of river flows.

Regardless of generation type, it is vital to reduce energy demand to minimise environmental impacts. With the population increasing in the ACT, reducing energy usage and improving energy efficiency will negate the need for new energy generation infrastructure.

With the ACT moving to 100% renewable energy for electricity generation, transport will become the main focus for further reductions in non-renewable energy consumption. Reductions will necessitate an increase in the number of electric vehicles, which combined with renewable energy for charging, will further reduce ACT's energy consumption impacts. In addition, the phasing out of natural gas will also be important.

It was not possible to obtain data for the ACT's energy consumption by fuel other than for electricity. Consequently, natural gas, petroleum and other fuel types are not reported here. It was also not possible to obtain data on energy consumption by sector. These are key data gaps which prevent a comprehensive assessment of the ACT's energy consumption and generation. For example, reporting on electricity alone excludes the contributions of oil and petroleum fuels which have been shown to account for the majority of energy consumption in most Australian jurisdictions.[3]

Electricity consumption

Total electricity demand for the ACT and use per capita is shown in Figure 11. Electricity demand in the ACT is relatively stable, despite population growth. This is due to reductions in electricity consumption per capita which decreased by 12% between 2010–11 and 2017–18. This decrease is likely due to a stronger focus on energy efficiency such as the uptake of energy efficient appliances, as well as general efforts to moderate electricity consumption and consumer response to price rises.

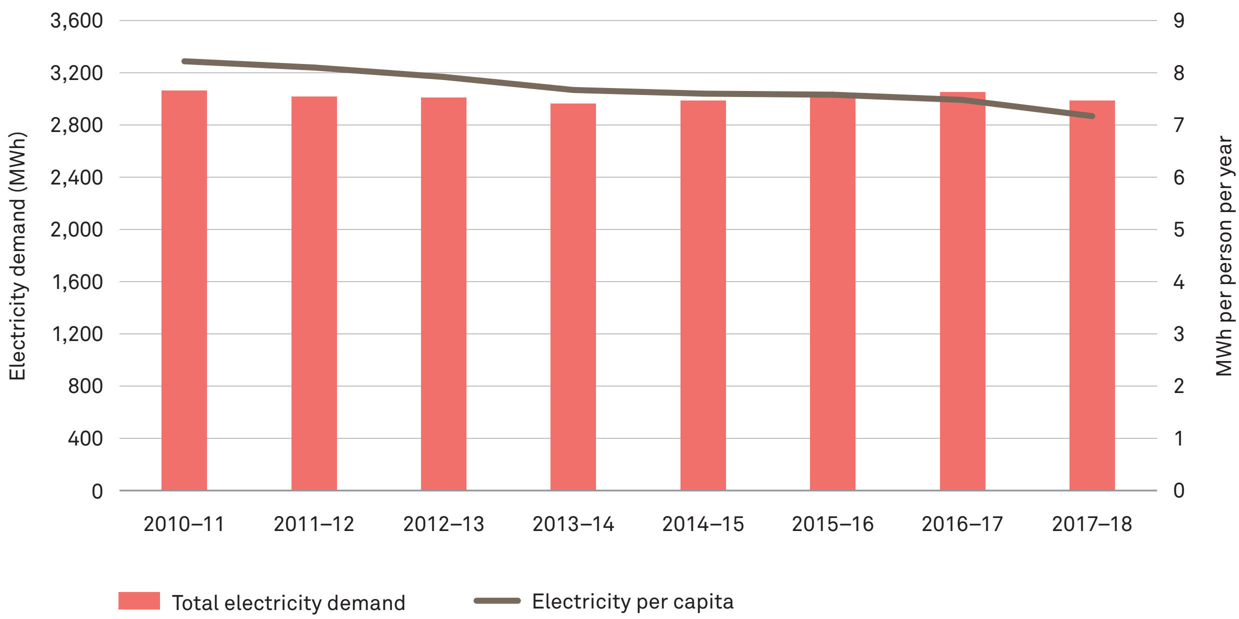


Figure 11:
ACT total and per capita electricity demand, 2010–11 to 2017–18.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

3 Department of the Environment and Energy, 2019, *Australian Energy Update 2019*, found at https://www.energy.gov.au/publications/australian-energy-update-2019 (accessed 6 October 2019).

Renewable electricity generation

The ACT's total renewable electricity generation significantly increased between 2015–16 and 2017–18, rising from 20% to nearly 50% of electricity generated (Figure 12). Predicted renewable electricity generation for the period 2018–19 to 2020–21 shows that the ACT is forecast to reach 100% in 2020. This significant achievement means that the ACT Government's renewable electricity consumption target of 100% by 2020 will be met.[4] It also means that the ACT will be the first jurisdiction in Australia, and the eighth jurisdiction globally with a population over 100,000, to achieve the transition from an electricity supply based largely on fossil fuels to procuring renewable generation equivalent to 100% of its consumption.[5] In addition, the ACT will be the first jurisdiction outside Europe to achieve 100% renewable electricity.

HOW DOES THE ACT'S RENEWABLE ELECTRICITY PROGRAM WORK?

Although the ACT will shortly reach 100% renewable electricity, it remains connected to the national electricity grid. This means that the ACT still receives electricity generated from non-renewable sources which may be consumed at any time. However, the ACT has purchased enough renewable energy to meet its electricity needs. This renewable electricity is available to the national grid and is used in other parts of Australia, offsetting the non-renewable energy consumed in the ACT. This is a system used by most of the European jurisdictions that have moved to 100% renewables.[6] The system also allows the ACT to keep using the national grid which is important during periods of high demand.

The ACT's renewable energy was purchased using what is known as a reverse auction, where companies were invited to bid to supply renewable energy at the lowest price for the ACT. This has resulted in the development of new renewable energy generation.

Ideally, all electricity should come directly from renewable sources where possible. However, this would be difficult for the ACT and other jurisdictions to achieve where sufficient generation opportunities are not available. Consequently, supplying renewable electricity into the national grid is an effective means to achieving 100% renewable electricity, and to reduce the impacts of energy use on the environment.

4 Environment and Planning Directorate, 2016, *Canberra 100% Renewable: Leading Innovation with 100% Renewable Energy by 2020*, ACT Government, Canberra, found at https://www.environment.act.gov.au/__data/assets/pdf_file/0007/987991/100-Renewal-Energy-Tri-fold-ACCESS.pdf

5 Cass, D., 2019, Class ACT. How the Australian Capital Territory Became a Global Energy Leader, The Australia Institute, Canberra, found at https://www.tai.org.au/sites/default/files/P708%20Class%20ACT%20%5BWEB%5D_0.pdf (accessed 6 October 2019).

6 Cass, D., 2019, Class ACT. How the Australian Capital Territory Became a Global Energy Leader, The Australia Institute, Canberra, found at https://www.tai.org.au/sites/default/files/P708%20Class%20ACT%20%5BWEB%5D_0.pdf (accessed 6 October 2019).

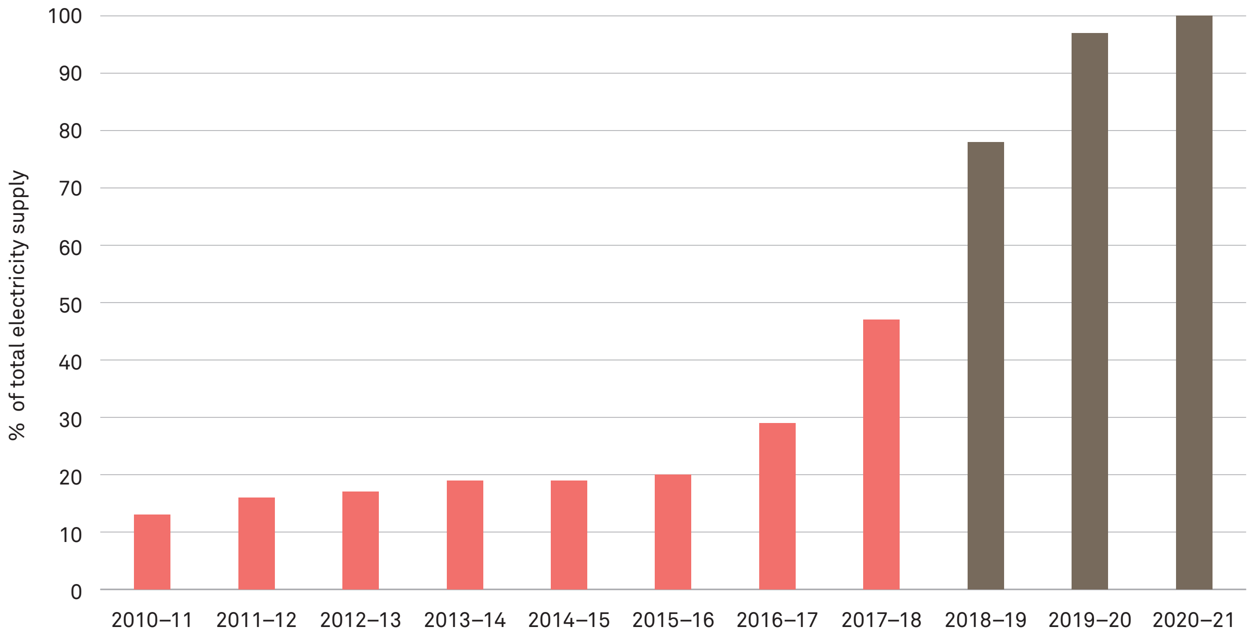


Figure 12:
Total renewable electricity generation for the ACT, 2010–11 to 2017–18, and projected renewable generation for 2018–19 to 2020–21.
Data sourced from: Environment, Planning and Sustainable Development Directorate.

Wind farms supply the majority of the ACT's renewable electricity. Wind farm generation significantly increased from 7% in 2016–17 to over 50% in 2018–19, and will supply over 70% of total renewable electricity in 2019–20 and 2020–21 (Figure 13). The second largest renewable electricity source for the ACT comes from the ACT Government's mandatory contribution to the national renewable energy target. This accounts for around 20% of ACT's renewable electricity and has remained fairly consistent, increasing by around 1% per year.

Solar farm and rooftop solar generation each account for 3% of the current renewable electricity. Rooftop solar PV generation continues to be installed in the ACT, and despite the large increases in other generation, has increased its share of renewable electricity generation in recent years.

The location of the ACT's wind and solar farms supplying the National Electricity Market are shown in (Figure 14). The only renewable electricity generated in the ACT comes from solar farm and rooftop solar generation. The bulk of the power from wind farms and the national renewable energy target are sourced from outside the ACT. There are currently five wind farms, one in South Australia, two in Victoria, and two in NSW.

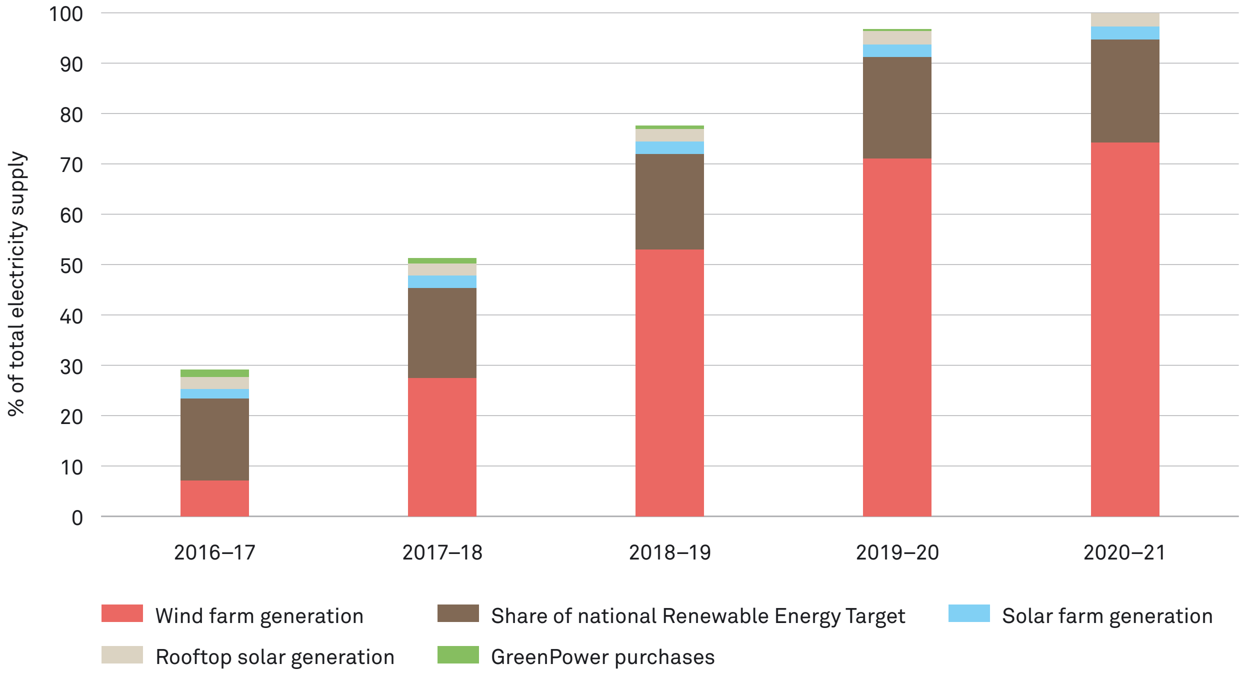


Figure 13:
Sources of renewable electricity generation for the ACT, 2016–17 to 2020–21.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

Notes: Figures for 2020–21 are predicted only. Share of national Renewable Energy Target is the component paid for by ACT electricity consumers as part of their normal electricity bills. Greenpower purchases is the total amount of Greenpower purchased by all ACT electricity consumers.

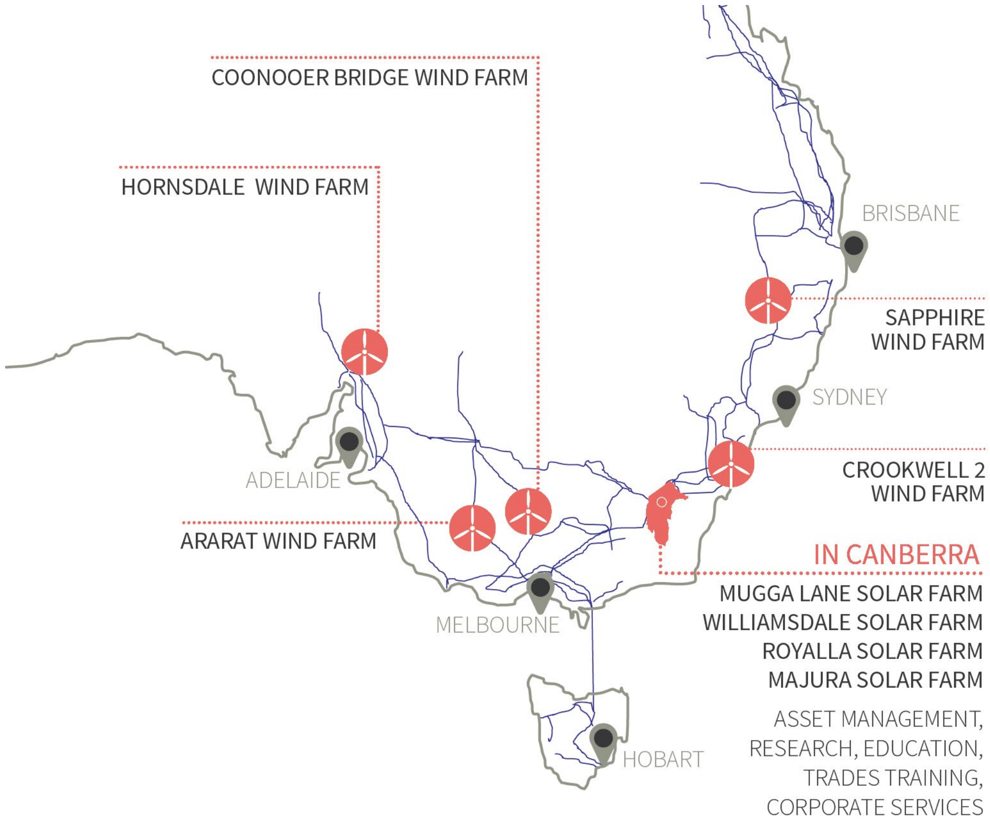


Figure 14:
Location of the ACT’s wind and solar farms supplying the National Electricity Market

Source: Environment, Planning and Sustainable Development Directorate, 2016, *Canberra 100% Renewable: Leading Innovation with 100% Renewable Energy by 2020*, ACT Government, Canberra.

Indicator HS3: Solid waste generation and management

The generation of waste places pressure on the environment, requiring land for its disposal, and ongoing management to prevent contamination and pollution. Waste can also have adverse impacts on human health and the liveability of our environment. Depending upon the way it is managed, waste can have a number of different environmental impacts including:

- land use change and pollution leading to the degradation of ecosystems and biodiversity loss
- increased greenhouse gas emissions
- contamination and pollution of soils, groundwater and waterways
- presence of hazardous substances
- impacts on human health and amenity, and
- increased demands on resources required to dispose of and recycle waste.

The amount of waste generated is not only determined by population, but also the level of consumption of material resources and manufactured goods. Increased consumption has significant consequences for the environment and for resource demand and depletion, particularly outside the ACT where goods and materials are sourced and manufactured. Waste is also highly influenced by the level of activity in the commercial, industrial, construction and demolition sectors. Waste is produced at all stages in the manufacture of products and services, as well as at the end of a product's lifecycle.

When waste is not reused, recycled or used efficiently there is an opportunity lost, as the material can no longer be used to contribute to the economy. Recycling waste also reduces the demand for resource extraction, and conserves energy and water compared to manufacturing products from raw materials.

A large proportion of waste in the ACT comes from construction and demolition activities. Poor planning in design and assembly can lead to inefficient use of resources in manufacturing or construction, leading to unnecessary material waste. The management of such waste can be an economic burden which is passed on down the supply chain of products, increasing the price to the consumer. In the case of construction, poor design can not only create unnecessary material waste, but also a legacy of inefficiency throughout a building's life.

Waste generated in Queanbeyan is processed at ACT recycling facilities and deposited in ACT landfills. Consequently, the waste data reported here includes both the ACT and Queanbeyan. Waste data also currently excludes waste taken to landfill outside the ACT. This means that the data reported understates the actual volume of waste sent to landfill. The waste activity management system that is currently being implemented by the ACT Government will capture this data which is expected to be available in the 2019–20 financial year.

Wind Farm. Source: Environment, Planning and Sustainable Development Directorate.

Total waste generation and resource recovery

The annual total waste generated in the ACT between 2009–10 and 2018–19 ranged from 816,000 to 1.2 million tonnes, with no consistent trend over time (Figure 15). Waste to landfill ranged from 21% (256,000 tonnes) to 49% (511,000 tonnes), and resources recovered ranged from 51% (534,000 tonnes) to 79% (957,000 tonnes). Despite this variation, it is clear that resource recovery is generally much higher than waste sent to landfill with most years recording a resource recovery rate of 70% or higher.

Total waste generation, waste to landfill and resources recovered are highly variable in the ACT with changes mostly occurring in response to specific activity from the construction and demolition sector and increases in garden waste. These waste types are also responsible for most of the resource recovery in the ACT; for example in 2018–19 waste from these sources represented 85% of the total tonnes recovered.

The resource recovery rate in recent years has been impacted by the Mr Fluffy program which involves the buyback and demolition of houses containing loose fill asbestos. By 2018–19, the impact was lower than the previous three years, with the majority of the program completed.

Excluding waste from the Mr Fluffy program, resource recovery in the ACT has plateaued to around 70% to 75% of the total waste generated.

The highest percentage of resources recovered was 79% in 2018–19, due to an increase in construction and demolition materials as well as green waste. The lowest percentage of resource recovery occurred in 2016–17, with only 51% recovered. This low rate was the result of an increase in waste to landfill from asbestos-contaminated waste from the Currong apartments, and contaminated waste from a leachate dam excavation at Mugga lane landfill.

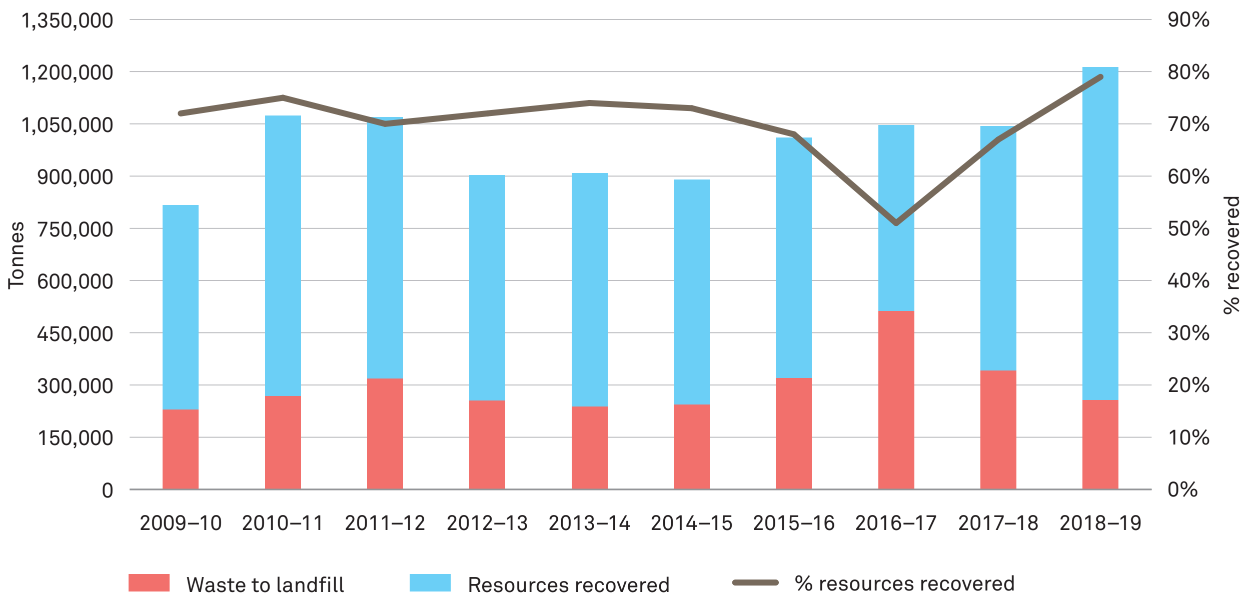


Figure 15:
Waste generation and management in the ACT, 2009–10 to 2018–19.

Data sourced from: Transport Canberra and City Services

Per capita waste generation and management

Waste generation and management per person is an important measure for assessing trends in waste practices and behaviours. For example, results in per capita assessments can demonstrate improvements in recycling and consumer awareness, as well as improved industry standards in packaging practices. Such changes can be masked by total waste assessments which are more closely aligned to population increases.

Results for per capita resource recovery, landfill and total waste also show the same variation in response to specific activity from the construction and demolition sector. Landfill per capita ranged from 0.5 to 1.1 tonnes per person, resources recovered from 1.2 to 2 tonnes per person, and total waste between 2 and 2.6 tonnes per person with no consistent trend over time (Figure 16).

Excluding the Mr Fluffy program, per capita waste to landfill has plateaued around 0.55 tonnes per person. The 2018–19 result is slightly lower than this trend at 0.52 tonnes per person due to lower commercial and industrial waste to landfill.

Over last few years the resource recovery tonnes per person has plateaued around 1.5 to 1.6 tonnes per person, except for 2016–17 which was only 1.2 tonnes per person. The 2016–17 result was affected by a reduction in the recycling of construction and demolition waste and the absence of data from a major recycler who declined to provide its data. If these impacts are excluded, the 2016–17 result is estimated to be around 1.5 tonnes per person.

The highest resources recovered per capita was in 2018–19 at around 2 tonnes per person. This is mainly the result of the increased activity in the construction and demolition sector and an increase in green waste recovered.

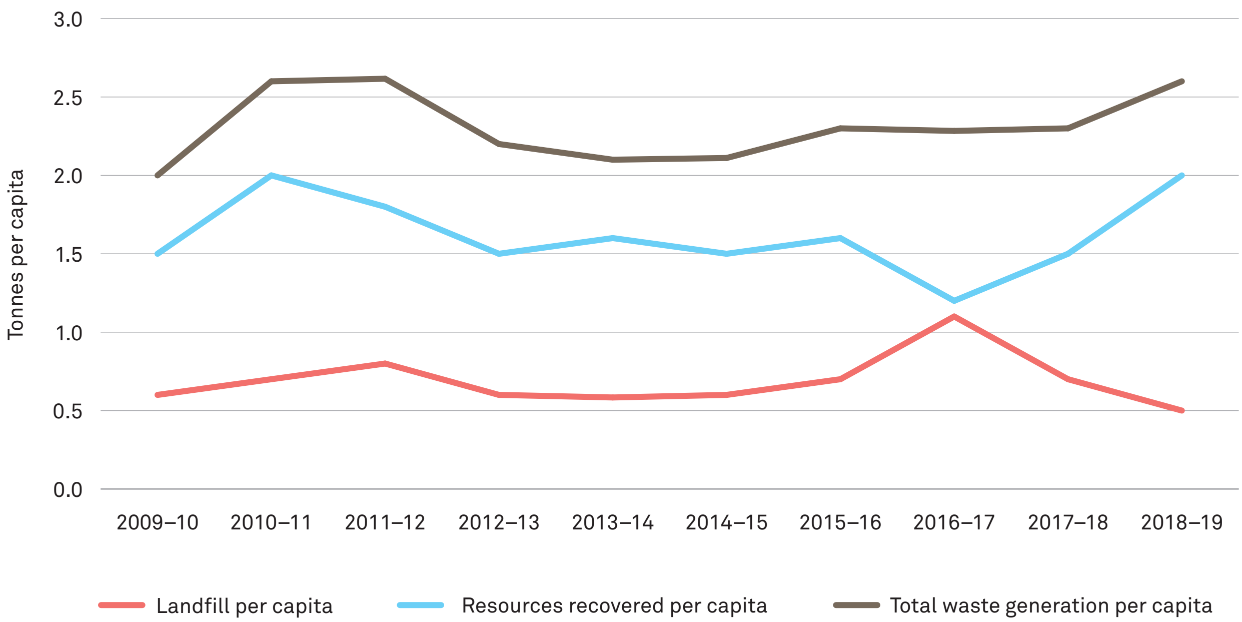


Figure 16:
Per capita waste generation and management in the ACT, 2009–10 to 2018–19.

Data sourced from: Transport Canberra and City Services

Waste sent to landfill by sector

Changes in the methodology used to report waste in the ACT means that it is not possible to include long-term trends for waste by sector in the ACT. Consequently, it is only possible to report sector contributions from 2016–17.

Waste from the Mr Fluffy program accounted for 40% (202,000 tonnes) of the total waste sent to landfill in 2016–17. This declined to 26% (90,000 tonnes) in 2017–18 and 5% (12,000 tonnes) in 2018–19 with the majority of the program already completed.

Sector waste to landfill excluding the Mr Fluffy program is shown in Figure 17. Municipal solid waste accounts for the highest proportion of the waste sent to landfill, closely followed by commercial and industrial waste. Over the three years of available data, municipal solid waste contributed between 39% and 49% of the waste sent to landfill; however, in terms of tonnes, there was little variation over the period. Commercial and industrial waste contributed between 35% and 47% of the total waste sent to landfill. Construction and demolition waste varied widely over the period, from 25% of the total waste sent to landfill in 2016–17 to only 6% and 9% in the following years. The high amount in 2016–17 was from asbestos-contaminated waste from the Currong apartments, and contaminated waste from a leachate dam excavation at Mugga lane landfill.

Given the short data period, it is not possible to determine any trends in sector contributions to landfill. However, municipal solid waste appears to be stable despite the annual population increase in the ACT. This may indicate improved recycling behaviours and/or changes in the consumption of goods and services leading to a decline in waste per person. Construction and demolition waste, and to a lesser degree, commercial and industrial waste, are more variable and are related to activity changes in those sectors.

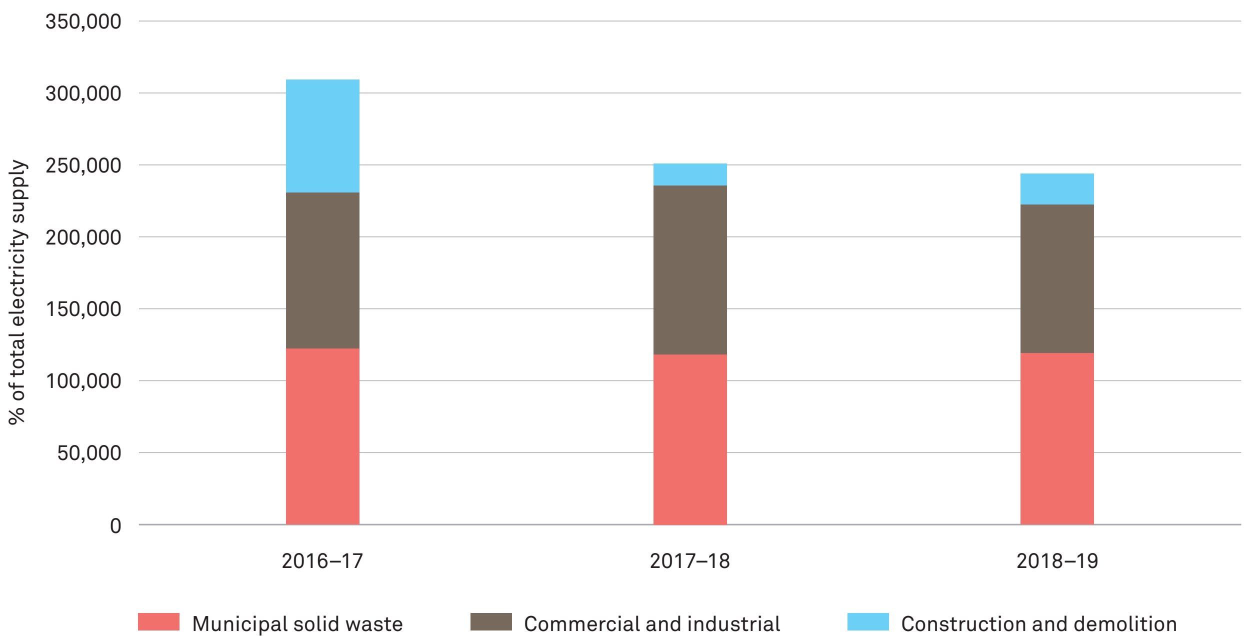


Figure 17:
Waste sent to landfill by sector, 2016–17 to 2018–19.

Data sourced from: Transport Canberra and City Services

Compliance with waste National Environment Protection Measures

There are two National Environment Protection Measures (NPEM) related to waste:

- Movement of Controlled Waste between States and Territories NPEM: provides a means of tracking the movement of controlled waste between states and territories to minimise the potential for adverse impacts associated with the movement of controlled waste on human health and the environment.
- Used Packaging Materials NEPM: aims to reduce environmental degradation arising from the disposal of used packaging and to conserve virgin materials.

The ACT must report compliance with these measures to the National Environment Protection Council. During the reporting period, ACT was found to comply with both waste NEPMs.[7]

For the Used Packaging Materials NEPM, the ACT previously met this obligation under the Waste Minimisation (Used Packaging Materials Industry Waste Reduction Plan). This was repealed on 30 June 2017 when the *Waste Management and Resource Recovery Act 2016* commenced. The Used Packaging Materials Industry Waste Reduction Plan was not replaced until 30 June 2019, when the used packaging material compliance measure was reinstated. Development is currently underway to ensure the ACT meets its obligations under the Used Packaging Materials NEPM.

Indicator HS4: Transport

This section assesses private and public transport which accounts for the vast majority of transport demand in the ACT. Transport undertaken for business and industry purposes are not assessed.

Transport is an essential part of modern living, enabling the movement of people and goods for work, education, industry, social connection and recreation. However, road-based transport in the ACT and globally is dominated by vehicles, mainly private cars. This requires continual investment in extensive infrastructure such as roads and parking areas to cope with growing transport needs, as well as increased demand for fossil fuels. This has many environmental impacts including:

- air pollutants including carbon monoxide, nitrogen dioxide and particulate matter (see section **5.3 Air**)
- greenhouse gas emissions (see section **5.1 Climate Change**)
- reliance on non-renewable fuels
- land clearing and habitat loss for roads and other infrastructure, and
- loss of amenity due to noise.

Transport emissions are particularly important for the ACT. With the Territory moving to 100% renewable electricity in 2019–20, transport will account for over 60% of greenhouse gas emissions, by far the dominant source (see section **5.1 Climate Change**).

Most of the ACT's transport emissions come from passenger vehicles. Private modes of transport such as cars are less efficient at moving large numbers of people and so have greater impacts on the environment than public transport. In addition to environmental impacts, the increased use of private vehicles leads to greater congestion and travel times, and demand for new road infrastructure. Consequently, improving the uptake of public and alternative forms of transport, as well as increasing the number of electric vehicles, is important for the ACT.

Urban expansion and population growth are the main drivers for escalation in private car usage. Urban spread has also increased requirements for transport infrastructure in the ACT, including the expansion of freeways.

7 National Environment Protection Council (NEPC), 2019, NEPC *Annual Report 2017–2018*, Canberra, found at http://www.nepc.gov.au/system/files/resources/1ed358dc-9aee-442f-9821-78ce95bf20a6/files/nepc-annual-report-2017-18.pdf (accessed 13/10/2019).

Transport modes in the ACT

The ACT community is highly dependent on cars. A 2017 survey of daily travel undertaken in the ACT and Queanbeyan-Palerang Regional Council, found that 78% of all trips were undertaken by car including 55% as a driver and 23% as a passenger (Figure 18).[8] Bus transport only accounted for 4% of trips, and cycling only 2%. Walking was the second highest mode with 14% of the total trips taken. However, it should be noted that walking data includes that undertaken for recreation (for example, dog walking or for exercise) which accounted for nearly 40% of all walking trips, and so does not necessarily represent travel to a specific destination.

The survey also determined that the most common purpose for car travel was work related which accounted for 27% of all car travel (Figure 19). Other common reasons for car use included picking up or dropping off someone (19%), social and recreation (15%) and to buy something (13%). This spread of car use across a range of purposes means that cars are the main transport choice for a range of daily activities.

The ACT community's dependence on cars is further shown in a comparison of the transport modes used to travel to work. Cars were used for over 80% of travel to work (Figure 20) with car as driver accounting for 74%. This not only shows the dominance of car use for travel to work, but also that most commuting by car is undertaken with the driver as the sole vehicle occupant. Public transport was used for only 8% of travel to work, cycling 5% and walking 3%.

The ACT Government has commuting-to-work targets to be achieved by 2026.[9] These include increasing the mode share of public transport to 16%, and walking and cycling to 7% each. The travel- to-work data reported here shows that these targets are currently not being met.

The Australian Bureau of Statistics also reports on methods of travel to work. A comparison of results between 2011 and 2016 show little change in transport modes in the ACT over the 5-year period.[10]

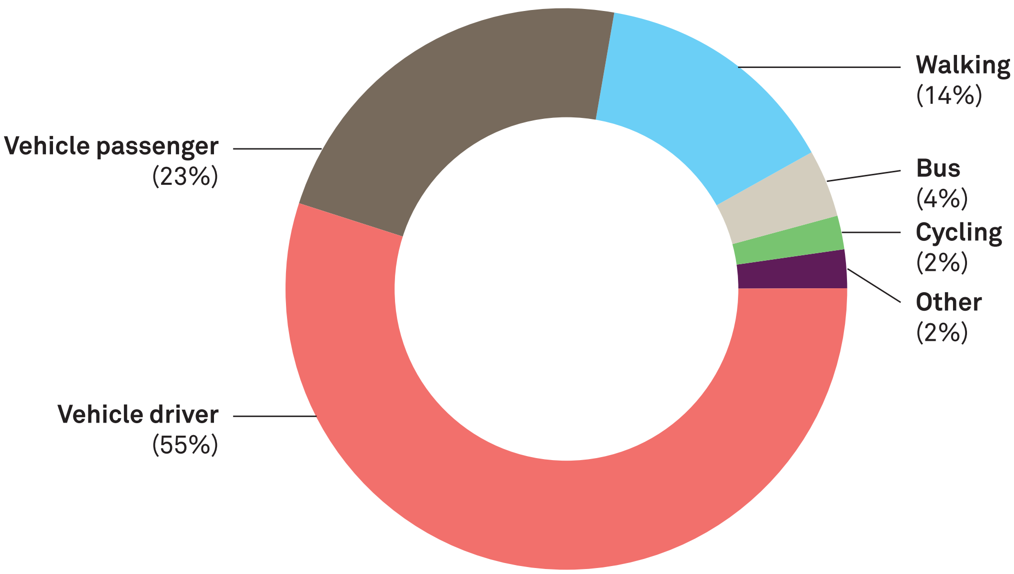


Figure 18:
Daily travel mode undertaken in the ACT and Queanbeyan-Palerang region.

Data sourced from: ACT and Queanbeyan-Palerang Regional Council, 2017, Household Travel Survey (ACTQP HTS).

Notes: Based on a survey of 1,785 households and 4,611 people in both the ACT and Queanbeyan. Each participant completed a travel diary for a single specified day across October and November 2017. Walking includes all purposes, including for recreation such as fitness and dog walking.

8 ACT and Queanbeyan-Palerang Regional Council, 2017, Household Travel Survey (ACTQP HTS), found at https://www.transport.act.gov.au/about-us/planning-for-the-future/household-travel-survey (accessed 15 October 2019).

9 Environment and Planning Directorate, 2015, *Building an Integrated Transport Network, Active Travel*, ACT Government, Canberra, found at https://www.transport.act.gov.au/about-us/active-travel?a=888712 (accessed 15 October 2019).

10 Australian Bureau of Statistics (ABS), 2011 and 2016, Census of Population and Housing 2011, 2016, ABS, Canberra.

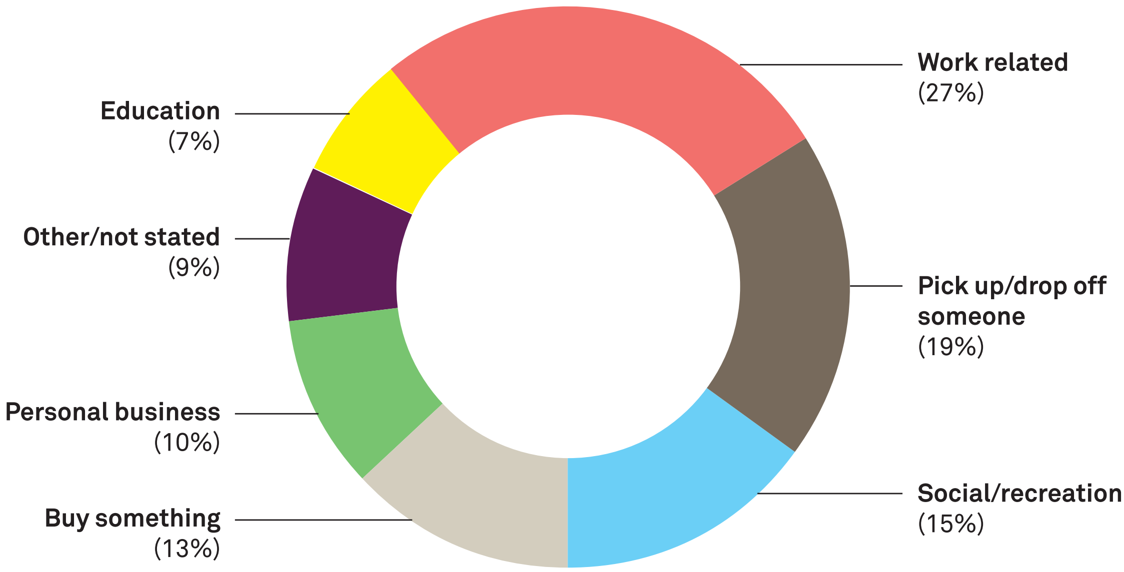


Figure 19:
Daily car use by travel purpose for the ACT and Queanbeyan-Palerang region.

Data sourced from: ACT and Queanbeyan-Palerang Regional Council, 2017, Household Travel Survey (ACTQP HTS).

Notes: Based on a survey of 1,785 households and 4,611 people in both the ACT and Queanbeyan. Each participant completed a travel diary for a single specified day across October and November 2017.

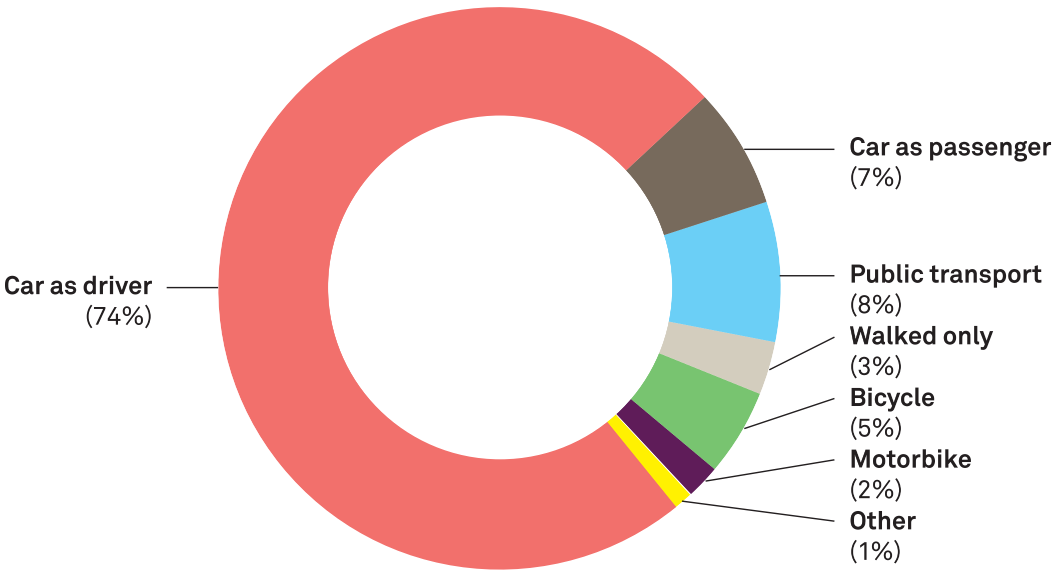


Figure 20:
Commute to work by mode for the ACT and Queanbeyan-Palerang region.

Data sourced from: ACT and Queanbeyan-Palerang Regional Council, 2017, Household Travel Survey (ACTQP HTS).

Notes: Based on a survey of 1,785 households and 4,611 people in both the ACT and Queanbeyan. Each participant completed a travel diary for a single specified day across October and November 2017.

Vehicle numbers and kilometres travelled

The number of registered vehicles in the ACT has grown from around 253,000 vehicles in 2010, to over 304,000 in 2018, an increase of 20% (Figure 21). In 2018, passenger vehicles were responsible for 84% (255,000) of the total vehicle registrations (Figure 22). Light commercial vehicles accounted for 10% of the total vehicle registrations. Light commercial vehicles include some types of sports utility vehicles, which are being increasingly used by the community for non-work purposes. These large vehicles are more damaging to the environment, with increased emissions of air pollutants due to higher fuel usage. The number of registered vehicles per 1,000 population has also increased in the ACT from 726 in 2014 to 731 in 2019.[11] This is mainly due to an increase in passenger vehicles from 607 per thousand people in 2014 to 611 in 2019.

The annual kilometres travelled by vehicles was variable between 2010 and 2018, but data shows that vehicle usage is increasing. In 2018, the distance travelled by ACT's vehicles was nearly 3,900 million kilometres (Figure 21). Similar to registrations, passenger vehicles were responsible for 82% of the total kilometres travelled, with light commercial vehicles accounting for 13% (Figure 23).

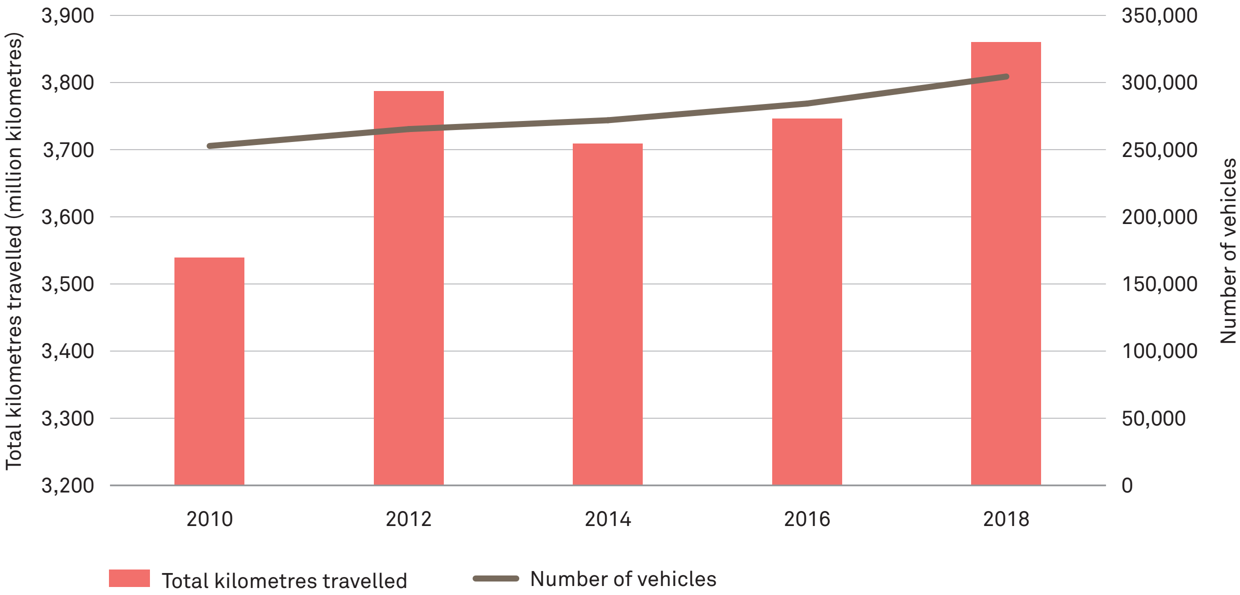


Figure 21:
Total kilometres travelled and number of registered vehicles in the ACT, 2010 to 2018.

Data sourced from: Australian Bureau of Statistics, 2019, 9309.0 Motor Vehicle Census, Australia, 31 Jan. 2019.

Notes: The average number of vehicles registered for 12 months of the year. Data includes registered vehicles that did not travel during the reference period.

11 Australian Bureau of Statistics (ABS), 2019, 9309.0 Motor Vehicle Census, Australia, 31 January 2019, ABS, Canberra

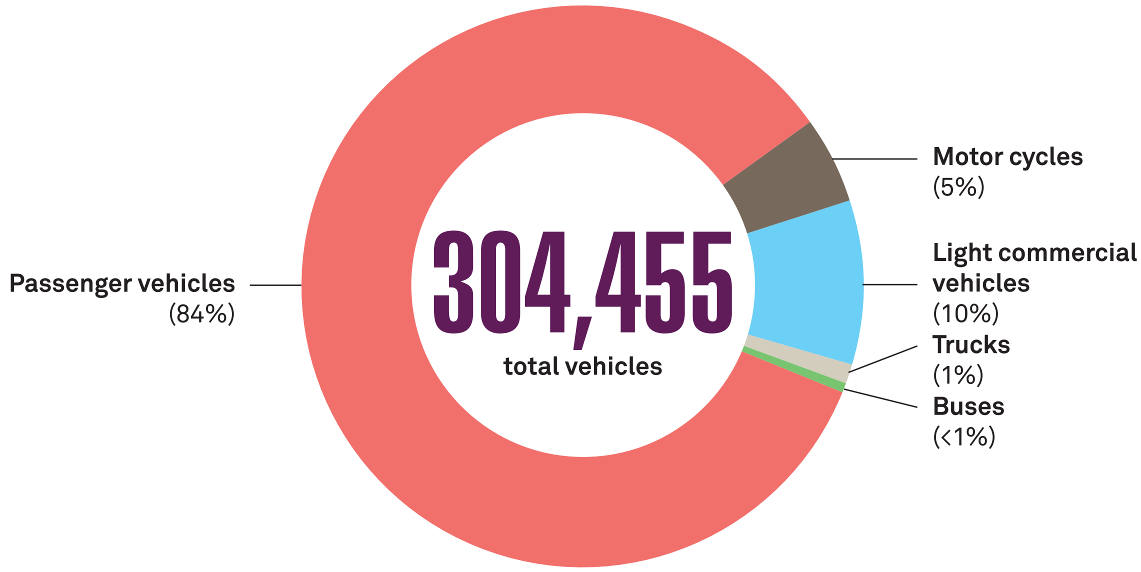


Figure 22:
Registered vehicle types in the ACT, as at 2018.

Data sourced from: Australian Bureau of Statistics, 9309.0 Motor Vehicle Census, Australia, 31 Jan 2019.

Notes: Data shows the average number of vehicles registered for 12 months per year. Includes registered vehicles that did not travel during the reference period. Trucks include rigid, articulated and non-freight carrying categories.

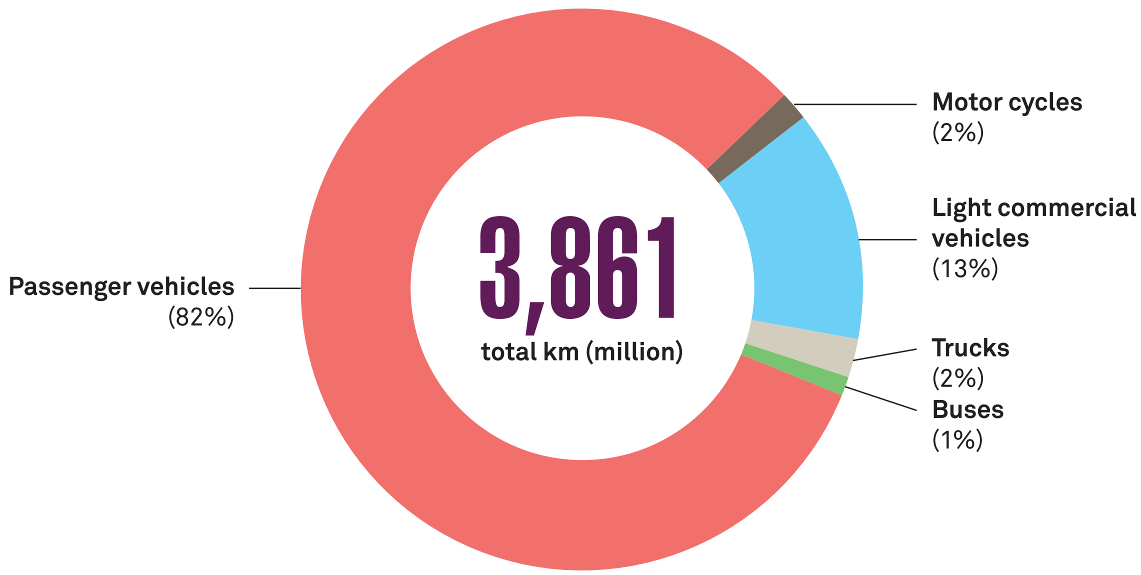


Figure 23:
Percentage of total vehicle kilometres travelled by vehicle type in the ACT, as at 2018.

Data sourced from: Australian Bureau of Statistics, 9309.0 Motor Vehicle Census, Australia, 31 Jan 2019.

Notes: Trucks include rigid, articulated and non-freight carrying categories.

The growth in registered vehicles and kilometres travelled not only impacts on the environment, but also congestion on the roads in the ACT. Increased time spent on travel to work and other daily activities, and the level of inconvenience and stress experienced in travel, are major factors affecting the liveability of a city. Congestion also has an economic cost because of losses in time at work.

Between 2002 and 2017, daily commute times increased by 65% in the ACT, the highest of any Australian city (Figure 24).[12] The mean daily commute time in 2017 was 52 minutes compared to 31 minutes in 2002, although the time estimate for 2017 was a slight decline on 2014 which was 55 minutes (Figure 25). The ACT's commute times are now approaching those recorded in other Australian cities.

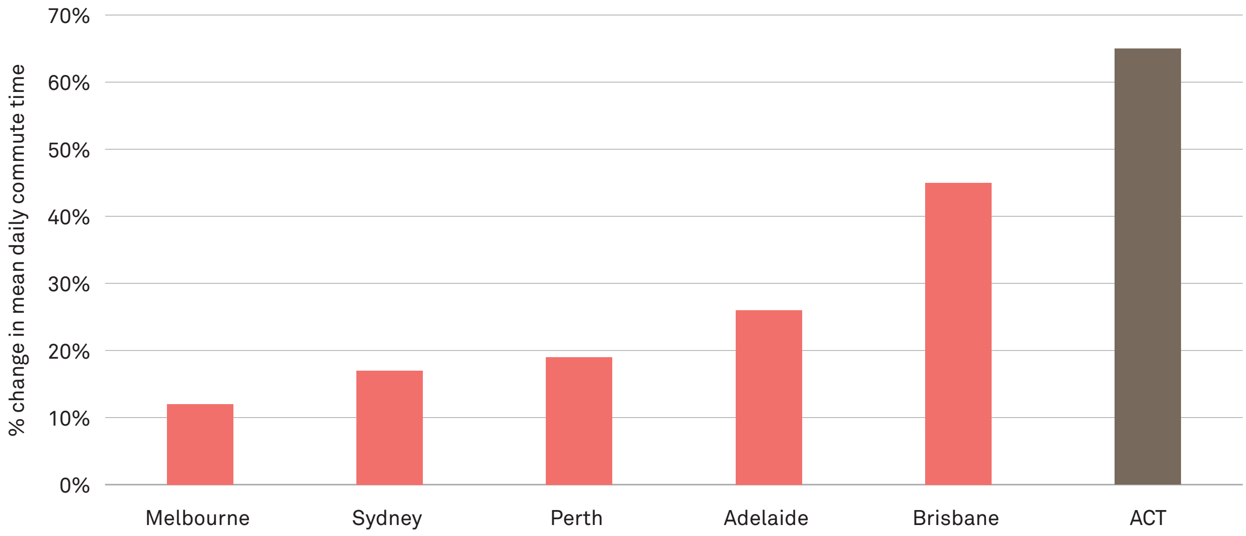


Figure 24:
Percentage change in mean daily commute time for selected Australian cities, 2002 to 2017.

Data sourced from: Wilkins R. et al., 2019, *The Household, Income and Labour Dynamics in Australia Survey: Selected Findings from Waves 1 to 17*, Melbourne Institute: Applied Economic & Social Research, University of Melbourne.

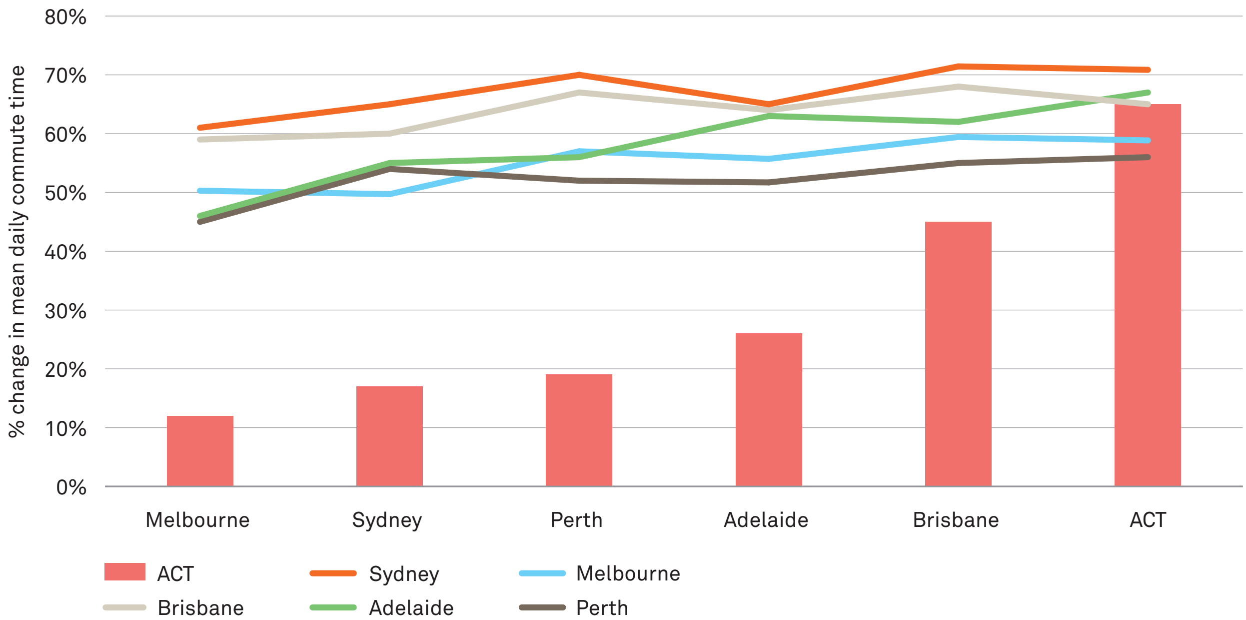


Figure 25:
Mean daily commute time for selected Australian cities, 2002 to 2017.

Data sourced from: Wilkins R. et al., 2019, *The Household, Income and Labour Dynamics in Australia Survey: Selected Findings from Waves 1 to 17*, Melbourne Institute: Applied Economic & Social Research, University of Melbourne.

12 Wilkins, R. et al., 2019, *The Household, Income and Labour Dynamics in Australia Survey: Selected Findings from Waves 1 to 17*, Melbourne Institute: Applied Economic & Social Research, University of Melbourne.

Vehicle fuel types in the ACT

In 2019, 86% of registered passenger vehicles were fuelled by petrol making it the dominant fuel type in the ACT (Figure 26). This represents a decline in the proportion of petrol vehicles, which fuelled 94% of all passenger vehicles in 2010. This decline is the result a threefold increase in diesel-powered passenger vehicles over the same period, from 4% of total passenger vehicles in 2010 to 12% in 2019. The large increase in diesel vehicles is of concern as their impact on air pollution is becoming recognised as a problem in both Australia and globally. For example, diesel engines generally have higher emissions of nitrogen oxides and much higher emissions of particulate matter (see section **5.3 Air**).

Hybrid and electric cars only make up 1% of the total passenger vehicles in the ACT, but in terms of vehicle numbers, have increased from around 150 in 2010 to nearly 2,900 in 2019. The ACT, along with South Australia, have the highest number of electric car purchases in Australia, with 21 electric cars per 10,000 vehicles sold.[13]

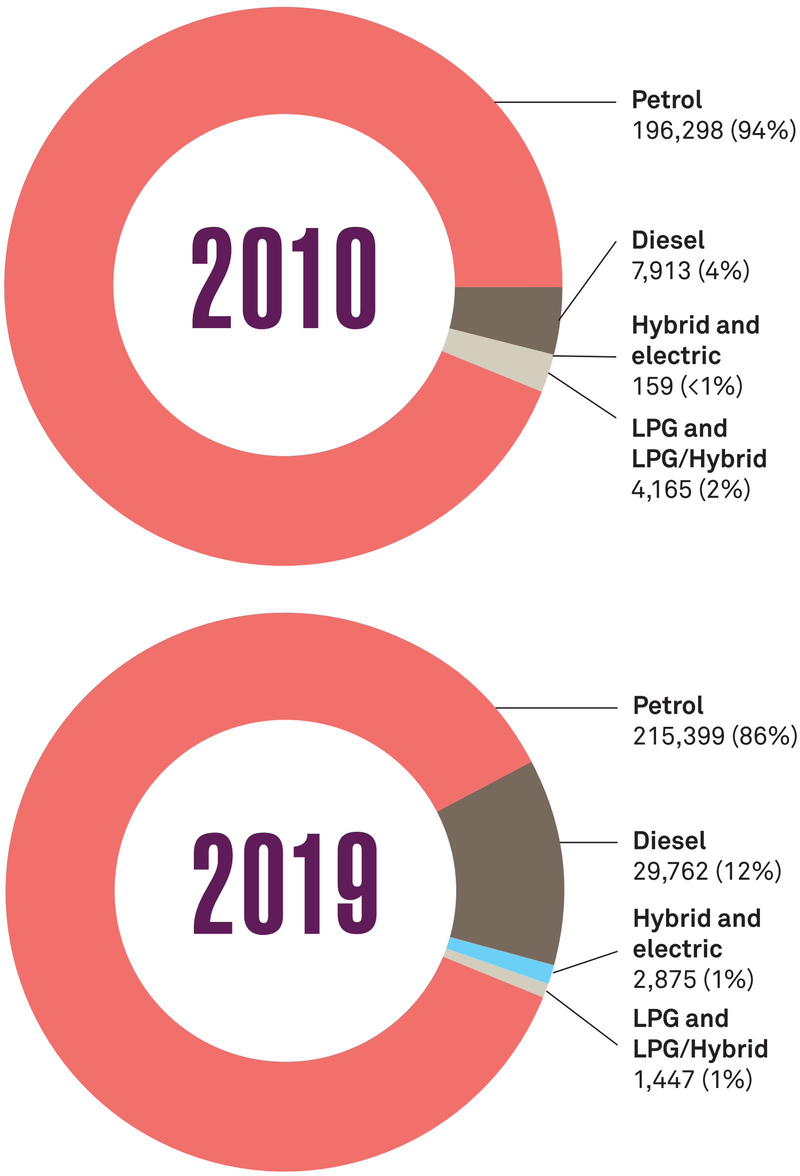


Figure 26:
Vehicle fuel type for registered passenger vehicles in the ACT, 2010 and 2019.
Data sourced from: Access Canberra.

13 ClimateWorks Australia, 2018, *The State of Electric Vehicles in Australia. Second Report: Driving Momentum in Electric Mobility*, ClimateWorks Australia, Melbourne.

Public transport uptake

Bus use in the ACT declined sharply from the 1980s to the 2000s (Figure 27), which may have been due to an increase in car affordability.[14] Since then, public transport use has remained relatively stable at around 45 to 50 boardings per person each year. However, public transport use has increased in recent years, growing from 17.6 million boardings annually (45 per capita) in 2014–15 to 20.1 million (48 per capita) in 2018–19.

The light rail commenced operation on 20 April 2019, with nearly 878,000 boardings to the end of June 2019. The opening of the light rail also coincided with updates to the bus network, and this combination of changes is thought to have contributed to the growth in public transport uptake in 2018–19.

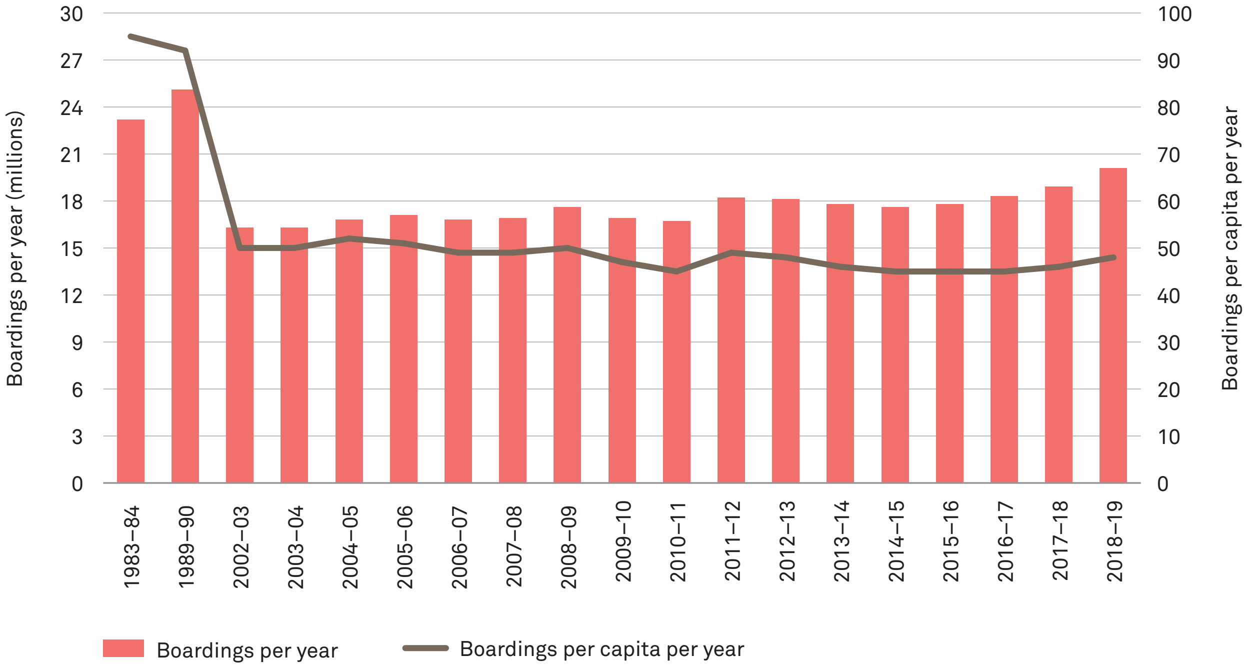


Figure 27:
Public transport boardings per year and per capita for the ACT, 1983–84 to 2018–19.
Data sourced from: Transport Canberra and City Services.

14 Office of the Commissioner for Sustainability and the Environment, 2015, *ACT State of the Environment Report 2015*, ACT Government, Canberra.

Cycling uptake

Cycling is highly variable across the ACT with the Civic area having a significantly greater uptake of cycling than other parts of Canberra.[15] This is likely due to a flatter terrain and shorter distances to work and study centres.

Between 2011 and 2019, cycling participation in the ACT was higher than the national average for weekly, monthly and annual participation (Figure 28). In 2019, the ACT had the highest cycling rate of Australian jurisdictions for both weekly and monthly participation, and second highest for annual participation.[16] Despite this, there are wide variations in cycling participation across survey years and a statistically significant decline in ACT's weekly cycling participation between 2017 and 2019. It must be noted that the cycling data includes physical activity participation (the most common reason for cycling). This means that changes in cycling participation may not reflect changes in the use of cycling for actual transport to work or for other purposes.

The absence of a growing trend in cycling participation in Australia is contrary to the investment made by governments in promoting and encouraging cycling.[17] This is certainly the case for the ACT which has extensive cycling infrastructure. In 2019, the ACT had around 3,100 km of shared paths and some 600 km of on-road cycling lanes. The paths cover 10 principal cycle routes in the ACT, links between these routes, and connect town centres and major employment districts. Given the high level of cycling infrastructure in the ACT, there is much scope for improving cycling participation, including across gender and age groups.

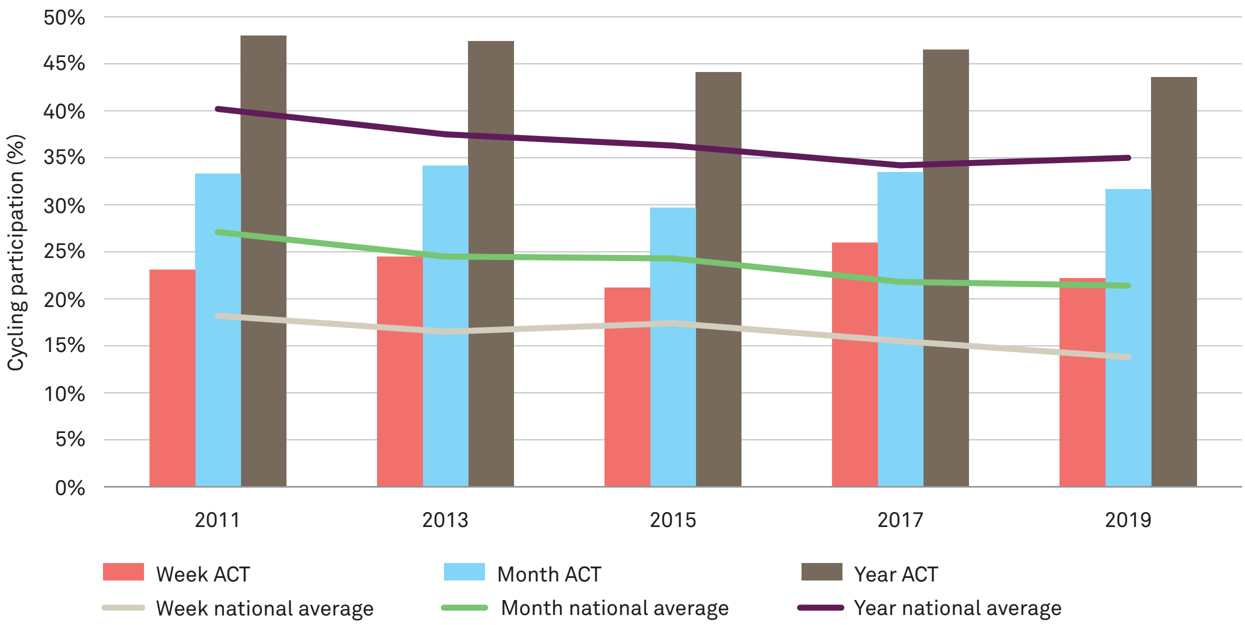


Figure 28:
Cycling participation for the ACT and the national average for weekly, monthly and annual use, 2011 to 2019.

Data sourced from: Austroads, 2019, *Australian Cycling Participation 2019*, Austroads Ltd, Sydney.

15 Based on 2014 data reported in: Office of the Commissioner for Sustainability and the Environment, 2015, *ACT State of the Environment Report 2015*, ACT Government, Canberra.
16 Austroads, 2019, *Australian Cycling Participation 2019*, Austroads Ltd, Sydney.
17 Austroads, 2019, *Australian Cycling Participation 2019*, Austroads Ltd, Sydney.

CASE STUDY
BIKE BAROMETER

The ACT Government installed a bike barometer at the juncture between the Sullivan's Creek shared path and MacArthur Avenue in O'Connor in November 2017. Data is provided on an hourly basis in two directions, capturing trips coming from the north towards Civic and from the south heading towards Gungahlin. It does not capture trips coming from Belconnen. The data can be viewed online in real time at: http://macarthuravedisplay.visio-tools.com/

Between December 2017 and May 2019, the barometer counted over 710,000 cyclists (Figure 29). March followed by October had the highest number of cyclists. There is a clear seasonal variation in the number of cyclists with winter and summer having the lowest counts, although this is not significant. This suggests that climatic conditions may have an impact on cycling numbers, particularly for days of high temperature, rainfall and wind. Of particular interest is the impact of extreme temperatures given the increase in hotter days due to climate change. During such weather, cyclists may benefit from planning decisions that increase thermal comfort such as shading, material choices or location away from infrastructure that increases urban heat effects.

The data also showed that cycling is highest from Tuesday to Thursday and lowest on Saturdays, Sundays and public holidays suggesting that most of the trips recorded are for work and education.

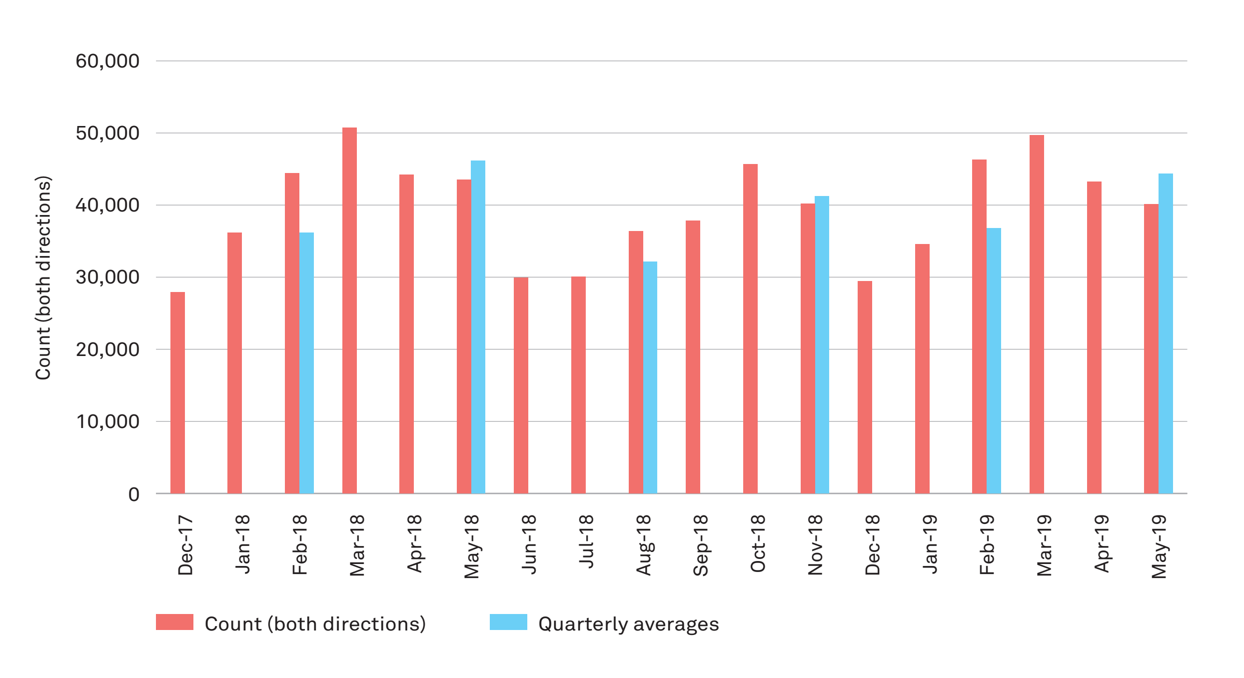


Figure 29:
Bike barometer counts, December 2017 to May 2019.

Data sourced from: Transport Canberra and City Services

Indicator HS5: Water resources

Water resources and consumption

This section examines the availability of water resources and the consumption of potable water in the ACT. For information on aquatic ecosystem health, water quality and river flows see section **5.6 Water**. Whilst some groundwater is used in the ACT for non-potable water supply, it is a small resource compared with surface water, and current use does not represent a risk to groundwater resources. Therefore, the use and availability of groundwater resources is not included in this section.

Water underpins almost every aspect of life and is a vital component for human health and wellbeing as well as the health of the ACT's landscapes and urban environments. The availability of water is key for residential supply, commercial and industrial activities, and agriculture. Water availability is also essential for supporting the ACT region's population growth.

The availability of water resources is largely determined by the spatial and temporal variability of rainfall, temperature and evaporation, as well as impacts of land use on catchment hydrology. Stream flows in the ACT are highly variable, with drier conditions punctuated by wet years that replenish water storages and river systems. Extended dry periods, such as the Millennium Drought, can lead to severely reduced surface water flows and storage levels in the ACT. While such conditions may necessitate restrictions on water use, it is important that water is used sustainably at all times to ensure secure levels of water resources prior to dry periods.

In response to the Millennium Drought, the ACT Government enlarged the Cotter Dam to increase water storage capacity for long-term droughts. Climate change is predicted to increase the frequency and severity of droughts and will have consequences for the ACT's water resources in the future (see section **5.1 Climate Change**).

Water consumption is determined by a range of factors including population, urban densification, changes in household usage, restrictions on use due to water availability, changes in demand due to rainfall, and water use by commercial, industrial and agricultural sectors (within consumptive entitlements).

Water reuse and recycling, both by households and larger users reduces the need to harvest water from the natural environment. In addition, the volume of wastewater that the community produces is relatively stable, so recycling provides a reliable source of water.

Point Hut Crossing, Murrumbidgee River. Source: Ryan Colley.

CASE STUDY
ACT'S URBAN WATER SUPPLY

The ACT draws water from three separate catchments (Figure 30):

- the Cotter River Catchment and its three reservoirs Cotter, Bendora and Corin.
- the Queanbeyan River Catchment which supplies Googong Dam in New South Wales (NSW).
- the Murrumbidgee River Catchment, via the Cotter Pumping Station and the Murrumbidgee to Googong water transfer.

Water storages in the ACT have a combined capacity of 278 gigalitres. This includes the Corin (70.8 gigalitres), Bendora (11.4 gigalitres) and Cotter (76.2 gigalitres) storage reservoirs on the Cotter River and the Googong (119.4 gigalitres) storage reservoir on the Queanbeyan River. The Googong reservoir is the largest water supply reservoir and represents 43% of the ACT's storage capacity.

The ACT sources water from each catchment depending on water availability, water quality, ability to meet demand, operational cost and infrastructure performance. Corin and Bendora reservoirs are the cheapest sources of water in the ACT due to their gravity-fed supply to the Stromlo water treatment plant and cleaner water requiring less treatment.

Water can also be sourced come from:

- Googong Reservoir: this is more expensive because the Googong water treatment plant is supplied from Googong Reservoir via pumps and the water quality from this rural catchment is not as good and requires more expensive treatment.
- Cotter Reservoir: pumping from the Cotter Dam to the Stromlo water treatment plant requires water to be moved to a higher elevation, resulting in higher pumping costs than Googong.
- Water can be pumped from the Murrumbidgee River to Googong Reservoir, but the combination of pumping and treating the poorer water quality from the Murrumbidgee River means that higher costs are incurred.

The use of various water sources in 2018 demonstrates the flexibility of the ACT's water supply. In response to significantly low rainfall in that year, Cotter Reservoir was used as the main source of supply and was supplemented by Bendora and Googong.

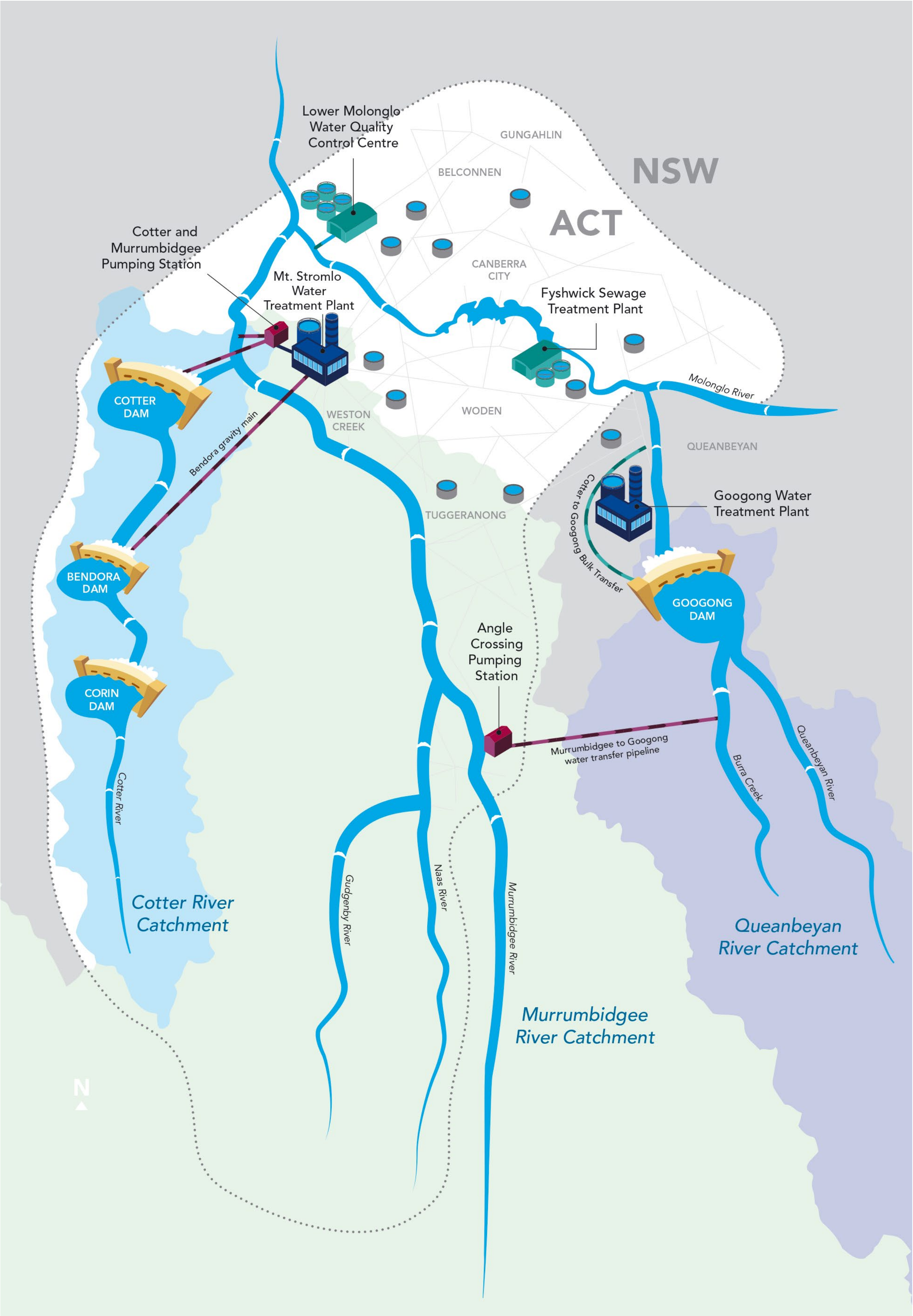


Figure 30:
The ACT's water supply network

Source: Icon Water

Water storage volume trends for the 2015–2019 period are presented below. Volumes are determined by inflows from rainfall, evaporation, the volume of water consumed, and spills and releases for environmental flows. This means that changes in the storage volumes of individual reservoirs will be highly variable, regardless of inflows. This is particularly the case for the Cotter catchment reservoirs which are generally the main sources for ACT's water. For example, during 2018–19, the Cotter catchment reservoirs provided 78% of the water supplied to the ACT and Queanbeyan, of which Bendora reservoir contributed 29% and the Cotter reservoir 49%.

Over the reporting period (2015 to 2019), storage volumes were variable for all ACT reservoirs in response to annual changes to inflows and water use (Figure 31). However, by June 2019 all reservoirs were at their lowest levels over the 5-year period:

- Corin reservoir fell to 24% (17 gigalitres) of capacity from a reporting period high of 62% in June 2017.
- Bendora reservoir fell to 44% (5.0 gigalitres) of capacity from a reporting period high of 92% in June 2015 and 79% in 2018. Bendora has the lowest total capacity of all the ACT's reservoirs and shows greater variation in response to inflow and outflow changes.
- Googong reservoir fell to 61% (73 gigalitres) of capacity from a report period high of 100% in June 2015 and 2016, and
- Cotter reservoir retained the highest volume, only falling to 82% (62 gigalitres) of capacity from a reporting period high of 98% in June 2017 and 2018.

At the end of June 2019, the ACT's four reservoirs were holding 57% (157 gigalitres) of the total ACT storage capacity (Figure 32). The enlargement of the Cotter Dam in 2013 increased the ACT's water storage by 72 gigalitres. In the absence of this increase, the combined ACT storages would have been around 30% of their total capacity – similar to levels during the Millennium Drought.

The water storage volumes between 2015 and 2019 are consistent with a long-term trend in reduced storage inflows. Available water resources have declined significantly in the past 20 years, with mean storage volumes 41% below the long-term average.[18]

The total inflows to the ACT's four drinking supply reservoirs from 2001–02 to 2018–19 are shown in Figure 33. For all but two years (2010–11 and 2011–12), inflows were below the long-term average. The total inflows during 2018–19 were 32 gigalitres, the lowest since records began in 1912, and 86% below the long-term average (228 gigalitres).

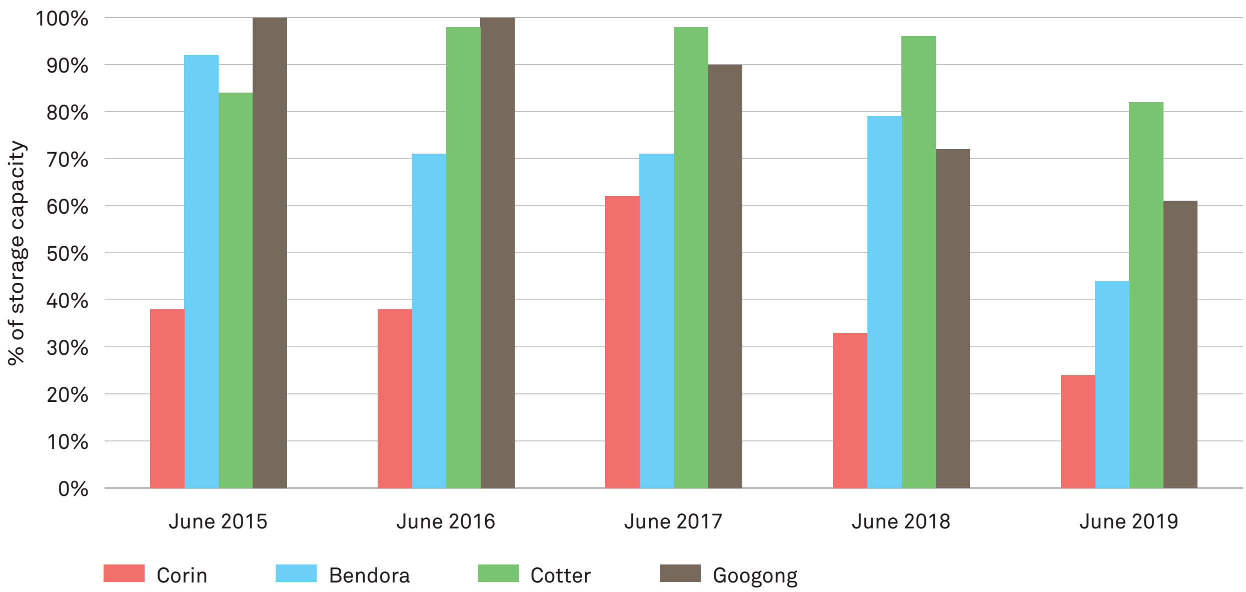


Figure 31:
Percentage of storage capacity for ACT reservoirs, June 2015 to June 2019.

Data sourced from: Icon Water

18 Source: Icon Water

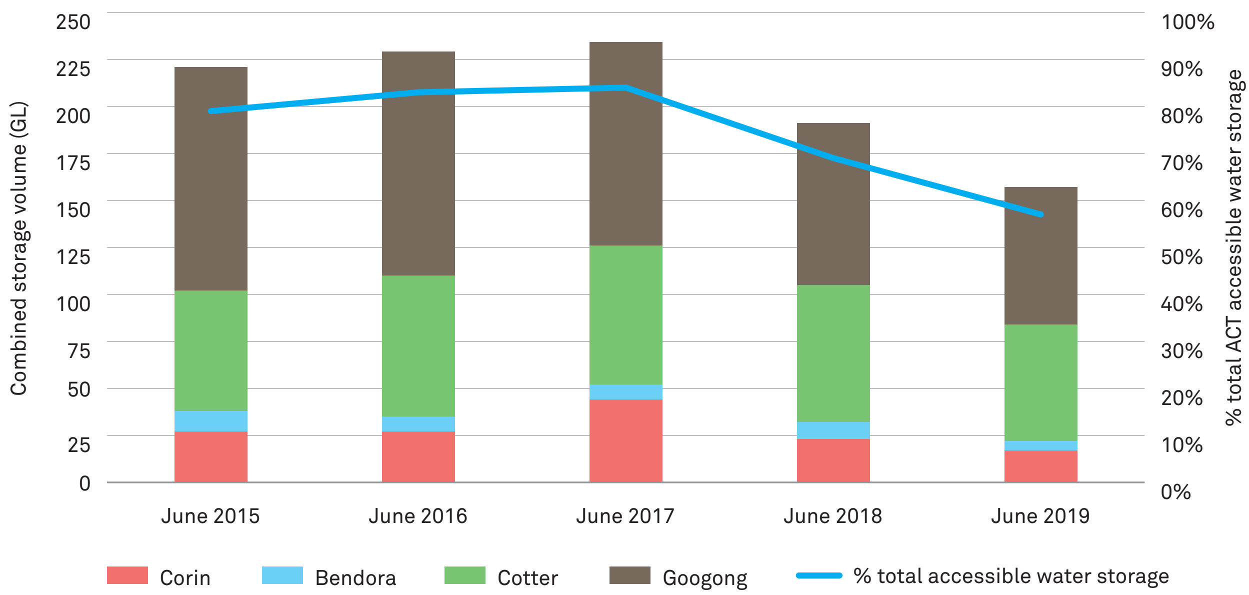


Figure 32:
Total storage volumes for ACT reservoirs, June 2015 to June 2019.

Data sourced from: Icon Water

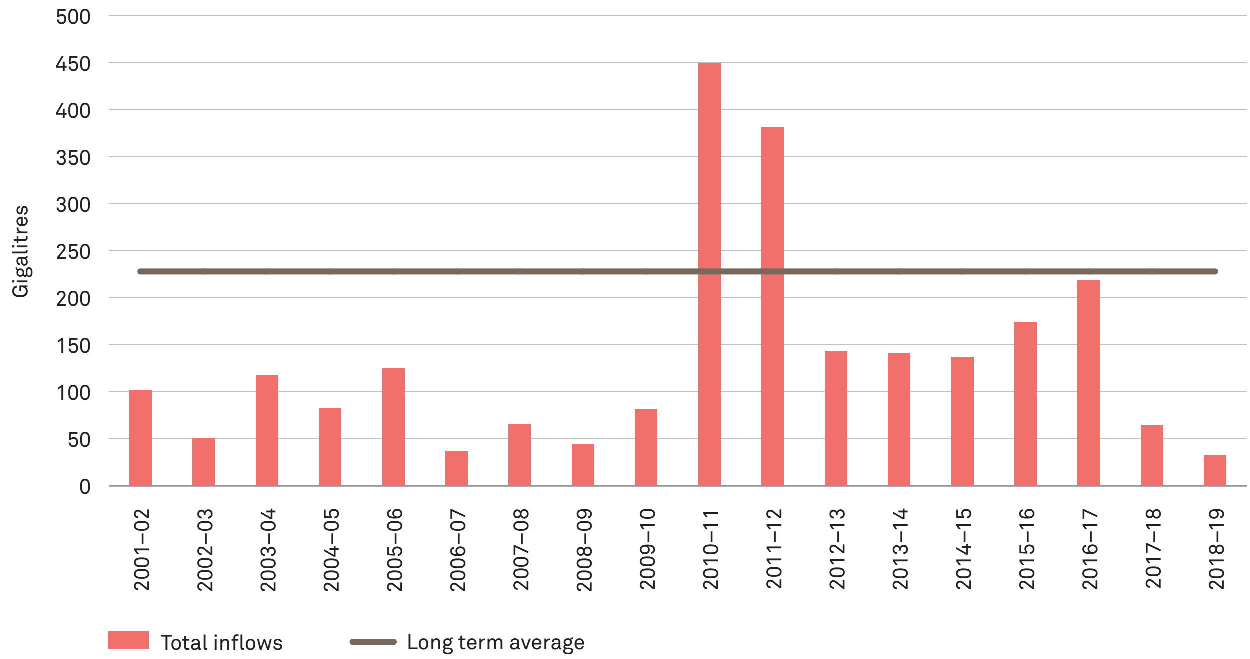


Figure 33:
Total inflows to the ACT's four water storage reservoirs, 2001–02 to 2018–19.

Data sourced from: Icon Water

Wastewater recycling

The Lower Molonglo Water Quality Control Centre (LMWQCC) non-drinking water scheme is the primary supply of non-drinking water in the ACT. Between 2009–10 and 2018–19, there was little variation in the ACT's wastewater recycling with volumes remaining around 4,000 megalitres to 4,500 megalitres (Figure 34). This represented around 12% to 17% of the ACT's total wastewater produced. The remaining treated wastewater from LMWQCC is either reused at the plant or is discharged into the Molonglo River providing environmental flows, protecting riverine ecosystems and providing for downstream use.

Wastewater recycling is largely dependent on the annual demand for such water and can also be affected by periods of high rainfall which can reduce the need for recycled water. There is currently low demand for recycled water in the ACT; however, if drought conditions continue, there may be a growing need for recycled water.

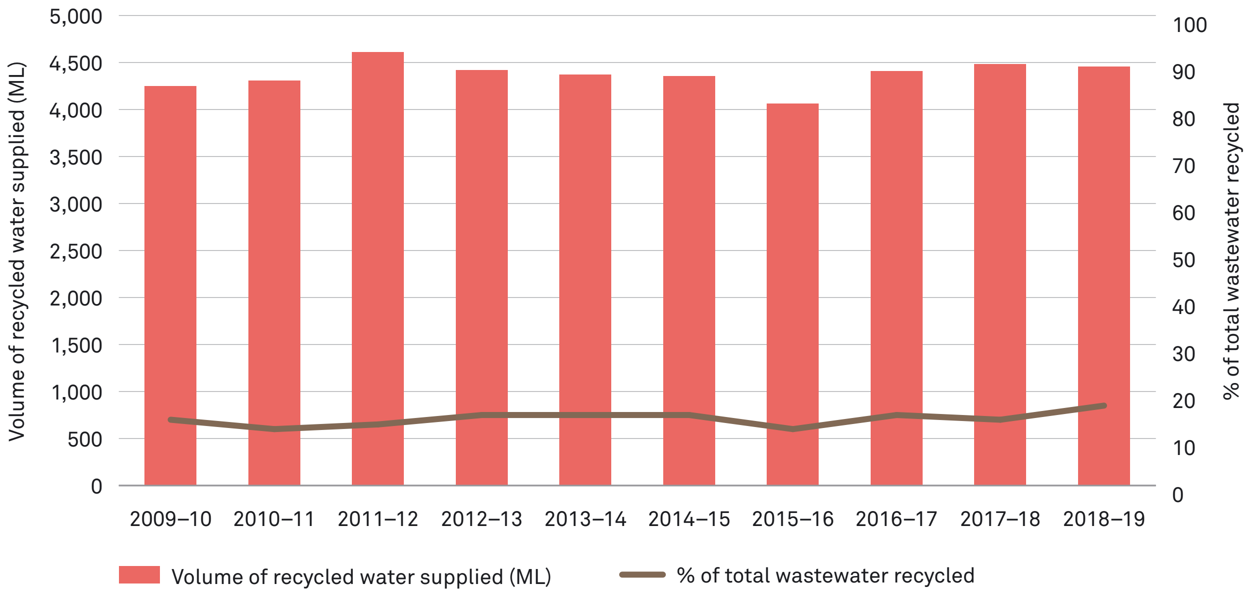


Figure 34:
Wastewater recycling in the ACT, 2009–10 to 2018–19.

Data sourced from: Icon Water

Indicator HS6: Water consumption

Potable water consumption in the ACT and Queanbeyan has remained fairly consistent since 2012–13, at around 50,000 megalitres per year (Figure 35). This consistent use has remained despite population growth in the ACT of around 1.7% per year. However, usage in 2017–18 was 54,000 megalitres, the highest volume over the past 10 years. This increase has been driven by hotter and drier weather conditions and is not considered indicative of an increasing trend in water usage.

The consistency in total annual water use since 2012–13 has occurred due to a decrease in per capita water use (Figure 36). Between 2001–02 and 2017–18, per capita water use dropped from 124 kilolitres per year, to 78 kilolitres per year, a decrease of around 37%. Although there are annual variations in annual per capita water use, the level has remained between 70 to 80 kilolitres per year since 2007–08. Reasons for the decrease in per capita consumption include:

- a significant cultural shift regarding attitudes to saving water in response to the Millennium Drought
- changes in landscaping to reduce irrigation
- the community understands and supports the importance of water conservation
- reduction in irrigated areas – smaller block sizes, larger houses and reduced outdoor space, less irrigation of playing fields and urban open spaces
- the shift towards urban densification has seen a transition away from freestanding single residential homes, which often have a garden
- water-sensitive urban design in buildings and developments
- water-efficient appliances and fittings, and
- the use of grey and rain water for irrigation has increased significantly.[19]

The ACT uses over 90% of the supplied water, with Queanbeyan using around 8% annually. Residential supply is responsible for most water use in the ACT, accounting for around 60% of the total supplied annually, which has remained consistent since 2008–09 (Figure 35). This means that most gains in water use efficiency can be made at the household level. Non-residential uses typically accounted for between 20% and 25% of the total water supplied annually.[20]

Cotter Dam. Source: OCSE.

19 Source: Icon Water

20 Non-residential usage includes the commercial and industrial sectors, city parks, hospitals and schools, and government buildings.

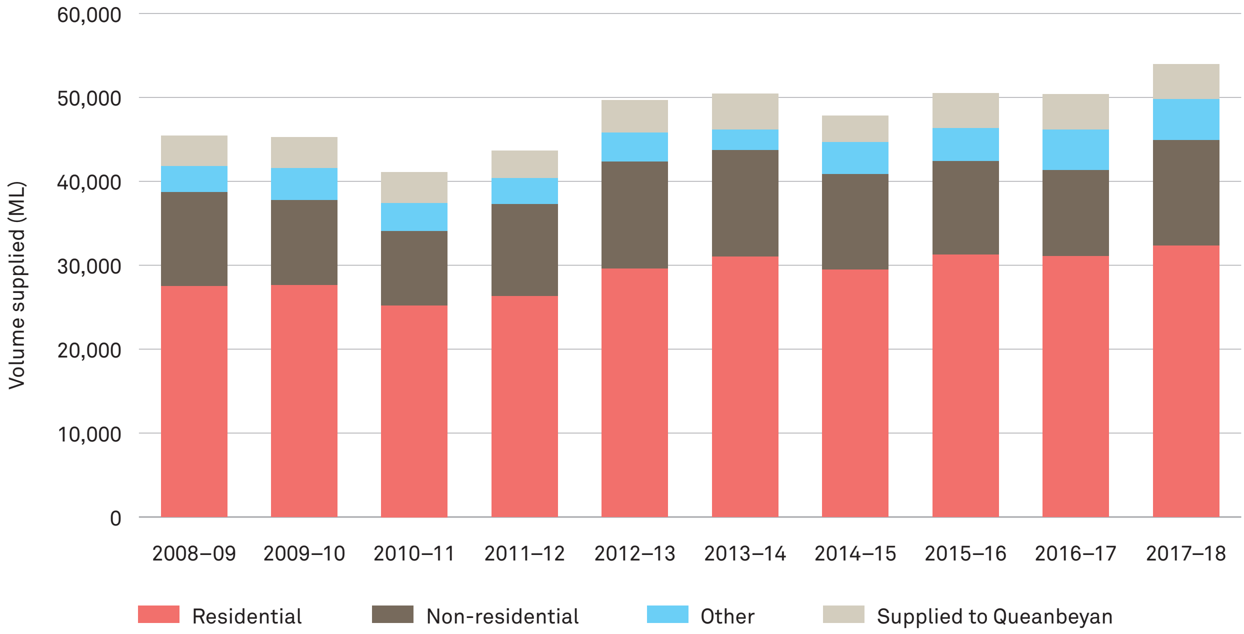


Figure 35:
Water consumption in the ACT by user, 2008–09 to 2017–18.

Data sourced from: Icon Water

Notes: Non-residential users include the commercial and industrial sectors, hospitals and schools, city parks, and government buildings. Other includes non-potable water, raw water, leakage, and the North Canberra Effluent Reuse Scheme

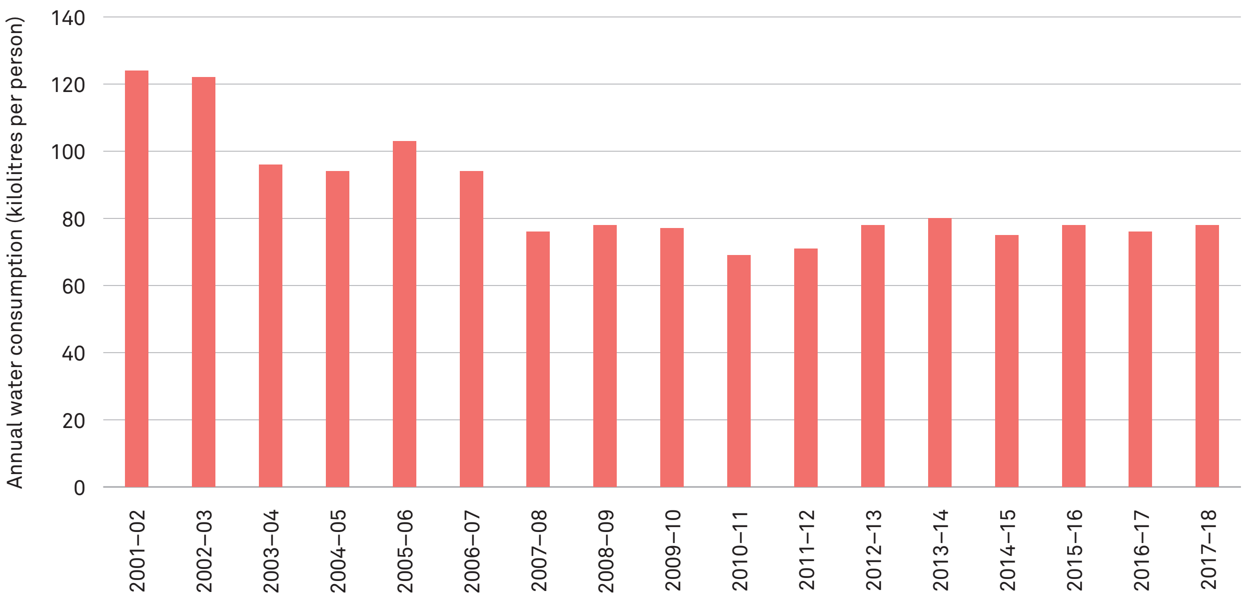


Figure 36:
Annual per capita water use in the ACT, 2001–02 to 2017–18.

Data sourced from: Icon Water

CASE STUDY
WATER SENSITIVE URBAN DESIGN

Supplied by Transport Canberra and City Services

Canberra is the largest city in the Murray–Darling Basin. Recent water quality issues in Canberra's lakes and waterways have reinforced the need for a more coordinated and improved approach to managing catchments in the ACT. Population growth, climate change, ageing infrastructure and residential development all increase the pressure on the Territory's water demand and water quality.

The ACT Government has been incorporating new or retro-fitted wetlands and ponds across the urban landscape. Wetlands and ponds create aquatic habitat for plants and animals, and improve water quality by removing nutrients and other pollutants from urban waterways. They also improve flood protection and capture stormwater for irrigating urban green spaces. Wetlands and ponds also provide many social benefits such as places for recreation and volunteering, and opportunities for education.

Together with other water-sensitive design measures, such as rainwater tanks, rain gardens and permeable paving, wetlands and ponds help slow down stormwater flows. This helps to retain and absorb more water into the landscape, recharge the groundwater system and protect downstream ecological systems. Water-sensitive urban design measures can support more streetscape vegetation to help mitigate the urban heat island effect and cool the landscape on hot summer days. More water-efficient household appliances, rainwater tanks and stormwater harvesting can reduce demand on our drinking water supplies and improve our water security for future droughts.

Sullivans Creek and Inner North Reticulation Network

The Sullivans Creek and Inner North Reticulation Network is a practical example of integrated water cycle management and water-sensitive urban design principles in action in Canberra. It is Canberra's first neighbourhood-scale stormwater harvesting and managed aquifer recharge system.

The scheme captures and treats urban stormwater in constructed wetlands, before pumping though a reticulation network for irrigation of urban green spaces. The scheme also includes managed aquifer recharge, which involves storing filtered stormwater in an underground aquifer during wetter periods for later retrieval and use during the peak irrigation season.

The scheme's infrastructure includes pipelines, pump stations, filtration systems, flow meters, valves, level sensors, water quality monitoring equipment, bores and a telemetry operation system. The end users have constructed tanks to receive and store the water before pumping it into their irrigation systems.

The Sullivans Creek and Inner North Reticulation Network is expected to deliver significant environmental, social and economic benefits, including:

- Protecting Lake Burley Griffin
  - Removing nutrient-rich stormwater from Sullivans Creek and using it for irrigation reduces nutrient loads and algal blooms in Lake Burley Griffin.
  - Reducing the stormwater flows into Sullivans Creek, thereby improving the regulation of inflows to Lake Burley Griffin.
- Reducing demands on our precious potable drinking water supply
  - Substituting high-quality drinking water currently used for irrigation with fit-for-purpose stormwater.
  - Improving the efficiency of water use for irrigators.
- Reliable stormwater supply and reduced costs of water
  - Storing filtered stormwater in an aquifer during cooler months replenishes the groundwater system and enables use during the peak irrigation season in the summer months.
  - Providing stormwater for irrigating urban green spaces provides a cheaper source of water compared to drinking water. The nutrients in stormwater can also represent a valuable resource for irrigation use, reducing the requirement for fertiliser.

The Sullivans Creek and Inner North Reticulation Network will be evaluated over a five-year trial period to inform future decisions regarding water-sensitive urban design, integrated water cycle management and the further potential for stormwater harvesting in the ACT.

Figure 37:
Inner North Stormwater Reticulation Network

Source: Transport Canberra and City Services

DATA GAPS

Energy

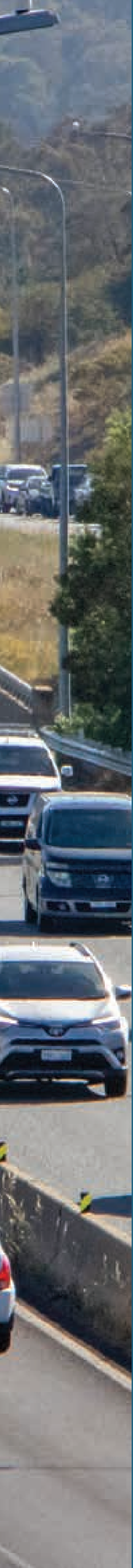
- Data on the ACT's energy use is not sufficient to enable a comprehensive assessment of the ACT's energy generation and consumption. This includes a lack of data on energy consumption for fuel types other than for electricity, and the consumption of energy by sector.

Waste

- Data is required on the level of resource recovery for each waste sector.
- Data is currently unavailable for the amount and type of waste exported to other jurisdictions.
- There is incomplete reporting of waste managed by waste industry participants operating within the ACT. This is because current regulatory arrangements do not require complete reporting – only voluntary reporting arrangements are in place.
- The lack of comprehensive and consistent waste data makes it difficult to assess waste trends in the ACT. This has implications for the review of current policy effectiveness and the development of future policies, programs and infrastructure.
- Changes to regulatory arrangements to ensure tracking of waste through to its final destination and to implement mandatory reporting need to be developed to achieve the required quality of data.

Urban development with rooftop solar panels. Source: Ryan Colley

5.3 AIR



Section contents

Air quality in the ACT 2015–18

All levels of air pollution are associated with adverse health effects

$PM_{2.5}$

is the most serious air quality issue in the ACT

31 exceedances of the air quality standard for $PM_{2.5}$

28 exceedances in the Tuggeranong Valley

24 exceedances from wood heater smoke

CO O_3 NO_2

ZERO

exceedances of air quality standards for CO, NO_2 and ozone

wood heaters have the greatest impact on ACT's air quality

controlled burns, bushfires and dust storms impact on air quality and are likely to increase with climate change

transport emissions are responsible for most of the year round ambient air pollution

NOISE

is a significant problem, responsible for **80%** of complaints to the EPA over the 2017–18 and 2018–19 period

Indicator assessment

Indicator	Status	Condition	Trend	Data quality
A1: Compliance with air quality standards	With the exception of particulate matter ($PM_{2.5}$) air quality levels were compliant with the with National Environment Protection (Ambient Air Quality) Measure standards. $PM_{2.5}$ remains a concern for the Tuggeranong Valley, particularly given the current consensus that there is no safe concentration of particles for sensitive people. Smoke from wood heaters is the main cause of $PM_{2.5}$ exceedances in the ACT.	Fair	–	● ● ● High
A2: Health impacts of air pollution	There is currently no data available on the impacts of air pollution on human health in the ACT, nor the associated costs to the health system and the economy. Current expert and research consensus suggests that air pollution, even at concentrations below the current air quality standards, is associated with adverse health effects.	Unknown	?	● ○ ○ Low
A3: Emissions of major air pollutants	Data on the sources and emissions of diffuse source air pollution, which make up the majority of emissions in the ACT, has not been updated since 1999. In the absence of current data it is not possible to assess changes in air pollution emissions over the reporting period. The ACT's annual monitoring and reporting activities for point source (industry) emissions complied with the National Environment Protection National Pollutant Inventory Measure over the reporting period.	Unknown	?	● ○ ○ Low
A4: Amenity	Over the 2017–18 and 2018–19 periods, the EPA received 5,562 environmental complaints. Concerns about noise were responsible for 80% of all complaints and is clearly a significant issue for the ACT community. Amplified noise was the source of most noise complaints. Air pollution received the second highest number of complaints (13%), with smoke the source of most complaints. With only 2 years of data available, it is not possible to assess trends over the reporting period.	Unknown	?	● ○ ○ Low

Indicator assessment legend

Condition

- **Good** = Environmental condition is healthy across the ACT, **OR** pressure likely to have negligible impact on environmental condition/human health.
- **Fair** = Environmental condition is neither positive or negative and may be variable across the ACT, OR pressure likely to have limited impact on environmental condition/human health.
- **Poor** = Environmental condition is under significant stress, OR pressure likely to have significant impact on environmental condition/ human health.
- **Unknown** = Data is insufficient to make an assessment of status and trends.
- **NA** = Assessments of status, trends and data quality are not appropriate for the indicator.

Trend

- ↑ Improving
- ↓ Deteriorating
- – Stable
- ? Unclear
- **NA** = Assessments of status, trends and data quality are not appropriate for the indicator.

Data quality

- ● ● ● **High** = Adequate high-quality evidence and high level of consensus
- ● ● ○ **Moderate** = Limited evidence or limited consensus
- ● ○ ○ **Low** = Evidence and consensus too low to make an assessment
- ○ ○ ○ **NA** = Assessments of status, trends and data quality are not appropriate for the indicator.

Key actions

That the ACT Government:

ACTION 1: continue to promote the replacement of wood heaters, particularly in the Tuggeranong Valley.

ACTION 2: increase the community's uptake of pubic and active transport to reduce private vehicle emissions.

ACTION 3: increase the number of National Environment Protection (Ambient Air Quality) Measure compliant air quality monitoring stations to improve the assessment of localised air pollution issues.

ACTION 4: improve knowledge of the impacts of air pollution on human health and associated costs to the health system and economy.

ACTION 5: undertake an assessment of air pollutant emissions from diffuse sources to update the National Pollutant Inventory data from 1999.

Main findings

Air quality over the reporting period (2015 to 2018)

- $PM_{2.5}$ is the most serious air quality issue for the ACT with levels that are likely to have health implications for sensitive individuals.
- Over the reporting period, there were 31 exceedances of the daily National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM) standard for $PM_{2.5}$. The Monash station accounted for 28 of the exceedances.
- Exceedance results show that $PM_{2.5}$ pollution is far more likely in the Tuggeranong Valley.
- Smoke from wood heaters accounted for 23 (82%) of Monash station exceedances. For the Florey station, there was one exceedance due to wood heaters. All other exceedances were caused by controlled burns and dust storms.
- High $PM_{2.5}$ levels and annual variations are likely due to the occurrence of calm autumn and winter days which increase the accumulation of urban pollution from wood heaters.
- The replacement of wood heaters with energy-efficient electric heating is critical to improve air quality in the ACT, particularly in the Tuggeranong Valley.
- Over the reporting period, there were no exceedances of AAQ NEPM standards for Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), ozone (O_3) and particulate matter less than 10 micrometres in size (PM10).
- Dust storms, controlled burns and bushfires will continue to cause deterioration in air quality in the ACT. These will vary from year to year depending on weather conditions.
- Climate change is likely to increase the frequency and severity of smoke and dust impacts on air quality, and increased ozone formation.

Health impacts of air pollution

- There is currently no data available on the impacts of air pollution on human health in the ACT, nor the associated costs to the health system and the economy.
- Current expert and research consensus suggests that air pollution, even at concentrations below the current air quality standards, is associated with adverse health effects.
- In recognition of health impact evidence, national standards are moving towards the position that there is no safe concentration for sensitive people, especially for particles (PM_{10}, $PM_{2.5}$).
- Any reduction in air pollution will result in health benefits, even where pollutant concentrations are within the air quality standards.

Emissions of air pollutants

- Data on the sources and emissions of diffuse source air pollution has not been updated since 1999. In the absence of current data it is not possible to assess changes in air pollution emissions over the reporting period.
- Diffuse sources of air pollutants, especially from transport and wood heaters, are known to be the main contributors to air pollution in the ACT.
- The monitoring and reporting of point source emissions is required under the National Environment Protection National Pollutant Inventory Measure (NPI NEPM). The ACT's monitoring and reporting activities complied with the NPI NEPM over the reporting period (2015 to 2018).

Amenity

- Over the 2017–18 and 2018–19 period, the ACT Environment Protection Authority (EPA) received 5,562 environmental complaints.
- Noise issues were responsible for 80% of all complaints and is clearly a significant problem for the ACT community.

INTRODUCTION

This section provides an assessment of air quality, the impacts of air pollution on human health, the sources and emissions of air pollutants, and amenity. The following indicators are assessed:

- A1: Compliance with air quality standards
- A2: Health impacts of air pollution
- A3: Emissions of major air pollutants
- A4: Amenity

For the emissions of greenhouse gases see section **5.1 Climate change**.

Air quality

Air quality is one of the most tangible indicators of the state of our local environment, and directly affects human health and wellbeing. If air pollutants reach high enough concentrations, they can endanger human health and the environment. Clean air is associated with better physical and mental health, longer life and significant financial savings from reduced health-care expenses and work absences. Clean air is also essential for biodiversity and ecosystem health.

The sources of air pollution in the ACT and their impacts on health are shown in Figure 1.

Currently, the main sources of air pollution in Canberra are wood heaters, motor vehicles (especially diesel exhaust), wind-blown dust, bushfires, planned burning activities and industry. Everyday choices, such as driving cars and burning wood for domestic heating, can have a significant impact on air quality.

Air quality is primarily of concern in areas with high concentrations of population, transport and industrial activities. Such areas can experience localised air quality problems which have the potential to cause adverse health impacts.

Higher temperatures and reduced rainfall associated with climate change is likely to increase the impact of smoke and dust on air quality. Planned burning measures to reduce the severity of bushfires is also likely to increase smoke impacts. In addition, higher temperatures are likely to increase ozone formation.

Pollen concentrations are also a challenge in the ACT, which was reported to have the highest rate of allergic rhinitis in Australia (29% of the population) in 2017–18.[1] For more information see the *Health impacts of pollen and spores* case study at the end of the Air section.

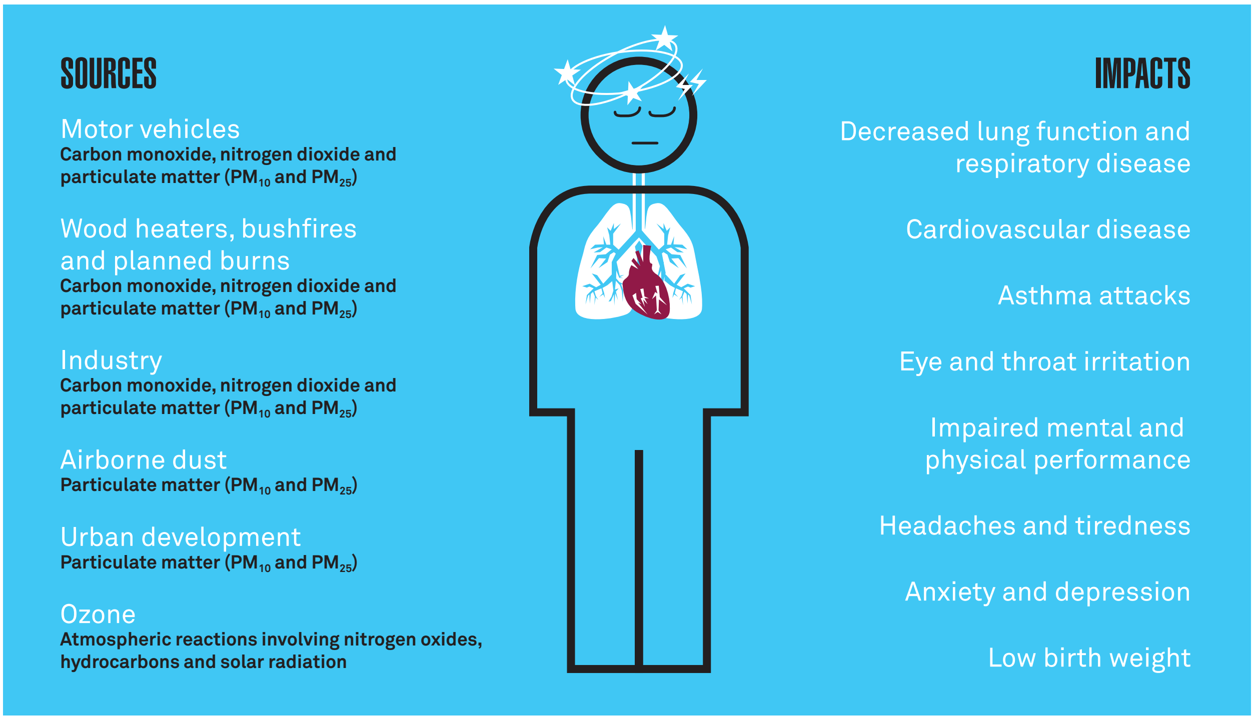


Figure 1:
Sources of air pollution and impacts on human health

1 Australian Bureau of Statistics, 2018, *National Health Survey: First Results, 2017–18*, ABS cat. no. 4364.0.55.001, Canberra.

Amenity

Amenity refers to environmental nuisance, such as the occurrence of noise, smoke, dust, light and pollution incidents. These can interfere with daily activities and the quality of life by impacting on the quiet enjoyment of households (for example, the ability to sleep, study, relax and use outdoor space) and use of recreational areas. Impacts on amenity can have significant health consequences such as sleep deprivation, as well as economic consequences such as the ability to work.

Identification of deterioration in amenity comes from community complaints received by the ACT government. The number of complaints is dependent on a range of factors such as the sensitivity of community members to particular issues, and the number of complaints made about each individual event. Consequently, it is difficult to assess trends in amenity. Despite this, complaints data does provide information on the everyday environment concerns of the ACT community.

DATA TRENDS

Indicator A1: Compliance with air quality standards

Measuring air quality in the ACT

The ACT's air quality monitoring network has only two National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM) compliant monitoring stations at Monash and Florey. The Monash station is situated in the Tuggeranong Valley, the Florey station in Belconnen (Figure 2). A third station at Civic does not satisfy AAQ NEPM compliance requirements and is not reported here. The Florey station was established in February 2014 to comply with AAQ NEPM monitoring requirements for the ACT's growing population.

The National Environment Protection Council (NEPC) sets ambient air quality reporting standards and goals through the AAQ NEPM. This AAQ NEPM prescribes targets for pollutants in ambient air, as well as the methods that should be used to monitor the pollutants. The ACT EPA reports annually against the AAQ NEPM standards and goals. Compliance with the AAQ NEPM standards ensures that the ACT is achieving the national environment protection standards for ambient air quality and that monitoring of AAQ NEPM pollutants is being undertaken appropriately.

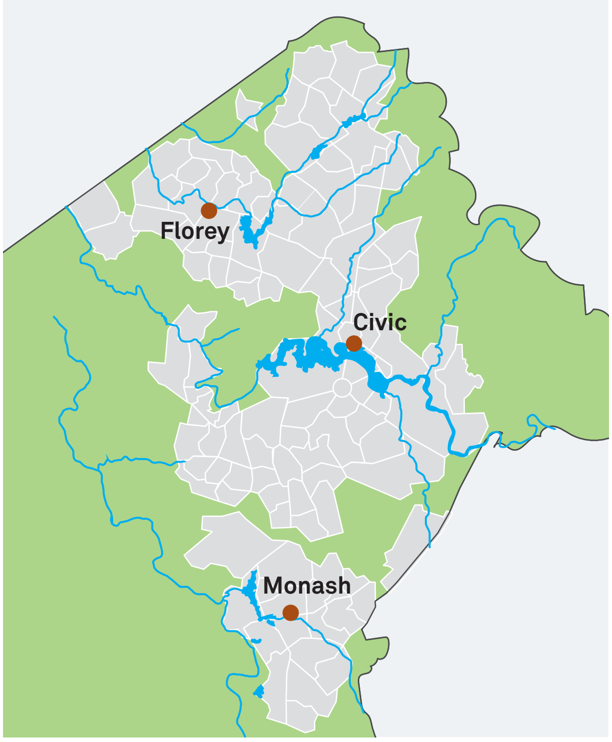


Figure 2:
Air quality monitoring stations in the ACT.
Data sourced from: ACT Health Directorate

The pollutants included in the AAQ NEPM are:

- carbon monoxide (CO)
- lead
- nitrogen dioxide (NO_2)
- ozone
- sulfur dioxide
- particulate matter less than 10 micrometres in size (PM_{10})
- particulate matter less than 2.5 micrometres in size ($PM_{2.5}$).[2]

The ACT monitors the levels of CO, NO_2, ozone, PM_{10} and $PM_{2.5}$ in ambient air. The ACT does not monitor sulfur dioxide due to the lack of heavy industry in the region, and lead levels have not been monitored since the phase-out of leaded petrol in 2002.

To comply with the AAQ NEPM, the ACT Government must demonstrate that air quality meets the specified standards (Table 1). For PM_{10}, the ACT Government has set a lower annual standard of 20 µg/m^3, as opposed to the NEPM standard of 25 µg/m^3. Poor air quality arising from fire (both unplanned and controlled burns), or pollution events such as dust storms, are excluded from AAQ NEPM compliance assessments.

Information on air quality monitoring and annual results can be found in the ACT Air Quality Reports.[3]

2 The $PM_{2.5}$ standard came into effect in February 2016. Before this date, the $PM_{2.5}$ standard was advisory only.
3 Environment Protection Authority, 2019, *ACT Air Quality Report 2018*, ACT Government, Canberra.

Table 1:
National Environment Protection (Ambient Air Quality) Measure standards and goals

Pollutant	Averaging Period	Maximum concentration	Maximum allowable exceedances
Carbon monoxide	8 hours	9.0 ppm	1 day a year
Nitrogen dioxide	1 hour	0.12 ppm	1 day a year
	1 year	0.03 ppm	None
Photochemical oxidants (as ozone)	1 hour	0.10 ppm	1 day a year
	4 hours	0.08 ppm	1 day a year
Particles as PM_{10}	1 day	50 µg/m^3	None
	1 year	25 µg/m^3	None
Particles as $PM_{2.5}$	1 day	25 µg/m^3	None
	1 year	8 µg/m^3	None

Notes: µg/m3 = micrograms per cubic metre; $PM_{2.5}$ = particulate matter less than 2.5 micrometres; PM_{10} = particulate matter less than 10 micrometres; ppm = parts per million.

Air pollutant levels in the ACT

Interpreting the data

The concentration of air pollutants depends on several factors, including the rate of emissions, the weather and the topography of the area. For example, wood smoke levels are more pronounced in winter in the Tuggeranong Valley than in other areas of the ACT largely because of the topography of the area. These factors need to be taken into account when interpreting monitoring results.

Particulate matter less than 2.5 micrometres in size ($PM_{2.5}$)

PARTICULATE MATTER

Smoke from domestic wood heaters, controlled burns and bushfires, are the most significant sources of particulate matter in the ACT. Particle pollution is also produced by industry and motor vehicle emissions. Particle pollution can also result from anthropogenic sources (smoke from wood heaters and controlled burning, motor vehicles – particularly diesel, and industry) and natural sources (dust storms, bushfires and pollen). Particle pollution is usually the community's main indicator of air quality, as it is often evident as a haze which reduces visibility. Climate change is likely to increase the occurrence of particle pollution with conditions leading to dust storms and more prevalent fires.

Particle pollution is the most significant air quality problem in the ACT with high levels associated with respiratory and cardiovascular illness. Current research suggests that there is no level of PM at which health impacts do not occur. The specific effect of a particle on health depends on its size, composition and concentration. Particles are associated with increased respiratory symptoms, aggravation of asthma, increased mortality and hospital admissions for heart and lung diseases.

The most common measures of particles are PM_{10} (particulate matter that is 10 micrometres or less in diameter) and $PM_{2.5}$ (particulate matter that is 2.5 micrometres or less in diameter). In comparison, a human hair is about 100 micrometres in diameter. Particles smaller than 2.5 micrometres are considered to have more significant health impacts due to their deeper penetration into the lungs.

Because the $PM_{2.5}$ standard came into effect in February 2016, all prior exceedances for $PM_{2.5}$ are for the advisory standard only. However, there is no difference between the previous advisory standard and the current $PM_{2.5}$ standard, so all annual exceedances are comparable regardless of reporting year.

There were 31 exceedances of the daily AAQ NEPM standard for $PM_{2.5}$ recorded over the reporting period (2015 to 2018). This included:

- 28 exceedances for the Monash station – 6 in 2015, 8 in 2016, 12 in 2017, and 2 in 2018 (Figures 3 and 4).
- Three for the Florey station – 1 in 2016, 2 in 2018 (Figure 4).

These results show that $PM_{2.5}$ pollution is far more likely in the Tuggeranong Valley. In addition, exceedances have occurred at the Monash station in every year since 2009.

For the Monash station between 2015 and 2018, there were 23 exceedances due to smoke from wood heaters, 4 from controlled burns and 1 from a dust storm event (Figure 4). For the Florey station, there was one exceedance due to smoke from wood heaters, one from controlled burning, and one from a dust storm event. Natural events such as dust storms, controlled burns and bushfires, which cannot be controlled through normal air quality management programs, are not included in the assessment of AAQ NEPM standard compliance.

Results for annual average $PM_{2.5}$ levels for the Monash station and the Florey station are both compliant with the AAQ NEPM standard of 8 μg/m^3 (Figure 5). However, the annual average levels recorded for Monash station over the reporting period were between approximately 85% and 96% of the standard. For Florey, annual average levels were between approximately 81% and 93% of the standard. This shows that whilst $PM_{2.5}$ levels are within the AAQ NEPM standard, they are closer to exceeding the annual standard than for other monitored pollutants.

Overall, results show no long-term trends in $PM_{2.5}$ levels. High levels and annual variations are likely due to the occurrence of calm autumn and winter days which increase the accumulation of urban pollution from wood heaters.

It is clear that $PM_{2.5}$ is the most serious air quality issue for the ACT with levels that are likely to have health implications for sensitive individuals.

Impact of wood heaters on air quality

The replacement of wood heaters with energy efficient electric heating is critical to improving air quality in the ACT, particularly in the Tuggeranong Valley. Wood heaters were responsible for 82% of the daily $PM_{2.5}$ exceedances from the Monash station between 2015 and 2018. Seasonal averages for the Monash station clearly show the impact of wood heaters on $PM_{2.5}$ levels (Figure 6). During the late autumn and winter months, $PM_{2.5}$ levels were elevated in response to peak wood heater usage.

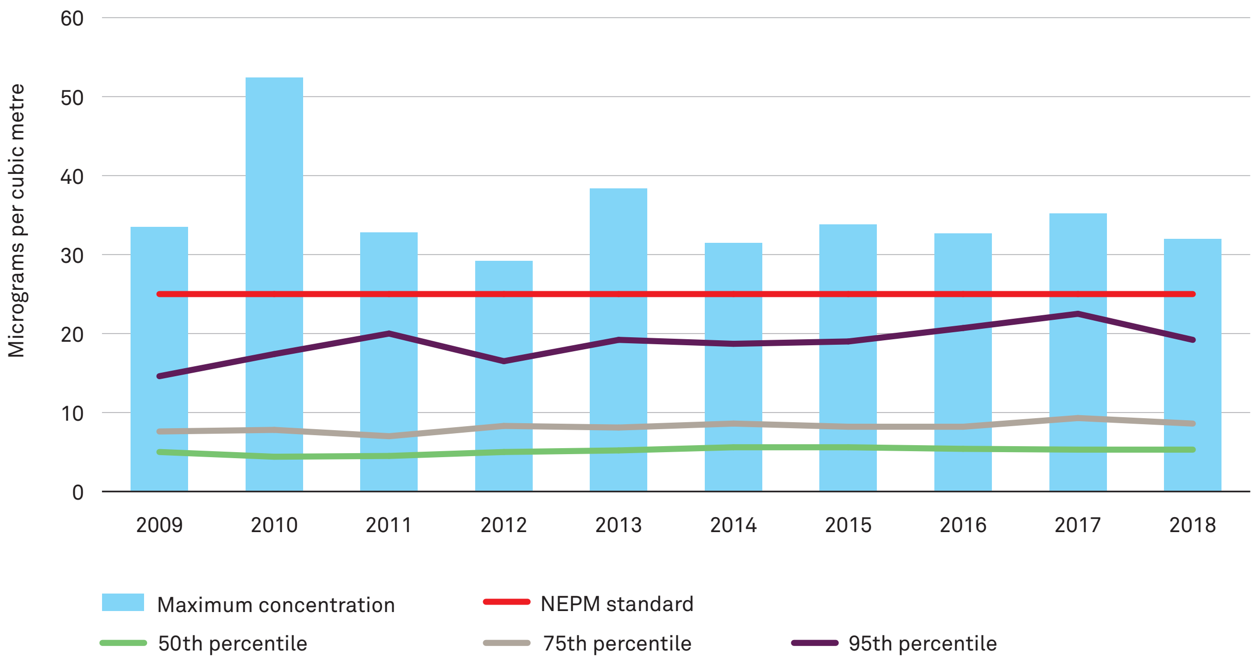


Figure 3:
Daily maximum $PM_{2.5}$ levels, Monash station, 2009–2018

Data sourced from: ACT Health Directorate

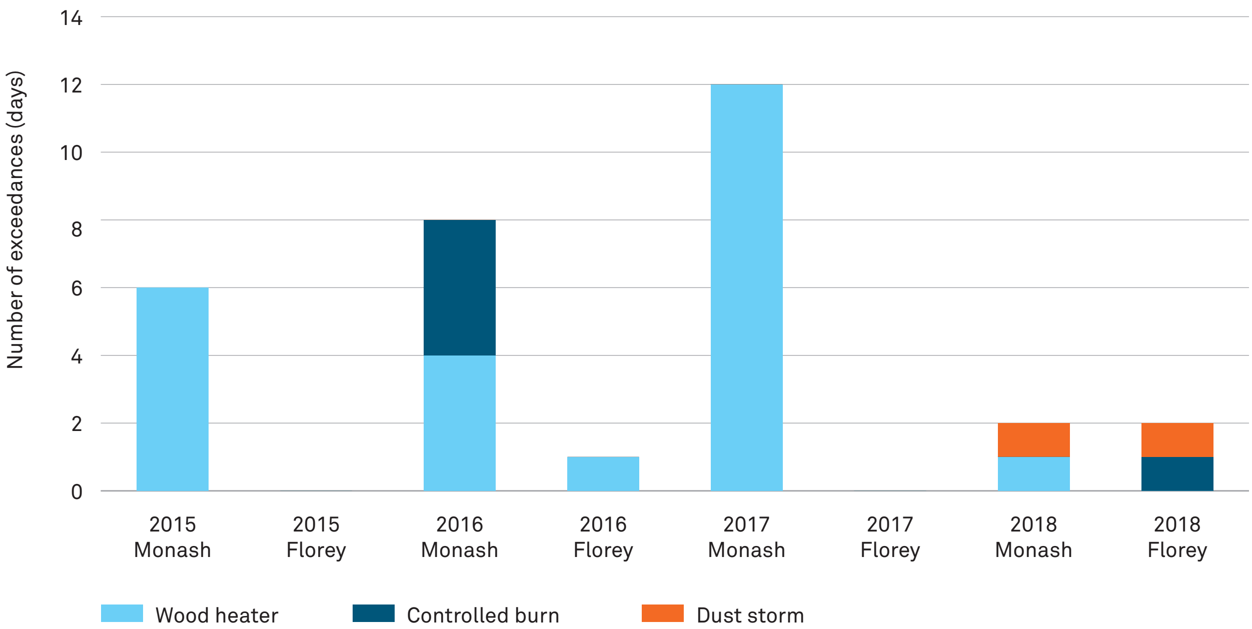


Figure 4:
Number of $PM_{2.5}$ exceedances by cause, Monash and Florey stations, 2015–2018.
Data sourced from: ACT Health Directorate

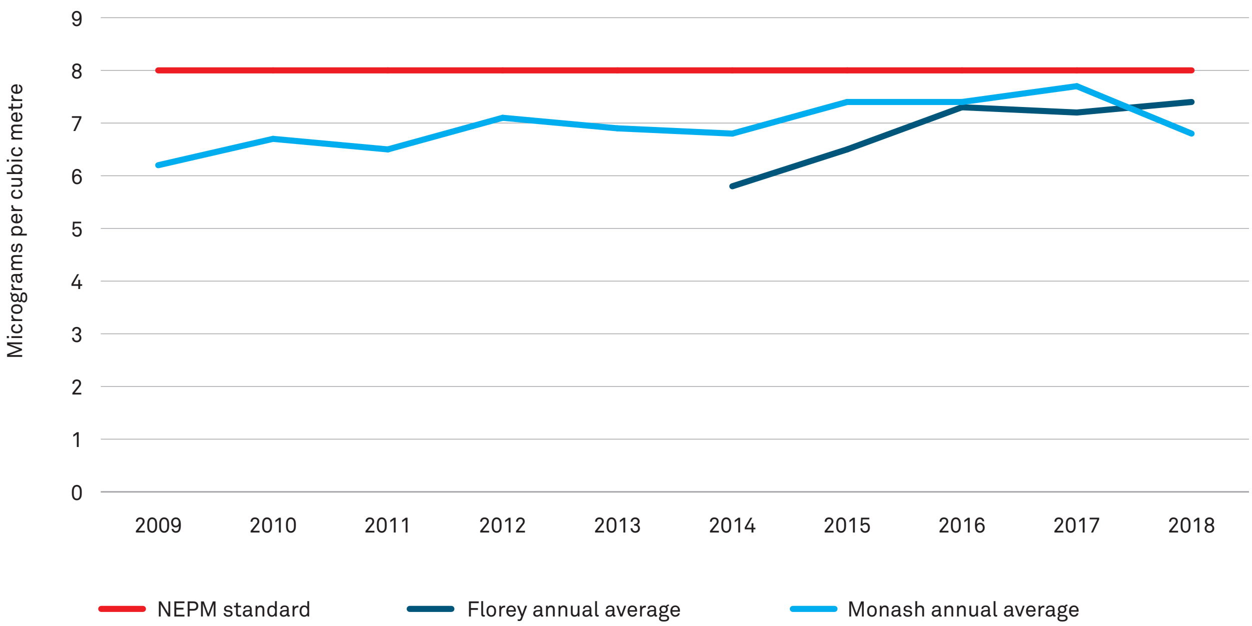


Figure 5:
Annual average $PM_{2.5}$ levels: Monash station (2009–2018) and Florey station (2014–2018).
Data sourced from: ACT Health Directorate

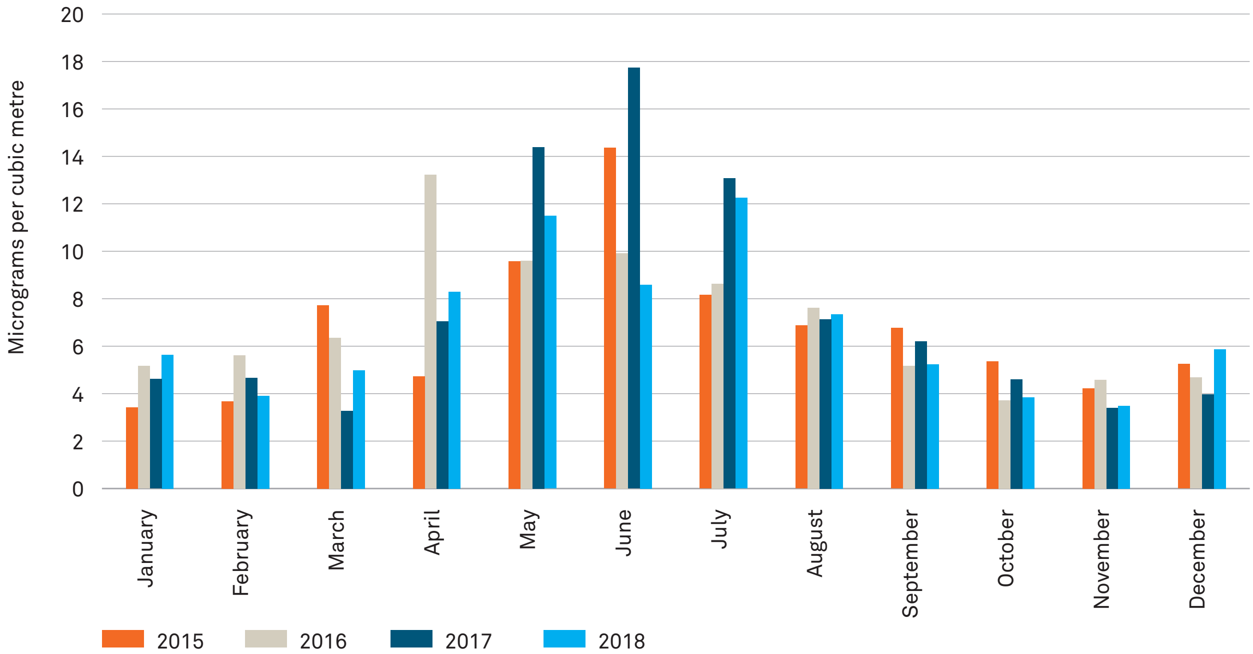


Figure 6:
Monthly average daily maximum $PM_{2.5}$ levels, Monash station, 2009–2018.

Data sourced from: ACT Health Directorate

Note: High monthly average in April 2016 due to controlled burns.

Particulate matter less than 10 micrometres in size (PM_{10})

There were 8 exceedances of the daily AAQ NEPM standards for PM_{10} recorded during the reporting period. This included 4 exceedances for the Monash station in 2018, and 4 exceedances for the Florey station (1 in 2015 and 3 in 2018). All of the exceedances were due to dust storms. Natural events such as dust storms, controlled burns and bushfires, which cannot be controlled through normal air quality management programs, are not included in the assessment of AAQ NEPM standard compliance. With the exclusion of dust storms, results for PM10 are compliant with the AAQ NEPM standard for both the Monash and Florey stations.

Overall, results show no long-term trends in PM_{10} levels, with events such as dust storms, controlled burns and bushfires responsible for increased levels.

Ozone

OZONE

Ozone is not directly emitted into the air; it is formed when volatile organic compounds (from industry, vehicles and vegetation) and oxides of nitrogen (from industry, vehicles and natural gas use) react in sunlight. These reactions only produce significant amounts of ozone on warm sunny days with light or recirculating winds. Ozone can also form downwind of bushfires when the chemicals in smoke react in the presence of sunlight. In the future, the higher temperatures predicted as a result of climate change are likely to lead to a greater potential for ozone formation.

Human exposure to high concentrations of ozone can result in decreased lung function, increases in asthma attacks, and increases in hospital admissions for people with heart and lung conditions. Higher levels of ozone can also affect vegetation growth and ecosystems.

There were no exceedances of the daily maximum 1-hour and 4-hourly AAQ NEPM standards for ozone recorded during the reporting period for both the Monash and Florey stations. Despite this, 4-hourly maximum levels recorded for Monash station during the reporting period were between approximately 60% and 70% of the standard. Such levels may have health implications for sensitive individuals. Maximum results for the Florey station are also similar, with the exception of 2015 which was lower than Monash.

Overall, results show no long-terms trends in ozone levels, with annual variations in maximum concentrations likely due to hazard reduction burns in the region.

Carbon monoxide CO

CARBON MONOXIDE

Carbon monoxide (CO) is mainly produced from vehicle engine exhaust. High levels of CO can affect human health, especially for children, the elderly and those with asthma. Very high levels of CO may cause health problems for birds and animals. CO also plays a role in climate change. Although CO is a weak greenhouse gas, it can affect the concentrations of other stronger greenhouse gases, including carbon dioxide and methane.

Despite vehicle exhaust being the primary source of CO in the ACT, progressive improvement in motor vehicle emissions has meant that levels of CO have not increased with the growth in traffic over time.

There were no exceedances of AAQ NEPM standards for CO recorded during the reporting period for both the Monash station and the Florey station. All levels recorded were well within the compliance range. There was also little difference in CO levels between the stations.

Overall, CO levels appear to be slightly declining, likely due to improvements in vehicle emissions which are the main source of CO pollution in the ACT.

Nitrogen dioxide NO_2

NITROGEN DIOXIDE

Nitrogen dioxide (NO_2) is mainly produced from vehicle engine exhaust. NO_2 is also produced by the burning of fuels such as natural gas and diesel. NO_2 is harmful to human health, especially for children, the elderly and those with asthma. Low levels of NO_2 can irritate the eyes, nose, throat and lungs of humans and animals. Very high levels of NO_2 can affect the environment by killing plants and roots, and damaging the leaves of agricultural crops. Very high levels of NO_2 can also cause an increase in rain acidity, which can harm ecosystems.

Despite vehicle exhaust being the primary source of NO_2 in the ACT, progressive improvement in motor vehicle emissions has meant that levels of NO_2 have not increased with the growth in traffic over time.

There were no exceedances of AAQ NEPM standards for NO_2 recorded during the reporting period for either the Monash or Florey stations. All levels recorded were well within the compliance range. There was also little difference in NO_2 levels between the stations.

Overall, results show that NO_2 levels appear to be stable, with some slight annual variations in maximum concentrations.

Indicator A2: Health impacts of air pollution

There is currently no data available on the impacts of air pollution on human health in the ACT, nor the associated costs to the health system and the economy. At the time of writing this report, the Office of the Commissioner for Sustainability and the Environment (OCSE) was unable to obtain data on doctor visits and hospital admissions during periods of poor air quality, or data on increases in respiratory and cardiovascular problems associated with periods of poor air quality.

Polluted air causes a range of short and long-term negative health outcomes. The common air pollutants present in the ACT – particles, nitrogen dioxide, carbon monoxide and ozone – are all associated with a range of harmful effects on human and environmental health.

The impacts of air pollution on human health is dependent on a range of factors including exposure level and the age and background health status of individuals. Many people, such as those with chronic respiratory conditions, are at greater risk of experiencing adverse health events when exposed to poor-quality air. Cardiovascular and respiratory complaints are some of the most common effects, with acute cases resulting in increased doctor and hospital visits, and even death in extreme cases.

The AAQ NEPM standards are designed to adequately protect human health and wellbeing. However, there is a large body of evidence that demonstrates that air pollution, even at concentrations below the current air quality standards, is associated with adverse health effects.[4] The strongest evidence relates to premature mortality and effects on the respiratory and cardiovascular system. Particulate matter is estimated to be the individual pollutant responsible for the largest burden of disease from outdoor pollution.

In recognition of the evidence on health impacts, national standards are moving towards the position that there is no safe concentration for sensitive people, especially for particles (PM_{10}, $PM_{2.5}$). In 2013, the International Agency for Research on Cancer classified outdoor air pollution and particulate matter as carcinogenic to humans.[5]

Any reduction in air pollution will result in health benefits, even where pollutant concentrations are within the air quality standards.

Indicator A3: Emissions of major air pollutants

Knowledge on the sources of air pollutants is important for the management of air pollution. The sources and amounts of pollutants emitted into the atmosphere are influenced by many factors including population, economic activity, prosperity, mobility and personal behaviour.

Due to the low level of industrial activity in the ACT, air quality is largely determined by activities and conditions in our urban areas. For instance, the number of cars being driven and the use of wood heaters in Canberra's suburbs are major factors influencing air quality.

The sources and volumes of emissions of air pollutants in the ACT is reported in the National Pollutant Inventory (NPI). Whilst point source emissions are reported annually, data on the sources and emissions of diffuse source air pollution dates from a single 1999 study. It is important to note that diffuse sources of air pollutants, especially from transport and wood heaters, are the most significant contributors to air pollution in the ACT.[6] Consequently, in the absence of current data it is not possible to assess changes in air pollution emissions for this reporting period.

National Environment Protection National Pollutant Inventory Measure (NPI NEPM)

Point-source emissions are regulated by the ACT Government. Maximum concentration limits are placed on certain substances being emitted from industrial sources; these limits are regulated through the *Environment Protection Act 1997*. There are several industrial facilities in the ACT that must report to the EPA on their total point-source emissions each year. The annual monitoring and reporting of point source emissions is required under the NPI NEPM. During the reporting period (up to and including 2017–18), the ACT's monitoring and reporting activities complied with the NPI NEPM.[7]

Indicator A4: Amenity

Impacts on amenity such as increased noise, smoke, odour, dust and other pollution can affect health and wellbeing. Noise is the second most common form of pollution experienced by the community, after air pollution, and is increasing with growth in population, urbanisation and traffic. The Environment Protection Authority is responsible for investigating noise, odour, smoke, dust, light and other pollution complaints, and for enforcing compliance with guidelines in the ACT. As the number of complaints increase, so does the burden on compliance and enforcement resources.

Noise can significantly impact on quality of life, community health and can reduce economic performance. Noise can cause disturbance to sleep, interfere with reading and relaxing, and can be a barrier to spending time outdoors. Health impacts from chronic or acute noise include sleep deprivation,

4 Environment Protection Authority Victoria, 2018, *Air Pollution in Victoria – A Summary of the State of Knowledge, August 2018*, Carlton, Victoria. Found at https://www.epa.vic.gov.au/~/media/ Publications/1709.pdf

5 International Agency for Research on Cancer, 2016, *IARC Monographs: Outdoor Air Pollution*, *Volume 109.* Found at monographs.iarc.fr/ENG/Monographs/vol109/index.php, accessed August 2019.

6 Office of the Commissioner for Sustainability and the Environment, 2015, *ACT State of the Environment Report 2015*, ACT Government, Canberra.

7 National Environment Protection Council, 2019, *National Environment Protection Council Annual Report 2017–2018*, Canberra. Found at www.nepc.gov.au/system/files/resources/afef0a22-b780-41ed-ab10-416162bb201e/files/nepc-annual-report-2016-17.pdf, accessed August 2019.

contribution to heart disease, impaired learning, hypertension, raised blood pressure, and stress.

Identification of impacts on amenity come from community complaints received by the ACT government. The number of complaints are dependent on a range of factors such as the sensitivity of community members to particular issues, and the number of complaints made about each individual event. Consequently it is difficult to assess trends in amenity. Despite this, complaints data does provide information on everyday environment impacts concerning the ACT community.

Complaints data is only available for the 2017–18 and 2018–19 period. Data for these years have been combined to determine the problems impacting on the community.

Over the two years a total of 5,562 complaints were received by the EPA regarding environmental conditions. Noise was responsible for 80% of complaints (4,459), with air pollution responsible for 13% (Figure 7). Noise is clearly a significant concern in the ACT. Although air pollution is the second most common complaint, the EPA only received 727 complaints, significantly fewer than for noise.

Noise complaints were dominated by amplified noise (mostly loud music) which accounted for 53% (2,364) of the total noise complaints over this two year reporting period. Construction noise accounted for 20% of the total noise complaints.

Air pollution complaints were dominated by smoke (wood heaters and controlled burns) which accounted for 55% (403) of the total air pollution complaints over 2017–18 and 2018–19. Odour accounted for 22%, and dust 18%.

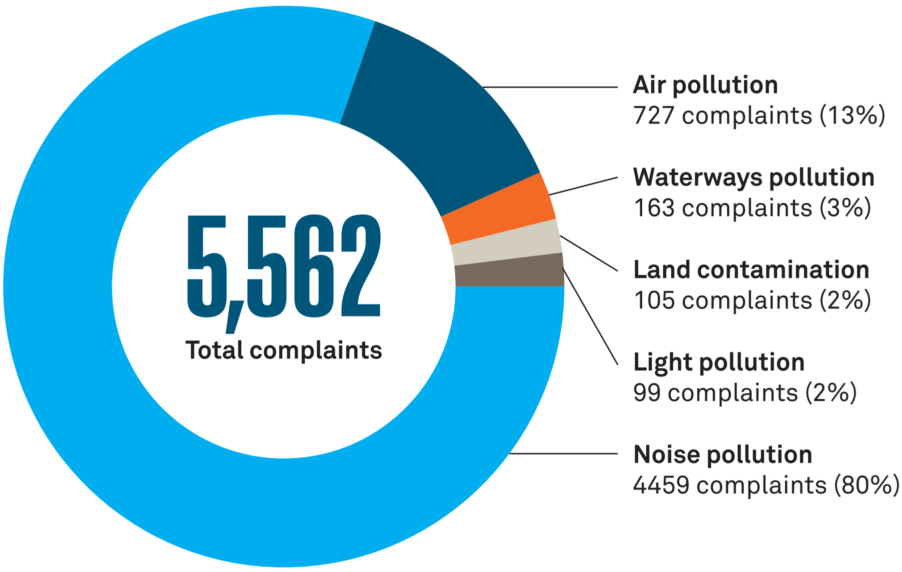


Figure 7:
Complaints received by the EPA, 2017–2018 to 2018–2019.

Data sourced from: ACT Environment Protection Authority

DATA GAPS

The ACT air quality monitoring network consists of only two AAQ NEPM monitoring stations at Monash and Florey. The third station at Civic does not satisfy AAQ NEPM compliance requirements. For a comprehensive assessment of air quality in the ACT, a wider monitoring coverage is required. This would assist the detection of localised air pollution related to differing topography, road traffic and levels of industry and land development. For example, differences in local air pollution levels are clearly demonstrated in the number of particulate matter ($PM_{2.5}$) exceedances recorded at the Monash station when compared to the Florey station.

Information is lacking on the human health impacts of air pollution and associated costs to the health system and economy in the ACT.

There has been no diffuse air pollution assessment since 1999. Consequently, in the absence of current data it is not possible to assess this indicator for this reporting period.

CASE STUDY
HEALTH IMPACTS OF POLLEN AND SPORES

Supplied by: Simon G. Haberle, Ben Keaney, Victoria Miller, Janelle Stevenson, Feli Hopf and Susan Rule, The Australian National University.

The ACT has the highest rate of allergic rhinitis in Australia (29% of the ACT population), increasing by around 10% between 2007 and 2018.[8]

The geography and climate of Canberra has a lot to do with its status as the nation's number one hotspot for hay fever. Its land-locked location in the heart of a rich agricultural region, plus a climate and urban landscaping history that supports a high diversity of introduced plants, means that there is little chance for relief during the months when allergy-related plants produce pollen.

The Canberra Pollen Calendar

The Canberra Pollen Calendar (Figure 8) shows the duration and peak periods of the pollen season for the top allergenic plants in the ACT. Although there is a strong correlation between the amount of grass pollen and people suffering from allergic rhinitis during the spring and summer flowering season (late September to February), there are also many other pollen types that trigger allergic reactions.[9] The calendar shows that the actual season for Canberra's pollen–related allergic rhinitis extends well beyond the limits of the grass season.

There is also a clear trend in increasingly allergenic airborne pollen load over the past 90 years, coinciding with Canberra's urban development and associated tree-planting scheme.[10] As the climate warms and the population grows in Canberra, it will be important for allergic rhinitis sufferers, health experts and city landscape planners to be aware of the potential impact that environmental change can have on allergic diseases. Education and awareness about the impacts of allergy causing plants on population health and productivity will help to better guide decisions on reducing health impacts from pollen.

Future impacts and management

Predicting how pollen seasons might change in the future is difficult due to our limited understanding of the interaction between climate, pollen production and people. Climate change is likely to affect the onset, duration, and intensity of the pollen season, as well as the allergenicity of the pollen. Studies on plant responses to elevated atmospheric levels of Carbon Dioxide indicate that plants exhibit enhanced photosynthesis and reproductive effects and produce more pollen.[11]

In 2007, the Canberra Pollen Count and Forecast Project was established at the Australian National University by a team of pollen experts (palynologists).[12] The aim of the program is to develop a long-term record of airborne pollen in the city and enhance the understanding of the impact of pollen-related allergic rhinitis on the local community. This is being achieved through the development of a citizen science approach designed to provide the public with daily pollen information, while allowing users to give feedback on their hay fever symptoms. This information is providing the first insights into the impact of airborne pollen on people in the ACT (AirRater and CanberraPollen).[13]

By increasing the data available for research, and the general public's awareness of the impacts of different pollen types on population health and wellbeing, we can help to understand and begin to mitigate an increasingly significant health and economic burden in the ACT. This will lead to reduced allergy symptoms, improved quality of life, and will empower sufferers to self-manage their condition.

An important step will be to increase the monitoring of airborne particles across the urban landscape of the ACT. There is currently only one central monitoring station for pollen in the ACT. The addition of more stations across the urban area would greatly improve the understanding of pollen levels and impacts on health across the ACT.

8 Australian Bureau of Statistics, 2018, *National Health Survey: First Results, 2017–18*, ABS cat. no. 4364.0.55.001, Canberra.
9 Haberle S.G., 25/9/2014, Canberra Pollen Count and Forecast website, found at www.canberrapollen.com.au/news-events/video-explaining-new-canberra-pollen-app-anuchannel/, accessed August 2019.
10 Pritchard J., J. Stevenson, A. Zawadski, 2019, 'Increasingly Allergenic Airborne Pollen Revealed in Sediment of Lake Burley Griffin, Canberra', *Journal of Urban Ecology,* 5(1):1–14.
11 D'Amato G., S.T. Holgate, R. Pawankar et al., 2015, 'Meteorological Conditions, Climate Change, New Emerging Factors, and Asthma and Related Allergic Disorders. A statement of the World Allergy Organization', *World Allergy Organization Journal*, 8(1):25.
12 Haberle S.G., D.M.J.S. Bowman, R.M. Newnham et al., 2014, 'The Macroecology of Airborne Pollen in Australian and New Zealand Urban Areas', *PLoS ONE*, 9(5).
13 Find out more at www.airrater.org.au and www.canberrapollen.com.au and on Twitter @AirRaterUTAS and @CanberraPollen.

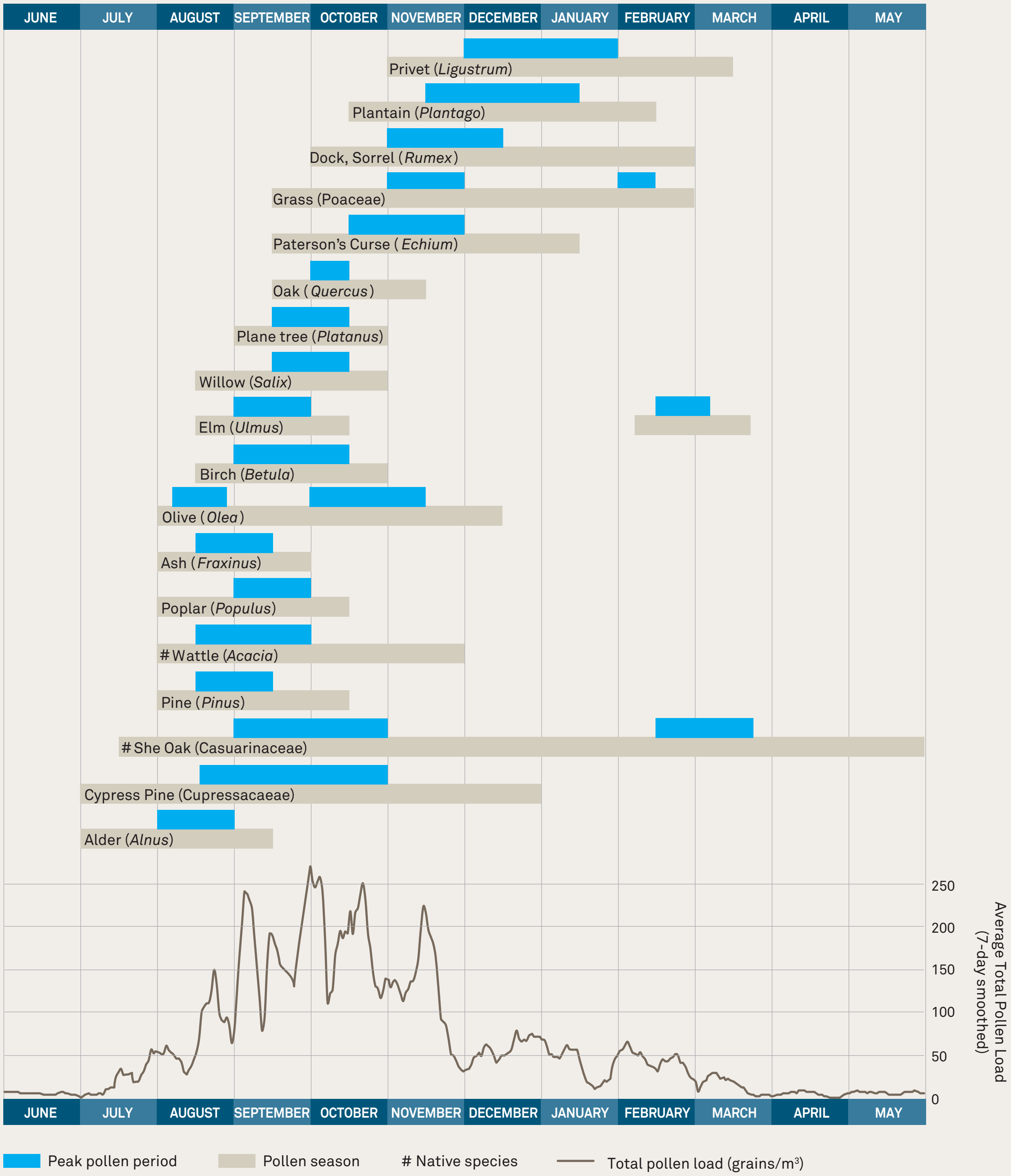
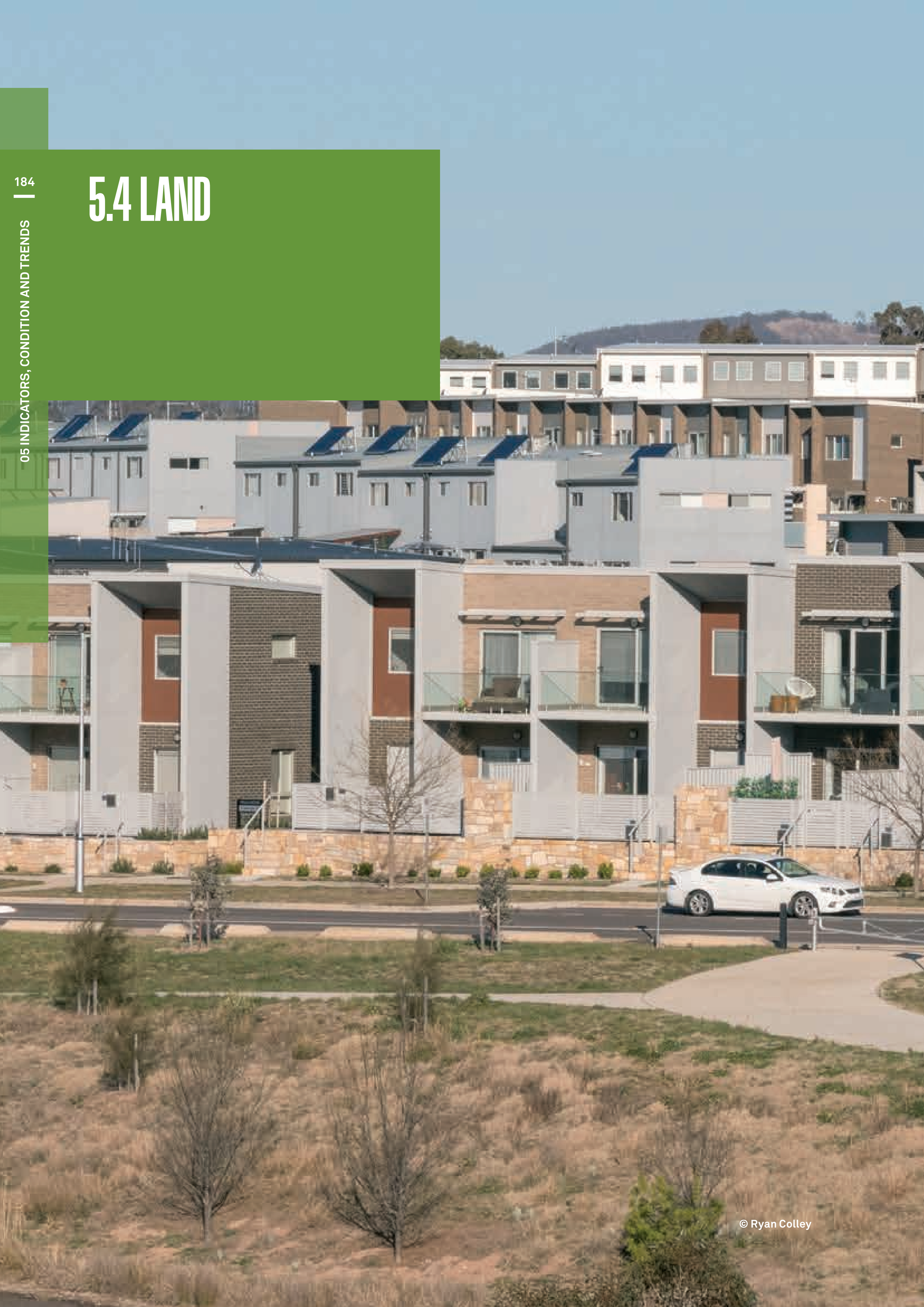


Figure 8:
Pollen calendar for Canberra and the region based on the Canberra Pollen Monitoring Programs data derived from 2007 and 2014–2019.

Source: Canberra Pollen Count and Forecast Project, ANU

Notes: The calendar provides a preliminary assessment of the pollen season and peak periods within that season. Some pollen types represent more than one species and can result in more than one peak period in the calendar. The period of highest average total pollen load occurs between September and November in Canberra and the region.

5.4 LAND



© Ryan Colley

Section contents

Land use in the ACT

Land use

75% of ACT Government land is zoned for natural ecosystems and greenspace

Main land uses

- **63%** conservation and protected
- **17%** urban and intensive
- **15%** rural
- **4%** plantation forests

Urban expansion

- **57%** increase in urban land between 1991 and 2016, compared to a 43% increase in population
- **46%** increase in urban area by 2041 at current urban expansion rates
- **100,000** estimated new dwellings required to accommodate 2041 projected population
- **2nd** lowest population and residential dwelling density for Australia's major capital cities[A]

ACT dwelling types

- **65%** single dwellings
- **18%** medium density
- **17%** high density

Greenfield versus infill development

- **70%** ACT Government target for new housing to be from infill development
- **58%** average infill rate between 2011–12 and 2017–18
- ✓ all years from 2015–16 to 2017–18 met the infill target
- **16%** predicted increase in urban area by 2041 if the 70% infill target continues to be met

A – excludes Hobart and Darwin

Indicator assessment

Indicator	Status	Condition	Trend	Data quality
L1: Land use change	Over the reporting period, it was not possible to determine changes in the area of urban and rural lands. However, any changes are estimated to be small. Although nearly 75% of ACT Government land is zoned for natural ecosystems and greenspace, urban expansion continues to be an environmental challenge for the ACT. To minimise urban growth, the proportion of medium and high-density housing is increasing. The rates of infill development are improving with all years from 2015–16 meeting (or close to meeting) the 70% infill target.	Fair	–	●●○ Moderate
L2: Land health	There is a general lack of knowledge about land health in the ACT, both for long-term changes and current conditions. This lack of information does not enable an assessment of land and soil health and remains a critical gap in our understanding of environmental condition.	Unknown	?	●○○ Low

Indicator assessment legend

Condition

- **Good** = Environmental condition is healthy across the ACT, **OR** pressure likely to have negligible impact on environmental condition/human health.
- **Fair** = Environmental condition is neither positive or negative and may be variable across the ACT, OR pressure likely to have limited impact on environmental condition/human health.
- **Poor** = Environmental condition is under significant stress, OR pressure likely to have significant impact on environmental condition/ human health.
- **Unknown** = Data is insufficient to make an assessment of status and trends.
- **NA** = Assessments of status, trends and data quality are not appropriate for the indicator.

Trend

- ↑ Improving
- ↓ Deteriorating
- – Stable
- ? Unclear
- **NA** = Assessments of status, trends and data quality are not appropriate for the indicator.

Data quality

- ●●● **High** = Adequate high-quality evidence and high level of consensus
- ●●○ **Moderate** = Limited evidence or limited consensus
- ●○○ **Low** = Evidence and consensus too low to make an assessment
- ○○○ **NA** = Assessments of status, trends and data quality are not appropriate for the indicator.

Key actions

That the ACT Government:

ACTION 1: improve knowledge on land use change in the ACT. This could be achieved through the development of annual land accounts using the United Nations System of Environmental-Economic Accounting framework.

ACTION 2: continue to increase the number of medium and high-density dwellings to minimise future growth in the ACT's urban area.

ACTION 3: encourage and provide opportunities for further increases in urban residential infill developments.

ACTION 4: ensure current and future greenfield developments incorporate actions to minimise impacts on natural ecosystems and biodiversity.

ACTION 5: improve knowledge on land and soil health to address this critical data gap in environmental condition assessments.

Main findings

Land use change 2015–16 to 2018–19

It was not possible to determine changes in the area of urban and rural lands. However, any changes are estimated to be small.

For land under the tenure of the ACT Government, the main land uses are conservation and protected 63% (141,000 hectares), urban and intensive 17% (37,000 hectares), rural 15% (33,000 hectares), and plantation forests 4% (8,700 hectares).

Under the Territory Plan, zoning categories for lands managed by the ACT Government are mountains and bushlands (62%), rural (15%), urban and intensive (9%), hills, ridges and buffers (7%), river corridor (5%), and urban open space 2%.

Nearly 75% of ACT Government land is zoned for natural ecosystems and greenspace.

In 2019, there were 8,700 hectares of pine plantations in the ACT, although 1,560 hectares were fallow (inactive and unplanted). In 2017–18, 307 hectares were harvested with a value of nearly $5.5 million.

ACT's pine forests are extensively used and managed for recreational activities, including walking, jogging, horse riding and cycling.

The ACT has a relatively small agricultural sector with beef cattle farms the most common, accounting for 40% of all farms. The gross value of the ACT's agriculture in 2017–18 was over $10.6 million.

Urban expansion

Land development continues to be an environmental challenge for the ACT.

Population growth is a key driver of urban land use change.

Between 1991 and 2016, the ACT's urban land area grew by 57%, compared to a population increase of 43% over the same period. If this ratio of urban growth to population continues, the ACT's current urban footprint would need to increase by a further 46% by 2041 to accommodate projected population growth.

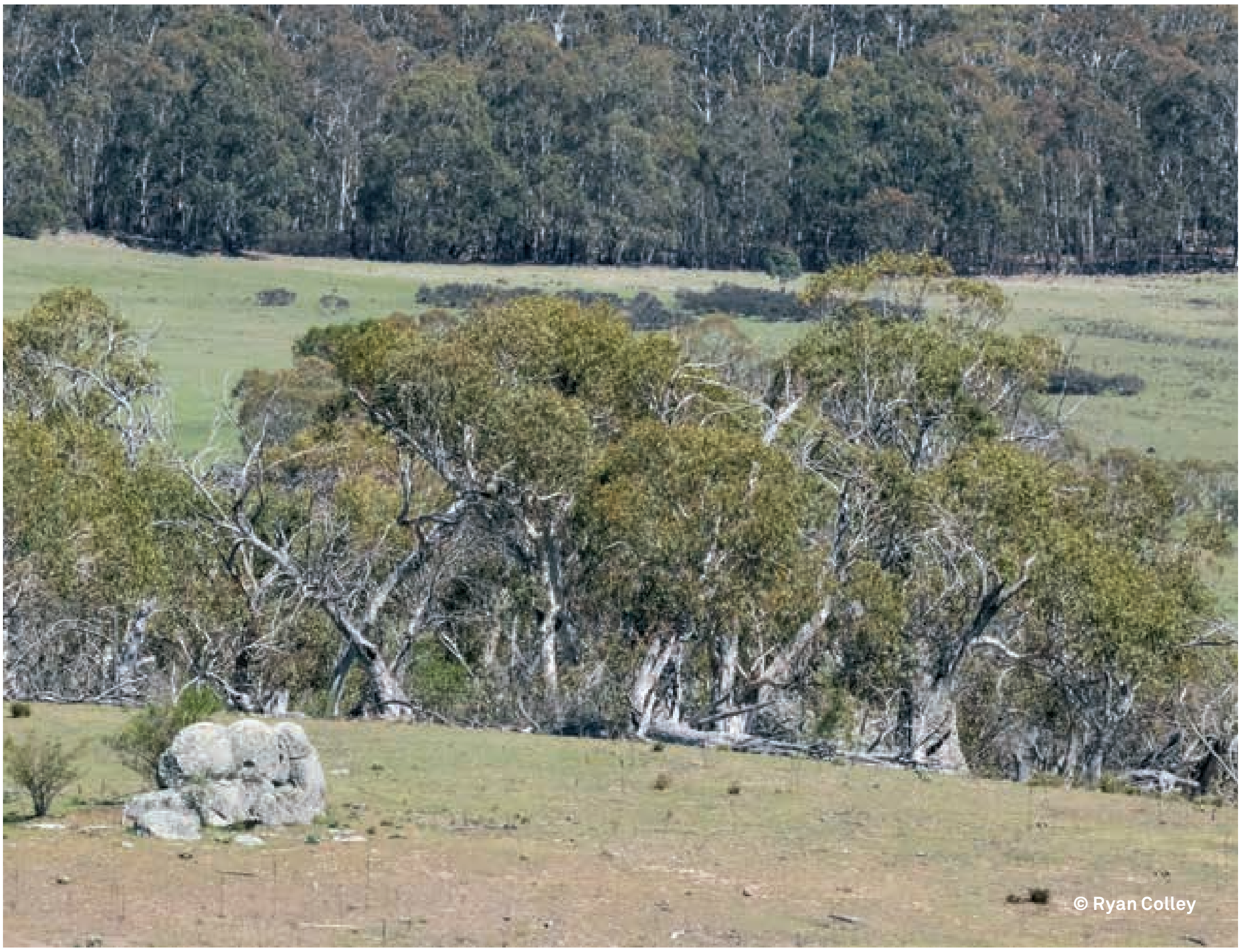
It is estimated that the ACT will need 100,000 new dwellings by 2041 to accommodate the projected population growth. Current estimates suggest there is potential for approximately 29,000 new homes in existing greenfield areas zoned as future urban areas.

To minimise the growth of the ACT's future urban footprint there needs be an increase in population density, the number of medium and high-density dwellings, and the amount of urban infill compared to greenfield development.

In 2016, Canberra had a population density of 1,062 people per square kilometre, the second lowest of the major Australian capital cities (excluding Hobart and Darwin), and the second lowest residential dwelling density with 437 private dwellings per square kilometre.

In 2016, single dwellings were the dominant form of housing accounting for 65% of total residences, 18% were medium density, and 17% high density.

The proportionate share of single dwellings has decreased from 80% of total residential dwellings in 1991.



Treescape. Source: Ryan Colley.

Greenfield versus infill development

The ACT Planning Strategy 2018 sets a target for up to 70% of new housing to be provided as infill development within the existing urban footprint.
The rate of infill development in the ACT has varied widely since 2011–12, from a low of 36% of all urban development in 2013–14 to a high of 77% in 2017–18.
The average infill rate between 2011–12 and 2017–18 was 58% of all development.
The rate of infill urban development has increased since 2013–14, with all years from 2015–16, meeting (or close to meeting) the 70% infill target.
If the 70% urban infill target continues to be met, it is estimated that the ACT's projected 2041 population could be accommodated within a 42,900 hectare footprint, a 16% increase from the 2016 urban area.

Land health

There is a general lack of knowledge about land health in the ACT, both for long-term changes and current conditions. This lack of information does not enable an assessment of land and soil health and remains a critical gap in our understanding of environmental condition.
There is no routine monitoring for soil health indicators such as erosion, salinity, structure decline, and reductions in organic content. Consequently, understanding of the actual extent of these problems is limited.
Up to and including 2017–18, monitoring and reporting activities for the ACT's contaminated sites were found to comply with the National Environment Protection (Assessment of Site Contamination) Measure.

INTRODUCTION

This section provides an assessment of land use and condition in the ACT. The following indicators are assessed:

- Indicator L1: Land use change
- Indicator L2: Land health

Human wellbeing as well as terrestrial and aquatic ecosystems are dependent on healthy land. The interactions of soil, air, water, plants, animals and natural processes provide a diverse range of services, including fertile soil for agriculture, clean water production, nutrient recycling, and erosion control. How land is used and managed can significantly affect its capacity to provide these services.

Land use is a key driver of environmental change affecting ecological functions, attributes and the integrity of land health. Many environmental problems in the ACT result from current and historic land use and management. The maintenance of land health requires consideration of the needs of urban and other development in conjunction with environmental protection.

The main pressures on land health are from vegetation clearing for urban expansion (particularly greenfield development) and agriculture, and severe fire that can expose and alter the structure of soils increasing the risk of significant erosion. The degradation of land has consequences for both terrestrial and aquatic ecosystems. Poor land health can lead to the loss of vegetation and habitat, and severely impact on water quality and aquatic biodiversity (see section **5.6 Water**). Poor land health also impacts on agricultural production through the loss of soil nutrients and organic matter, reductions in crop yields and pasture production, and increased erosion.

The ACT's land is used for urban areas, conservation, agriculture and plantation forestry. Land use change can be driven by a range of social, economic and environmental pressures such as population growth, land values that support housing development, preference for traditional housing, and agricultural drivers such as climate (for example, water availability) and commodity prices.

Changes in the area of one land use type can have negative consequences for others. For example, urban expansion results in the loss of natural habitat as well as agricultural land. Land use change can also have consequences for a range of other environmental pressures, for example the expansion of urban areas creates increased demand for transport infrastructure such as roads and public transport. This means that urban development can have a greater impact on the environment because of the degree of land change required and the resources consumed.

Climate change will increase pressures on land health with higher temperatures, reduced rainfall, more extreme weather events, and an increase in fire risk and severity (see section **5.1 Climate Change** and **5.7 Fire**). These are likely to affect land use and management through significant changes to landscape functions and vegetation cover.

DATA TRENDS

Indicator L1: Land use change

For land use change, only urban and rural land uses are discussed here; for changes in conservation areas see section **5.5 Biodiversity**.

The data used for this indicator are from the Territory Plan Zones. Under the *Planning and Development Act 2007*, the Territory Plan sets out zoning that identifies the types of land use and activities that are permitted in an area. Because the data are based on land zoning, they may not reflect actual current land use. For example, land zoned for urban areas may still be undeveloped. In addition, land zoning related to specific objectives such as ecological protection, cultural and heritage resources, and environmental integrity (for example, hills, ridges and buffers, mountains and bushland, and river corridors) will differ to conservation and protected areas as shown in section **5.5. Biodiversity** because some of this zoned land is under the tenure of rural lease holders and not managed by the ACT Government.

The total area of the ACT is around 236,000 hectares and the area of land under the tenure of the ACT Government is around 224,700 hectares. The remainder of the ACT's land is national land managed by the National Capital Authority (also known as 'designated land') and largely includes urban areas around central Canberra and Lake Burley Griffin.

For land under the tenure of the ACT Government, the main land uses are (Figures 1 and 2):[1]

- conservation and protected lands which protect around 141,000 hectares (63%)
- urban and intensive lands which account for around 37,000 hectares (17%)[2]
- rural lands which account for around 33,000 hectares (15%), and
- plantation forests which account for around 8,700 hectares (4%).

It was not possible to determine changes in the area of urban and rural lands over the reporting period (2015–16 to 2018–19). However, any changes are estimated to be small.

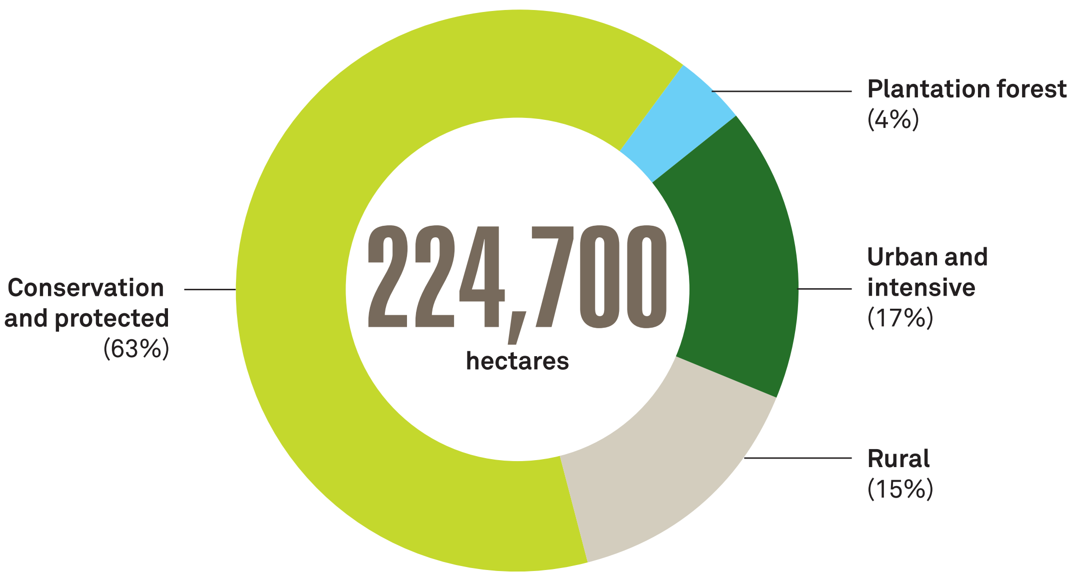


Figure 1:
Main land uses under the tenure of the ACT Government, 2019.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

Note: Data is from Territory Plan zones. There may be some variation compared to actual land use area due to the amalgamation of categories used.

1 Note that there may be some variation compared to actual land use area due to the amalgamation of categories used and the inclusion of some areas in more than one land use type.
2 'Urban and intensive' includes lands zoned as residential, commercial, industrial, transport, urban open space, and hills/ridges/buffer areas.

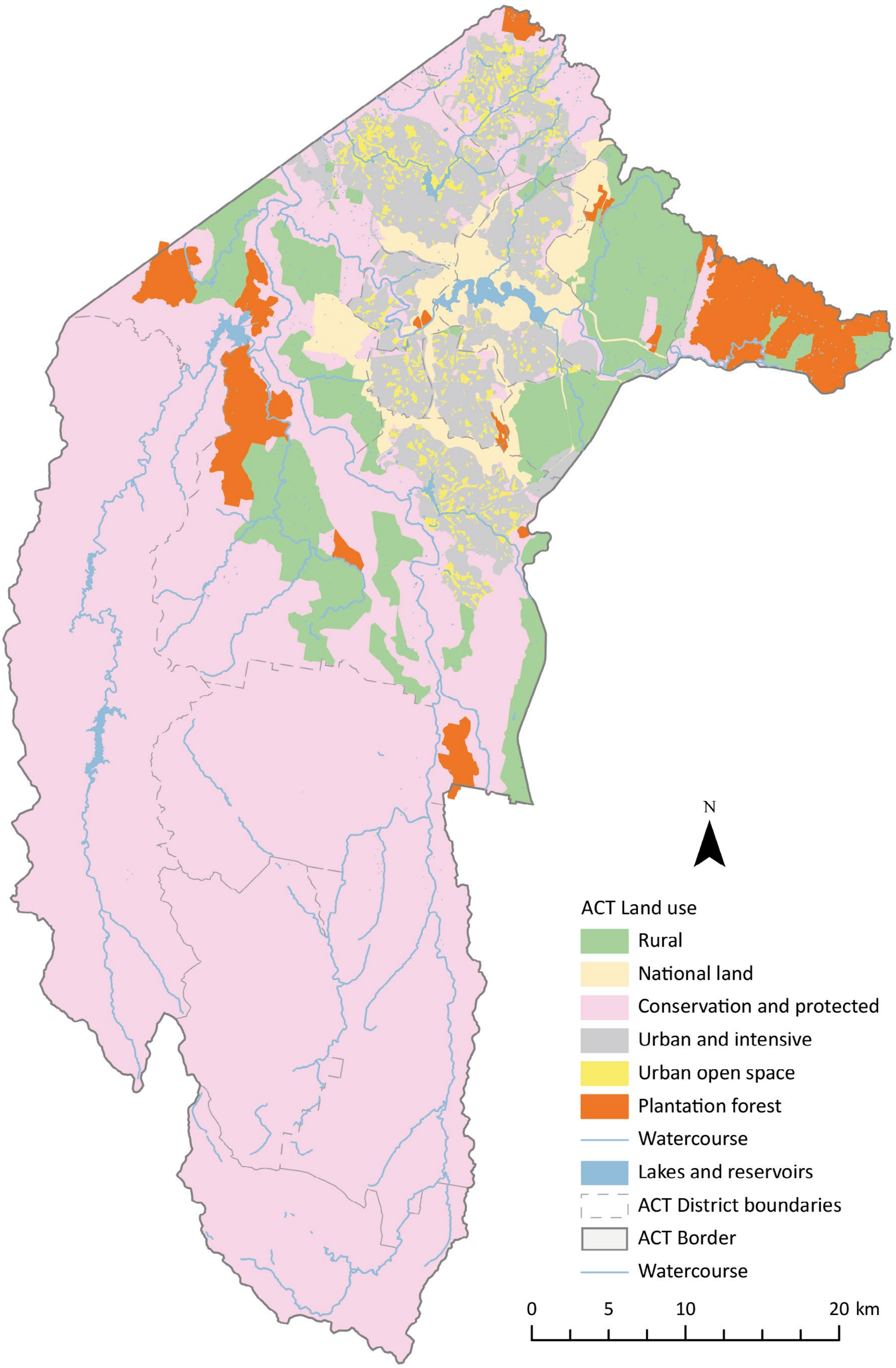


Figure 2:
Main land use types in the ACT.

Source: Environment, Planning and Sustainable Development Directorate.

Note: Data is from Territory Plan zones. There may be some variation compared to actual land use area due to the amalgamation of categories used.

Under the Territory Plan, zoning categories for lands managed by the ACT Government are mountains and bushlands (62%), rural (15%), urban and intensive (9%), hills, ridges and buffers (7%), river corridor (5%), and urban open space 2% (Figure 3). This means that nearly 75% of ACT Government land is zoned for natural ecosystems and greenspace. Highly modified land uses such as urban and rural account for around 25% of ACT Government land.

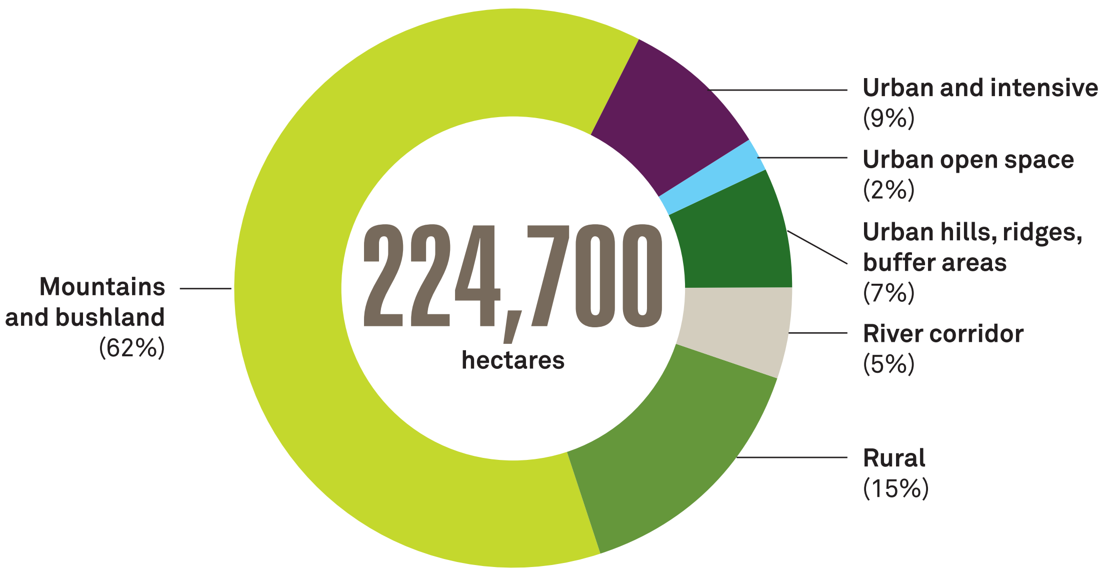


Figure 3:
Territory Plan zones for land under the tenure of the ACT Government, 2019.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

Note: Data is from Territory Plan zones. There may be some variation compared to actual land use area due to the amalgamation of categories used.

Rural and plantation forest land use

The ACT has a relatively small agricultural sector. Beef cattle farms are the most common, accounting for 40% of all farms.[3]

In 2019, there were 8,700 hectares of pine plantations in the ACT, although 1,560 hectares were fallow (inactive and unplanted). Some 10,000 hectares of the pine plantation estate was destroyed in the 2003 bushfires with only the Kowen Forest plantation unburnt. Some burnt plantation areas were replanted with pine trees, particularly where soil stabilisation and water quality protection were a priority, and boundaries were redefined with some areas converted to native vegetation. In 2017–18, 307 hectares were harvested with a value of nearly $5.5 million.[4] The pine forests are also extensively used and managed for recreational activities, including walking, jogging, horse riding and cycling.

Urban expansion[5]

Population growth is a key driver of urban land use change in the ACT. The ACT has experienced strong and sustained population growth – in the 10-year period between 2008 and 2018 the population grew by approximately 72,000 people, an average annual increase of 7,200 or 1.7% per year (see section **5.2 Human Settlements**). In 2018, the ACT's population was around 423,000 and is projected to increase to 589,000 people by 2041.

The ACT consumes significantly more land for urban development compared to population growth. Between 1991 and 2016, the ACT's urban land area grew by 57%, compared to a population increase of 43% over the same period. If this ratio of urban growth to population continues, the ACT's current urban footprint would need to increase by a further 46% by 2041 to accommodate population growth.

3 Australian Bureau of Statistics, 2019, 'Value of Agricultural Commodities Produced, Australia, 2017–18', (7503.0), Canberra.
4 Plantation forest data from the Environment, Planning and Sustainable Development Directorate.
5 The urban land use trends, population and housing projections in this section are taken from: EPSDD, 2018, *ACT Planning Strategy 2018*, ACT Government, Canberra, found at https://www.planning.act.gov.au/__data/assets/pdf_file/0007/1285972/2018-ACT-Planning-Strategy.pdf, accessed 13 August 2019.

This would mean that the current urban area of around 37,000 hectares would grow to 54,000 hectares. This growth pattern does not support a compact and efficient city and would increase travel times and limit transport options, raise infrastructure-servicing costs, and result in significant increases in the ACT's ecological footprint. Continued urban expansion also places pressure on Canberra's rural and greenspace environments, and the connectivity of its ecosystems.

It is estimated that the ACT will need 100,000 new dwellings by 2041 to accommodate the projected population growth. This growth will also necessitate the construction of associated infrastructure. The ACT's growth area is shown in Figure 4. Current estimates suggest there is potential for approximately 29,000 new homes in existing greenfield areas zoned as future urban areas. If no new greenfield areas are identified, this supply is expected to be sufficient until around 2030–40.

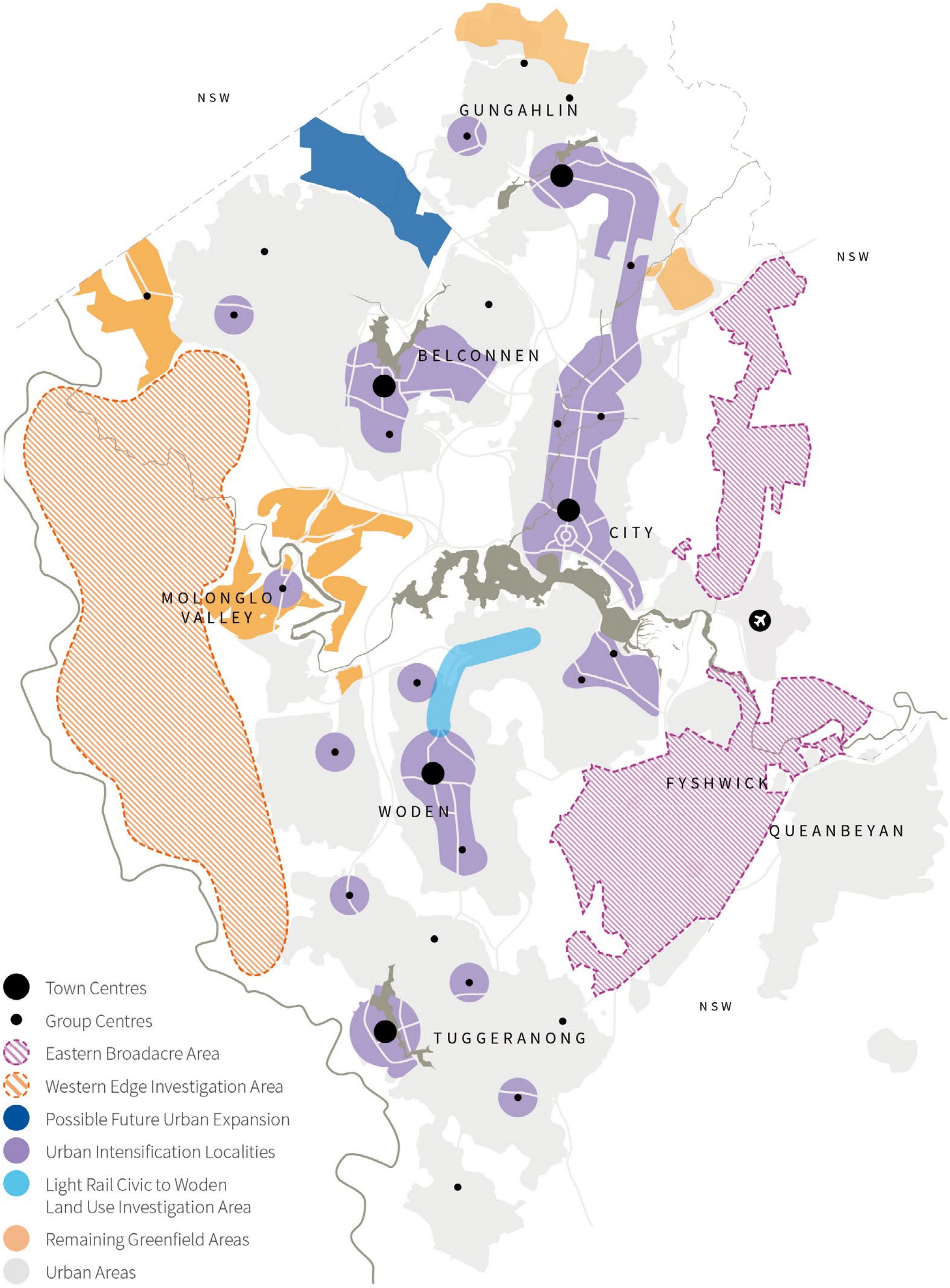


Figure 4:
Current and future urban growth in the ACT.

Source: Environment, Planning and Sustainable Development Directorate.

Minimising the growth in the ACT's urban footprint

Much of the growth in the ACT's urban area has been in the form of single low-density dwellings with fewer and fewer people living in them. To minimise the growth of the ACT's future urban footprint there needs be an increase in population density, the number of medium and high-density dwellings, and the amount of urban infill compared to greenfield development. The relationship between population density and the growth in urban area is shown in Figure 5. The amount of land required for higher population densities is significantly less than that required for low densities, which reduces the need for new urban areas.

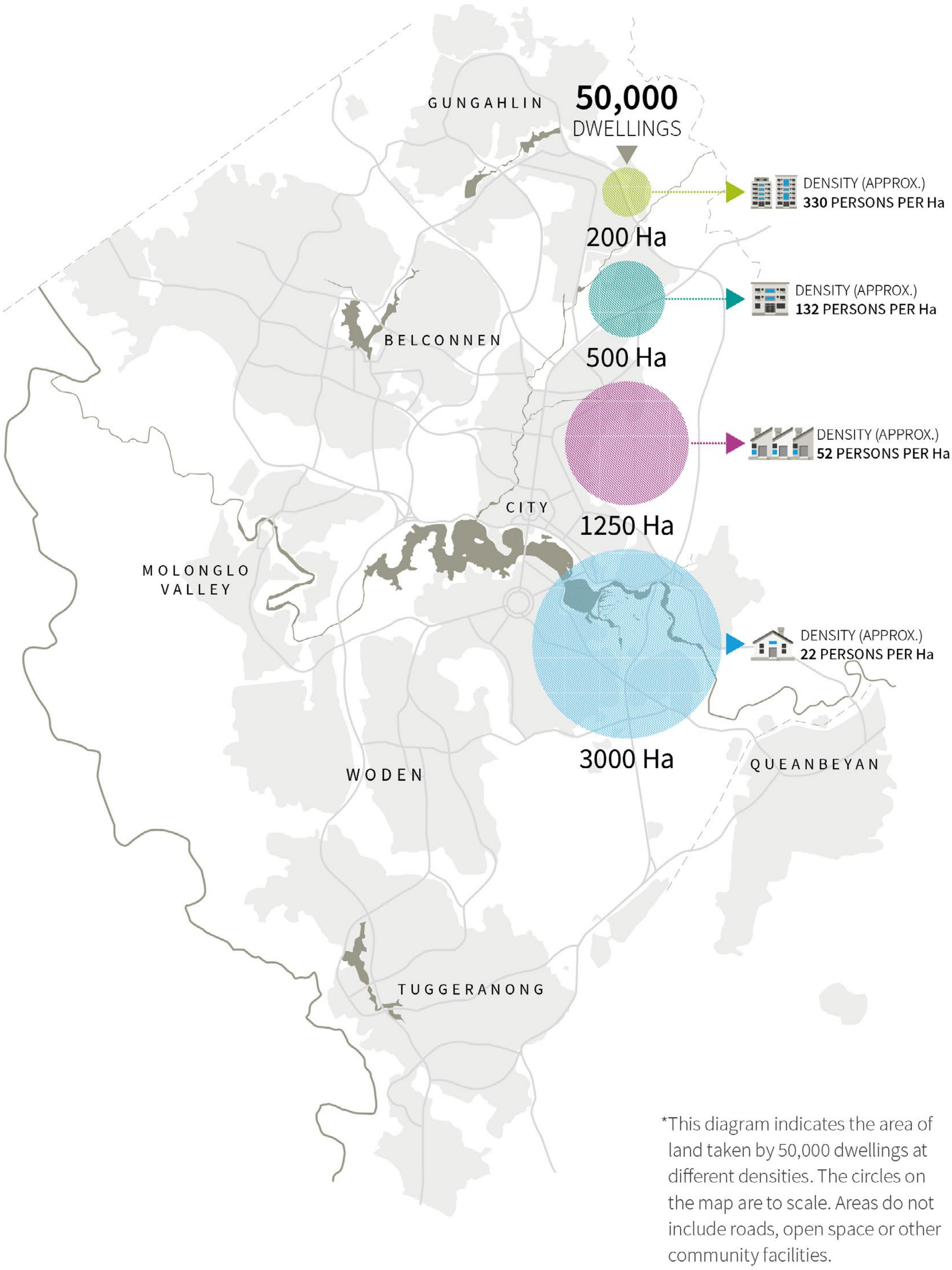


Figure 5:
Area of land taken by 50,000 dwellings at different population densities.

Source: Environment, Planning and Sustainable Development Directorate.

In 2016, Canberra had a population density of 1,062 people per square kilometre, the second lowest of the major Australian capital cities (excluding Hobart and Darwin). This is due to:

- a reduction in Canberra's household size from 2.9 people in 1991 to 2.5 in 2016
- 55% of ACT households having 2 or fewer people, and
- an increase of 125% in single-person households from 1991 to 2016, the fastest growing household type in Canberra.

Canberra also had the second lowest residential dwelling density compared to other major Australian capital cities, with 437 private dwellings per square kilometre. Nevertheless, housing preferences are changing, with a greater demand for medium-density housing such as townhouses. In 2016, 18% of Canberra's residential dwellings were medium density, and 17% high density (Figure 6). Single dwellings remain the dominant form of housing at 65%, although its proportionate share has decreased from 80% of residential dwellings in 1991.

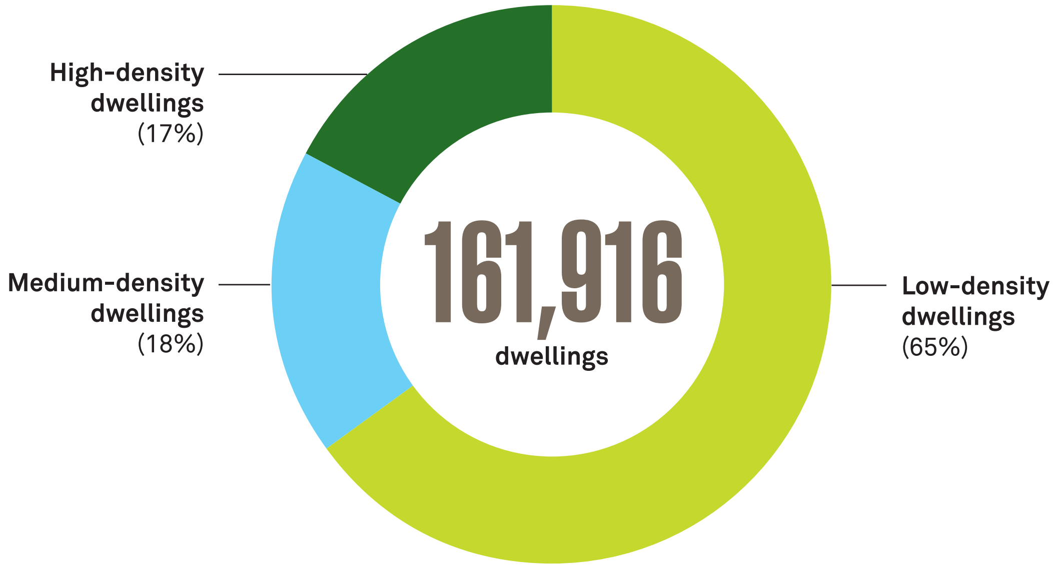


Figure 6:
Dwelling density in Canberra, 2016.

Data sourced from: Australian Bureau of Statistics.

Notes: Low density comprises separate houses; Medium density is made up of semi-detached, row or terrace houses, townhouses etc. with one, two or more storeys as well as flats or apartments attached to a house. High density comprises flats or apartments in any number of storied buildings. Only low, medium and high-density residential dwellings are included in the total.

Greenfield versus infill development

Greenfield urban development is that which occurs outside the boundary of the established urban area. This development extends the urban footprint and requires the construction of new utility, transport and social infrastructure. Infill urban development is undertaken within the existing urban area and provides greater intensity and efficiency of existing land and infrastructure. Urban infill can include the redevelopment of commercial and industrial areas, and the development of unimproved land within the urban boundaries.

Greenfield development places greater pressure on the environment through impacts such as:

- vegetation clearance
- degraded land condition
- increased waterway pollution
- increased recreational use and access tracks
- garden weed invasion, and
- the need for extensive fire management for asset protection.

Greenfield development can also significantly increase demand and consumption of resources as well as greenhouse gas emissions through additional infrastructure and transport needs.

Another consideration for greenfield developments is the potential requirement for the creation of environmental offsets to address potential development pressures. In the ACT, offsets provide environmental compensation for a development that is likely to have adverse environmental impacts on a protected matter (see section **5.5 Biodiversity**).

Urban infill generally has a much reduced environmental impact compared to greenfield development because it requires a smaller development footprint and a reduced need for new infrastructure. The benefits can be increased with sensitive design and adoption of low environmental impact types of land use.

Higher rates of urban infill are required for the ACT to meet a range of social, environmental and economic needs, including commitments to a net zero emissions future, improved public transport and demographic trends favouring greater housing choice.

The ACT Planning Strategy 2018 sets a target for up to 70% of new housing to be provided as infill development within the existing urban footprint.[6] The rate of infill development in the ACT has varied widely since 2011–12, from a low of 36% of all urban development in 2013–14 to a high of 77% in 2017–18 (Figure 7). The average infill rate between 2011–12 and 2017–18 was 58% of all development. However, the rate of infill urban development has increased since 2013–14, with all years from 2015–16, meeting (or close to meeting) the 70% infill target.

If the 70% urban infill target continues to be met, it is estimated that the ACT's projected 2041 population could be accommodated within a 42,900 hectare footprint (Figure 8). This would mean a 16% increase from the 2016 urban area compared to a 46% increase if the current ratio of urban growth to population continues. Regardless of the size of urban growth in the future, it is clear that urban land development will continue to be an environmental challenge for the ACT.

6 EPSDD, 2018, *ACT Planning Strategy 2018*, ACT Government, Canberra, found at https://www.planning.act.gov.au/__data/assets/pdf_file/0007/1285972/2018-ACT-Planning-Strategy.pdf, accessed 30 November 2019.

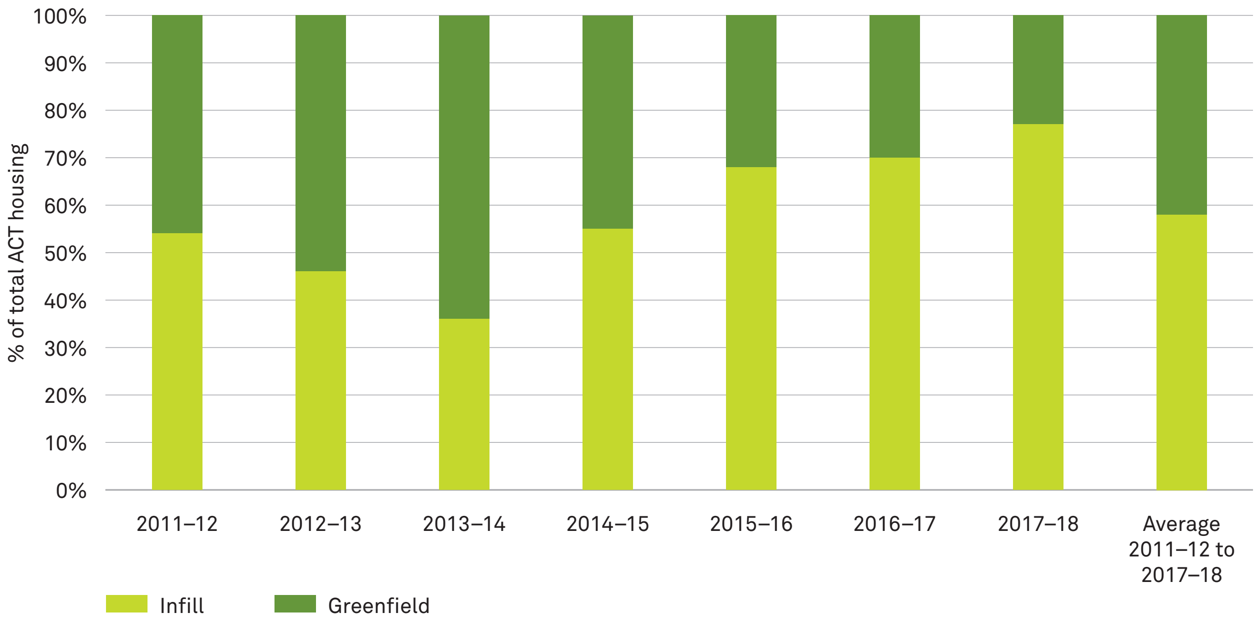


Figure 7:
Rates of greenfield and infill urban development, 2011–12 to 2017–18.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

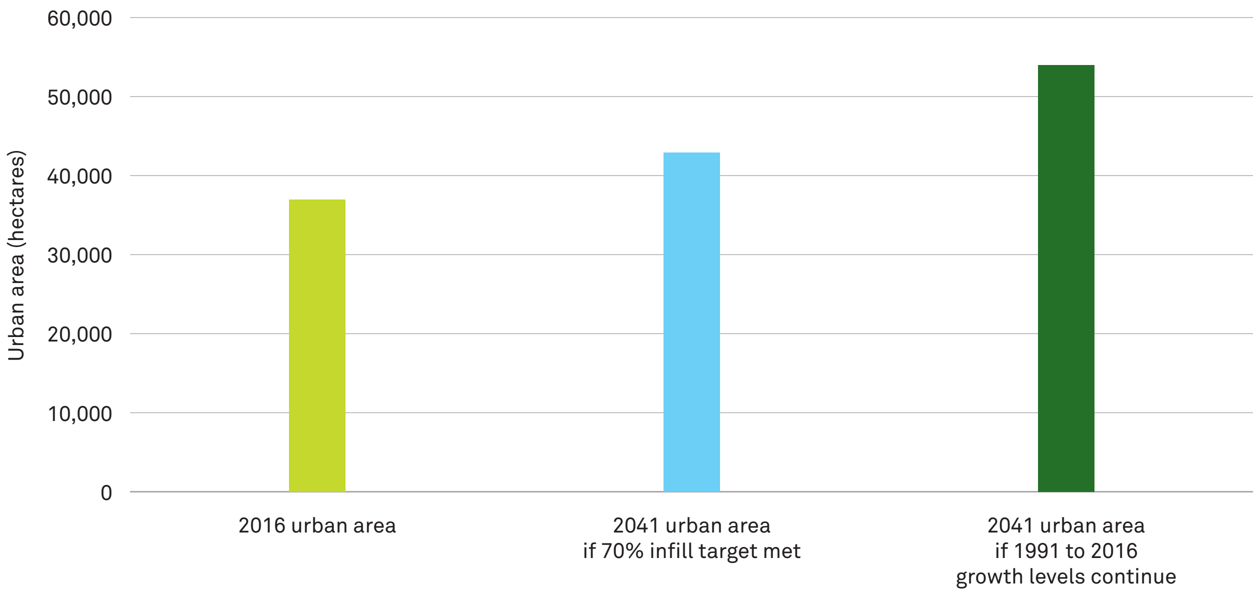


Figure 8:
Estimated urban area required for the ACT's projected 2041 population (589,000 people) using a 70% urban infill rate compared to a continuation of the 1991 to 2016 urban growth rate.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

EXPERT COMMENTARY: MINIMISING THE BIODIVERSITY IMPACTS OF GREENFIELD DEVELOPMENT IN THE MOLONGLO VALLEY

Dr Philip Gibbons, Associate Professor, Fenner School of Environment and Society, The Australian National University

Urban development poses several threats to biodiversity. However, there are actions that governments and residents can take in the Molonglo Valley to minimise these impacts.

Edge effects

Suburbs pose several threats to native flora and fauna in neighbouring bushland: unrestrained pets, invasive plants and animals, stormwater runoff and bushfire.

Pet cats in Australia collectively kill around 167,000 birds per day.[7] They also kill a range of small reptiles, mammals and even invertebrates such as butterflies. A cat containment policy is an important conservation measure in suburbs within one kilometre of natural areas since pet cats can roam this distance.[8]

Although there is mandatory cat containment in all new suburbs of the Molonglo Valley, there is evidence from the RSPCA that compliance with cat containment declines with time.[9] Ongoing education and enforcement of cat containment is therefore critical.

Development of new suburbs in Canberra has coincided with declines of native birds from adjacent bushland.[10] Reasons for this are unclear, but some of Australia's most aggressive native birds such as the Red Wattlebird, Noisy Miner, Rainbow Lorikeet and Pied Currawong thrive in suburbs and may be pushing other native birds out of neighbouring bushland. Avoiding garden plants that attract these aggressive species to our suburbs (for example, nectar-rich Grevilleas and Callistemons and prolific fruiting plants such as Cotoneaster) may be one solution.[11]

Approximately 15% of Australia's plant species are exotic and this is increasing at the rate of about 10 new species annually.[12] Weeds represent a threat to biodiversity in Australia because they displace native plants and change habitat, and are virtually impossible to eradicate once established.

Urban areas are a known source of weeds that invade adjacent bushland. Garden escapes in the ACT include Cootamundra Wattle, Common Pampas Grass and Cotoneaster. Urban open space in Canberra's suburbs often becomes dominated by two significant weeds: African Lovegrass and Chilean Needlegrass. Weed control within reserves is undermined where adjacent suburbs support large-source populations of invasive plants.

Suburbs contain many hard surfaces such as roofs, roads and footpaths and therefore represent a source of considerable stormwater runoff. Stormwater runoff carries large quantities of sediment and nutrients from lawns, leaves, wildlife faeces and leaking sewage infrastructure. This all drains into adjacent waterways. Blooms of blue-green algae in Canberra's waterways have been traced to these sources.[13] Unless managed carefully, stormwater from new suburbs in the Molonglo Valley will impact upon native species in the Molonglo River and downstream, such as the Platypus, Murray Cod and Murray River Crayfish.

Bushfires represent a threat to urban communities located next to bushland, but protecting urban communities from bushfires can also represent a threat to wildlife. Asset Protection Zones (APZs), cleared of most trees and shrubs, are maintained around suburbs adjacent to bushland in the ACT.

7 Woinarski, J.C.Z. et al., 2017, 'How Many Birds Are Killed by Cats in Australia?', *Biological Conservation*, 214: 76–87.
8 Meek, P.D., 2003, ,Home Range of House Cats *Felis Catus* Living Within a National Park', *Australian Mammalogy*, 25(1): 51–60.
9 Brown, A., 25 February 2017, 'Cats Captured from Canberra's Cat Containment Suburbs on the Increase', *The Canberra Times*, Canberra.
10 Rayner, L. et al., 2013, 'Are Protected Areas Maintaining Bird Diversity?', *Ecography*, 37(1): 43–53.
11 Ikin, K. et al., 2015, Key Lessons for Achieving Biodiversity-sensitive Cities and Towns, *Ecological Management and Restoration*, 16(3): 206–214.
12 Department of the Environment and Energy, 2017, 'Why are Weeds a Problem?', found at https://www.environment.gov.au/biodiversity/invasive/weeds/weeds/why/index.html
13 Neil, R., 2012, *Report on the State of the Watercourses and Catchments for Lake Burley Griffin, Part 1*, Office of the Commissioner for Sustainability and Environment, Canberra.

Good planning can limit the impact of APZs on biodiversity. Designing new suburbs so the perimeter is a road and APZs are within the urban footprint – rather than adjacent bushland – reduces impacts on native wildlife.

Some ecological restoration can be undertaken within APZs without increasing the risk to houses during bushfires. For example, rock quarried from new suburbs in the Molonglo Valley has been used to create additional habitat for the Pink-tailed Worm-lizard (a vulnerable species). These areas also support low levels of fire fuel hazard.[14]

Connectivity

Urbanisation also contributes to the fragmentation of wildlife populations. Connectivity between wildlife populations is important because it reduces inbreeding, facilitates recolonisation of bushland patches when species have become locally extinct (for example, because of bushfire) and it allows species to move across landscapes, which is important for those affected by climate change. Stepping stones of suitable habitat within urban areas helps connect wildlife populations.

For example, one study found that nearly a third of Canberra's native birds depend on mature eucalypts.[15] However, most mature trees are cleared as suburbs are developed and those retained are often removed when they begin senescing. Retention and protection of mature eucalypts within the suburbs of the Molonglo Valley will improve connectivity for native birds and bats.

Roads represent a physical barrier to movement by some native species and a significant source of mortality for others. Native species that are killed on roads in Australia include numerous mammals, birds, reptiles and amphibians. Increased roads and traffic in the Molonglo Valley will represent an increasing threat to native fauna. Underpasses, barrier fencing and speed limits have all been suggested as ways to mitigate impacts of roads on wildlife.

No silver bullet

Threats work together to affect biodiversity in urban areas. For example:

- nectar-rich plantings in gardens attract hyper-aggressive birds to suburbs
- APZs on the edges of suburbs provide less cover for small birds seeking to evade these hyper-aggressive species, and
- cats are more effective hunters of small birds in these open habitats.

Consequently, there is no silver bullet for conserving biodiversity in or adjacent to urban areas. Effective conservation in the Molonglo Valley will require a series of coordinated actions by government and the community.

14 McDougall, A. et al., 2016, 'Restoration Rocks: Integrating Abiotic and Biotic Habitat Restoration to Conserve Threatened Species and Reduce Fire Fuel Load', *Biodiversity and Conservation*, 25(8): 1529–1542.
15 Le Roux, D.S. et al., 2015, 'Single Large or Several Small? Applying Biogeographic Principles to Tree-level Conservation and Biodiversity Offsets', *Biological Conservation*, 191: 558–66.

Indicator L2: Land health

Healthy land supports agriculture, native ecosystems and ecosystem services such as clean water. Soil condition is the main driver of land health and a fundamental part of ecosystems and natural processes including biological activity, the cycling and storage of nutrients and carbon, and the decomposition of organic wastes.

Soil health is mostly determined by land use intensity and the degree of modification, or loss of, vegetation cover. The clearing of vegetation can result in accelerated erosion, acidification, salinity, and a reduction in soil nutrients and organic content. Pressures that leave soils bare of vegetation and promote soil degradation include land clearing, fire, high-intensity storms, and agriculture (cropping and grazing). In addition, soil erosion can increase due to the compaction of soil from urban and industrial activities, vehicle use, stock grazing, and invasive species such as horses, deer and feral pigs which can also degrade soil structure.

ACT soils are highly variable, but most are considered to be infertile, fragile, and prone to becoming impermeable and eroded. Consequently, soil management is vital to maintain and improve soil health.

Degraded soil and land health has a range of consequences, including:

- degradation of water quality from increased sediment and other pollutants deposited into rivers and streams (see section **5.6 Water**)
- air quality and human health impacts from dust storms (see section **5.3 Air**)
- loss of topsoil limiting the establishment of new vegetation, removing native seedbanks, and promoting the spread of weeds
- reduction in agricultural land productivity through reduced yields and pasture growth
- increased agricultural costs from greater fertiliser use and land restoration activities, and
- erosion damage to infrastructure such as fencing, roads and buildings.

Climate change impacts, such as more frequent drought, increased storms and fires, will add to current pressures on land health, particularly through the reduction of vegetation cover and erosion of exposed soils.

Assessing ACT's land health

Land health assessments are most commonly made through soil measures such as salinity, acidity, erosion and carbon. Baseline data and ongoing monitoring are required to determine changes in soil condition.

There has been no recent systematic assessment of soil condition in the ACT. Consequently, it is not possible to assess the condition of soils and land health in the ACT due to the lack of data.

It should be noted that research has been undertaken on the types and characteristics of soil landscapes in the ACT, the nature and consequences of potential soil degradation and the management required to reduce risks, and the salinity risks and priority areas for management.[16,17,18]

This information will be valuable to assist planning for the most appropriate land use, and improve management to prevent soil degradation. It can also be used to determine where soil monitoring will be most beneficial. However, these studies do not measure the actual extent of soil degradation in the ACT, nor the impacts of such degradation.

For private land, assessments of soil health and remediation may be undertaken by community natural resource management groups such as Landcare and Greening Australia with participating landholders. This is discussed in **Chapter 3 Community leadership in sustainability and science**.

16 Cook, W. et al., 2016, *Soil Landscapes of the Australian Capital Territory*, Office of Environment and Heritage, Queanbeyan, NSW.
17 Muller, R., Jenkins, B. and Nicholson, A., 2017, *Soil and Land Degradation Management for the Australian Capital Territory*, Office of Environment and Heritage, Wagga Wagga, NSW.
18 Muller, R. et al., 2017, *Hydrogeological Landscapes of the Australian Capital Territory*, Second edition, Office of Environment and Heritage, Wagga Wagga, NSW.

Land contamination

Contaminated sites include former petrol stations, landfills, and sites with previous chemical uses (such as sheep dips). These sites can impact on human health and the environment through the leaching of chemicals into groundwater and waterways, the release of air toxics, or through direct contact with contaminated soils and other substances.

As the rate of urban infill and greenfield development increases, it is reasonable to expect an increasing number of contaminated sites. The identification of contaminated sites allows their remediation, if required, and allows appropriate land use to be considered for the sites. In this way, development can be a driver for both the increased reporting and remediation of contaminated sites.

The Environment Protection Authority has the regulatory responsibility for the oversight of the remediation of contaminated sites. Contaminated sites such as old petrol stations, or those that were used for fuel storage, often require ongoing monitoring to determine any continuing impacts; other sites may be remediated with no further monitoring required.

Remediated sites are not currently removed from the contaminated sites register to ensure that any future use of these sites is compatible with site remediation. For example, a site may be remediated to a level that can accommodate industrial development, but may not be appropriate for residential development.

As at 2019, there were 1,088 contaminated sites in the ACT. These are mostly sites of former petrol stations or other fuel storage activities which accounted for 587 of the total. Other contaminated sites included 153 former sheep dips and 121 landfills.

Compliance with site contamination National Environment Protection Measure (NEPM)

Compliance with the National Environment Protection (Assessment of Site Contamination) Measure ensures that the ACT is achieving the national environment protection standard for the assessment of contaminated sites. This NEPM does not include site remediation.

The ACT must report annually on compliance with the site contamination NEPM to the National Environment Protection Council. Up to and including 2017–18, the ACT's contaminated sites monitoring and reporting activities were found to comply with the NEPM.[19]

Gully erosion. Source: OCSE.

19 National Environment Protection Council (NEPC), 2019, *Annual Report 2017–2018*, Canberra, found at http://www.nepc.gov.au/system/files/resources/1ed358dc-9aee-442f-9821-78ce95bf20a6/files/nepc-annual-report-2017-18.pdf, accessed 13 October 2019.

Urban development in Belconnen. Source: Ryan Colley.

DATA GAPS

- Data on land use in the ACT is poor with assessments reliant on planning zones rather than actual physical changes. Consequently, it is difficult to make assessments of land use changes.
- There is a general lack of knowledge on land health in the ACT, both for long-term changes and current conditions. This lack of information means that an assessment of land health over time is not possible and remains a critical gap in our understanding of environmental condition.
- There is no routine monitoring for soil health indicators such as erosion, salinity, structure decline, and reductions in organic content. Consequently, understanding of the actual extent of these problems is limited.

5.5 BIODIVERSITY

Section contents

Biodiversity and conservation in the ACT

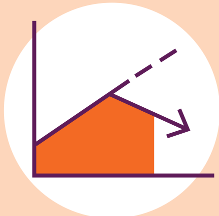
52 species listed as THREATENED

- **7** critically endangered
- **18** endangered
- **26** vulnerable
- **1** regionally conservation dependent
- **3** ecological communities are endangered

Conservation area

141,000
hectares protecting
60%
of the ACT

Environmental Offsets



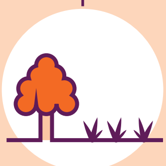
1,865
hectares
47%
in nature reserves

Revegetation[A]

100,000
tubestock and
200kg
of seed planted on public land

1,500
hectares of revegetation on private land

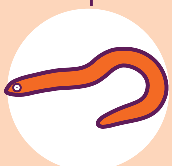
Representation in conservation areas



Threatened species which are dependent on grasslands and woodlands are the least represented in conservation areas

50%
of the Yellow Box / Red Gum Grassy Woodland communities are outside conservation areas

70%
of woodland, grassland and open forest communities are outside conservation areas



46%
of Striped Legless Lizard habitat is outside conservation areas

Only 34%
of native vegetation is within optimal tolerable fire interval

54,000
hectares of control for over 100 invasive plant species [B]

Rabbit control is the most common invasive animal management undertaken

A - Public land revegetation 2015–16 to 2018–19. Private land revegetation 2015–2018.
B - Between 2015–16 to 2018–19.

Indicator assessment

Indicator	Status	Condition	Trend	Data quality
B1: Threatened species and ecological communities	As at 2019, there were 7 critically endangered species, 18 endangered species, 26 vulnerable species and one regionally conservation dependent species in the ACT. Over the reporting period (2015–16 to 2018–19), 17 additional species were listed as threatened and 7 species were transferred to critically endangered to align with their Commonwealth status. There are 3 ecological communities classed as endangered, with High Country Bogs and Associated Fens added during the reporting period. In addition, 'the loss of mature native trees (including hollow-bearing trees) and a lack of recruitment' was listed as a key threatening process. While changes in listings do not necessarily represent a decline, it is clear that the future of some species and communities in the ACT are threatened without management intervention.	Poor	?	●●● High
B2: Extent and condition of conservation areas	Extent: Conservation areas protect 60% of the total ACT area and continue to increase as environmental offsets are added to the Canberra Nature Park network.	Extent: Good	↑	●●● High
	Condition: At the time of reporting, it was not possible to determine the condition of conservation areas in the ACT. It is also not currently possible to assess whether offsets have ensured no net loss of biodiversity as a result of land development. However, assessments for offsets will likely take many years. Recently initiated monitoring programs will greatly improve condition knowledge in the future.	Condition: Unknown	?	●○○ Low
B3: Representation of threatened species and ecological communities in conservation areas	While many of the ACT's threatened species and ecological communities are well represented in conservation areas, some flora and fauna species and ecological communities remain poorly represented. This is particularly the case for Natural Temperate Grassland and Yellow Box/Red Gum Grassy Woodland. For species with large proportions of non-reserved habitat, this is due to their dependence on grassland and woodland habitats, which are not as well protected in conservation areas as other ecosystems (such as forests).	Fair	↑	●●○ Moderate
B4: Extent and condition of native vegetation	Extent: Due to the large area of conservation reserves, the ACT has extensive areas of native vegetation. Any recent native vegetation losses are estimated to be small and mainly due to changes in land use from urban development. There have also been substantial revegetation efforts to restore habitat and connectivity.	Extent: Good	↑	●●○ Moderate
	Condition: It was not possible to determine an overall assessment of vegetation condition for the ACT, or changes over the reporting period (2015–16 to 2018–19). Available condition assessments show an increased occurrence of dieback in the ACT, large areas of poor riparian connectivity, much vegetation outside tolerable fire intervals and vegetation dominated by early and young growth stages. However, woodlands, Natural Temperate Grasslands and secondary grasslands have shown an increase in native plant species richness suggesting an improvement in condition.	Condition: Fair	?	●○○ Low
B5: Distribution and abundance of terrestrial invasive plants and animals	Invasive plants and animals continue to have a significant impact on native species and ecosystem health, and also represent a significant management burden. In areas where invasive species are controlled, outcomes clearly demonstrate the value of well-resourced and ongoing invasive species management to control established populations and to eradicate new outbreaks where possible.	Poor	–	●●○ Moderate

Indicator assessment legend

Condition

- **Good** = Environmental condition is healthy across the ACT, **OR** pressure likely to have negligible impact on environmental condition/human health.
- **Fair** = Environmental condition is neither positive or negative and may be variable across the ACT, OR pressure likely to have limited impact on environmental condition/human health.
- **Poor** = Environmental condition is under significant stress, OR pressure likely to have significant impact on environmental condition/ human health.
- **Unknown** = Data is insufficient to make an assessment of status and trends.
- **NA** = Assessments of status, trends and data quality are not appropriate for the indicator.

Trend

- ↑ Improving
- ↓ Deteriorating
- – Stable
- ? Unclear
- NA = Assessments of status, trends and data quality are not appropriate for the indicator.

Data quality

- ●●● **High** = Adequate high-quality evidence and high level of consensus
- ●●○ **Moderate** = Limited evidence or limited consensus
- ●○○ **Low** = Evidence and consensus too low to make an assessment
- ○○○ **NA** = Assessments of status, trends and data quality are not appropriate for the indicator.

Key actions

That the ACT Government:

ACTION 1: increase the protection of mature and hollow-bearing trees to maintain critical habitat.

ACTION 2: continue monitoring to evaluate the effectiveness of environmental offset conservation outcomes and the condition of conservation areas.

ACTION 3: increase the representation of the threatened Natural Temperate Grasslands and Yellow Box/ Red Gum Grassy Woodland communities in conservation areas, and improve protection for all grassland and open forest communities to support threatened species dependent on these ecosystems.

ACTION 4: improve knowledge on changes in vegetation extent from land use change and chronic degradation such as dieback.

ACTION 5: continue revegetation programs to improve native vegetation extent and connectivity.

ACTION 6: improve knowledge on vegetation condition across the ACT.

ACTION 7: ensure tolerable fire intervals are considered in prescribed burn decision frameworks.

ACTION 8: continue to undertake invasive and pest species management and ongoing control to minimise the impacts of established populations and to eradicate new outbreaks.

ACTION 9: improve funding and resourcing for biodiversity management on private land, and provide incentives to rural landholders to protect paddock trees.

ACTION 10: improve funding for citizen science groups that significantly contribute to the ACT's biodiversity knowledge

Main findings

Threatened species and ecological communities

As at 2019, a total of 52 species of fauna and flora across all habitats (terrestrial and aquatic) were listed as threatened under the Nature Conservation Act 2014.

These species include 7 critically endangered, 18 endangered, 26 vulnerable and 1 regionally conservation dependent.

During the reporting period (2015–16 to 2018–19), 17 additional species were listed as threatened and 7 species were transferred to critically endangered to align with their Commonwealth status.

Critically endangered species include the Regent Honeyeater (*Anthochaera phrygia*), Swift Parrot (*Lathamus discolor*), Northern Corroboree Frog (*Pseudophryne pengilleyi*), the locally extinct Yellow-spotted Bell Frog (*Litoria castanea*), Canberra Spider Orchid (*Caladenia actensis*), Brindabella Midge Orchid (*Corunastylis ectopa*), and the Kiandra Greenhood (*Pterostylis oreophila*).

Action plans and/or conservation advice have been developed for all species listed as threatened in the ACT.

Three ecological communities are listed as endangered. These are Natural Temperate Grassland, Yellow Box/ Red Gum Grassy Woodland, and High Country Bogs and Associated Fens which was added to the endangered category in 2019.

In 2018, 'the loss of mature native trees (including hollow-bearing trees) and a lack of recruitment' was listed as a key threatening process in the ACT, adversely affecting 4 vulnerable bird species including the Superb Parrot (*Polytelis swainsonii*), Brown Treecreeper (*Climacteris picumnus*), Glossy Black Cockatoo (*Calyptorhynchus lathami*) and Little Eagle (*Hieraaetus morphnoides*).

Conservation

Extent of conservation areas

In 2019, 141,000 hectares have conservation status in the ACT, protecting 60% of the total ACT area. This not only represents a significant proportion of the ACT's natural environment, but is also a much higher proportion than any other jurisdiction in Australia.

The Namadgi National Park and Bimberi Wilderness Area account for nearly 80% of the conservation area and around 46% of the total area of the ACT. Nature reserves (including Canberra Nature Park) account for 14% of the conservation estate, with water supply and special purpose reserves accounting for 5% and 3% respectively.

Over the reporting period (2015–16 to 2018–19), just over 1,000 hectares were added to the reserve system, primarily through environmental offsets added to the Canberra Nature Park network.

The area of environmental offsets has grown from 18 hectares in 2009 to 1,865 hectares in 23 offset areas in 2019.

This increase reflects the need to compensate for adverse environmental impacts from the significant increase in the ACT's urban footprint that has taken place since 2000, and continues today.

In 2019, 47% (871 hectares) of offsets were protected by nature reserve. Environmental offsets now contribute to around 16% of the ACT's urban and peri-urban reserve areas.

Outside of protected areas, progress in conservation of biodiversity, including both habitats and species, remains a challenge.

Although conservation areas provide protection by excluding damaging land uses and activities, they are still at risk from a range of pressures. Invasive species, inappropriate fire regimes, pathogens and diseases can all threaten ecosystem health and require ongoing intervention to minimise impacts.

Condition of conservation areas

At the time of reporting, it was not possible to determine the condition of conservation areas in the ACT.

It is also not currently possible to assess whether offsets have ensured no net loss of biodiversity following land development. However, assessments for offsets will likely take many years, particularly given that management interventions need to be undertaken over long periods of time to effect the desired ecosystem and biodiversity outcomes.

The ACT Government is implementing a Conservation Effectiveness Monitoring Program to evaluate the effectiveness of management actions in achieving conservation outcomes. This will greatly improve knowledge of conditions in the future.

Climate change will threaten conservation areas, especially where changes to temperature and rainfall, and the occurrence of fire, exceed the tolerances of ecosystems.

Representation of threatened fauna in conservation areas

The Broad-toothed Rat, Greater Glider, Northern Corroboree Frog, and Smoky Mouse threatened species have all, or close to all, of their known and potential habitat in ACT conservation areas.

Other threatened fauna with significant proportions of their known and potential habitat in ACT conservation areas include the Pink-tailed Worm-lizard (80%) and Spotted-tailed Quoll (70%).

Threatened fauna with less than 50% of their known and potential habitat in ACT conservation areas include the Perunga Grasshopper (47%), Golden Sun Moth (44%), Striped Legless Lizard (33%), and Grassland Earless Dragon (25%). However, these species have a substantial proportion of their habitat on national land (between 20% and 50%) and are subject to management as required under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The Grey-headed Flying Fox does not have habitat in ACT conservation areas but there are colonies occurring in Commonwealth Park (national land) and at Lake Ginninderra (urban open space).

Threatened species with substantial proportions of their known and potential habitat on non-reserved land (outside both ACT reserved and national lands) include the Pink-tailed Worm-lizard (20%), Spotted-tailed Quoll (27%), Golden Sun Moth (28%), Perunga Grasshopper (32%), and the Grassland Earless Dragon (33%). Of particular concern is the lack of reserved habitat for the Striped Legless Lizard with 46% of habitat not reserved.

For species with large proportions of non-reserved habitat, this is due to their dependence on grassland and woodland habitats which are not as well protected in conservation areas as other ecosystems such as forests.

All of the ACT-listed aquatic species have around 90% to 100% of their potential distribution in conservation areas.

Representation of threatened flora in conservation areas

Over half of the known threatened plant sites in the ACT are located in reserves or on other land managed by the ACT Parks and Conservation Service (PCS). An additional 20% occur on national land, which is managed by the National Capital Authority.

Threatened flora species with a substantial proportion of known locations outside ACT conservation areas include Black Gum (*Eucalyptus aggregata*), Button Wrinklewort (*Rutidosis leptorrhynchoides*), Tarengo Leek Orchid (*Prasophyllum petilum*), Canberra Spider Orchid (*Caladenia actensis*), Small Purple Pea (*Swainsona recta*), and Murrumbidgee Bossiaea (*Bossaiea grayi*).

Representation of threatened ecological communities in conservation areas

Of the three ecological communities listed as endangered in the ACT, only High Country Bogs and Associated Fens are fully protected in ACT conservation areas.

Natural Temperate Grassland has just over half of its known distribution in ACT conservation areas, and Yellow Box/Red Gum Grassy Woodland has only 30% reserved. However, both Natural Temperate Grasslands and Yellow Box/Red Gum Grassy Woodland have substantial proportions of their extent on national land at nearly 30% and 20% respectively, and are subject to management as required under the EPBC Act.

Despite this, nearly half of the ACT's Yellow Box/Red Gum Grassy Woodland is not reserved, and some 20% of Natural Temperate Grasslands are also unreserved. The low levels of reservation add to the pressures on these communities and the species they support.

For the 11 vegetation classes assessed, 8 had more than 80% of their extent protected, and another 2 had over 60% of their extent protected. The most under-represented vegetation class was Southern Tableland Grassy Woodlands which only has 30% of its extent in conservation areas.

The least protected vegetation communities in the ACT are woodland, grassland and open forest communities, with under 30% of their extent protected in conservation areas.

Native vegetation

Extent

It was not possible to determine changes in the extent of native vegetation over the reporting period (2015–16 to 2018–19).

Native vegetation losses are estimated to be small and mainly due to changes in land use due to urban development.

It is important that there is consideration of the cumulative impacts of small modifications to habitat, because these can lead to thresholds being crossed unknowingly and unintentionally for at least some aspects of vegetation and ecosystem health.

Most of the ACT's vegetation loss has been from historic clearing on lowlands and modification of ecosystems for agriculture and urban development. It is estimated that there has been little change in the distribution of upland vegetation types.

Prior to European settlement, Natural Temperate Grasslands were thought to cover over 25,000 hectares or 11% of the ACT area, but today they only cover around 1,100 hectares, less than 1% of the ACT.

For Lowland Box Gum Woodlands, the pre-European settlement distribution was thought to be over 47,000 hectares or 20% of the ACT area, but these woodlands now only cover some 11,500 hectares, around 5% of the ACT.

While the loss of native vegetation due to urban development remains of concern, it is unlikely to be the largest source of native vegetation change in the ACT. Chronic degradation of habitat condition, mainly in fragmented landscapes, is a significant problem in the ACT.

There has been substantial revegetation in the Murrumbidgee River Corridor nature reserves, Lower Cotter Catchment and other areas of public lands to restore habitat and connectivity. This has included planting some 100,000 tube stocks and 200 kilograms of native seed.

In addition, there were revegetation activities on some 1,500 hectares of private land between 2015 and 2018, mainly through works undertaken by Greening Australia.

Condition

It was not possible to determine changes in the condition of native vegetation over the reporting period (2015–16 to 2018–19). Nor was it possible to provide an overall assessment of vegetation condition.

Climate change has led to an increased occurrence of dieback in the ACT.

There has been a significant increase in the incidence of dieback in Blakely's Red Gum (*E. blakelyi*).

Significant areas of riparian vegetation on the Murrumbidgee and Molonglo Rivers have poor connectivity particularly in areas outside of reserves.

Since 2009, woodlands, Natural Temperate Grasslands and secondary grasslands have shown an increase in native plant species richness suggesting an improvement in condition.

However, woodland native species richness has seen a slight overall decline since 2014, possibly due to drought conditions experienced in 2018.

Native grass cover across all vegetation formations has been declining since 2012. This decline does not appear to be linked to drought. More analysis is required to determine if it is linked to management practices. The decline in this indicator is a concern because it has implications for fauna habitat and for weed invasion.

In 2018, only 34% of the total area of native vegetation assessed was found to be within the optimal tolerable fire interval to maintain vegetation communities, 53% was below minimum TFI (fire interval too short to maintain vegetation in its optimal state), 7% above the maximum TFI (fire interval too long to maintain vegetation in its optimal state), and 6% classed as long unburnt.

Native vegetation growth stages across the ACT reflect a similar pattern to tolerable fire interval status, with extensive areas of the uplands being dominated by early and young growth stages due to the 2003 bushfires. This has significant implications for biodiversity, especially for fauna that require older growth stages.

In the longer term, conservation needs to focus on diversifying growth stages. In the lowlands, this can be achieved through the ecological burning of late and mature growth stages for vegetation resilient to fire. However, in the uplands achieving growth stage diversity will require time and deliberate protection of the relatively rare older growth stages from prescribed fire and bushfire until more of the landscape reaches post-fire maturity.

Invasive terrestrial plants and animals

Invasive plant and animal species continue to pose a major threat to biodiversity, ecosystem health, primary production, social amenity and human health.

Data on management outcomes clearly demonstrates the value of invasive species management to control established populations and to eradicate new outbreaks where possible.

Management results also show the risk of invasive plant and animal populations re-establishing themselves in the absence of ongoing control.

Invasive plants

There have been 592 invasive plant species recorded in the ACT.

Data on management activities clearly demonstrates the value of invasive plant management to control established populations and to eradicate new outbreaks where possible.

Management results also show the risk of invasive plant populations re-establishing themselves in the absence of ongoing control.

Over the reporting period (2015–16 to 2018–19), 54,000 hectares of invasive plant control was undertaken in the ACT for over 100 invasive plant species.

Serrated tussock accounted for the largest area treated at nearly 14,000 hectares, followed by St. John's wort (over 10,000 hectares), blackberry (7,700 hectares) and African lovegrass (6,900 hectares).

Invasive animals

It was not possible to comprehensively determine the distribution and abundance of invasive animals in the ACT for this report.

Records show the presence of 64 introduced animal species in the ACT, including 17 mammals, 33 birds, 2 lizards, 1 frog and 11 fish.

The invasive animal species of most concern in the ACT are feral pigs, deer, foxes, rabbits, horses and wild dogs, with control programs undertaken for all these pests.

Rabbits are the most widespread and damaging invasive animal in the ACT, impacting on natural and rural lands. Rabbit control is the most common invasive animal management undertaken.

Deer and horses have the potential to cause significant environmental damage to sensitive alpine bogs and fens, woodlands and agriculture.

As with invasive plants, to be effective the management of mobile and rapid breeding animals such as rabbits requires ongoing control.

Despite the significant impacts on native wildlife, the ACT has no formal programs to manage stray or feral cats. The exception is cat containment legislation for new suburban developments.

Foxes have been shown to have a devastating impact on native wildlife in the ACT with the potential to cause local extinctions of vulnerable native species. Foxes were responsible for the loss of Bettongs released in the Lower Cotter Catchment between 2015 and 2017.

The restoration of native populations is dependent on the effective control of invasive species.

Annual kangaroo culls are undertaken to protect the ACT's grassy ecosystems from overgrazing. Between 2009 and 2019, over 22,000 kangaroos were culled. The largest annual cull was 4,035 kangaroos conducted in 2019. The annual cull numbers have increased annually since 2013, mainly due to the increased number of management sites.

INTRODUCTION

This section provides an assessment of biodiversity in the ACT, including threatened and important species, conservation of ecosystems and species, native vegetation, and invasive plants and animals. The following indicators are assessed:

- B1: Threatened species and ecological communities
- B2: Extent and condition of conservation areas
- B3: Representation of threatened species and ecological communities in conservation areas
- B4: Extent and condition of native vegetation
- B5: Distribution and abundance of terrestrial invasive plants and animals

Healthy biodiversity is essential to the natural world and fundamental to human life. The complex and dynamic interactions between plants, animals, microorganisms and soil, water and air underpin the health of the ecosystems. Whilst biodiversity is dependent on good ecosystem health, biodiversity itself plays a pivotal role in maintaining ecosystems. Biodiversity loss or decline can have significant consequences for natural processes, decrease the availability of habitat, and impact on predator–prey relationships. In severe cases, biodiversity loss can lead to significant changes in ecosystems and the functions they provide.

Biodiversity may also make ecosystems more resilient to pressures such as climate change and fire. A diversity of species and ecological processes can help ecosystems to maintain their core functions in the face of environmental change.

Because terrestrial ecosystems are intimately connected to aquatic ecosystems, their degradation has consequences for the condition of the ACT's rivers, lakes, and wetlands.

Healthy ecosystems, biodiversity and land provide a range of benefits to human wellbeing, including climate regulation, clean air and water, nutrient cycling, pollination, control of pests, carbon sequestration, and the supply of foods and fibres. It is important to maintain and, where necessary, improve the health of ecosystems to ensure the continued availability of the services they provide.

Pressures on biodiversity

The main pressures on biodiversity in the ACT are land use change (particularly greenfield development), climate change, invasive plants and animals, vegetation loss, habitat fragmentation and changes to fire regimes. The use of chemicals such as pesticides can also have significant impacts on biodiversity, especially insects.

Climate change is predicted to compound existing pressures on biodiversity. Projections of significant shifts in local climates and increases in drought, bushfires and storms, will have an impact on biodiversity and natural ecosystems.

Climate change is likely to impact species with limited capacity to migrate, such as those restricted to particular habitats and fragmented landscapes, or those that tolerate only narrow ranges of temperature and rainfall. Species dependent on wetland and mountainous ecosystems have been identified as being at greatest risk. Climate change will exacerbate current environmental pressures; therefore the capacity of natural ecosystems to adapt to climate change will improve if existing threats are addressed.

DATA TRENDS

Indicator B1: Threatened species and ecological communities

Biodiversity is the variety of life. This can include the diversity of genes within a species, the diversity of species within a landscape and the diversity of ecosystems across landscapes. It can also include the diversity of ecological processes that underpin the functioning of ecosystems such as seed dispersal, pollination and nutrient cycling.

The ACT's terrestrial and aquatic ecosystems are home to many flora and fauna species. The urban environment also supports many species, either as a food source or a place to live. Records from Canberra Nature Map show that there have been 2,815 fauna species sighted in the ACT.[1] This includes 2,751 native species – 67 mammals, 298 birds, 14 snakes, 49 lizards, 37 frogs, 2 turtles, 28 fish, 188 spiders and 2068 insects. There have also been 64 introduced species recorded – 17 mammals, 33 birds, 2 lizards, 1 frog and 11 fish.

For flora, the 2017 *Census of the Flora of the Australian Capital Territory* found 2,088 indigenous species (1,032 vascular plants, 263 fungi, 490 lichens, 3 hornworts, 77 liverworts, 195 mosses and 28 slime moulds). It also found 592 introduced species, 53 of which were introduced from elsewhere in Australia.[2] The ACT has 4 endemic plant species from 3 families: Canberra Spider Orchid, Brindabella Midge Orchid, Ginninderra Peppercress and Tuggeranong Lignum.

It is not possible to accurately measure the distribution and abundance of all species in the ACT. This is because not all species occurring in the ACT are known, let alone counted, and not all areas of the ACT can be surveyed and monitored. Consequently, assessment of biodiversity is mainly focused on the monitoring and management of threatened species.

It is important to note that some species found in the ACT are temporary residents. Migratory and highly mobile species such as birds may only be present for breeding, or in response to food and water availability. For such species, changes in their annual abundance and distributions in the ACT may result from external influences including changes to food availability, loss of habitat or increase in invasive species. Consequently, populations can increase or decrease regardless of the condition of the ACT environment.

Listing of Threatened Species and ecological communities in the ACT

The *Nature Conservation Act 2014* (ACT) establishes a formal process for the identification and protection of threatened species and ecological communities, as well the identification of ecologically significant threatening processes.[3] The ACT Scientific Committee is responsible for providing advice on listings under the Act.[4]

The listing of threatened species reflects the International Union for the Conservation of Nature categories and criteria to improve alignment with the Commonwealth's listing categories. The different categories provide a guide as to the level of management which a species may require. A species may be assessed at the national scale and listed in a national category as extinct, extinct in the wild, critically endangered, endangered, vulnerable, or conservation dependent. A native species occurring in the ACT may be listed in a regional category if it does not meet national criteria.

1 More information on the Canberra Nature Map can be found at https://canberra.naturemapr.org/
2 Australian National Herbarium, Centre for Australian National Biodiversity Research, 2017, Census of the Flora of the ACT, found at https://www.anbg.gov.au/cpbr/ACT-census-2017/index.html
3 The *Nature Conservation Act 2014* can be found at https://www.legislation.act.gov.au/a/2014-59/default.asp
4 EPSDD, ACT Scientific Committee, more information found at https://www.environment.act.gov.au/cpr/advisory-bodies/act-scientific-committee

Limitations of threatened species and community lists

The extent and abundance of threatened flora and fauna species and associated changes in threatened status may provide a measure of the condition of biodiversity and highlight those species at risk. For example, if a species moves from vulnerable to endangered it may indicate potential biodiversity loss. However, the number of threatened species needs to be interpreted with caution as listings are influenced by factors such as effort and attention given to different species, improved knowledge rather than actual changes in status, changes in the methodology used to assign status, and the number of taxa reviewed regularly. It is also important to note that conservation status for a species is assessed for all of the ACT; it does not reflect local variations in population status, nor the status of species in other parts of Australia.

The status of threatened species may also be of limited value in determining changes in environmental condition. This is because a species may be affected by a combination of pressures, or by subtle drivers that do not impact on the wider ecosystem. Despite these factors, the listing of threatened species and ecological communities, as well as changes to threat status over time, can be useful for assessing the effectiveness of management actions.

Threatened species in the ACT

In 2019, a total of 52 species of fauna and flora across all habitats (terrestrial and aquatic) were listed as threatened under the *Nature Conservation Act 2014* (Figure 1). These species included:

- 7 critically endangered species, with 1, the Yellow-spotted Bell Frog (*Litoria castanea*), locally extinct.
- 18 endangered species.
- 26 vulnerable species, with 2, the Green and Golden Bell Frog (*Litoria aurea*) and the Southern Bell Frog (*Litoria raniformis*), locally extinct.
- 1 species, the Eastern Bettong, regionally conservation dependent.

Birds, mammals and flora accounted for the majority of threatened species in the ACT.

All local extinctions occurred decades ago and were amphibian species which are among the most threatened group of animals in Australia and globally.

Changes to species listed as threatened over the reporting period (2015–16 to 2018–19) include:

- 17 additional species have been listed as threatened.
- 7 species transferred to critically endangered to be consistent with Commonwealth status. These are the Regent Honeyeater (*Anthochaera phrygia*), Swift Parrot (*Lathamus discolor*), Northern Corroboree Frog (*Pseudophryne pengilleyi*), the locally extinct Yellow-spotted Bell Frog (*Litoria castanea*), Canberra Spider Orchid (*Caladenia actensis*), Brindabella Midge Orchid (*Corunastylis ectopa*), and the Kiandra Greenhood (*Pterostylis oreophila*).
- 4 species added as endangered to be consistent with Commonwealth status.
- 11 species added as vulnerable due to assessment of additional data and/or to be consistent with Commonwealth status.

Action plans and/or conservation advice have been developed for all species listed as threatened in the ACT.

Some of the ACT's threatened fauna species lack wild populations, only occurring in managed sanctuaries. These species include:

- Eastern Quoll and New Holland Mouse: there are no known wild populations in the ACT, although both species have been reintroduced to the Woodland Sanctuary at Mulligans Flat Nature Reserve.
- Eastern Bettong: there are reintroduced populations at Tidbinbilla and Mulligans Flat Nature Reserve.
- Southern Brown Bandicoot: has a reintroduced population at Tidbinbilla. The species was recorded outside Tidbinbilla after the 2003 fires but has not been recorded since then, despite targeted survey effort in 2011.
- Koala and Brush-tailed Rock-wallaby: there are no recent records of both species and are presumed extinct in the ACT. There is a reintroduced population of Brush-tailed Rock-wallaby in an enclosure at Tidbinbilla and areas of potential habitat occur in Namadgi National Park.

A full list of threatened species and their main threats are shown in Table 1 at the end of the Biodiversity section.

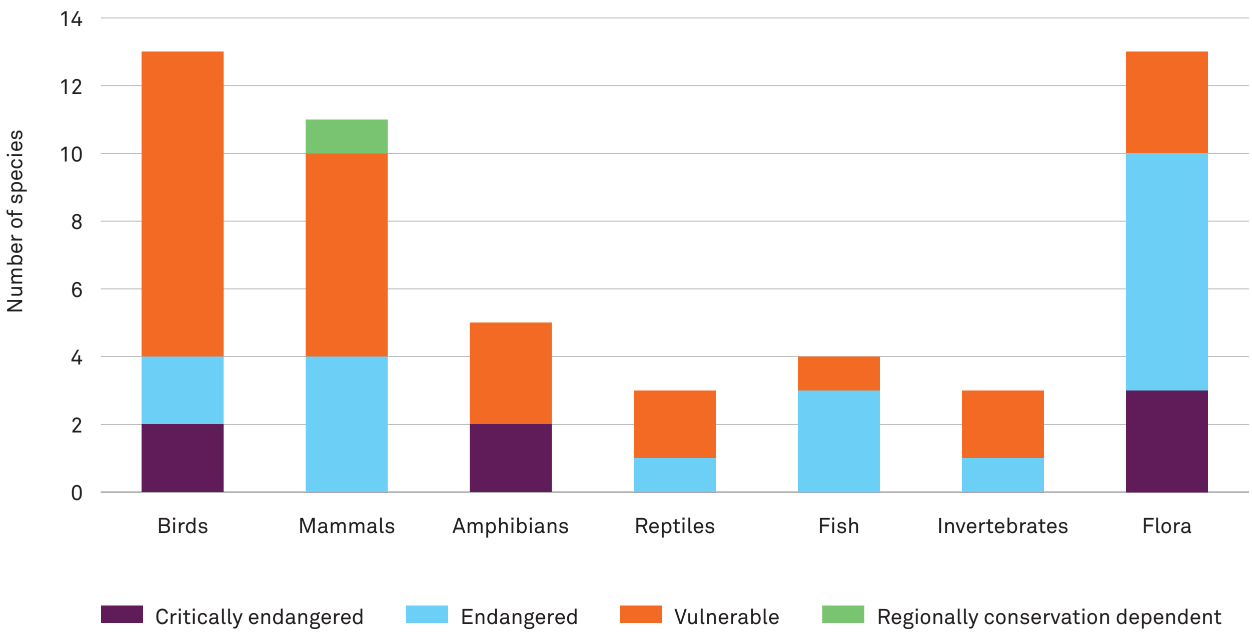


Figure 1:
Species listed as threatened under the *Nature Conservation Act 2014*

Data sourced from: Environment, Planning and Sustainable Development Directorate

Notes: *Critically endangered*: a species is facing an extremely high risk of extinction in the wild in the immediate future; *Endangered*: a species is facing a very high risk of extinction in the wild in the near future; *Vulnerable*: a species is facing a high risk of extinction in the wild in the medium-term future; *Regionally conservation dependent*: either a species of fish and/or the subject of a plan of management that if ended may result in the species becoming threatened.

Superb Parrot. Source: Ryan Colley.

CASE STUDY: TRENDS IN BROWN TREECREEPER POPULATION

Supplied by the Canberra Ornithologists Group

The Brown Treecreeper (*Climacteris picumnus*) is listed as vulnerable under the *Nature Conservation Act 2014*. The Canberra Ornithologists Group (COG) Annotated Checklist for the Birds of the Australian Capital Territory (November 2017) lists the Brown Treecreeper as a rare, breeding resident.

The Brown Treecreeper inhabits open Box Gum Woodland, with an open understorey and fallen timber, and requires suitable breeding hollows. The species appears to be at a disadvantage if the vegetation remains ungrazed and the grassy herb layer becomes tall and dense.

The Brown Treecreeper is a species that declines or disappears in response to increased urbanisation. The greatest threat to the Brown Treecreeper is habitat loss from land clearing, habitat fragmentation, clearance of hollow-bearing trees, a lack of tree recruitment, or removal of fallen timber. The fragmentation of woodlands may mean that the small pockets of surviving birds are not resilient enough to overcome disturbance events such as droughts, fire and vegetation loss.

Distribution and abundance

Once common in the ACT, the Brown Treecreeper has been absent from several sites for many years, including Mount Ainslie and Campbell Park. Surveys conducted in association with the COG woodland surveys have shown that over the period 2000 to 2017 the Brown Treecreeper has disappeared from 11 woodland survey sites in the ACT. The survey sites in this project include reserves within peri-urban Canberra, some leasehold sites, and Department of Defence-managed land. Reports from other sites within the ACT and surrounding NSW from which long-term records have been collected also suggest that the birds are no longer present. There are some birds remaining around Googong foreshores and south of Canberra on the Monaro.

From 2000 to 2009, the Brown Treecreeper reporting rate across the ACT and surrounding area remained relative stable at around 3–4%, but this decreased to 0.7% in 2018 (Figure 2). In addition, the largest number reported in 2018 was of 8 individuals and only 5 of the 82 reports received were in the ACT. Surveys of 15 woodland sites conducted between 1998 and 2018 shows a general downward trend in the reporting rate for the Brown Treecreeper.

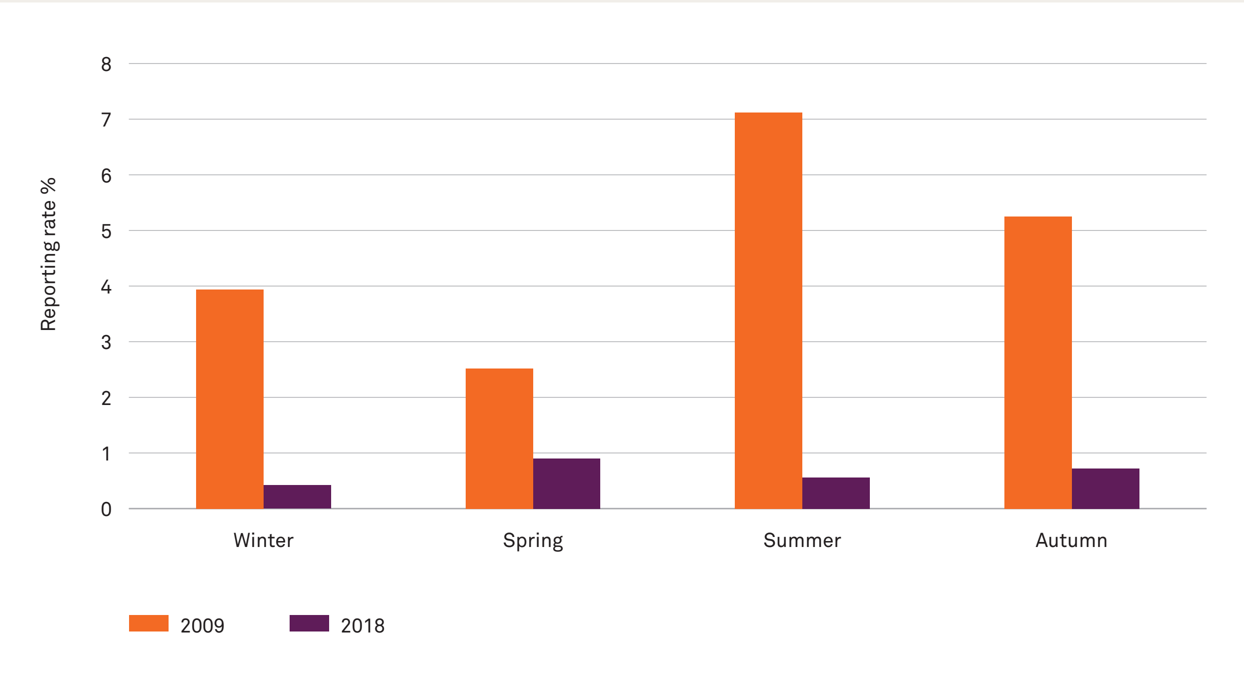


Figure 2:
A comparison of reporting rate for Brown Treecreeper across the ACT and surrounding area over four seasons in 2009 and 2018.

Notes: Data taken from records held by the Canberra Ornithologists Group where reporting rate is taken as the number of recorded occurrences, divided by the total number of lists expressed as a percentage

These results suggest that the future presence of the Brown Treecreeper in the ACT is in some doubt.

Despite the creation of reserves and improvements in woodland management, the Brown Treecreeper, along with other woodland species such as the Hooded Robin (*Melanodryas cucullata cucullata,* also listed as vulnerable), continue to decline in the ACT. For example, management intervention at Kama South Nature Reserve in the Molonglo Valley – such as the creation of a dedicated reserve, revegetation, grazing exclusion, and weed control – has not prevented the decline and subsequent disappearance of the Brown Treecreeper from the area.

Research

There are two Brown Treecreeper research or monitoring projects currently active in the ACT:

- The Canberra Ornithologists Group continues to receive ad hoc sightings on the location and number of Brown Treecreeper seen in the ACT and local region. These continuing observations started in 1981.
- An analysis and interpretation of results of a long-term dataset collected from woodland sites within the ACT is under way including an analysis of Brown Treecreeper observations.

Brown Treecreeper. Photo: Harvey Perkins.

CASE STUDY: GRASSLAND EARLESS DRAGON

Source: ACT Parks and Conservation Service (PCS)

The Grassland Earless Dragon is a small species of dragon lizard. It was previously thought to be one species, with disjointed populations spanning from near Melbourne to the Bathurst region. However, research in 2019 revealed that there are actually four distinct species of Grassland Earless Dragon with much smaller ranges and population sizes.[5] The species found in the ACT region (*Tympanocryptis lineata)* is not found anywhere else in Australia.

The Canberra Grassland Earless Dragon lives solely in patches of Natural Temperate Grassland in the ACT, and just across the NSW border in Queanbeyan. The species was previously thought to be extinct until its rediscovery in the early 1990s. It is currently listed as endangered in the ACT and nationally. Since its rediscovery, there has been a concerted effort to understand more about the dragon's biology, ecology and population trends.

The Canberra Grassland Earless Dragon inhabits fairly undisturbed Natural Temperature Grasslands dominated by wallaby grasses (*Rytidosperma spp.*) and spear grasses (*Astrostipa spp.)*. They use burrows for shelter, temperature regulation, and to lay their eggs in spring. These burrows are thought to be made, or enhanced, by invertebrates such as wolf spiders and the Canberra Raspy Cricket (*Cooraboorama canberrae).*

Distribution and abundance

The current population size of the Canberra Grassland Earless Dragon is small. Long-term monitoring at four grassland sites in the ACT over the last two decades has found that while there are some short-term fluctuations in population numbers, there has been an overall decline in both the number of sites where the lizards are found and a general decline in numbers detected at each site.

A significant decline in population numbers occurred during the millennium drought (1999–2009), which coincided with overgrazing, mostly by kangaroos. Although the population showed a general recovery in response to post-drought average and above average rainfall, the lack of recovery at some sites is of major concern. This appears to be related to unsuitable habitat conditions such as grass that is either too long or too short, as well as weed infestations. This in turn is related to the pressure of kangaroo grazing and weeds. The recent dry conditions have resulted in very low numbers detected at monitoring sites.

Breeding program

In 2019, a breeding program for Canberra Grassland Earless Dragons was established at Melbourne Zoo through collaboration between the ACT Government and Zoos Victoria. Twelve dragons were sourced from grassland in the ACT as the initial founders for the program. The breeding program will allow for the future reintroduction of dragons back into the wild, including at sites where they have not been detected for some years.

Habitat restoration

From 2013 to 2015, vegetation density at the monitoring sites increased due to above average rainfall and a reduction in herbivore grazing pressure. This has led to a reduction in habitat quality and corresponding decline in the dragon population. To improve grassland habitat, the ACT Government, with funding from the National Landcare Program, implemented a large-scale ecological burning program in 2015. Since then, over 50 hectares of dragon habitat has been burned in either spring or autumn. Over this period, seven monitoring grids where the dragon had been lost were also burned. These burns successfully opened up the vegetation and have led to very positive outcomes, with all areas subsequently being re-colonised by the Canberra Grassland Earless Dragon.

5 Melville, J. et al., 2019, 'Taxonomy and Conservation of Grassland Earless Dragons: New Species and an Assessment of the First Possible Extinction of a Reptile on Mainland Australia', *Royal Society Open Science* 6(5).

Grassland Earless Dragon captured in 2019 monitoring at Jerrabomberra East. The green mark is used to track individual dragons throughout the monitoring period. Photo: ACT Parks and Conservation Service.

Small-scale patch burns being undertaken at Jerrabomberra West grassland by the Parks and Conservation Service. This area was previously occupied by the grassland earless dragon. Photo: ACT Parks and Conservation Service.

Threatened ecological communities

An ecological community is defined as a naturally occurring group of native plants, animals and other organisms that are interacting in a unique habitat. The community's structure, composition and distribution are determined by environmental factors such as soil type, position in the landscape, altitude, climate, and water availability. The native plants and animals within an ecological community have different roles and relationships that, together, contribute to the healthy functioning of the environment and to the provision of ecosystem services.

Under the *Nature Conservation Act 2014* a community may be listed as collapsed, critically endangered, endangered, vulnerable or provisional.

In 2019, there were three ecological communities in the ACT listed as endangered:

- Natural Temperate Grassland (listed 15 April 1996).
- Yellow Box/Red Gum Grassy Woodland (listed 30 May 1997).
- High Country Bogs and Associated Fens (listed 8 February 2019).

CASE STUDY:
HIGH COUNTRY BOGS AND ASSOCIATED FENS

Source: Environment, Planning and Sustainable Development Directorate

High Country Bogs and Associated Fens was added to the endangered category of the ACT Threatened Ecological Communities List on 8 February 2019. This is consistent with national and other jurisdictional listings.

The majority of bogs and fens in the ACT occur within Namadgi National Park (Figure 3). Bogs and fens are significant because they provide critical refuge and habitat for endemic and threatened animal species, including the Critically Endangered Northern Corroboree Frog (*Pseudophryne pengilleyi*), as well as the Broad-toothed Rat (*Mastacomys fuscus mordicus*) and Verreaux's Alpine Tree Frog (*Litoria verreauxii alpina*). Bogs and fens also play an important role in protecting water quality within the ACT's water catchment.

The Ginini Flats Wetland Complex is one of the most significant intact Sphagnum bog and fen communities in the Australian Alps and is listed under the Convention on Wetlands of International Importance (known as the Ramsar convention).

Climate change and its associated impacts pose the greatest threat to the bogs and fens in the long term, with potentially severe consequences. In the short term, fire, weed invasion, trampling and wallowing by hoofed pest animals, tourism and recreational activities are key threats to bogs and fens in the ACT.

Hard-hoofed animals can be particularly destructive to bogs and fens. Changes to feral horse policy in NSW combined with the increase in numbers and range of feral deer means that the risk is increasing.

The ACT feral horse management plan has been successful in quickly controlling the occasional horse incursions from Kosciuszko National Park. However, feral horses are considered a potential significant threat to this fragile ecological community if ACT control measures are insufficient to deal with increased incursions arising from changes to NSW legislation to protect wild horses.

The overall objective is to conserve High Country Bogs and Associated Fens in perpetuity as a viable and well-represented community across its natural geographic range in the ACT by:

- protecting all areas of bogs and fens in the ACT through reservation
- managing threats (particularly hard-hoofed animals and fire)
- improving the condition and ecological function of bogs and fens
- improving understanding of bog and fen ecology, restoration principles and best practice threat management, particularly in light of climate change, and
- strengthening stakeholder and community collaboration in the conservation of bogs and fens.

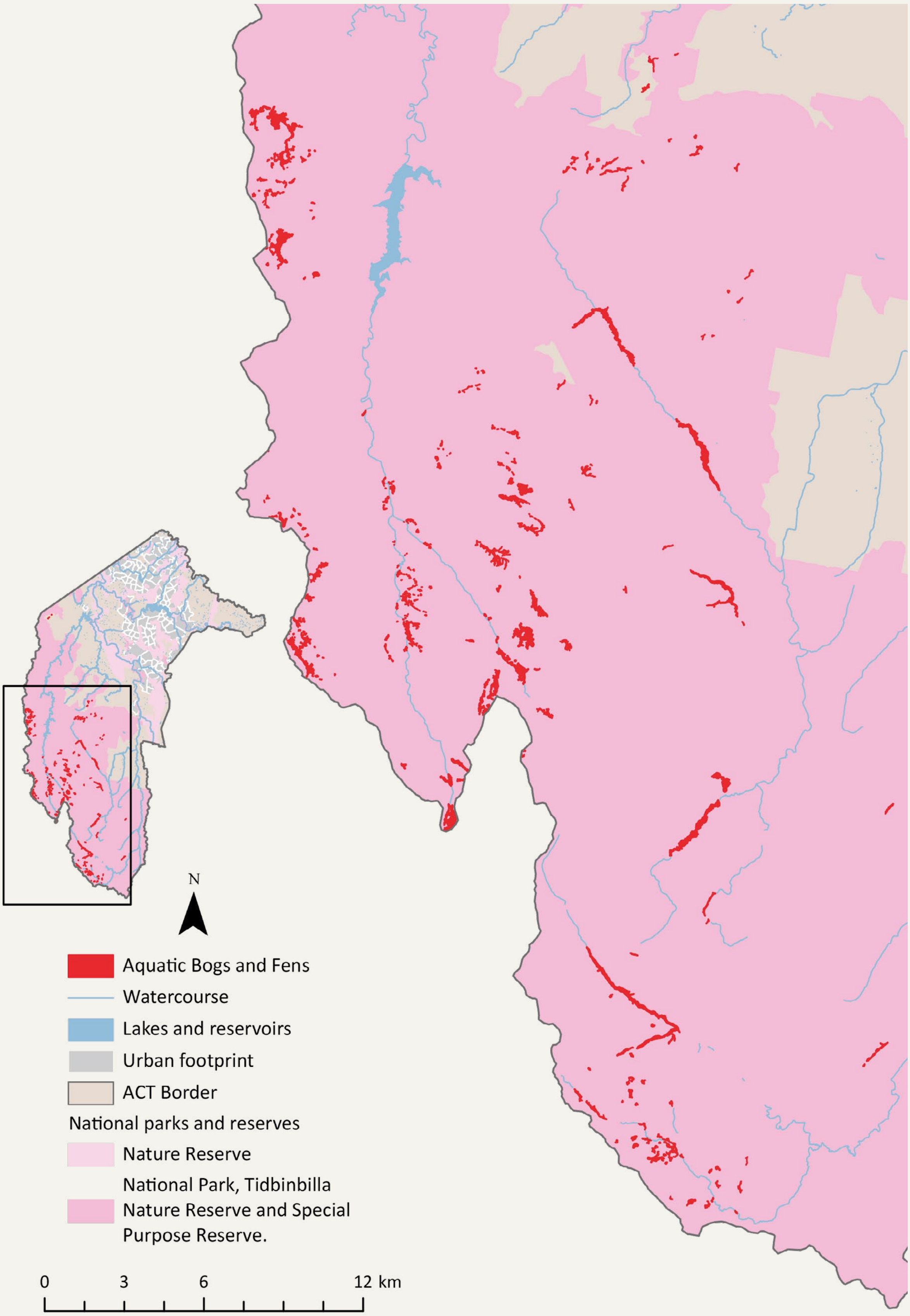


Figure 3:
Bogs and Fens in the ACT.

Data sourced from: Environment, Planning and Sustainable Development Directorate

Key threatening processes

A process is defined as threatening if it has the potential to threaten the survival of a species or ecological community in the ACT. These processes include effects of past clearing, fragmentation and modification of habitat, the impacts of invasive plants and animals, the alteration of hydrological regimes and the increasing threat of climate change.

Under the *Nature Conservation Act 2014*, a process may be listed as a key threatening process. This listing is a formal recognition of a conservation threat and requires an Action Plan to be prepared to address the threatening process.

In 2018, 'the loss of mature native trees (including hollow-bearing trees) and a lack of recruitment' *w*as listed as a key threatening process in the ACT. The significant loss of mature trees was determined by the Scientific Committee to be adversely affecting the Superb Parrot (*Polytelis swainsonii*), Brown Treecreeper (*Climacteris picumnus*), Glossy Black Cockatoo (*Calyptorhynchus lathami*) and Little Eagle (*Hieraaetus morphnoides*). These species are listed as vulnerable in the ACT.

The main threatening processes for all listed threatened species in the ACT are shown in Table 1 at the end of the Biodiversity section.

Indicator B2: Extent and condition of conservation areas

The ACT's conservation areas are critical for the protection of natural ecosystems and the biodiversity and services they support. Parks and reserves provide habitat for many threatened species and ecological communities. They represent the ACT's most extensive and least disturbed environments, as well as remnant ecosystems within urban and agricultural lands.

Conservation areas provide a range of benefits for the ACT community including ecosystem services such as clean air and water. Conservation areas also play an important role in nature-based recreation and tourism, which provides significant health and education benefits and contributes to the ACT economy.

Whilst conservation areas exclude damaging land uses and activities, the ecosystems and biodiversity they protect are still at risk from a range of pressures. Invasive species, inappropriate fire regimes, pathogens and diseases present a serious threat to the ACT's ecosystems and biodiversity and require ongoing intervention to minimise impacts. Climate change will also threaten conservation areas, especially where changes to temperature and rainfall, and the occurrence of fire, exceed the tolerances of ecosystems.

Environmental offsets

Environmental offsets are land added to environmental reserves to address potential development pressures. In the ACT, offsets provide environmental compensation for a development that is likely to have adverse environmental impact on a protected matter. In the ACT, offsets are categorised as those that are:

- required under the EPBC Act to compensate for the residual adverse impacts of an action on Commonwealth-listed threatened species and communities classed as Matters of National Environmental Significance (MNES).[6] MNES within the ACT that are currently protected in land offsets include White Box, Yellow Box, Blakely's Red Gum Grassy Woodland (Box Gum Woodland), Natural Temperate Grassland, Striped Legless Lizard (*Delma impar*), Golden Sun Moth (*Synemon plana*), Pink-tailed Worm Lizard (*Aprasia parapulchella*), Superb Parrot (*Polyteli swainsonii*), and Button Wrinklewort (*Rutidosis leptorhynchoides*).
- required under the ACT's *Planning and Development Act 2007* (the Planning Act) to provide environmental compensation for the likely impact on a declared protected matter.[7]

Almost all environmental offsets within the ACT are delivered via direct land offsets which protect, conserve and restore areas land with specific ecological values. Indirect offsetting is generally a last resort or an additional requirement such as the proposal of development funding research into a protected matter. Indirect offsets have been established in respect of Strategic Assessments in Gungahlin and the Molonglo Valley.

In response to a ministerial direction, independent audits of the Gungahlin and Molonglo Valley offsets have been undertaken.[8, 9] These assessments focused on the implementation of commitments in accordance with procedures established under the EPBC Act. For each audit, Corrective Action Requests were issued, all of which were addressed by the ACT Government and the audit closed. The next audits are due in 2022.

6 Department of Sustainability, Environment, Water, Population and Communities, 2012, *Environment Protection and Biodiversity Conservation Act 1999*, Environmental Offsets Policy, Commonwealth of Australia.

7 *Planning and Development Act 2007* (ACT), s. 111C.

8 Commissioner for Sustainability and the Environment, 2018, Independent Audit of the Gungahlin Strategic Assessment. ACT Government, Canberra, found at https://www.envcomm.act.gov.au/investigations/independent-audit-of-the-gungahl in-strategic-assessment

9 Commissioner for Sustainability and the Environment, 2018, Independent Audit of the Molonglo Valley Strategic Assessment, ACT Government, Canberra, found at https://www.envcomm.act.gov.au/investigations/independent-audit-of-the-molong lo-valley-strategic-assessment

Extent of conservation areas

In 2019, there was 141,000 hectares of conservation areas in the ACT, protecting 60% of the total ACT area (Figure 4). This not only represents a significant proportion of the ACT's natural environment, but is also a much higher proportion than any other jurisdiction in Australia.

Categories of conservation in the ACT include national park, wilderness area, nature reserve, water supply protection, and special purpose reserve. The Namadgi National Park and Bimberi Wilderness Area account for nearly 80% of the conservation area and around 46% of the total area of the ACT. Nature reserves (including Canberra Nature Park) accounts for 14% of the conservation estate, with water supply and special purpose reserves accounting for 5% and 3% respectively (Figure 5).

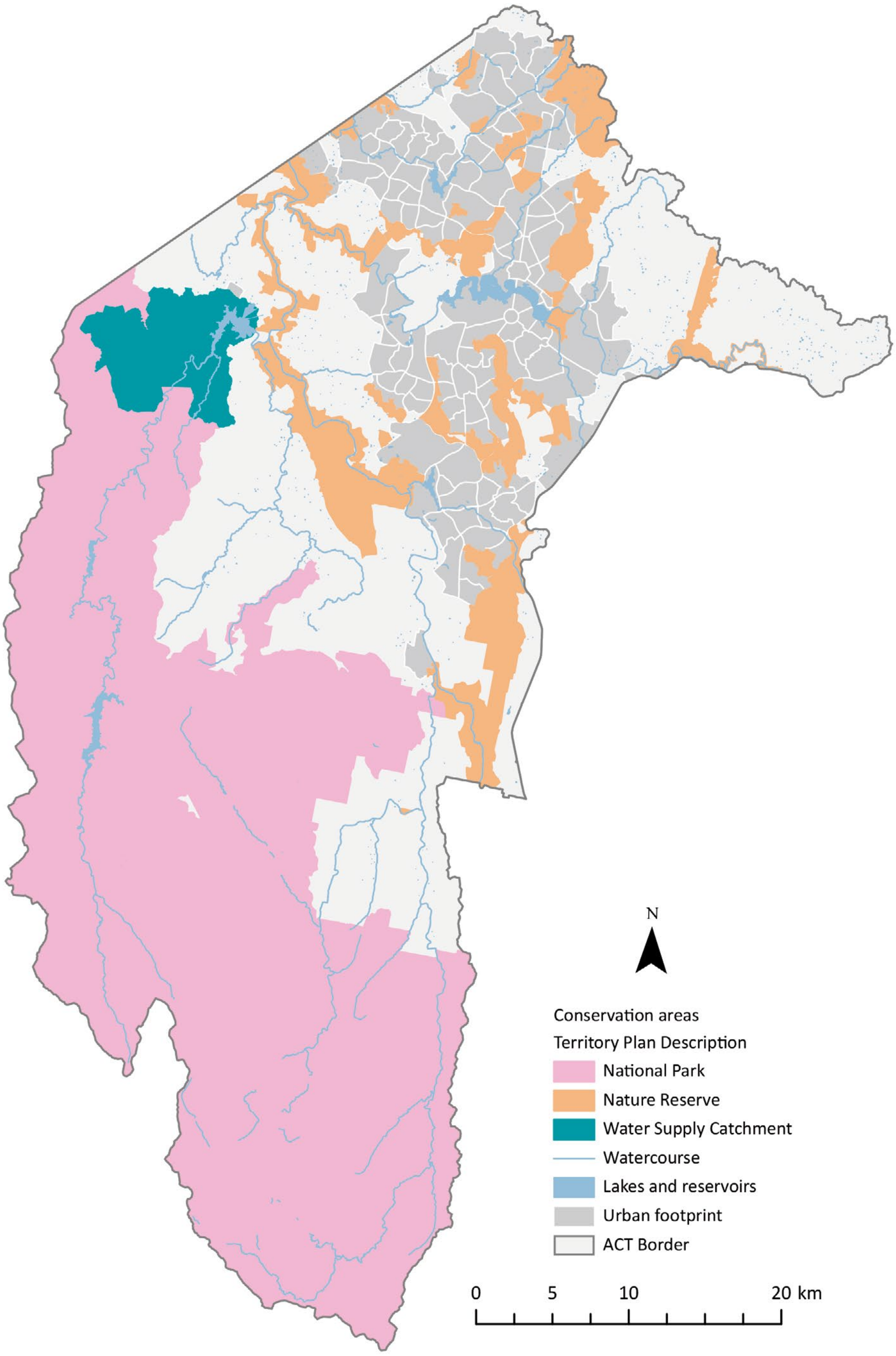


Figure 4:
ACT Conservation areas by type.

Data sourced from: Transport Canberra and Community Services

Notes: National Park includes the Namadgi National Park, Bimberi Wilderness Area and the Tidbinbilla Nature Reserve. Nature Reserve includes Canberra Nature Park, the Molonglo River Reserve, Murrumbidgee River Corridor and the Jerrabomberra Wetlands.

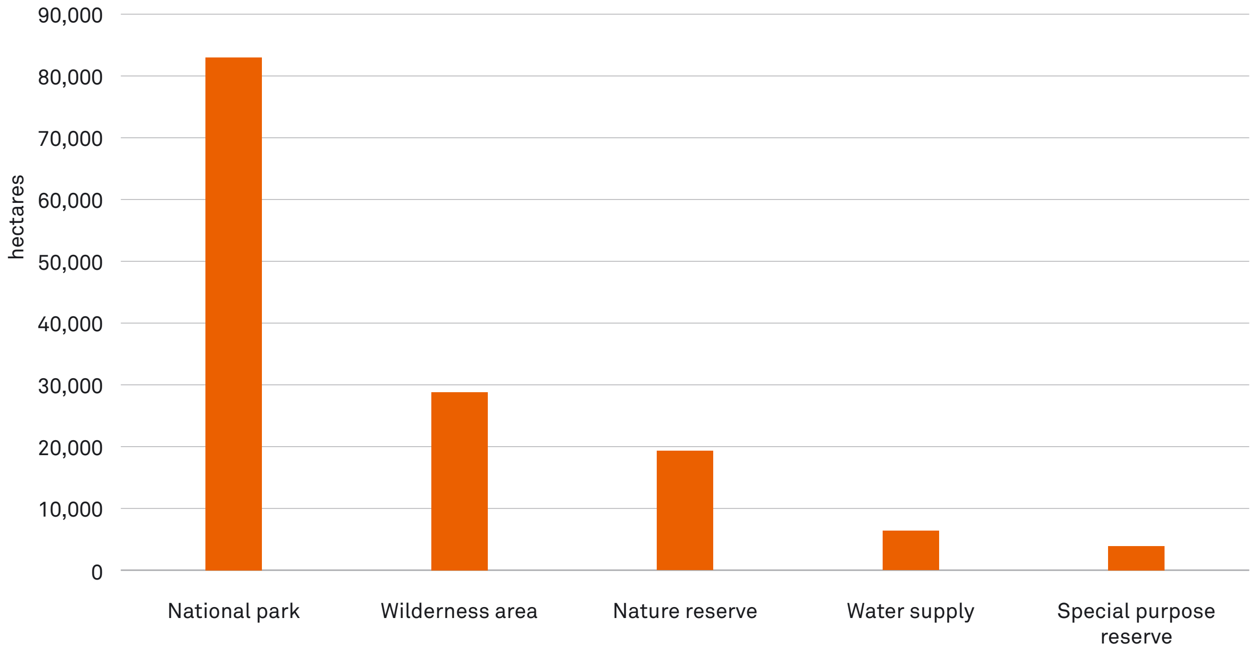


Figure 5:
Conservation categories in the ACT as at 2019.

Data sourced from: ACT Parks and Conservation Service

Conservation areas, as designated under the *Territory Plan 1993*, show an increase of nearly 13,000 hectares between 1997 and 2018 (Figure 6). The large increase in 2008 is due to the declaration of the Lower Cotter Catchment as a reserve. Over the reporting period 2015–16 to 2018–19, just over 1,000 hectares were added to the reserve system, primarily through environmental offsets added to the Canberra Nature Park network.

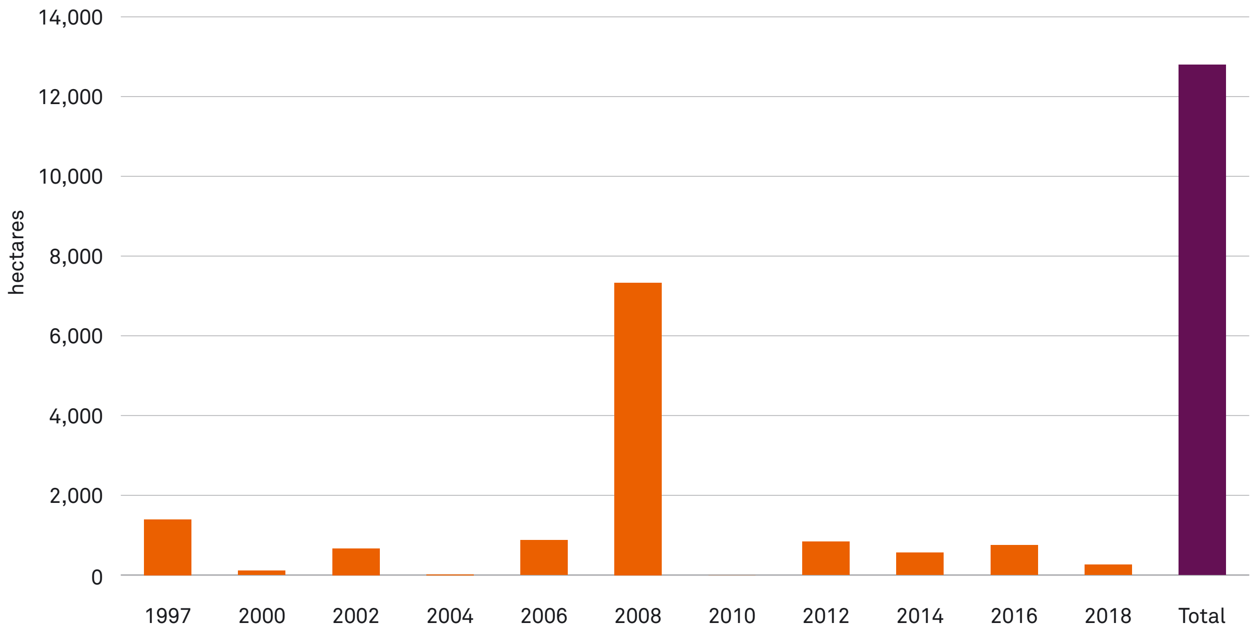


Figure 6:
Additions to conservation areas designated under the *Territory Plan*, 1993 to 2018.

Data sourced from: ACT Parks and Conservation Service

Environmental offsets

The area of ACT environmental offsets has grown from 18 hectares in 2009 to some 1,865 hectares of ACT land in 2019 (Figure 7).[10] This growth reflects the need to compensate for adverse environmental impacts from the significant increase in the ACT's urban footprint that has occurred since 2000, and continues today.

In 2019, 47% (871 hectares) of offsets were protected by nature reserve. This represents a significant increase in the area of offsets included in the reserve system since 2013 (Figure 7). Environmental offsets now contribute to around 16% of the ACT's urban reserve areas.

There are currently 23 offset areas in the ACT, with the 688 hectare Molonglo offset by far the largest area, contributing around a third of the total offset area (Figure 8). The ACT Parks and Conservation Service manage over 90% of the total offset area on behalf of the ACT Government. There are also a small number of other offset managers within the ACT who own and manage varying amounts of offset land.

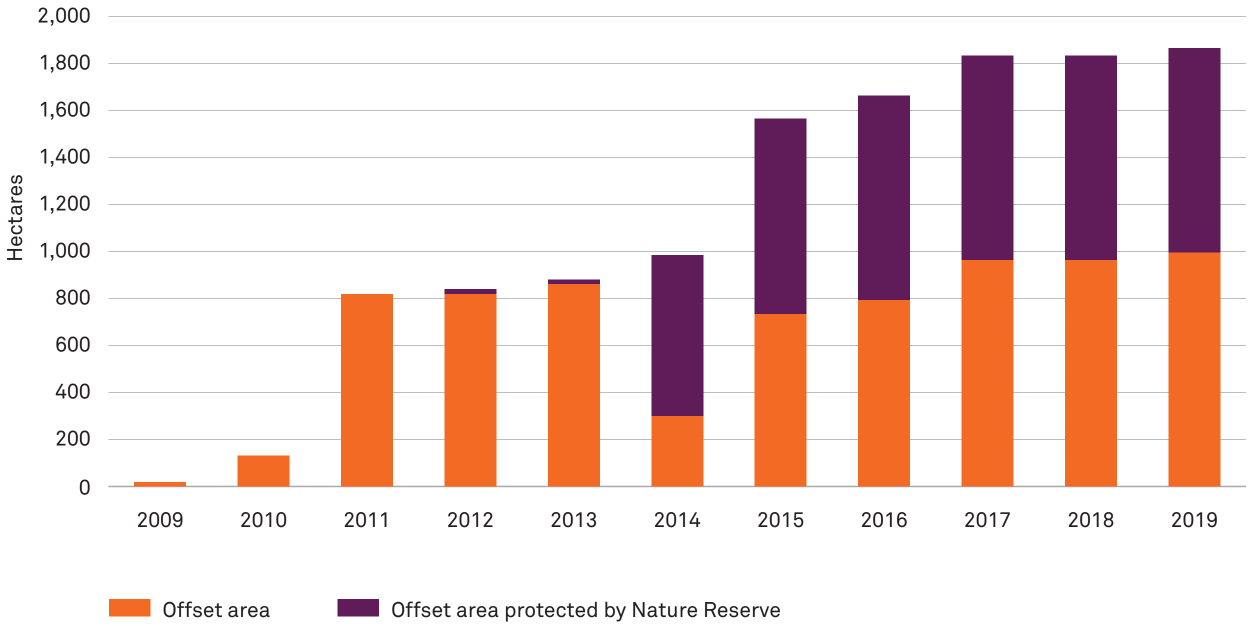


Figure 7:
Extent of Commonwealth Government-approved offsets in the ACT and area protected by nature reserve, 2009 to 2019.

Data sourced from: ACT Parks and Conservation Service

10 This area does not include the Kenny 160 hectare offset approved as part of the Gungahlin Strategic Assessment [Umwelt Pty Ltd, 2013, *Gungahlin Strategic Assessment: Biodiversity Plan: Final*, Umwelt, Canberra], which has not yet been established and is not yet in the reserve system.

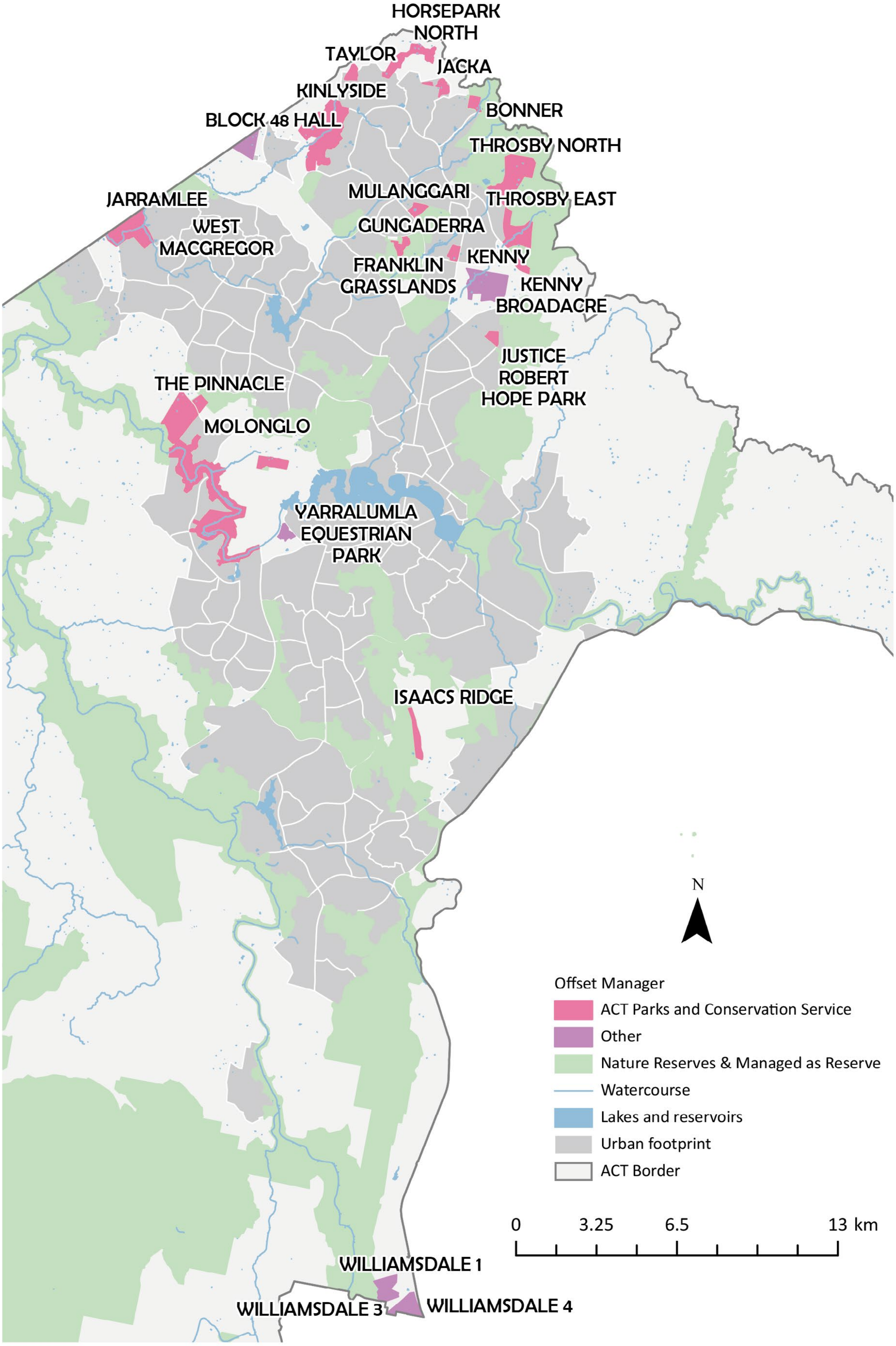


Figure 8:
Environmental offsets managed by ACT Parks and Conservation Service in the ACT.

Data sourced from: ACT Parks and Conservation Service

CASE STUDY: THE OFFSET PROGRAM IN THE ACT

Source: ACT Parks and Conservation Service (PCS)

The management of offsets involves a range of activities including the management of weeds and invasive plants as well as invasive and overabundant animals, utilisation of conservation grazing techniques, creation of small-scale infrastructure such as tracks, trails and fencing, and signage to help protect values by informing the public of the importance of those values and the threats they face.

The management and monitoring of offset areas involves collaboration with community groups such as the Woodlands and Wetlands Trust, ParkCare groups, rural lessees, private businesses, universities, research groups, and Friends of the Grasslands. The ACT offsets program also collaborates and works on significant research programs, including Superb Parrot foraging and breeding behaviour, and Golden Sun Moth translocation research.

An extensive monitoring program of MNES and associated values has been established by PCS across all offset sites. The monitoring program measures changes in condition, helps to understand the population status of MNES fauna within offsets, and informs management approaches. Currently, PCS monitors 450 permanent monitoring points annually for a variety of ecological values to inform population trends and management effectiveness.

Some examples of ACT environmental offsets and their management are discussed below.

Throsby North and Throsby East

The Throsby North and Throsby East environmental offset sites (required as part of the Gungahlin Strategic Assessment) added 273 hectares to the already established Goorooyarroo and Mulligans Flat Nature Reserves. Combined with other woodlands within the ACT and NSW, the offset areas are part of one of the largest, best-connected and most diverse patches of Box Gum Grassy Woodland remaining in south-eastern Australia. Throsby also contains over half of the Superb Parrot nesting sites in the ACT.

Works were undertaken in 2015 and 2016 in partnership with the Woodland and Wetlands Trust, ANU, developers, and other key stakeholders. These activities involved woody debris placement utilising trees removed from development sites. Weed and pest removal, as well as conservation grazing, are continuing on this site. Extensive monitoring is also conducted on site, including monitoring of the Golden Sun Moth, Box Gum Woodland, vegetation structure, woodland birds and detailed weed density surveys.

Throsby is also included in the Superb Parrot Monitoring and Research Program, which involves rigorous field monitoring to develop an understanding of the habitats used by this threatened parrot.

Placement of vertical stags at Throsby Environmental Offset area. Source: ACT Parks and Conservation Service.

Barrer Hill restoration project

In 2014, the ACT Government commenced the Barrer Hill project to restore a 50 hectare former pine plantation back to a Box Gum Woodland community. To date, works have included:

- planting of over 50,000 native trees, shrubs, grasses and wildflowers as habitat and a vital movement corridor for wildlife.
- placement of 80 tonnes of salvaged rock to extend and enhance habitat for the Pink-tailed Worm-lizard.
- placement of over 1,000 tonnes of salvaged coarse woody debris to enhance ground storey condition and provide habitat for declining woodland birds and other fauna species.

- enhancement of ground storey diversity at 3 forb enhancement sites.
- installation of 10 vertical habitat structures to mimic habitat characteristics of mature trees, and
- installation of a habitat sculpture designed to create a living artwork that engages the public and provides critical habitat, including natural hollows, peeling bark and perch sites.

The site demonstrates the successful implementation of cutting-edge restoration methods and serves as an outdoor laboratory where students and the community can see and learn about restoration practices first hand.

Tree plantings and coarse woody debris placement. Source: ACT Parks and Conservation Service.

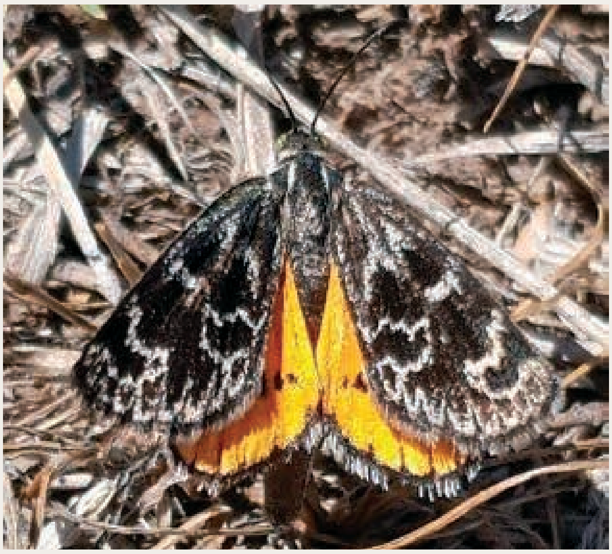
Before and after photo of forb enhancement site. Source: ACT Parks and Conservation Service.

Franklin Grasslands – Community engagement and opportunities for the future

Franklin Grasslands (also known as North Mitchell Grasslands) is a 20 hectare proposed nature reserve located within the suburb of Franklin in the north Canberra district of Gungahlin. The site contains Golden Sun Moth and Striped Legless Lizard habitat and Natural Temperate Grassland, as well as a population of the critically endangered Ginninderra Peppercress, a plant found only in the ACT.

Commitments for this offset include increasing the quality and extent of existing Golden Sun Moth habitat and maintaining the quality of the Natural Temperate Grassland.

The site is well placed to provide opportunities to increase community engagement and awareness of the importance and value of grasslands and the flora and fauna they support. As part of a consultation process with the public, community interest will be gauged to inform potential public involvement in the reserve's management. Once the site is restored, it will provide visual amenity for the local community. There is also potential for this site to incorporate environmentally sensitive infrastructure (paths, platforms and interpretation), in addition to increasing awareness of local conservation values through environmental and cultural education activities. The infrastructure could even link local residential areas to the light rail.



Golden Sun Moth. Source: ACT Parks and Conservation Service.

Condition of conservation areas

At the time of reporting, it was not possible to determine the condition of conservation areas in the ACT. Condition assessments will require significant monitoring of the health of vegetation (see *Indicator B4: Extent and condition of native vegetation*) and biodiversity, pressures (such as invasive plants and animals, fragmentation and fire intervals), and the level of management intervention for each conservation area.

It is also not possible to currently assess the condition of offsets or their effectiveness in providing the outcomes required that ensure no net loss of biodiversity has occurred following land development. Such assessment will likely take many years, particularly given that management interventions need to be undertaken over long periods of time to achieve the desired ecosystem and biodiversity outcomes.

The ACT Government is undertaking a Conservation Effectiveness Monitoring Program (CEMP) to provide an ecosystem condition monitoring framework for the ACT. The CEMP will evaluate the effectiveness of management actions in achieving conservation outcomes. The CEMP reports will be undertaken every 4 years for 8 ACT ecosystems including:

- upland and lowland native grasslands
- upland and lowland woodlands
- upland and lowland forests
- aquatic and riparian
- upland bogs and fens.

The results of the CEMP will enable an assessment of the condition of conservation areas, and the ecosystems they contain, in future ACT State of the Environment reports.

CONSERVATION EFFECTIVENESS MONITORING PROGRAM (CEMP)

Source: Environment, Planning and Sustainable Development Directorate

The CEMP is a framework for monitoring the condition of ecosystems in the ACT. The CEMP framework is based on an adaptive management approach and is an important tool that evaluates the effectiveness of management actions in achieving conservation outcomes.

Through CEMP, eight ecosystem condition monitoring plans will be developed. These ecosystems are:

- upland and lowland native grasslands
- upland and lowland woodlands
- upland and lowland forests
- aquatic and riparian
- bogs, fens and wetlands.

To assess the condition of an ecosystem, CEMP uses indicators for biodiversity values as well as for threatening processes. For each indicator, a baseline condition, reference condition (commonly thought of as pre-European condition), and a target condition (practical condition for management to strive for when reference condition is either unattainable or unknown) are defined to form the basis of condition assessments.

Key outcomes from CEMP include recommendations for monitoring programs, management actions and future research within the ecosystem. These outcomes are then used to inform on-the-ground actions through management, research and operational plans, completing the adaptive management cycle.

Indicator B3: Representation of threatened species and ecological communities in conservation areas

ACT's conservation areas contribute to the National Reserve System (NRS).[11] The NRS is Australia's network of protected areas, designed to conserve Australia's remaining biodiversity. To ensure that the ACT's reserve system meets the standards for comprehensiveness, adequacy and representativeness, it is essential that conservation areas protect the range of ecosystem types and biodiversity present in the region. This includes both threatened and common species and ecological communities.

Threatened fauna: representation in conservation areas

Figure 9 shows the reservation of known and potential habitat for threatened terrestrial fauna.[12] Bird species are excluded from the assessment due to the lack of data required to assess protection.[13] Four threatened species have all, or close to all, of their known and potential habitat in ACT conservation areas (includes reserves and other PCS-managed land); these are the Broad-toothed Rat, Greater Glider, Northern Corroboree Frog, and Smoky Mouse. The Pink-tailed Worm-lizard and Spotted-tailed Quoll also have significant proportions of their known and potential habitat in ACT conservation areas at 80% and 70% respectively.

Threatened fauna with less than 50% of their known and potential habitat in ACT conservation areas include the Perunga Grasshopper (47%), Golden Sun Moth (44%), Striped Legless Lizard (33%), and Grassland Earless Dragon (25%). However, these species have a substantial proportion of their habitat on national land (between 20% and 50%). Management of threatened species on national lands is undertaken by the National Capital Authority as required under the EPBC Act.[14] [15]

The Grey-headed Flying Fox has no habitat in ACT conservation areas with two recently established colonies occurring in Commonwealth Park (national land) and at Lake Ginninderra (urban open space).

Threatened species with substantial proportions (20% or higher) of their known and potential habitat on non-reserved land (outside both ACT-reserved and national land) include the Pink-tailed Worm-lizard (20%), Spotted-tailed Quoll (27%), Golden Sun Moth (28%), Perunga Grasshopper (32%) and the Grassland Earless Dragon (33%). Of particular concern is the lack of reserved habitat for the Striped Legless Lizard with 46% of habitat not reserved. For species with large proportions of non-reserved habitat, this is due to their dependence on grassland and woodland habitats which are not as well protected in conservation areas as other ecosystems such as forests (see sections on reservation of flora and ecological communities below).

Species listed as threatened in the ACT but not considered for this analysis due to the lack of wild populations include the Eastern Quoll and New Holland Mouse (both reintroduced to Mulligans Flat Nature Reserve), Eastern Bettong (reintroduced to Tidbinbilla and Mulligans Flat Nature Reserve), Southern Brown Bandicoot, and the Brush-tailed Rock-wallaby and Koala (reintroduced to Tidbinbilla Nature Reserve).

11 Department of the Environment and Energy, National Reserve System, found at https://www.environment.gov.au/land/nrs
12 Habitat assessment is based on single records, known habitat and modelled habitat.
13 Bird sightings data is available through annual reporting by the Canberra Ornithologists Group and from Canberra Nature Map. However, for this assessment, comprehensive data on roosting areas as well as feeding areas is required. Data on sightings alone is not sufficient to determine if all the required habitat is protected for these mobile species who may utilise a range of habitats over a wide area.
14 Sharp S., 2016, *Ecological Management Plan for National Capital Authority Conservation Areas*. Report to the National Capital Authority, Canberra.
15 Ecosure, 2019, *Commonwealth Park Grey-Headed Flying-fox Camp Management Plan*, Proposal to National Capital Authority, Burleigh Heads.

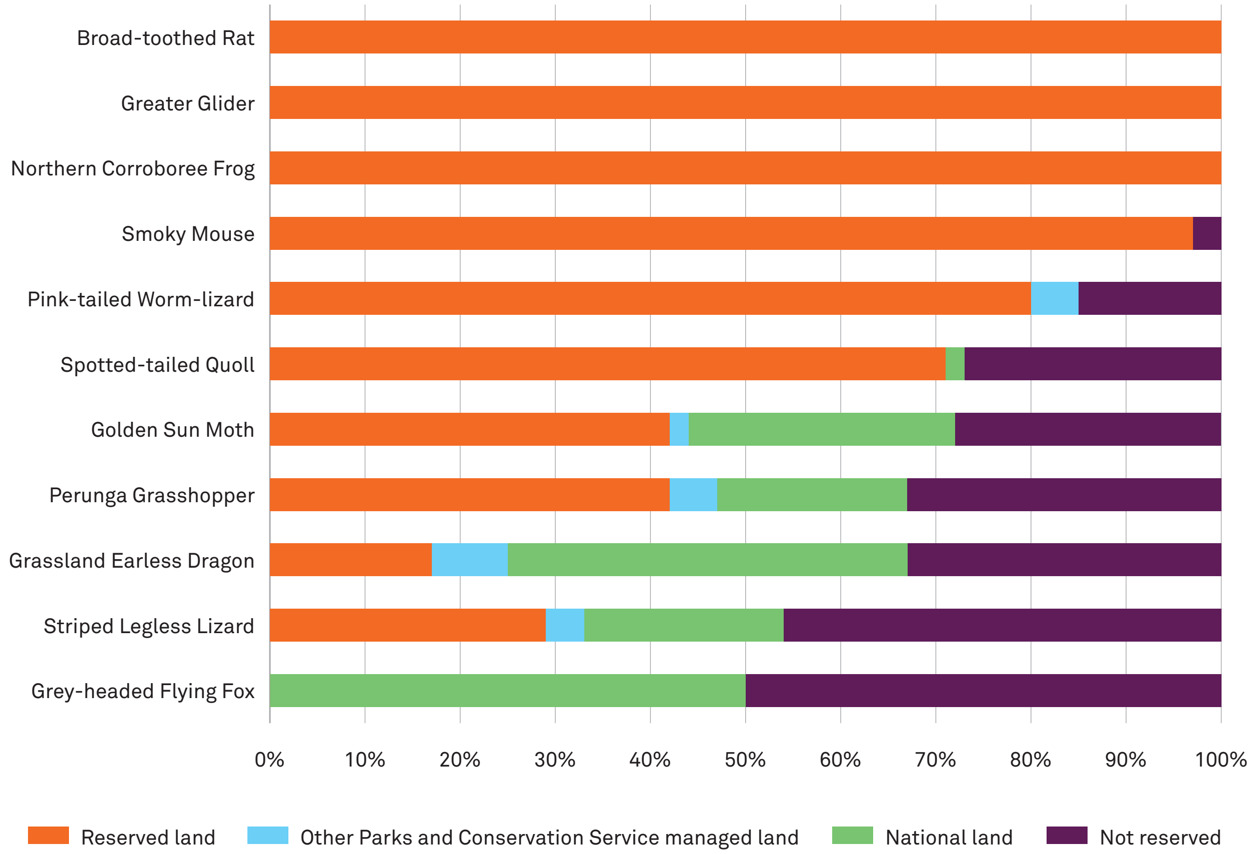


Figure 9:
Reservation of known and potential habitat for threatened terrestrial fauna

Data sourced from: Environment, Planning and Sustainable Development Directorate (Conservation Research and ACT Parks and Conservation Service)

Notes:

1) Habitat assessment is based on single records, known habitat and modelled habitat.
2) Reserved land is public land under the Territory Plan zoned as Nature Reserve, Wilderness Area, National Park, some Special Purpose Reserves (Tidbinbilla) or Protection of Water (Lower Cotter Catchment).
3) Other land managed by ACT PCS includes additional areas of land managed for nature conservation that are not part of the reserve system, including some Special Purpose Reserves and unleased land.
4) Not reserved land includes all other land not managed for nature conservation, including but not restricted to urban open space, road reserve, some special purpose reserves (recreational reserves), railway reserve, cemeteries, horse paddocks, private lease and other unleased land not managed for nature conservation.
5) National land is land owned by the Commonwealth and not under the jurisdiction of the ACT Government.

Aquatic fauna: representation in conservation areas

Potential habitat for threatened aquatic fauna is well represented in ACT conservation areas, as most of the major rivers in the ACT are included in reserves.

It should be noted that the majority of threatened aquatic fauna are mostly restricted to reserves, and that terrestrial reserve systems do not always adequately support the conservation of aquatic species. For example, dams within terrestrial reserve networks can impact on aquatic ecology values. In addition, the Murrumbidgee Reserves in the ACT are often places for high intensity recreation which can also impact on aquatic species, especially as recreation tends to be situated around large, deep pool habitats such as Kambah Pool and Casuarina Sands. Such habitats are not common and are likely to form key refuges for aquatic species during low flow periods, droughts and climate change scenarios.

All of the ACT-listed aquatic species have around 90% to 100% of their potential distribution in conservation areas (Figure 10).[16] Silver Perch, while listed as a threatened species in the ACT, is found in Googong Dam and the Queanbeyan River in NSW but has no wild distribution in the ACT. Macquarie

16 Distribution is potential expected distribution of these species. Data is not actual surveyed distribution or historic distribution. For example, Silver Perch have no wild current distribution in the ACT.

Perch currently occurs only within reserves although attempts have been made to translocate the species to other areas.

Although the Murray Cod is not listed as a threatened species under ACT legislation, it is managed as such due to its listing as vulnerable under the EPBC Act. Only 55% of the Murray Cod's potential distribution in the ACT is in the reserve system. Wild populations of Murray Cod exist in the Murrumbidgee River, including within the various reserves along the river, and have been identified as an important population in the *National Recovery Plan for the Murray Cod*.[17] Murray Cod also occur in the Molonglo River and are stocked in Canberra's urban lakes which would not naturally support the species – this accounts for the relatively low representation in reserves.

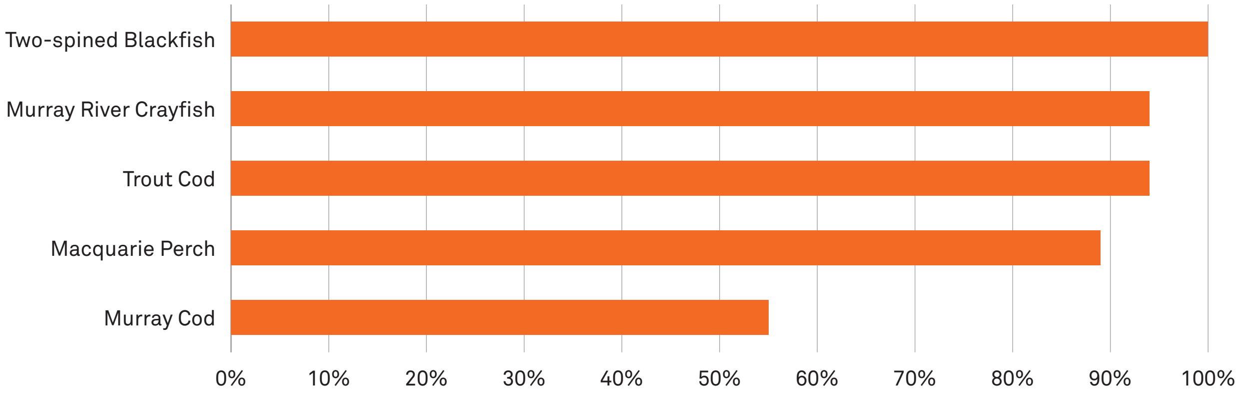


Figure 10:
Potential distribution of threatened aquatic fauna in ACT conservation areas

Data sourced from: Environment, Planning and Sustainable Development Directorate (Conservation Research and ACT Parks and Conservation Service)

Notes: This data reflects the potential expected distribution of threatened aquatic fauna species, not actual surveyed distribution or historic distribution. The majority of species are currently known only from reserves.

Threatened flora: representation in conservation areas

There are 605 records in the ACT Protected Plants Database of the 13 threatened plant species listed in the ACT. Data on threatened plants is collected from targeted surveys undertaken by the ACT Government and from citizen science records provided through Canberra Nature Map.

Over half of the known threatened plant sites in the ACT (349 or 58%) are located in reserves or on other land managed by the ACT PCS (Figure 11). An additional 118 (20%) occur on national land, which is managed by the National Capital Authority, and 138 (23%) occur outside both ACT-reserved and national lands, in areas such as urban open space, road reserves, railway reserves and cemeteries.

Threatened flora species with a substantial proportion of known locations outside ACT conservation areas include:

- Black Gum (*Eucalyptus aggregata*): the main and only natural population in the ACT occurs on public land managed as part of Kowen Forest. No management plan exists for this population but the area has been fenced off to allow for the natural regeneration of the trees and plantings may be undertaken in the future.
- Button Wrinklewort (*Rutidosis leptorrhynchoides*) occurs mainly on national land.

17 EPSDD, 2017, Native Species Conservation Plan, Murray Cod (*Maccullochella peelii*), ACT Government, Canberra.

- Tarengo Leek Orchid (*Prasophyllum petilum*) persists only at Hall Cemetery. The cemetery is public land and has a management plan focused on conserving the orchid population.
- Canberra Spider Orchid (*Caladenia actensis*): Mount Majura and Mount Ainslie Nature Reserves support significant populations of this species, but it also occurs on land owned by the Department of Defence in the Majura Valley. The Department of Defence has management plans in place for the conservation of this species.
- Small Purple Pea (*Swainsona recta*): the main ACT population is within a fenced-off area in the Mount Taylor Nature Reserve, and
- Murrumbidgee Bossiaea (*Bossaiea grayi*) occurs along the Murrumbidgee and Molonglo Rivers, some have not been found again in the field since the 2003 fires. It should be noted that records of locations in non-reserved areas may be historic, are no longer occurring, or have poor location accuracy.

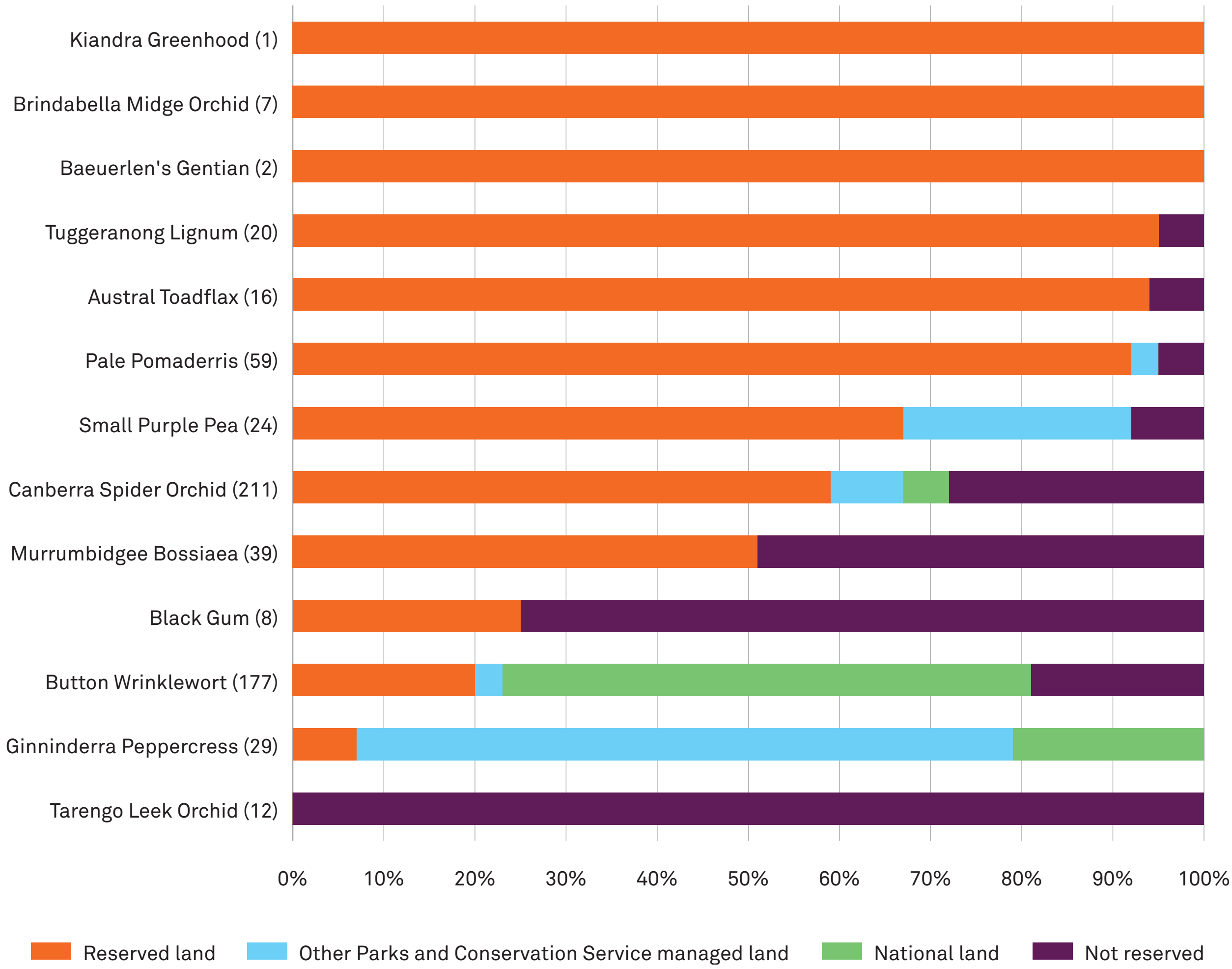


Figure 11:
Percentage representation of threatened plant locations in conservation areas

Data sourced from: Environment, Planning and Sustainable Development Directorate (Conservation Research and ACT Parks and Conservation Service)

Notes:

1) Data taken from records in the ACT Protected Plants Database. Number next to plant name is the number of plant records.

2) Data is based on incidental sightings, no analysis of survey effort is reflected in this data (e.g. urban areas and road reserves are more likely to have records than remoter places off track).

3) Reserved land is public land under the Territory Plan zoned as Nature Reserve, Wilderness Area, National Park, some Special Purpose Reserves (Tidbinbilla) or Protection of Water (Lower Cotter Catchment).

4) Other Land managed by ACT PCS includes additional areas of land managed for nature conservation that are not part of the reserve system, including some Special Purpose Reserves and unleased land.

5) Not reserved land/Other/Unreserved includes all other land not managed for nature conservation, including but not restricted to urban open space, road reserve, some special purpose reserves (recreational reserves), railway reserve, cemeteries, horse paddocks, private lease and other unleased land not managed for nature conservation.

6) National land is land owned by the Commonwealth and not under the jurisdiction of the ACT Government.

Threatened ecological communities: representation in conservation areas

Of the three ecological communities listed as endangered in the ACT, only High Country Bogs and Associated Fens are fully protected in ACT conservation areas (Figure 12). Natural Temperate Grassland has just over half of its known distribution in ACT conservation areas, and Yellow Box/ Red Gum Grassy Woodland has only 30% of its representation reserved. However, both Natural Temperate Grasslands and Yellow Box/Red Gum Grassy Woodland have substantial proportions of their extent on national land at nearly 30% and 20% respectively. Although this land is not managed by the ACT Government, threatened communities on ACT national lands are managed for conservation purposes by the National Capital Authority as required under the EPBC Act.[18]

Despite this, nearly half of the ACT's Yellow Box/ Red Gum Grassy Woodland is not reserved, and some 20% of Natural Temperate Grasslands are also unreserved. These results are a reflection of the historic and current use of these lands for agriculture and potential urban development. The low levels of reservation add to the pressures on these communities and the species they support.

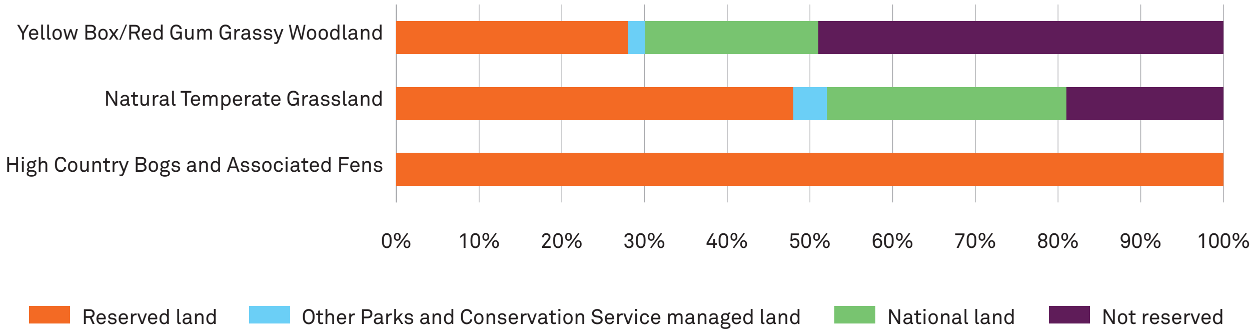


Figure 12:
Percentage representation of Endangered Ecological Communities in reserves

Data sourced from: Environment, Planning and Sustainable Development Directorate (Conservation Research and ACT Parks and Conservation Service)

Notes:

1) Does not include areas mapped as native grassland that may contain some areas of Natural Temperate Grasslands.

2) Comprises mapped vegetation communities Blakely's Red Gum – Yellow Box tall grassy woodland and Yellow Box + Apple Box tall grassy woodland, not all of which will meet the condition threshold required to be assigned to the Yellow Box/Red Gum Grassy Woodland Endangered Ecological Communities.

Greater Glider. Source: Ryan Colley.

18 Sharp S., 2016, *Ecological Management Plan for National Capital Authority Conservation Areas*. Report to the National Capital Authority, Canberra.

Vegetation classes and communities: representation in conservation areas

Figure 13 shows the percentage of selected vegetation classes protected in conservation areas. All classes occur in the ACT's reserve estate with 8 having more than 80% of their extent protected, and another 2 with over 60% of their extent protected. The most under-represented vegetation class was Southern Tableland Grassy Woodlands which only has 30% of its extent in conservation areas.

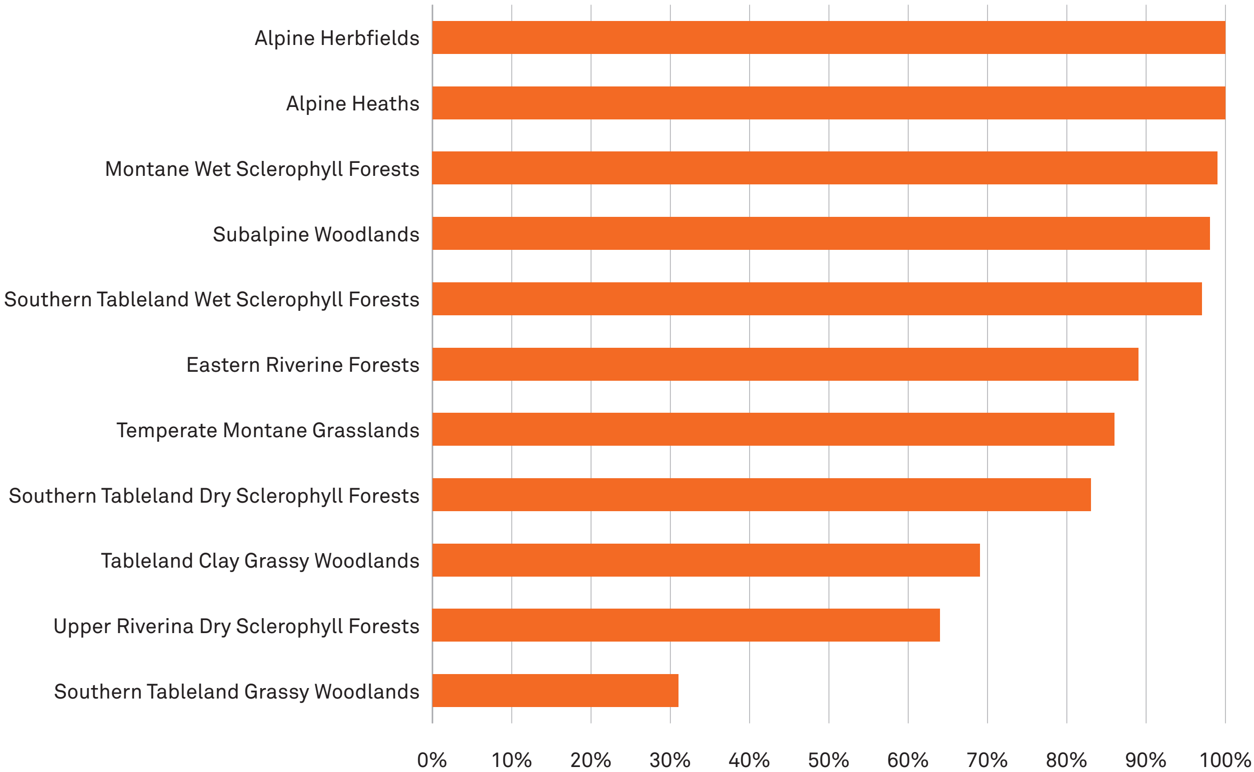


Figure 13:
Proportion of selected vegetation classes reserved in ACT conservation areas

Data sourced from: Environment, Planning and Sustainable Development Directorate

Notes: Based on Keith Class level classifications of structural formations separated by dominant overstorey species.

Figure 14 shows the least-protected vegetation communities, those with under 50% of their extent protected in conservation areas. These woodland, grassland and open forest communities are the least represented in the ACT's conservation areas. The low levels of protection for these communities, and for the Southern Tableland Grassy Woodlands vegetation class, are again the result of the historic and current use of these communities for agriculture and potential urban development. The low levels of reservation add to the pressures on these communities and the species they support.

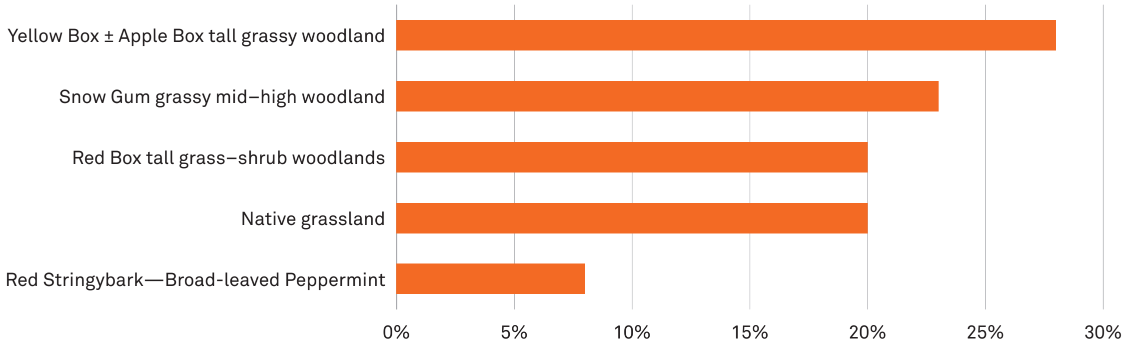


Figure 14:
Proportion of selected vegetation communities reserved in ACT conservation areas

Data sourced from: Environment, Planning and Sustainable Development Directorate

Notes: Native grassland does not include Natural Temperate Grasslands.

Indicator B4: Extent and condition of native vegetation

Native vegetation is integral to ecosystem services such as the protection of biodiversity, protection of water quality and soil health, and sequestration of carbon. Declines in the extent and quality of native vegetation have profound implications for the health of the ecosystem.

The loss of vegetation is considered to be the main threat to biodiversity in Australia.

Historic land clearing for agriculture and urban development has produced a legacy of fragmented native vegetation in some areas of the ACT. The diversity and resilience of ecological communities relate directly to their spatial configuration, patch size, contiguity, condition and connectivity. Fragmented landscapes prevent the movement of species, limiting opportunities for mating and dispersal, and potentially creating genetic isolation. Research suggests that most animals of southern Australian woodlands and forests will not usually cross a canopy gap of more than 100 metres, and will not travel more than 1.1 kilometres from a patch of at least 10 hectares of suitable living habitat.[19]

Although large-scale clearing is not an issue in the ACT, native vegetation remains under continuing pressure from urban expansion. Native vegetation in conservation areas has not been extensively cleared and is more intact than native vegetation on private land and those lands separated by urban developments. In these largely intact landscapes, vegetation communities are more likely to be resilient to natural disturbances such as fire and drought. In fragmented landscapes, native vegetation remnants are more vulnerable to natural disturbance as well as pressures arising from agriculture and residential activities. This results in the decline of vegetation, or being at risk of decline, in extent, quality and regenerative capacity. Declining vegetation quality is now a key driver of vegetation loss in the ACT. Fragmentation can also exacerbate the impacts of land use change and climate change by restricting opportunities for fauna to migrate or adapt.

It was not possible to determine changes in the extent of native vegetation over the reporting period (2015–16 to 2018–19) for inclusion in this report. Nor was it possible to provide an overall assessment of vegetation condition.

19 Barrett T. and J. Love, 2012, *Fine Scale Modelling of Fauna Habitat and Connectivity Values in the ACT Region*, prepared for Conservation Planning and Research, EPSDD, ACT Government, Canberra

The 2015 *ACT State of the Environment* report noted that comprehensive documented information on the condition of vegetation and the amount of clearing undertaken was lacking.[20] The cumulative impact of approved clearing of vegetation had also not been documented or assessed.

These issues limit the ability to report on vegetation extent and condition changes in the ACT. However, aspects of vegetation condition assessments have been undertaken in the ACT including studies of dieback, riparian connectivity, tolerable fire intervals and growth stage, and the condition of grassland and woodland endangered ecological communities (see section on *Condition of native vegetation*).

Extent of native vegetation

Native vegetation losses are estimated to be small and mainly due to land use change from urban development. Urban development is likely to be an increasing pressure on native vegetation and may have major impacts on vegetation and ecosystem health, as well as the ecosystem services they provide. It is important that there is consideration of the cumulative impacts of small modifications to habitat, because these can lead to thresholds being crossed unknowingly and unintentionally for at least some aspects of vegetation and ecosystem health.

Most of the ACT's vegetation loss has been from historic clearing and ecosystem modification for agriculture and urban development. Although there has not been a comprehensive assessment of the native vegetation extent in the ACT before European settlement, there are some examples of significant losses. For example, before European settlement, Natural Temperate Grasslands were thought to cover over 25,000 hectares or 11% of the ACT area,[21] but today they only cover around 1,100 hectares, less than 1% of the ACT (Figure 15).

For Lowland Box Gum Woodlands, the pre-European settlement distribution was thought to be over 47,000 hectares or 20% of the ACT area,[22] but these woodlands now only cover some 11,500 hectares, around 5% of the ACT (Figure 16). Most of the native vegetation changes are thought to be on lowlands due to the abundance of grass and absence of dense trees for agriculture, and later for urban development. It is estimated that there has been little change in the distribution of upland vegetation types.

While the loss of native vegetation remains of concern for urban development, it is unlikely to be the largest source of native vegetation change in the ACT. Chronic degradation of habitat condition, mainly in fragmented landscapes is a significant problem in the ACT. This degradation is compounded by climate change impacts such as decreasing rainfall and higher temperatures. Such degradation has led to an increased occurrence of dieback in the ACT (see section on *Condition of native vegetation*).

20 Office of the Commissioner for Sustainability and the Environment, 2015, *ACT State of the Environment Report 2015*, ACT Government, Canberra.

21 Gellie, N. J. H., 2005, 'Native Vegetation of the Southern Forests: South-east Highlands, Australian Alps, South-west Slopes, and SE Corner Bioregions', *Cunninghamia*, 9(2): 219–54.

22 Gellie, N. J. H., 2005, 'Native Vegetation of the Southern Forests: South-east Highlands, Australian Alps, South-west Slopes, and SE Corner Bioregions', *Cunninghamia*, 9(2): 219–54.

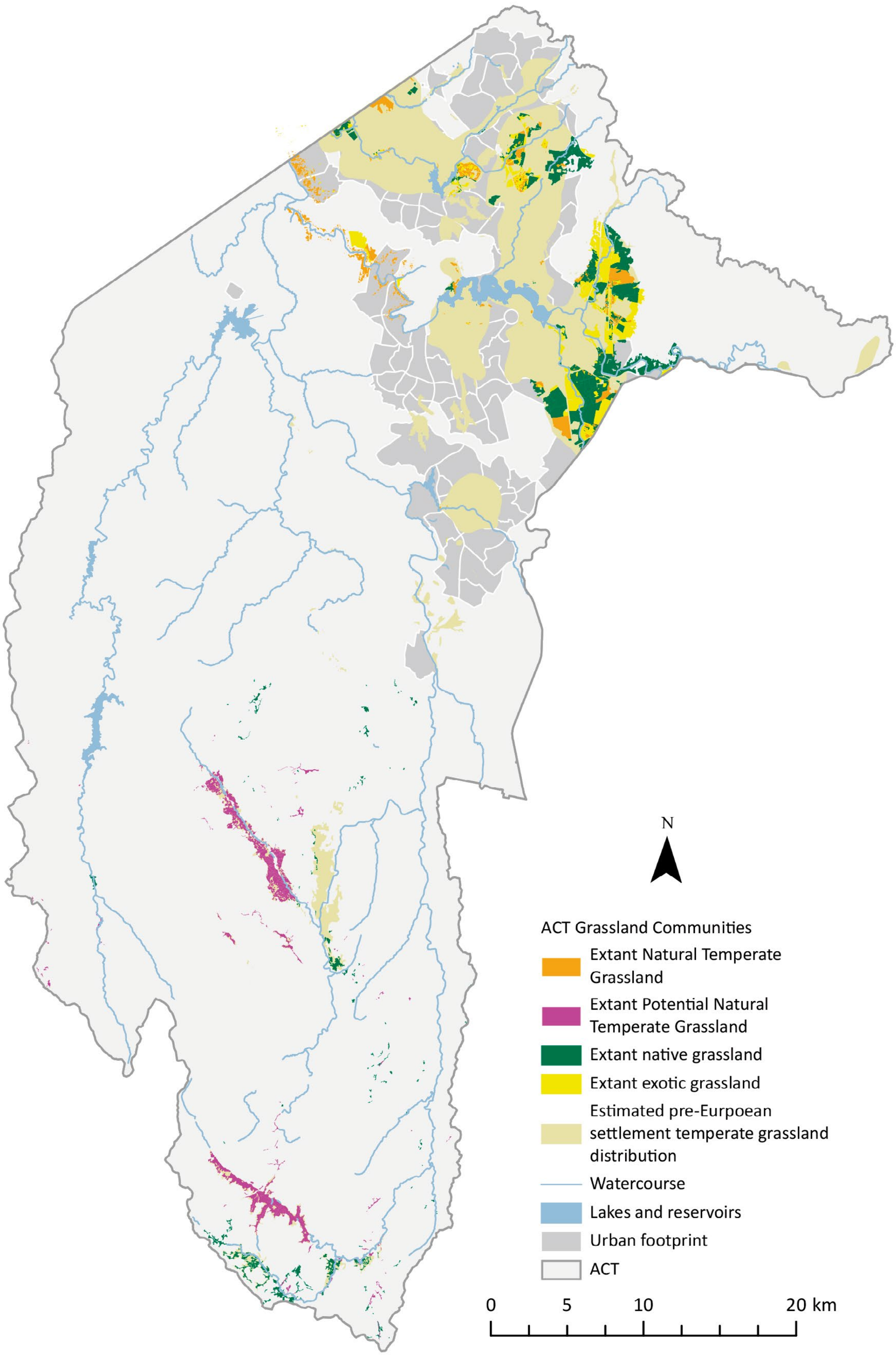


Figure 15:

Current grassland extent compared with estimated pre-European settlement grassland extent.

Data sourced from: Environment, Planning and Sustainable Development Directorate

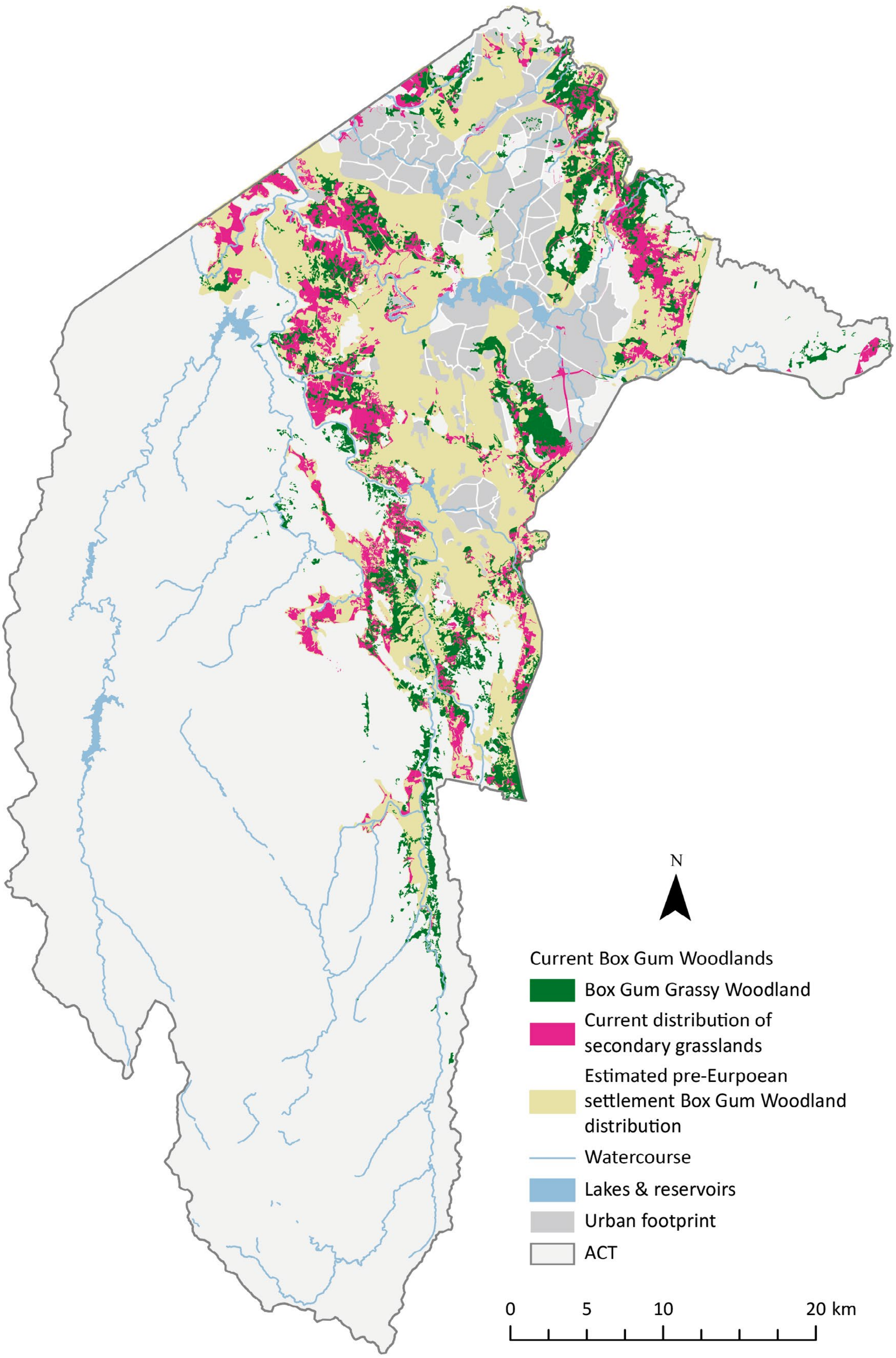


Figure 16:
Current Box Gum Woodland extent compared with estimated pre-European settlement Box Gum Woodland extent.

Data sourced from: Environment, Planning and Sustainable Development Directorate

Revegetation in the ACT

The ACT Government has undertaken extensive revegetation over the reporting period (2015–16 to 2018–19). This has been undertaken in cooperation with various organisations and programs including the Australian Government's million Trees Project, Greening Australia, and the Australian Government's Clean Energy Future Biodiversity Fund. The works will provide vegetation corridors, riparian restoration and bank stabilisation, woodland restoration, and post-fire rehabilitation. Restoration of habitat and connectivity increases effective habitat size and access for native species, enables migration and movement to avoid temporary stressors, and aids the recovery potential and recolonisation of degraded areas.

Between 2015 and 2019, revegetation included planting of:

- nearly 75,000 tube stock and 20 kilograms of native seed to revegetate nearly 1,100 hectares in the Murrumbidgee River Corridor nature reserves and other areas of public lands.
- nearly 25,000 tube stock and 180 kilograms of native seed to restore habitat in former pine plantations and other degraded areas in the Lower Cotter Catchment.

In addition, there were revegetation activities on some 1,500 hectares of private land between 2015 and 2018, mainly through works undertaken by Greening Australia. See **Chapter 3 Community leadership in sustainability and science** for more information.

These revegetation activities will increase native vegetation extent and improve the condition of ecosystems in the future.

Condition of native vegetation

Dieback

Dieback is the gradual deterioration of health in trees, sometimes leading to tree death, and is usually caused by a combination of factors including disease and pathogens, insect attack, and additional drought and temperature stress from climate change.

While dieback affects many species in the ACT (including *Eucalyptus viminalis, E. bridgesiana* and *E. melliodora*), recent observations have recognised a significant increase in the incidence of dieback in Blakely's Red Gum (*E. blakelyi*). Dieback of Blakely's Red Gum appears to affect any age class and is occurring across rural landscapes, urban environments and reserves within the ACT. High rates of mortality in younger trees have resulted in a lack of successful maturation across the ACT landscape. If younger trees are unable to replace the older, dying trees, the population will slowly thin out.

A great deal of uncertainty surrounds the cause of Blakely's Red Gum dieback in the ACT and is thought to be the result of a number of stress-inducing factors, impacts associated with climate change and reduced resilience within the landscape. The ACT Government and the University of Canberra has been undertaking research to better understand the causes and occurrence of red gum dieback in the ACT.[23]

Main findings include:

- confirmation that Blakely's Red Gum is currently experiencing dieback across the ACT (Figure 17).
- Yellow Box is experiencing an increase in condition and suitability to future projected climates.
- climate change and the compounded effects of an increasing temperature and variable precipitation over time is causing stress in trees and impacting their growth, and
- revegetation is needed to improve landscape connectivity and also assist dispersal to areas of climate refugia and distribution expansion.

23 Cowood A.L. et al., 2018, Blakely's Red Gum Dieback in the ACT, Report to Environment, Planning and Sustainable Development Directorate, Institute for Applied Ecology, University of Canberra, Canberra.

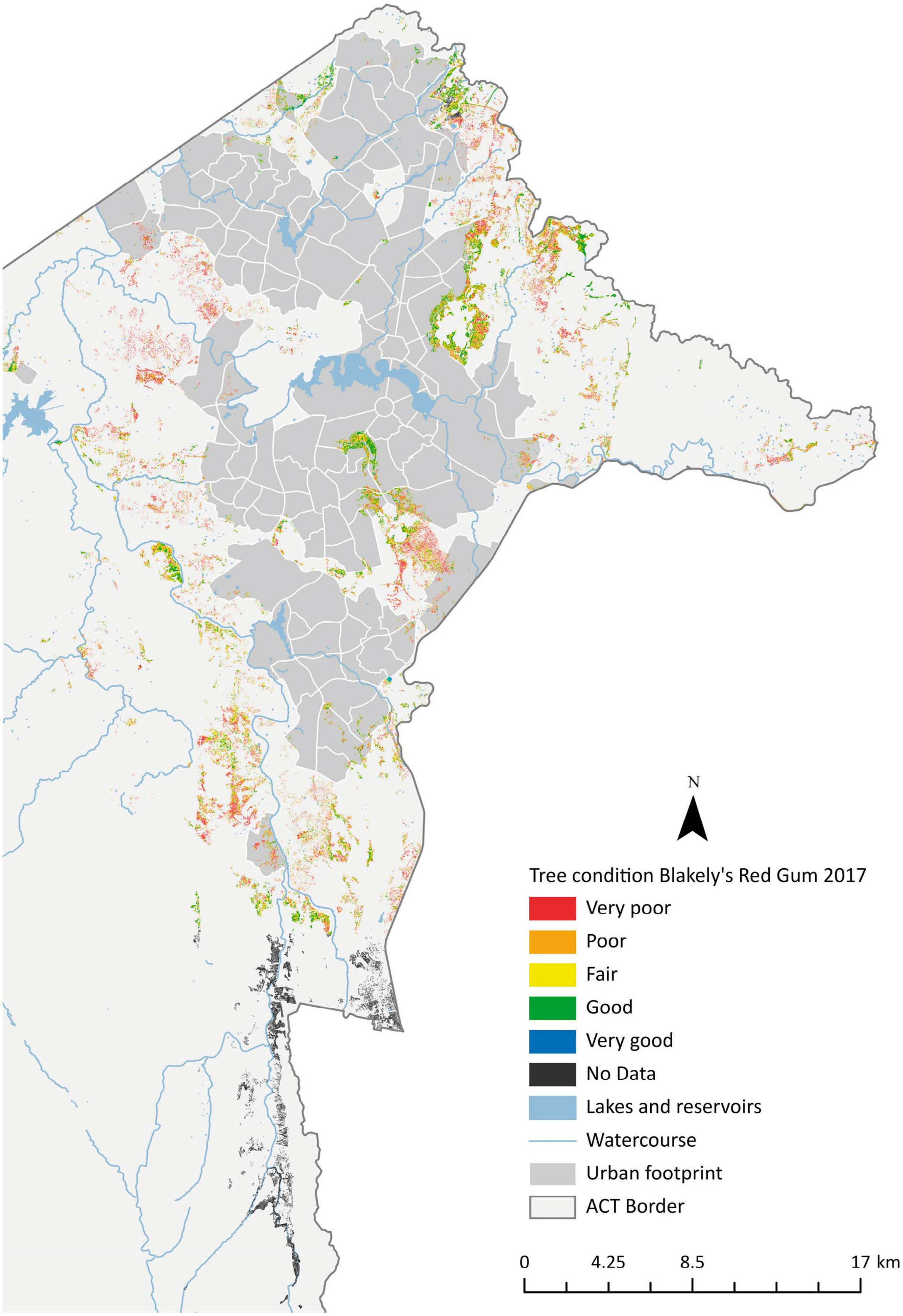


Figure 17:
Temporal condition mapping of Blakely's Red Gum (*Eucalyptus blakelyi*) as at 2017.

Source: Cowood A.L. et al., 2018, Blakely's Red Gum Dieback in the ACT, Report to Environment, Planning and Sustainable Development Directorate, Institute for Applied Ecology, University of Canberra, Canberra.

Riparian connectivity

Decline in connectivity within riparian areas is primarily due to historic clearing of vegetation for agriculture and urban development. Low river flow conditions, climate change impacts (higher temperatures, increased drought and storm events), drought and fire also impact on riparian vegetation causing loss of habitat and increased disconnection within riparian areas.

Riparian connectivity has been assessed for the Murrumbidgee and Molonglo Rivers in the ACT. Main findings include:

- significant areas of riparian vegetation on the Murrumbidgee and Molonglo Rivers have poor connectivity.
- 58% of surveyed riparian vegetation on the Molonglo River was found to have high to very high connectivity, compared to 45% for the Murrumbidgee River (Figures 18 and 19).
- the Murrumbidgee River had a higher proportion of riparian vegetation with low and poor connectivity at 36% of the area assessed, compared to 22% for the Molonglo River.
- areas of the Murrumbidgee River and lower Molonglo River that fall outside reserved areas generally showed very low levels of connectivity. This was particularly the case for the Murrumbidgee River which had 32% of low and poor connectivity inside reserves, compared to nearly 80% outside reserves (Figure 20).
- areas with poorest riparian connectivity include Molonglo River immediately below Scrivener Dam, Murrumbidgee River within Stony Creek Nature Reserve and the Lanyon Landscape Conservation area, and
- several areas with extensive riparian habitat and smaller pockets that should be maintained include the Murrumbidgee River at Gigerline Nature Reserve, downstream areas of the Bullen Range Nature Reserve, Woodstock Nature Reserve (particularly adjacent to the mouth of the Molonglo River and downstream areas), and Uriarra Creek within Swamp Creek Nature Reserve. For the Molonglo River, areas within the Molonglo River Reserve should be maintained.

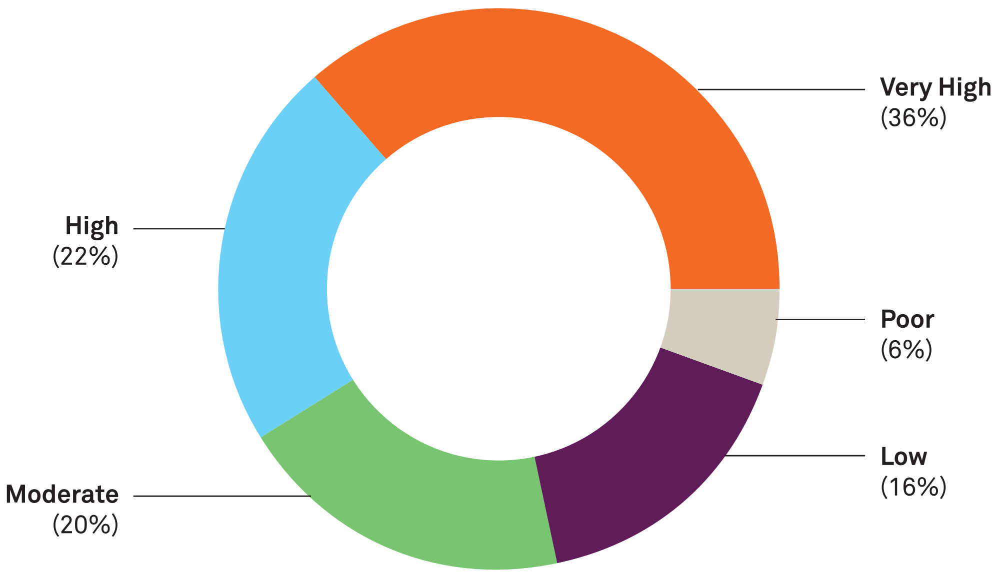


Figure 18:
Connectivity of riparian vegetation along the Molonglo River

Data sourced from: Environment, Planning and Sustainable Development Directorate

Notes: Based on a proximity index which assesses the area-weighted measure of the distance between vegetation patches. This analysis uses three vegetation riparian-dependent vegetation communities: Ribbon Gum Very Tall Woodland, River She-oak Riparian Forest, and River Bottlebrush–Burgan rocky riparian tall shrubland.

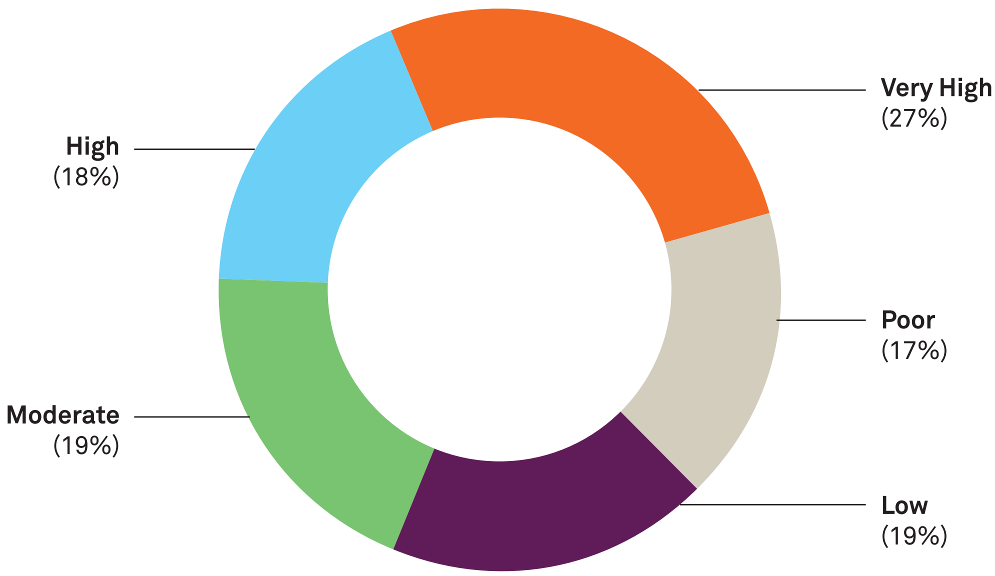


Figure 19:

Connectivity of riparian vegetation along the Murrumbidgee River

Data sourced from: Environment, Planning and Sustainable Development Directorate

Notes: Based on a proximity index which assesses the area-weighted measure of the distance between vegetation patches. This analysis uses three vegetation riparian-dependent vegetation communities: Ribbon Gum Very Tall Woodland, River She-oak Riparian Forest, and River Bottlebrush–Burgan rocky riparian tall shrubland.

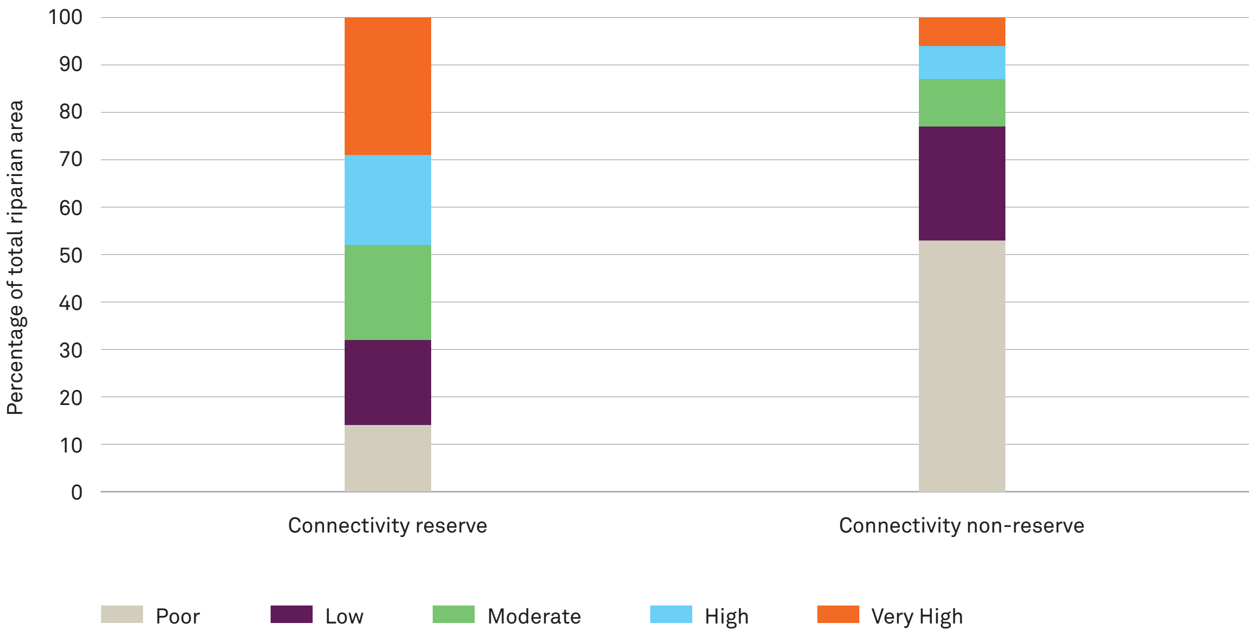


Figure 20:

Connectivity of riparian vegetation along the Murrumbidgee River

Data sourced from: Environment, Planning and Sustainable Development Directorate

Notes: Based on a proximity index which assesses the area-weighted measure of the distance between vegetation patches. This analysis uses three vegetation riparian-dependent vegetation communities: Ribbon Gum Very Tall Woodland, River She-oak Riparian Forest, and River Bottlebrush–Burgan rocky riparian tall shrubland.

Condition of grassland and woodland endangered ecological communities

The ACT Government has been monitoring the condition of Box Gum Woodland and Natural Temperate Grassland endangered ecological communities since 2009. Results to date show the following trends:

- Although the trend in native plant species richness differs significantly between Woodlands, Natural Temperate Grasslands and Secondary Grasslands, all vegetation formations have displayed an increase in native plant species richness since monitoring commenced in 2009.
- Woodland native species richness peaked in 2014 but has since seen a slight overall decline, possibly due to drought conditions experienced in 2018.
- Grassland species richness has continued to improve since surveys commenced.
- There has been an average increase of 1.4 rare species per survey plot per decade for the three vegetation formations. This suggests that Box Gum Woodland and Natural Temperate Grasslands are becoming more floristically diverse.
- Native grass cover across all vegetation formations has been declining since 2012. This decline does not appear to be linked to drought. More analysis is required to determine if it is linked to management practices. The decline in this indicator is of concern because it has implications for fauna habitat and for weed invasion.
- There has been a slight increase in exotic species richness across Box Gum Woodland and Natural Temperate Grassland. This trend is partly due to the decline of native grass cover that provides more opportunities for exotic species to establish themselves. There is evidence that the increase in exotic species richness has declined since a high in 2012, but it is not known if this more recent trend can be attributed to management.

Overall the long term condition is positive with Box Gum Woodland and Natural Temperate Grassland endangered ecological communities in the ACT becoming more diverse. However, it is clear that short-term variations are having an impact on grass cover and the number of exotic species. Ongoing monitoring and development of management practices will be important to maintain these important communities.

CASE STUDY: GRASSLAND RESTORATION PROJECT

Source: ACT Parks and Conservation Service

Natural Temperate Grassland is one of the most threatened natural plant communities in Australia with less than 1% of the original extent estimated to remain. Before European settlement, these grasslands were thought to cover 11% of the ACT area, but today they occupy less than 1%. This ecosystem was sought after for the abundance of grass and absence of trees for agriculture, and later for urban development. Not only are the remaining grasslands greatly reduced in area, they are highly fragmented (confined to 38 small and isolated patches in the ACT), often degraded, and face ongoing threats such as the spread of exotic plant species, and by human activity such as land use change.[24]

Despite this, the ACT has some of the largest, best quality and most connected patches of Natural Temperate Grassland remaining in south-eastern Australia, with most of these protected in nature reserves. However, protection alone will not be enough to conserve their unique biodiversity, which has evolved with frequent disturbance from both fire and grazing. In the absence of these disturbances, plant biomass can accumulate, leading to weed invasion, reduced cover of native grasses, decline in productivity, loss of plant diversity, and simplification of grass structure.

Fire has been largely absent across ACT grasslands for the past 50 years. Small-scale burns undertaken by the Ginninderra Catchment Group and the ACT Parks and Conservation Service have shown that fire could improve ecological values, but there remain many unknowns about the impact of fire on certain plant communities and threatened fauna.

To further explore the role of fire in grassland restoration and management, the Grasslands Restoration Project was established in 2015. This large-scale and long-term project is a joint venture between the ACT Government and the National Landcare Program. The project involves the application of fire and the monitoring of outcomes for grassland health at seven important grassland reserves. Burns are conducted to minimise impact on threatened fauna and maximise biodiversity response. The burns were undertaken in partnership with the Murumbung Rangers.

Since the commencement of the project, the following outcomes have been achieved:

- some 250 hectares of grasslands of variable quality have been burnt, with burn areas ranging from 5 to 15 hectares.
- vegetation monitoring has been undertaken in 140 locations, assessing some 1,702 monitoring plots.
- 310 plant species have been found, including 188 native species and 122 exotic species, and
- 156 reptile monitoring sites have been established with 14 species found.

In response to fire, the following has been observed:

- fire increased native plant richness up to 69% within 2 years.
- the diversity and abundance of weeds increased 6 to 12 months following a fire, indicating the need for further eradication work.
- the Grassland Earless Dragon recolonised patches of previously unoccupied habitat following burns.
- the abundance of the Striped Legless Lizard declined in the first 12 months after fire but later showed recovery.
- spring fires can be used effectively to reduce annual grass abundance, and
- the use of mosaic burning creates refuges for fauna after the burn.

The Grasslands Restoration Project has enabled grassland managers to significantly increase their knowledge and expertise in the application of ecological burns for positive ecosystem outcomes. Further work on the outcomes of fire frequency, and the longer-term impacts of fire on plant and animal communities, will increase this knowledge and improve the health of ACT Natural Temperate Grasslands in the future.

Natural Temperate Grassland in the Jerrabomberra Valley, ACT. Source: ACT Parks and Conservation Service.

24 Hodgkinson, K.C., 2014, *Condition of Selected Natural Temperate Grassland Sites in Urban and Peri-urban Canberra*, final report to the Commissioner for Sustainability and the Environment, ACT Government, Canberra.

CASE STUDY: ACT WOODLAND RESEARCH AND RESTORATION

Source: ACT Parks and Conservation Service

The ACT and Australian governments have contributed $3.1 million for the ACT and Greater Goorooyarroo woodlands restoration project (2012–2017) to consolidate and connect 60,000 hectares of the largest remaining Yellow Box–Blakely's Red Gum woodland landscape in Australia. Activities include:

- improving woodland habitat connectivity
- enhancing woodland habitat, for example, by adding coarse woody debris and a shrub layer
- improving landscape scale conservation
- implementing research outcomes, and
- encouraging community participation, including 43 community groups, schools and organisations and 18 rural landholders.

Achievements include:

- over 900 hectares of revegetation, including 28,548 tube stocks planted and 101 kilometres of direct seeding
- enhancement and protection of 844 hectares of remnant woodland (including the distribution of 4,415 tonnes of coarse woody debris)
- invasive species control over an area of 4,494 hectares
- feral animal control over an area of 9,555 hectares, and
- establishment of 10 monitoring sites to review different treatment types and techniques.

Activities towards restoring woodland areas as part of environmental offset requirements have been undertaken at Isaacs Ridge, Gungahlin Strategic Assessment Areas and Justice Robert Hope Park. Activities include, but are not limited to, weed and pest animal monitoring and control, monitoring threatened species and the endangered Yellow Box-Blakely's Red Gum woodland, the addition of coarse woody debris, kangaroo monitoring and control, and revegetation.

The Mulligans Flat and Goorooyarroo Woodland Experiment

Since 2004, Mulligans Flat and Goorooyarroo nature reserves have been the focus of a long-term research partnership between the ACT Government, the Australian National University, the Woodlands and Wetlands Trust, CSIRO and others to better understand and rehabilitate the structure and function of Box Gum woodland ecosystems. The Mulligans Flat and Goorooyarroo Woodland Experiment is aimed at developing a whole-of-ecosystem understanding of Box Gum grassy woodlands with a focus on restoring structure and function to increase biodiversity.

The partnership aims to inform evidence-based conservation management in the ACT. Conservation treatments to date include:

- construction of a large pest-proof enclosure encompassing 485 hectares of Box Gum woodland using 11 kilometres of rabbit, cat and fox-proof fencing
- replenishing fallen timber habitat
- excluding kangaroos from certain areas
- trialling fire regimes
- removing introduced predators, and
- reintroducing locally extinct fauna, including 'ecosystem engineers' such as the Eastern Bettong (*Bettongia gaimardi*).

Responses in the woodland biodiversity are monitored, including surveys of vegetation and fauna, research on arthropod assemblages, abundance of ground-dwelling skinks, the impact of kangaroo grazing, and monitoring plots to trial different fire regimes.

Threatened species, such as the Eastern Bettong (*Bettongia gaimardi*), Eastern Quoll (*Dasyurus viverrinus*), Bush Stone Curlew (*Burhinus grallarius*), Brown Treecreeper (*Climacteris picumnus*) and New Holland Mouse (*Pseudomys novaehollandiae*), have been reintroduced into the Mulligans Flat Sanctuary after many decades of local extinction with differing levels of success. There are plans to reintroduce Yellow-Footed Antechinus (*Antechinus flavipes*) and Eastern Chestnut Mouse (*Pseudomys nanus*) in the future. The sanctuary was extended in 2019 to include an additional 801 hectares of Box Gum Grassy Woodland surrounded by a predator-proof fence directly south of the Mulligans Flat Woodland Sanctuary. Feral animals such rabbits, hares, foxes and cats are currently being removed before planned reintroductions of native species takes place.

Eastern Quoll (*Dasyurus viverrinus*), Mulligans Flat Nature Reserve. Photo: Adrian Manning.

Researchers fitting a collar onto an Eastern Bettong (*Bettongia gaimardi*), Mulligans Flat Nature Reserve. Photo: Don Fletcher.

Release of an Eastern Bettong at Mulligans Flat Nature Reserve. Photo: Environment, Planning and Sustainable Development Directorate.

Impacts of fire on native vegetation

Bushfire is an important occurrence for many native vegetation communities in the ACT. Although fire can cause a temporary loss of vegetation, fire is necessary for the regeneration and regrowth of many plant species. The appropriate fire regime to promote native biodiversity (intensity, frequency, season, extent and type of fire) varies between native vegetation communities. Changes to ecologically appropriate natural fire regimes can have significant impacts on the composition of vegetation communities and the ecosystems they support.

The ACT's fire regimes have changed over time due to increased human sources of ignition, the suppression of natural fire to protect human life and assets, and prescribed burning practices for the management of fuel loads (see section **5.7 Fire**). In addition, periods of prolonged drought and higher temperatures increase the risk of more frequent and severe fires. Climate change is expected to further influence the occurrence of bushfires in the ACT.

TOLERABLE FIRE INTERVALS

Tolerable fire intervals (TFI) assess the likely ecological response of native vegetation communities to subsequent fire and are based on the requirements for sensitive plant species and key habitat elements. Assessments of TFI are based on:

- Minimum TFI: the minimum period of time between fires to avoid a loss of plant biodiversity. This period is based on the time it takes fire-sensitive plant species to grow to reproductive maturity and produce adequate viable seed banks. Frequent burning below minimum TFI can lead to localised loss of these fire-sensitive species, and can also prevent the development of key habitat features required by some fauna such as mature overstorey, tree hollows, and the accumulation of leaf litter and logs.
- Maximum TFI: the maximum period of time between fires to avoid a loss of plant biodiversity. Native vegetation communities not exposed to fire for extended periods can have reduced viability of shorter lived plant species which require fire to germinate seeds. Lack of fire may also result in a decline of key habitat features required by some fauna species such as dense mid-storey vegetation.

Minimum and maximum TFI are ecosystem-specific and are typically longer for vegetation communities that have evolved with less frequent fire, for example those occurring in cooler and moister environments where fires are naturally less frequent and where the growth rates of plants is slower.

It should be noted that the TFI status is only a potential issue should a large, high-severity fire occur in areas that are below minimum TFI. There is no requirement that ecosystems be within a specific TFI, only that fire outside of these thresholds be limited. To promote maximum biodiversity, a range of TFI status is required to provide different habitat resources.

In 2018, only 34% of the total area of native vegetation assessed was found to be within the required TFI to maintain vegetation communities; 53% was below minimum TFI (fire interval too short to maintain vegetation in its optimal state), 7% above the maximum TFI (fire interval too long to maintain vegetation in its optimal state), and 6% was classed as long unburnt (Figures 21 and 22).

Because over 50% of the total native vegetation assessed is below TFI, large areas of the ACT will remain outside optimal TFI irrespective of the level of prescribed burning and future fire events. This potentially places species with life cycles dependent on long inter-fire intervals at increased risk.

For the 10 native vegetation communities assessed, only 4 had 50% or more of their assessable area within the preferred TFI range (Figure 23). These are the Southern Tableland Grassy Woodlands (58%), Upper Riverina Dry Sclerophyll Forests (70%), Southern Tableland Dry Sclerophyll Forests (77%), and Tableland Clay Grassy Woodlands (89%). Five native vegetation communities had none of their assessable area within TFI, and one only has 3% within TFI. These communities had fire regimes mostly below minimum TFI, the exception being the Temperate Montane Grasslands which had 60% of the assessed area above maximum TFI. Other communities with high proportions of above maximum TFI include the Southern Tableland Grassy Woodlands (39%) and Upper Riverina Dry Sclerophyll Forests (28%).

The TFI assessment also showed the following trends:

- Extensive areas of the ACT uplands are below minimum TFI as a result of the 2003 Canberra bushfires which burnt some 90% of the Namadgi National Park. These upland ecosystems typically have longer minimum TFI and are still in an early recovery stage.
- In contrast, many areas of the ACT lowlands and on the lower margins of the uplands are within TFI or above maximum TFI. These areas either escaped 2003 bushfire and/or are communities that recover more quickly from fire.
- Much of the above maximum TFI in the northeast of the ACT are native grasslands which have a short minimum TFI and in which little burning has occurred in recent decades.
- Long unburnt areas are those areas in the Namadgi National Park that have had no recorded fire but support vegetation communities that were otherwise extensively impacted by the 2003 bushfire throughout the rest of park. Most of the long unburnt ecosystems in Namadgi National Park are restricted to the very southern portion on the NSW border. These areas therefore represent rare post-fire age classes for some vegetation communities and exclusion of fire in the foreseeable future is a particularly high conservation priority while other areas of these communities recover from the 2003 fires.

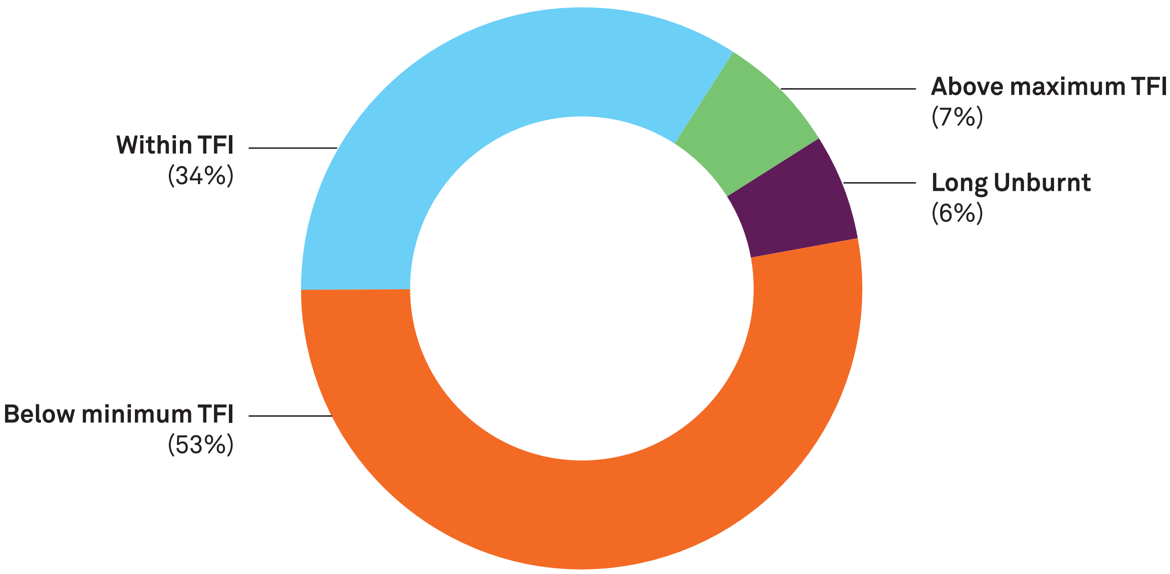


Figure 21:

Percentage area of assessed vegetation communities by tolerable fire interval status, as at 2018.

Data sourced from: Environment, Planning and Sustainable Development Directorate

Notes: Assessed using Keith Class level. Post-fire status of native vegetation communities is based on prescribed fire and bushfire history up to the end of 2018. Fire history records nominally begin in 1900 but are more reliable from 2003 onwards.

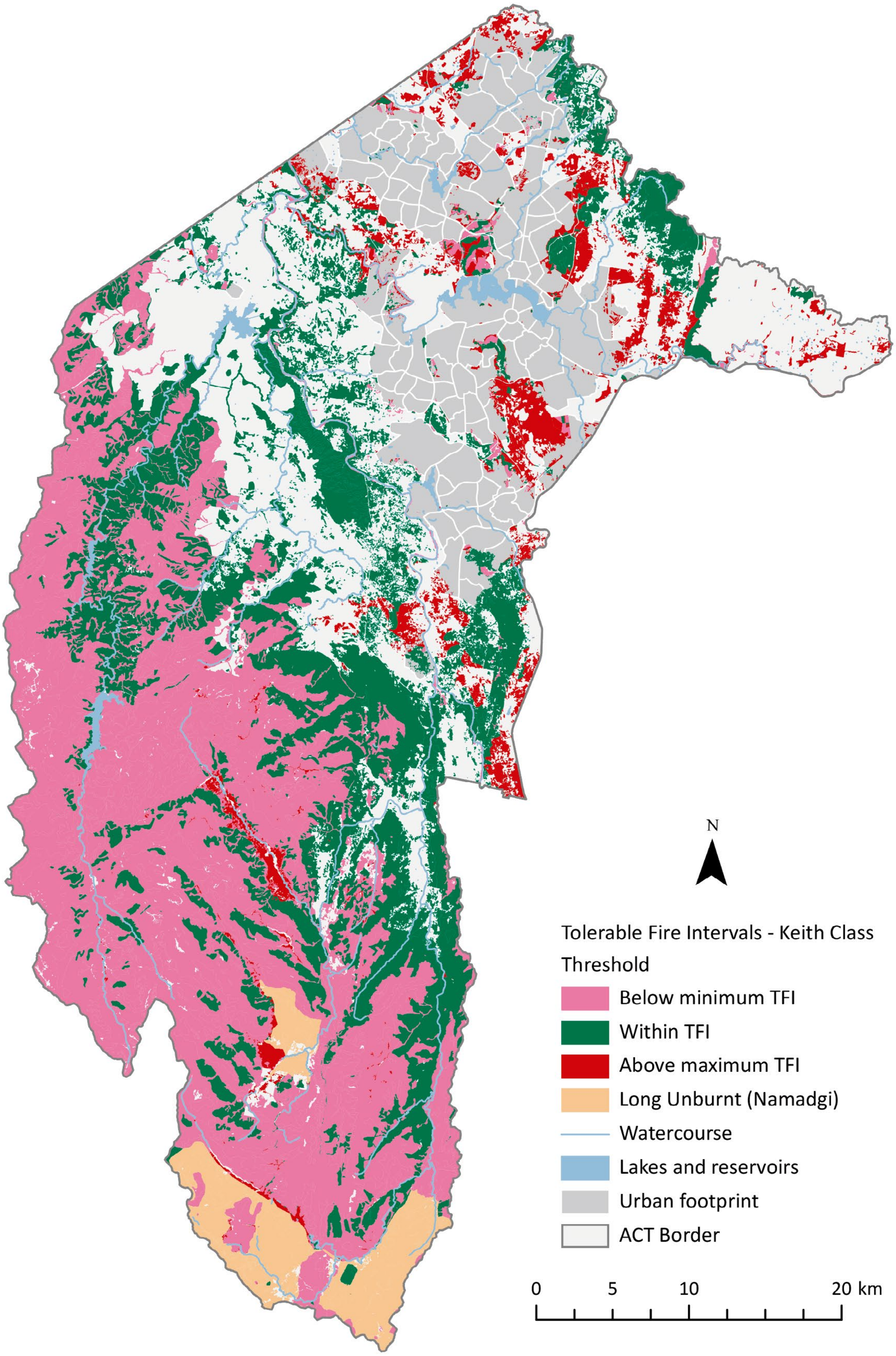


Figure 22:

Distribution of tolerable fire interval status for selected native vegetation communities in the ACT, as at 2018.

Data sourced from: Environment, Planning and Sustainable Development Directorate

Notes: Assessed using Keith Class level. Post fire status of native vegetation communities based on prescribed fire and bushfire history up to the end of 2018. Fire history records nominally begin in 1900 but are more reliable in later years from 2003 onwards. Blank areas are either non-native vegetation communities or urban areas.

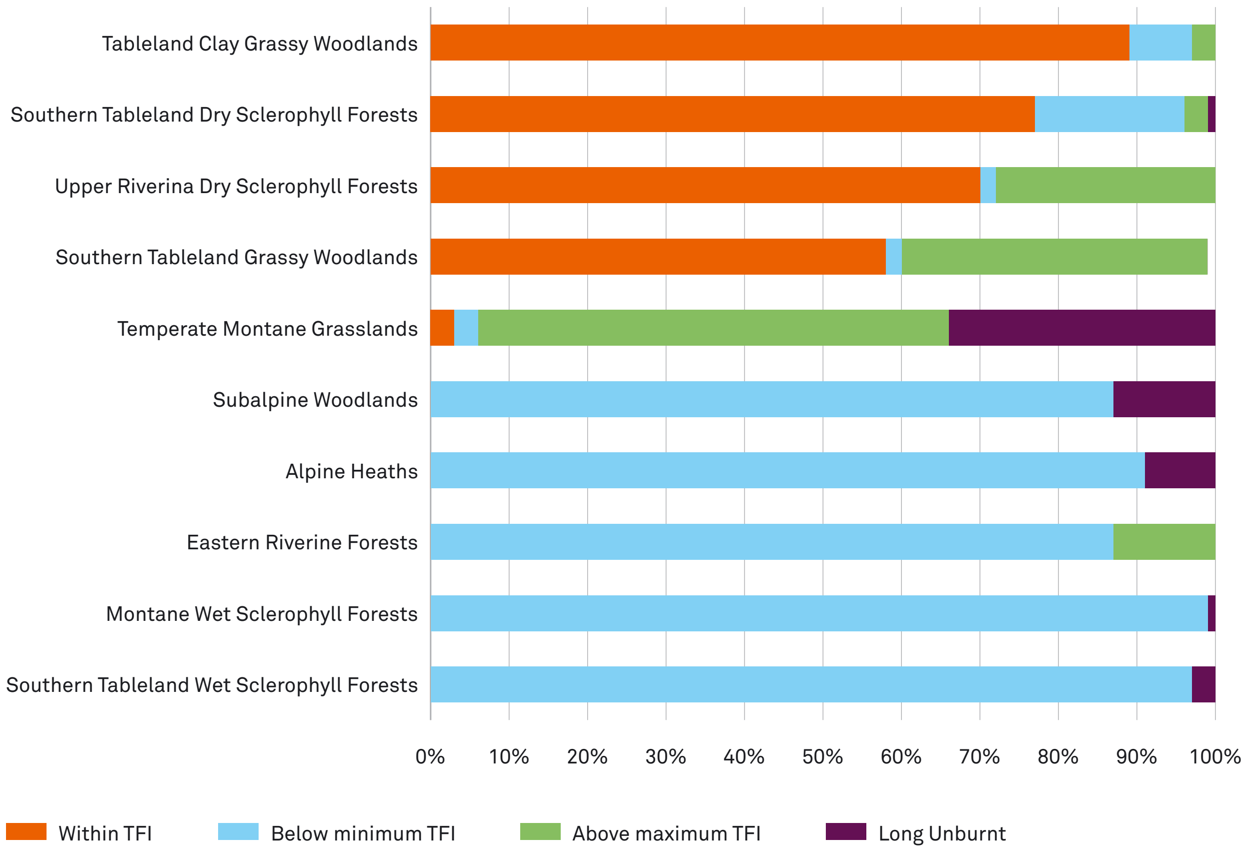


Figure 23:
Percentage area of selected native vegetation communities by tolerable fire interval status, as at 2018.

Data sourced from: Environment, Planning and Sustainable Development Directorate

Notes: Assessed using Keith Class level. Post-fire status of native vegetation communities is based on prescribed fire and bushfire history up to the end of 2018. Fire history records nominally begin in 1900 but are more reliable from 2003 onwards.

GROWTH STAGE

Post-fire growth stages represent the recovery of native vegetation communities after fire and the progression from early response (re-sprouting and seed germination) to the maturation of plant species and animal populations, and eventually senescence and species turnover at longer times subsequent to fire. Each growth stage is characterised by a different structural arrangement of vegetation and may be dominated by different component species. Similarly, the faunal community supported by an area will vary as the vegetation progresses through growth stages. Biodiversity values are most likely enhanced at a landscape scale by achieving a range of growth stages within each vegetation community and across the landscape.

In 2018, the adolescent growth was the most common growth stage accounting for 44% of the total area of native vegetation communities assessed (Figures 24 and 25). The next most common growth stage was mature at 38% of the total area of native vegetation assessed, with both juvenile and senescent both accounting for 9% each. While all growth stages are represented across the ACT, the landscape is dominated by early and young stages which account for over half of the assessed vegetation communities.

For the 13 native vegetation communities assessed, 8 had 50% or more of their assessable area within juvenile or adolescent growth stages (Figure 26). Five of these communities had over 80% of their assessed area in juvenile or adolescent growth stages, including Alpine Bogs and Fens, Alpine Herbfields, Subalpine Woodlands, Southern Tablelands Wet Sclerophyll Forests, and Montane Wet Sclerophyll Forests. Only 4 vegetation communities had greater than 50% of their assessed area within the mature growth stage including Montane Bogs and Fens, Southern Tableland Dry Sclerophyll Forests, Southern Tableland Grassy Woodlands, and Upper Riverina Dry Sclerophyll Forests.

Native vegetation growth stages across the ACT reflect TFI status, with extensive areas of the uplands being dominated by early and young growth stages. This is a result of the 2003 bushfires and the relatively slow recovery rate of many upland ecosystems. The dominance of early and young growth stages has significant implications for biodiversity, especially for fauna that require older growth stages.

The growth stage assessment also showed the following trends:

- Vegetation communities dominated by early post-fire growth stages include Alpine Bogs and Fens and Alpine Herbfields, and to a lesser extent Montane Bogs and Fens, which grow at lower altitudes and were not as extensively impacted in 2003.
- Most other upland ecosystems are also dominated by juvenile and adolescent growth stages including Subalpine Woodlands, Southern Tableland Wet Sclerophyll Forests and Montane Wet Sclerophyll Forests.
- Early recovery stages are extensive in parts of the Namadgi National Park which have been subjected to prescribed burning since 2003, primarily as a part of the Regional Fire Management Plan, between 2013 and 2018.
- Some lower elevation communities are also dominated by earlier growth stages including the Eastern Riverine Forests and Tableland Clay Grassy Woodlands.
- Mature growth stages are more common on the lower elevation eastern and northern margins of the upland where dry forest and woodlands that recover more quickly from fire dominate.
- Dry sclerophyll forest communities and Southern Tableland Grassy Woodlands have a significant proportion of their extent in mature and senescent growth stages.
- Older growth stages are currently rare in the ACT uplands and are known to support different collections of species to ecosystems dominated by younger growth stages. The biodiversity these areas support is at risk from future bushfires because of the time required to transition from early to later growth stages and to replace slow developing habitat features such as mature trees and tree hollows.
- Late post-fire growth stages are primarily distributed in the far south of Namadgi National Park (which escaped the 2003 bushfires and has not been burnt in recorded history) and in the lowland grasslands and woodlands around Canberra.

In the longer term, conservation priority needs to focus on diversifying growth stages within and between ecosystems to maximise persistence of biodiversity. In the lowlands, this can be achieved through the ecological burning of late and mature growth stages for vegetation resilient to fire. However, in the uplands achieving growth stage diversity will require time and deliberate protection of the relatively rare older growth stages from prescribed fire and bushfire until more of the landscape reaches post-fire maturity.

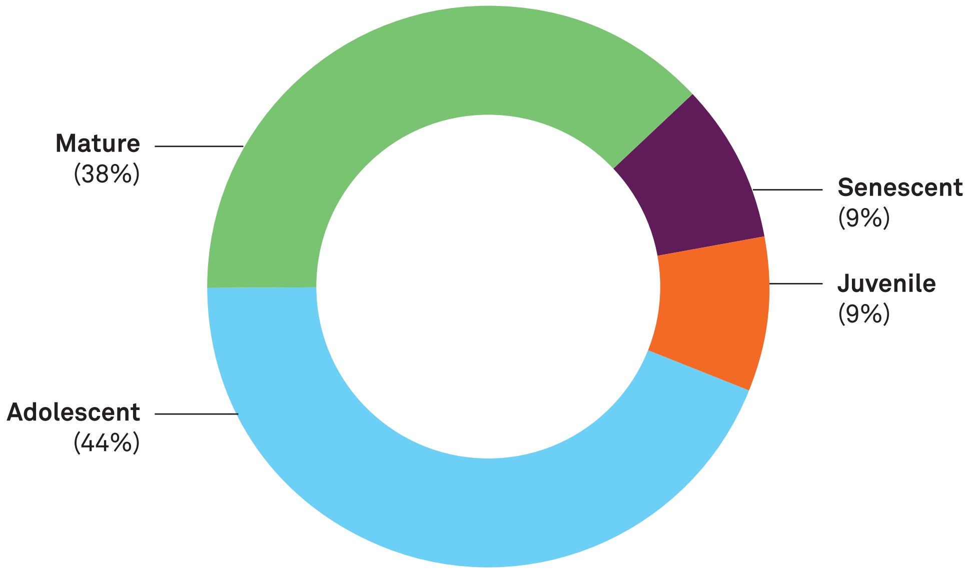


Figure 24:

Percentage area of assessed vegetation communities by growth stage, as at 2018.

Data sourced from: Environment, Planning and Sustainable Development Directorate

Notes: Assessed using Keith Class level. Post-fire status of native vegetation communities is based on prescribed fire and bushfire history up to the end of 2018. Fire history records nominally begin in 1900 but are more reliable from 2003 onwards.

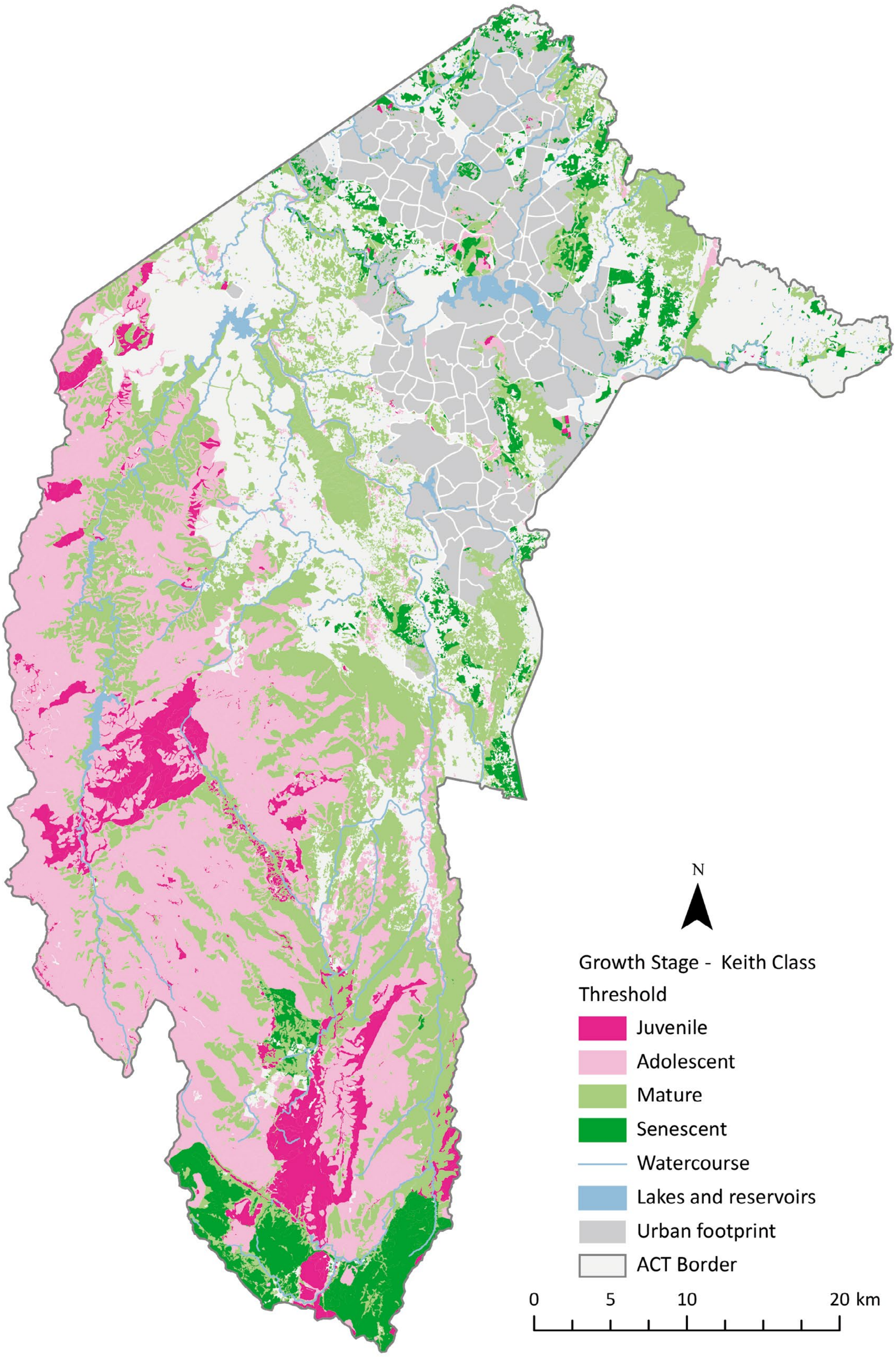


Figure 25:

Distribution of growth stages for selected native vegetation communities in the ACT, as at 2018.

Data sourced from: Environment, Planning and Sustainable Development Directorate

Notes: Assessed using Keith Class level. Post-fire status of native vegetation communities is based on prescribed fire and bushfire history up to the end of 2018. Fire history records nominally begin in 1900 but are more reliable from 2003 onwards. Blank areas are either non-native vegetation communities or urban areas.

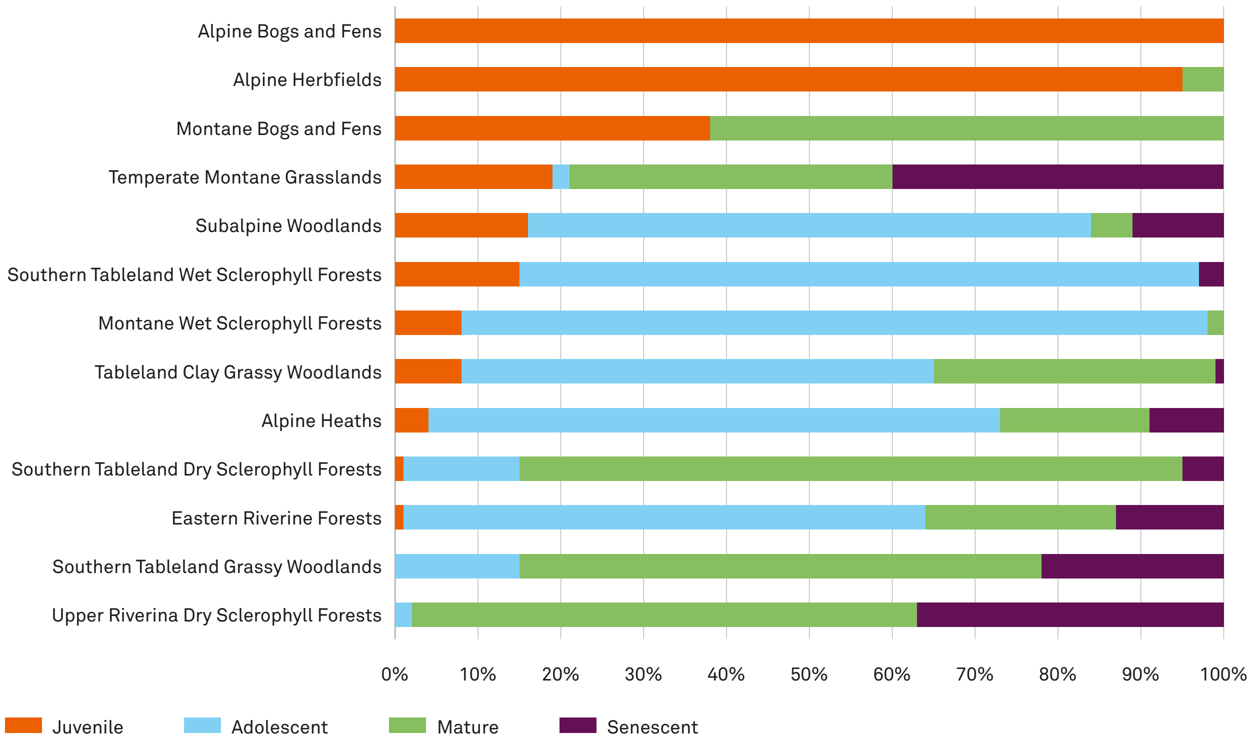


Figure 26:
Percentage area of selected native vegetation communities by growth stage, as at 2018.

Data sourced from: Environment, Planning and Sustainable Development Directorate

Notes: Assessed using Keith Class level. Post-fire status of native vegetation communities is based on prescribed fire and bushfire history up to the end of 2018. Fire history records nominally begin in 1900 but are more reliable from 2003 onwards.

Indicator B5: Distribution and abundance of terrestrial invasive plants and animals

Invasive plant and animal species are a costly and significant threat to the health of biodiversity and ecosystems in the ACT, as well as a threat to many of the ACT's endangered species (see Table 1 at the end of the Biodiversity section). In areas where invasive species are dominant, local extinctions of native flora and fauna can occur. They can also prevent the successful reintroduction of native species into otherwise suitable habitat. Exotic pests and diseases such as parasites of fish, dieback fungus (*Phytophthora cinnamomi)* and myrtle rust are an additional threat to biodiversity, with the potential to affect a wide range of native species.

In addition to biodiversity and ecosystem health impacts, invasive species have a negative effect on the region's agriculture through lost production and management costs, loss of social amenity, and human health.

Invasive plants, sometimes called environmental weeds, are one of the most significant threats to biodiversity in the ACT.[25] Invasive plants are a main cause of biodiversity loss by displacing native species, modifying habitat and ecological functions, and reducing food availability. Invasive plants can also impact soil and aquatic health, alter stream flows and increase flooding.

Invasive animals threaten biodiversity through predation, competition for food and habitat, and modification of ecosystems and ecological functions. Invasive animals can have significant environmental impacts due to soil disturbance from burrowing, grazing, and the action of hard hooves. These promote erosion and can lead to degradation of aquatic ecosystems. The actions of invasive animals are particularly damaging in sensitive ecosystems such as High Country Bogs and Associated Fens. Invasive animals can also spread disease and parasites.

Pest plants and animals are not restricted to introduced species (those not indigenous to the ACT region); overabundant native animals such as kangaroos can degrade ecosystem health. Some native species, particularly plants, can also become pests if they become established outside their natural range.

Invasive plants and animals require ongoing management to minimise impacts, both on public and private land (see **Chapter 3 Community leadership in**

25 EPSDD, 2016, *ACT Biosecurity Strategy 2016–2026*, ACT Government, Canberra.

sustainability and science for more information about invasive species management on private land). It is generally not feasible to eradicate widely established invasive species; therefore the goal of management is to reduce numbers to levels where they have no unacceptable impact. This goal is achieved through the monitoring and control of established species, and the detection and eradication of new invasive species before they become established. Prevention and early intervention are often the most cost-effective techniques for managing invasive species.

Climate change is likely to modify and increase the threat of invasive plants and animals in the ACT, through extensions of favourable conditions and the availability of new habitat caused by the loss of native species from increased temperatures, drought and fire.

It is not possible to monitor the distribution and abundance of all invasive species. Therefore, the monitoring of invasive species concentrates on those known to be causing significant problems or posing significant threats.

Invasive plants

There are a significant number of invasive species present in the ACT – the 2017 *Census of the Flora of the Australian Capital Territory* found 592 introduced plant species, 53 of which were introduced from elsewhere in Australia.[26]

Known locations of invasive plants are mapped, along with control activities undertaken.[27] Data on management activities and outcomes clearly demonstrates the value of invasive plant management to control established populations and to eradicate new outbreaks where possible. Management results also show the risk of invasive plant populations re-establishing themselves in the absence of ongoing control. Most management activity in the ACT focuses on environmental weeds that have high potential for invasiveness and impact.

Over the reporting period (2015–16 to 2018–19), 54,000 hectares of invasive plant control was undertaken in the ACT for over 100 invasive plant species. Figure 27 shows the area treated for the 10 invasive species that were most extensively controlled over the period. Serrated tussock accounted for the largest area treated at nearly 14,000 hectares, followed by St. John's wort (over 10,000 hectares), blackberry (7,700 hectares) and African lovegrass (6,900 hectares).

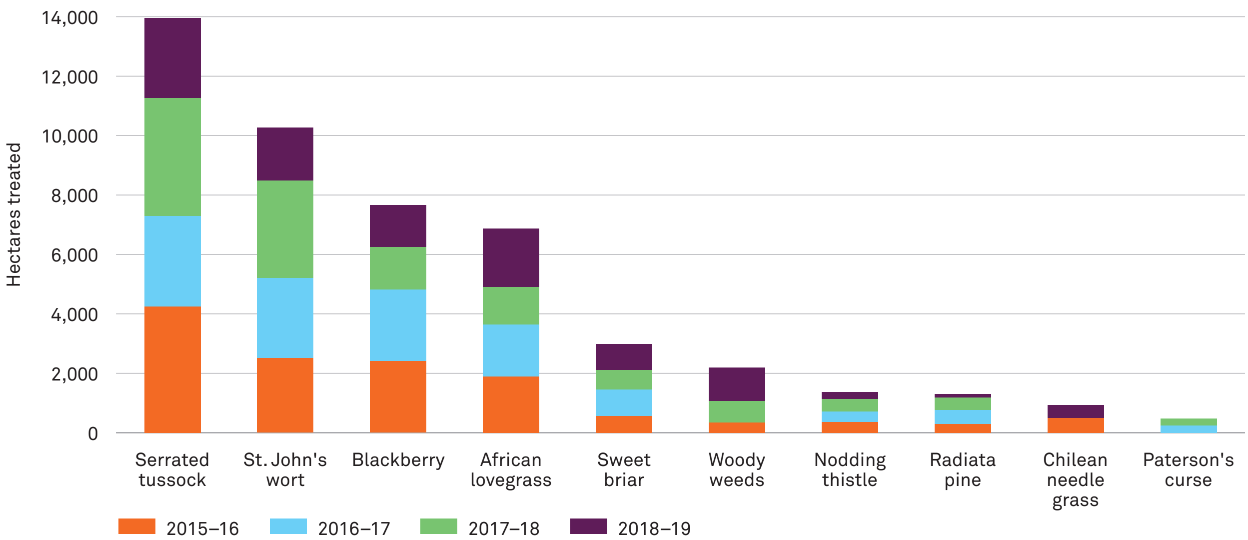


Figure 27:
Top ten controlled invasive plants in the ACT, areas treated, 2015–16 to 2018–19.

Data sourced from: ACT Parks and Conservation Service

In addition to the control of established invasive plants, it is important to detect and control new invasive species. Emerging priority species in the ACT include Fireweed, Coolatai grass, Mexican feather grass and Alligator weed. Early intervention is vital to successful management of these species. These invasive plants can lead to significant degradation of biodiversity and also represent a threat to grazing productivity due to low levels of protein and digestibility.

26 Australian National Herbarium, Centre for Australian National Biodiversity Research, 2017, Census of the Flora of the ACT, found at https://www.anbg.gov.au/cpbr/ACT-census-2017/index.html
27 Invasive plant locations and control activities can be found at https://www.environment.act.gov.au/parks-conservation/plants-and-animals/Biosecurity/invasive-plants#control

CASE STUDY:
THE IMPORTANCE OF INVASIVE PLANT MANAGEMENT IN THE ACT

Source: Environment, Planning and Sustainable Development Directorate

In the absence of management, invasive plants can significantly expand their coverage and negative impact over a short period of time. Figure 28 shows the increase in Chilean needle grass at Crace Grasslands between 2012–2013 and 2015–2016. Without effective ongoing control, the extent of Chilean needle grass more than doubled. Figure 29 shows the increase in African lovegrass infestation at Tuggeranong Hill Nature Reserve between 2014–2015 and 2017–2018. In the absence of ongoing control, African lovegrass extent more than tripled in the section of the reserve being monitored.

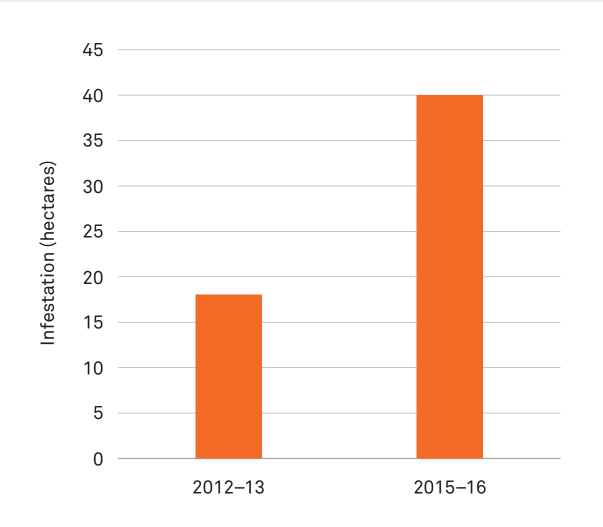


Figure 28:
Increase in Chilean needle grass infestation at Crace Grasslands Nature Reserve in the absence of ongoing control.

Source: Collector for ArcGIS and Environment, Planning and Sustainable Development Directorate

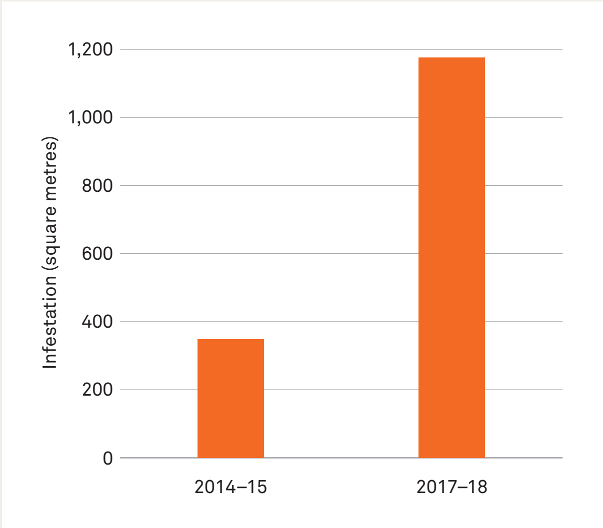


Figure 29:
Increase in African lovegrass infestation at Tuggeranong Hill Nature Reserve in the absence of ongoing control.

Source: Collector for ArcGIS and Environment, Planning and Sustainable Development Directorate

Effectiveness of control activities in reducing the spread of pest plants

AFRICAN LOVEGRASS IN NAMADGI NATIONAL PARK

African lovegrass is widespread in the ACT and a significant threat to native plant and animal habitat. It also increases fire risk in the areas it invades. Figure 30 shows the successful control of African lovegrass in Namadgi National Park between 2015 and 2019. Management actions ensured that this pest species was effectively contained during this period. But a slight increase in African lovegrass in 2019 shows the capacity for invasive plants to begin to re-establish after control activities, or in response to environmental changes such as disturbance or drought. Ongoing management is required to keep African lovegrass contained in Namadgi National Park due to the frequent discovery of new infestations.

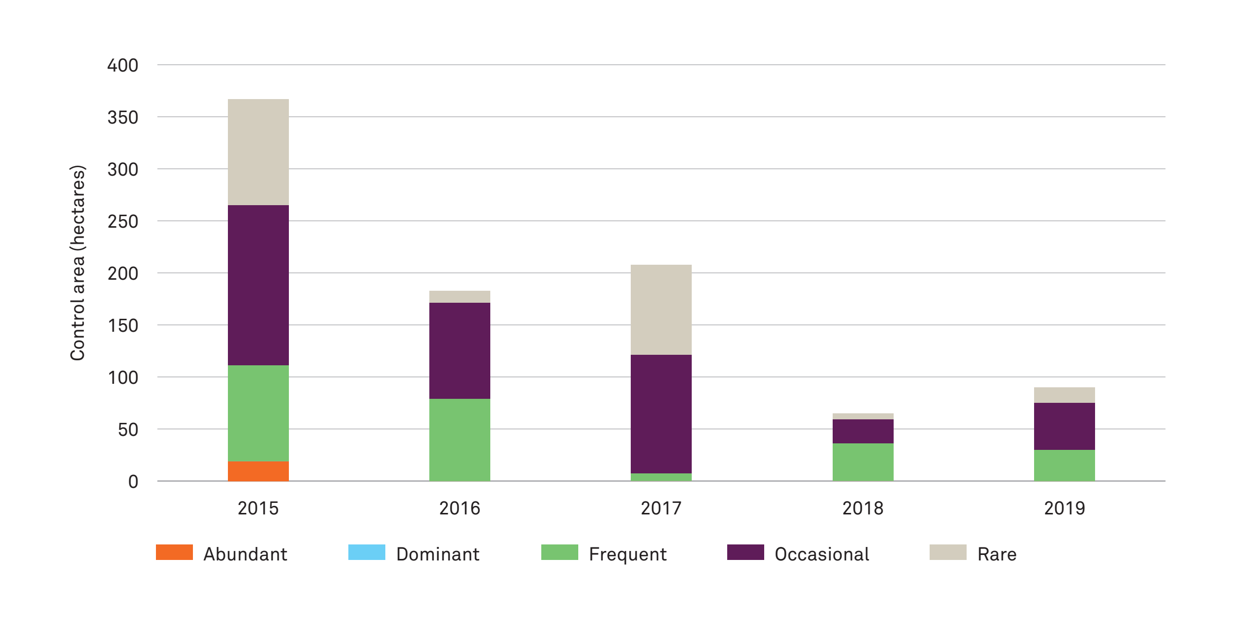


Figure 30:
African lovegrass control in Namadgi National Park, 2015 to 2019.

Source: Collector for ArcGIS and Environment, Planning and Sustainable Development Directorate

Notes: The categories of abundant, dominant, frequent, occasional and rare refer to abundance of the African lovegrass at control sites.

SERRATED TUSSOCK IN GRASSLANDS AND WOODLANDS

Inadequate resourcing for control activities before 2016 resulted in the increased spread of serrated tussock in the ACT's grasslands and woodlands. Increased control activities in subsequent years demonstrate the benefits of management. Between 2016 and 2019 serrated tussock was brought under control, reducing the threat of further spread and allowing the recovery of native species (Figure 31).

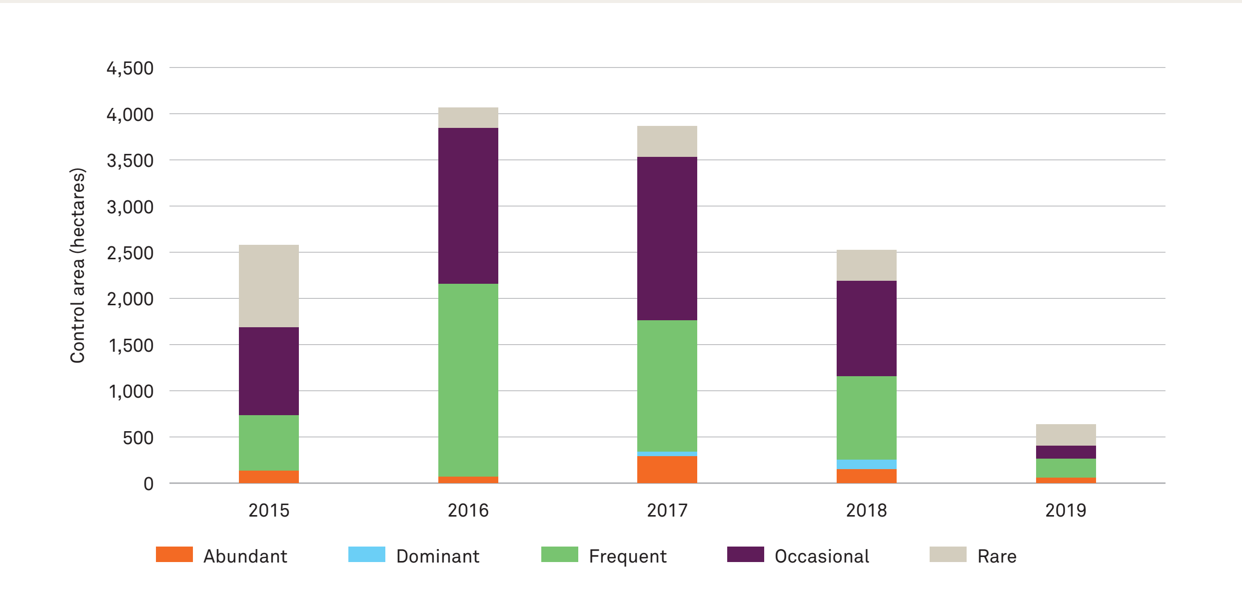


Figure 31:
Serrated tussock control in grasslands and woodlands

Source: Environment, Planning and Sustainable Development Directorate

Notes: The categories of abundant, dominant, frequent, occasional and rare refer to abundance of the Serrated tussock at control sites.

BLACKBERRY CONTROL IN NAMADGI NATIONAL PARK

The photos below show how native plants can recover after control of invasive plants. The blackberry invasion was starting to smother the Dicksonia tree ferns. Careful herbicide use killed the blackberry and saved this tree fern community. The final photo shows native colonising plants filling the space of the dead blackberry. Eventually taller native plants will regenerate at the site.

Photo: Blackberry control in wet sclerophyll forest Northern Namadgi National Park. Source: ACT Parks and Conservation Service and Environment, Planning and Sustainable Development Directorate.

Invasive animals

It was not possible to comprehensively determine the distribution and abundance of invasive animals in the ACT for this report. However, records from Canberra Nature Map show the presence of 64 introduced species in the ACT including 17 mammals, 33 birds, 2 lizards, 1 frog and 11 fish (see section **5.6 Water**).[28]

The invasive animal species of most concern in the ACT are feral pigs, deer, foxes, rabbits, horses and wild dogs. Where possible these species are managed with neighbouring land managers to minimise their negative impacts on conservation reserves and surrounding agricultural land.

As with invasive plants, the management of mobile and rapid breeding animals such as rabbits requires continuous control to be effective. Ongoing invasive animal control programs currently account for the majority of vertebrate pest management in the ACT. These include feral pigs in Namadgi National Park, rabbits in areas of Canberra Nature Park and Namadgi, as well as wild dogs at the rural/reserve interface. Rabbit control is the most common management undertaken, occurring in all but one reserve. All priority invasive animal species are controlled in Namadgi National Park; other reserves where management of multiple species takes place include the Tidbinbilla Nature Reserve, Murrumbidgee River Corridor, Googong Foreshores, Goorooyarroo Nature Reserve, and Molonglo River Nature Reserve.

General trends for selected invasive animal species are shown below.

Rabbits

Rabbits are the most widespread and damaging invasive animal in the ACT, impacting on both natural and rural lands. Rabbits pose a particular threat to native vegetation, as they prevent regeneration by removing seedlings. Loss of native vegetation from rabbit grazing threatens the survival of native birds, small mammals and insects that rely on groundcover plants for food and shelter. The presence of rabbits can sustain fox and feral cat populations then these predators in turn place further pressure on native prey species. Rabbits also cause erosion and weed colonisation.

Rabbit numbers have been increasing in the ACT and in all other Australian jurisdictions over the last five years. As with other fast-breeding, mobile invasive species like foxes, effective, sustained management of rabbits relies on coordinated management at the landscape scale to prevent recolonisation from neighbouring, untreated areas. After one or two years of intensive follow-up control, monitoring results show the successful suppression of rabbit populations, but ongoing management is then required to prevent populations from re-establishing themselves. This continuing control has been effective in reducing the densities of rabbits by around 90% in areas of Canberra Nature Park and Namadgi National Park (Figure 32). The rabbit's propensity to rapidly breed is also shown in Figure 32, with a significant increase in population in 2014, followed by a steep decline in response to effective control programs.

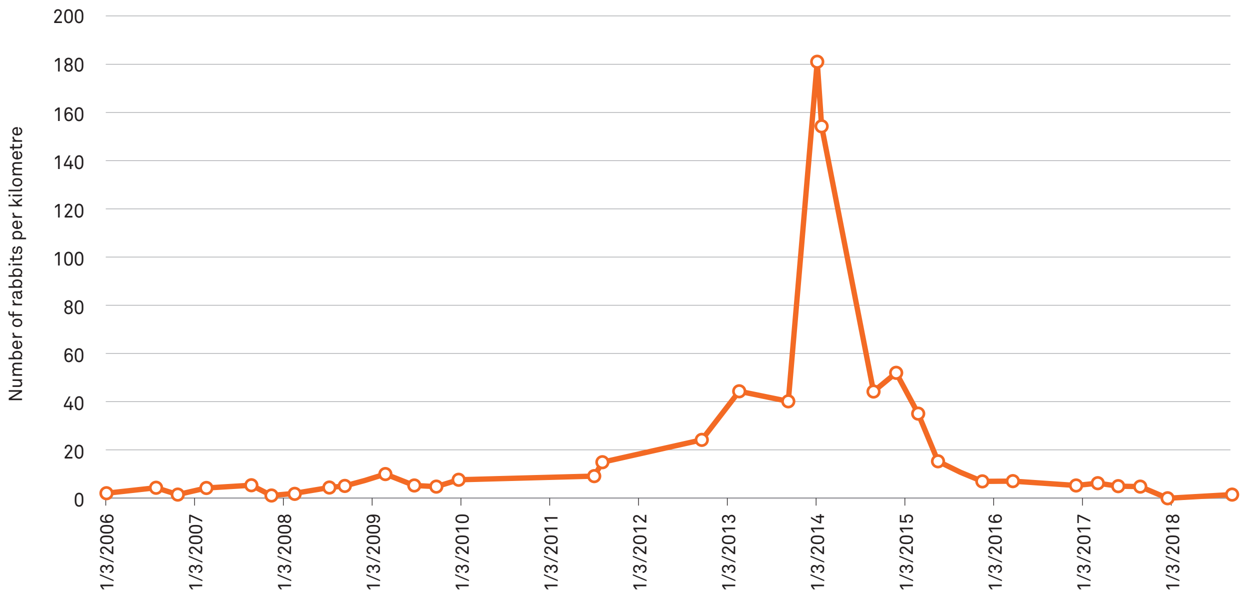


Figure 32:
Rabbit abundance at Gudgenby Valley, Namadgi National Park, 2006 to 2018

Source: ACT Parks and Conservation Service

28 More information on the Canberra Nature Map can be found at https://canberra.naturemapr.org/

Foxes

Foxes are ubiquitous in the ACT but effective management over large areas is constrained by restrictions on the use of 1080 poison close to residential areas, and by limited resources for 1080 poisoning in non-urban reserves. Predation by foxes has been shown to have a devastating impact on native fauna, causing local extinctions of vulnerable native species. For example, the ACT's Scientific Committee has advised that foxes were responsible for the loss of Bettongs released in the Lower Cotter Catchment between 2015 and 2017, with most dying shortly after release. The committee has also advised against future wild releases unless fox numbers can be significantly reduced. This shows the successful restoration of some native animals is dependent on the effective control of invasive species.

Horses

Feral horses within Namadgi National Park damage sensitive subalpine wetlands and bogs, which provide habitat for the rare and endangered Northern Corroboree Frog (see *Case study: High Country Bogs and Associated Fens*). Feral horse management along the south-western border region over the last decade has resulted in the ACT currently being free of resident feral horse populations. The last feral horse was removed in 2011. Management in this region now focuses on surveillance and prevention to detect and control feral horses. Responding promptly has proven successful to prevent feral horses returning to the ACT.

Feral horse management is likely to become more important in the future, particularly for the protection of Namadgi National Park alpine wetlands and water catchment. This is due to the NSW Government's decision to grant feral horses Heritage status and only allowing non-lethal methods for their removal. This will likely lead to an increase in feral horse populations and result in higher numbers moving into the ACT from NSW. If the feral horse population in Namadgi is permitted to grow and expand its range, there will be increasing damage to sensitive ecosystems, with deleterious consequences for biodiversity.[29]

Deer

Deer have the potential to cause significant environmental damage, as well as affecting agricultural productivity and social amenity. They can be particularly destructive to sensitive alpine bogs and fens (see *Case study: High Country Bogs and Associated Fens*). Deer are an emerging invasive species in the ACT and are common across eastern NSW and other parts of Australia. Three species of feral deer, Fallow (*Dama dama*), Red (*Cervus elaphus*) and Sambar (*Rusa unicolor*) are widespread in the ACT. Although these species have been present in low numbers in the territory for a considerable period, there has been an increase to the known range and distribution of all three species in recent years.

Deer management poses a challenge to public and private land managers due to the animals' cryptic and wary behaviour. To assess the effectiveness and feasibility of managing high priority emerging deer populations, the ACT Government has implemented several pilot management programs including:

- ground shooting of Fallow Deer at Googong Foreshores, and areas of the Murrumbidgee River Corridor
- ground shooting Sambar Deer in the Upper Cotter Region of Namadgi National Park, and
- the first aerial shooting program targeting fallow deer in the ACT took place in the Molonglo and Murrumbidgee river corridors in June 2019.

Feral Pigs

Feral pigs are widely distributed throughout non-urban parks and reserves in the ACT, and are occasionally found in areas of the Canberra Nature Park. Ground rooting by pigs creates bare ground, contributing to erosion and weed invasion, and impacting on visual amenity for park visitors. Pigs have a varied diet including small mammals, reptiles, amphibians, birds' eggs, soil invertebrates and roots and tubers of native plants. On rural land they dig up pasture, kill lambs, damage fencing and are a potential vector for several serious endemic and exotic livestock diseases such as foot and mouth disease.

Annual baiting and trapping programs are conducted in Namadgi National Park and the Murrumbidgee River Corridor. In recent years, cooperative control programs have been conducted with neighbouring landholders. The deleterious impact of feral pigs in Namadgi National Park has been assessed annually since the mid–1980s and the data shows a dramatic decline in damage as a result of sustained control activities.

Wild dogs

Populations of wild dogs (dingoes and dingo-like dogs which are dingoes with a small proportion of domestic dog genes) are found in Namadgi National Park, areas of the Murrumbidgee River Corridor, Rob Roy Nature Reserve and adjacent areas of timbered land in the ACT.

Wild dogs are controlled in these areas to minimise attacks on sheep on neighbouring rural properties.

29 ACT Department of Territory and Municipal Services, 2015, Feral Horse Management, ACT Government, Canberra.

Management involves a range of methods including 1080 poison baiting, trapping and opportunistic shooting. This integrated approach also achieves effective fox management in dog control areas. In contrast, wild dogs are protected in core reserve areas including the Gudgenby Valley, Cotter Catchment and the Tidbinbilla Nature Reserve where they are the top-order predator in the ecosystem.

In addition to controlling wild dogs on ACT rural lands to protect livestock, the ACT Government is also a signatory to three cooperative Wild Dog Management Plans with New South Wales authorities and landholders. These are aimed at protecting livestock from wild dogs originating from Namadgi National Park.

Cats

Despite the significant impacts on native wildlife, the ACT has no formal programs to manage stray or feral cats. Both domestic and feral cats prey on native animals including birds, reptiles and small mammals. Domestic cats are controlled in many new urban areas through cat containment legislation.

Indian Myna

Indian Mynas were introduced to the Canberra region in 1968. They have shown a distinct liking for woodland nature reserves and are strong competitors with native wildlife for food and nesting hollows. They are now well established across the ACT. Indian Mynas are very aggressive and intelligent, and are known to evict native birds (including parrots, kookaburras and peewees) from their nests, dumping out their eggs and chasing them from their roosting areas.

In 2006, the Canberra Indian Myna Action Group was formed to reduce the impact of this exotic invader on native birds and other animals. The group's concentrated trapping and removal efforts has been shown to reduce the population of Indian Mynas across Canberra (see **Chapter 3 Community leadership in sustainability and science**).

CASE STUDY: KANGAROOS AND GRASSY ECOSYSTEM MANAGEMENT

Source: Environment, Planning and Sustainable Development Directorate

Overabundant native animals such as kangaroos can have an impact on ecosystem health. Eastern Grey Kangaroos are managed in the urban reserves of Canberra Nature Park to protect conservation values from overgrazing. Conservation culling is undertaken annually, in accordance with the *Eastern Grey Kangaroo: Controlled Native Species Management Plan*. Kangaroos are managed within a kangaroo management unit (KMU), which are typically comprised of one or more nature reserves and any adjacent habitat available to an isolated kangaroo population. These adjacent land tenures include rural lease, Commonwealth land, parklands, and government horse paddocks.

The number of kangaroos to remain in each individual KMU is calculated annually in accordance with the Conservation Culling Calculator Determination (2018). This calculator formulates target densities based on ecological models of how much kangaroos eat coupled with how quickly pasture grows according to historical weather information. In an average grassland, this model indicates that approximately one kangaroo per hectare is consistent with maintaining appropriate grassy layer structure to maintain biodiversity values.

In 2018, the ACT Government hosted an expert workshop to review research undertaken since this original model was published in 2010. The workshop included national and international experts in wildlife management, grassy ecosystem dynamics, and kangaroo biology, as well as land management staff. Workshop participants identified that a more specific grassy layer structure target would benefit the evaluation of the kangaroo program effectiveness, and that routine measurements of grassy layer structure could help to inform a more sophisticated approach to establishing kangaroo target densities based on current ground layer vegetation conditions.

As a result of these recommendations, a working group is developing Herbage Mass Management Guidelines for Lowland Grassy Ecosystems of the ACT. These guidelines identify grassy layer structure targets based on empirical research into the preferred habitat attributes of grassy layer-dependent bird, reptile, invertebrate and plant species. These guidelines also include recommendations around the choice, deployment and integration of different management tools (such as fire, slashing, livestock grazing, macropod management, installation of physical barriers) for use when biannual monitoring identifies areas as being above or below the safe operating environment thresholds.

Eastern Grey Kangaroo conservation culling program

The annual conservation culling program protects the critically endangered grassy ecosystems of the ACT from the threat of overgrazing by kangaroos.

Managing kangaroos at any given site usually involves larger initial reductions in kangaroo population density over 1–3 years, followed by smaller annual maintenance programs to maintain an equilibrium between kangaroo grazing pressure and grassy habitat.

The capacity of the program has increased over time, enabling new sites within Canberra Nature Park to be added to the program based on prioritisation of conservation values and consideration of operational constraints.

Between 2009 and 2019, over 22,000 kangaroos were culled to protect grassy ecosystems (Figures 33 and 34). The largest annual cull was 4,035 kangaroos conducted in 2019. The annual cull numbers have increased annually since 2013, mainly due to the increased number of management sites. Cull numbers are also dependent on the kangaroo population which varies in response to a range of conditions including food availability.

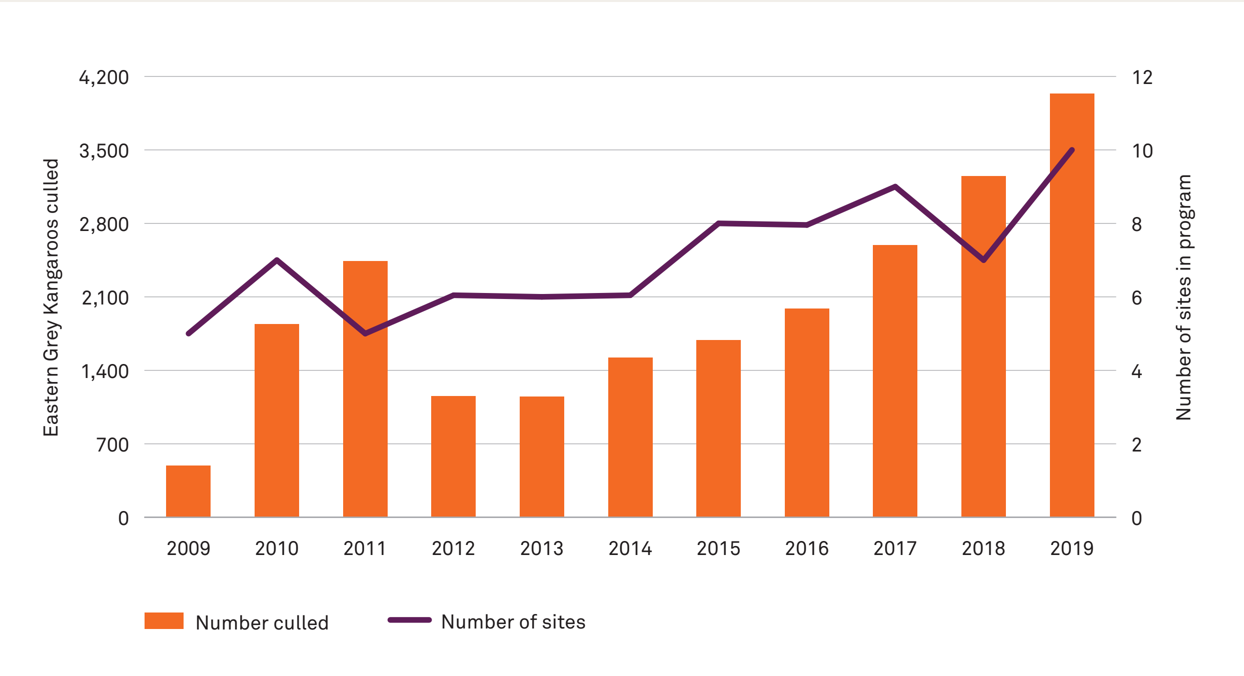


Figure 33:
Annual number of Eastern Grey Kangaroos culled and number of program sites, 2009 to 2019.

Source: Environment, Planning and Sustainable Development Directorate

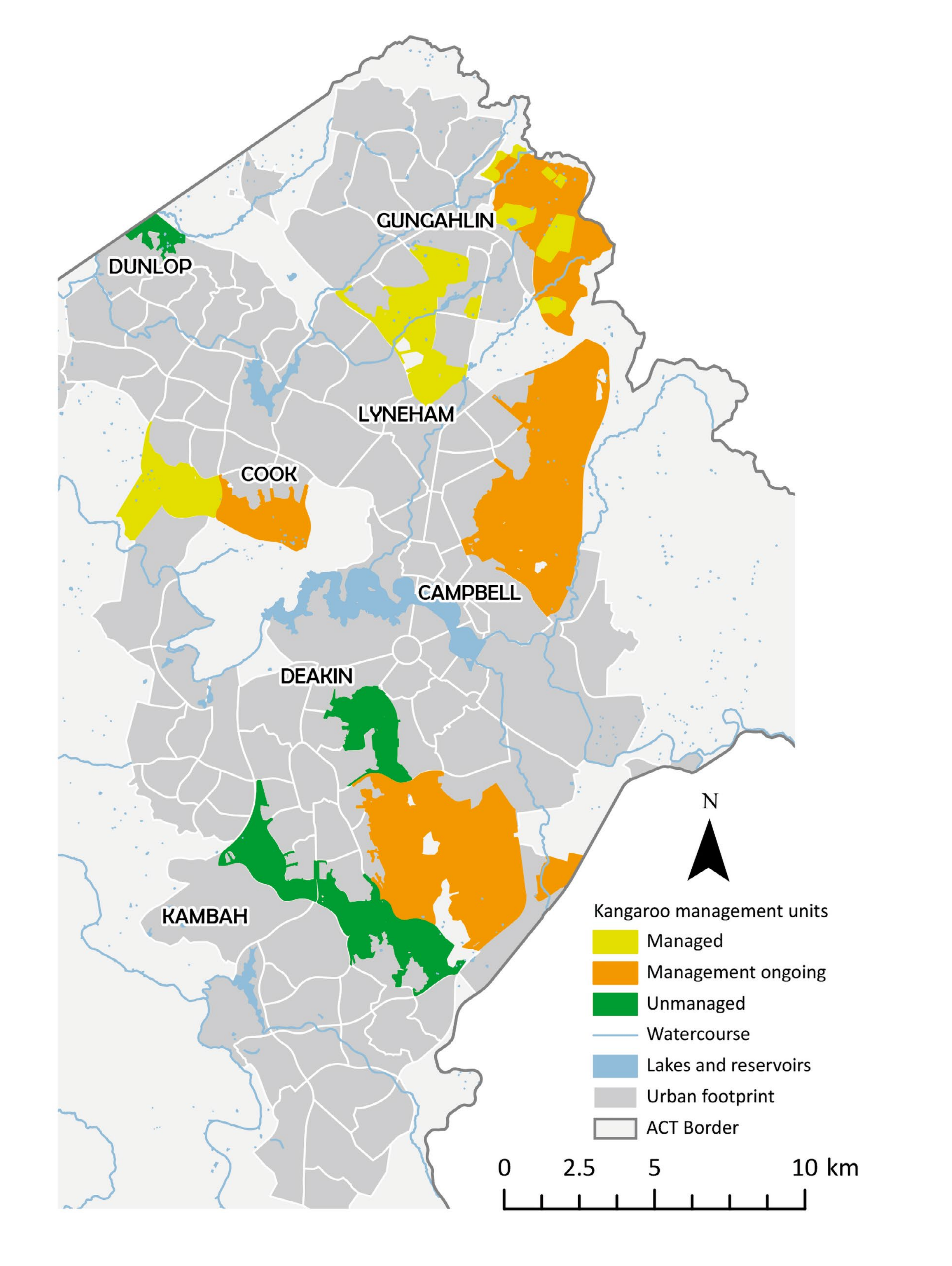


Figure 34:
Kangaroo management areas

Data sourced from: ACT Parks and Conservation Service

DATA GAPS

Biodiversity

- Information on biodiversity is often lacking due to the difficulties and resources required in undertaking comprehensive and extensive monitoring. It is currently not possible to accurately measure the distribution and abundance of all species in the ACT, and not all areas of the ACT can be surveyed and monitored. This means that the knowledge required to answer key biodiversity status and management questions is lacking, such as the ability to track changes in species distribution and abundance. Consequently, data on conservation status is limited and the current number of threatened species likely to be vastly under-reported.
- Not all species occurring in the ACT are known, let alone counted. For example, knowledge is poor on the status of invertebrates (including the total number of invertebrate species), mainly due to the lack of dedicated research and monitoring.
- Although pressures that have an immediate or visible effect on biodiversity are well recognised – such as invasive weeds and invasive animal species, diseases, climate change and land development – incremental pressures over long periods of time are not as well understood. This means that management can be limited to addressing the known impacts on biodiversity, rather than the prevention of impacts.
- The accessibility of available data has been severely reduced by the disparate nature of biodiversity datasets which is collected across a range of government and community groups. However, this is now being addressed and it is expected that data accessibility will be much improved in the future.
- It is also difficult to determine biodiversity trends over time because of methodology changes. Whilst this can mean improved data quality, it is often unclear whether biodiversity changes are due to actual changes or increased accuracy.

Conservation

- At the time of reporting, it was not possible to determine the condition of conservation areas in the ACT.
- It is also not currently possible to assess whether offsets have ensured no net loss as a result of land development. However, assessments for offsets will likely take many years, particularly given that management interventions need to be undertaken over long periods of time to achieve the desired ecosystem and biodiversity outcomes.
- The ACT Government is implementing a Conservation Effectiveness Monitoring Program to evaluate the effectiveness of management actions in achieving conservation outcomes.

Native vegetation

- It was not possible to determine changes in the extent and condition of native vegetation over the reporting period (2015–16 to 2018–19). Nor was it possible to provide an overall assessment of vegetation condition.

Invasive species

- It was not possible to comprehensively determine the distribution and abundance of invasive animals in the ACT for this report.
- There are few reliable, quantitative measurements for the environmental damage inflicted by invasive species.

Table 1:

Species in the ACT listed as threatened under the *Nature Conservation Act 2014*, listing history and relevant threatening processes.

Information sourced from: Environment, Planning and Sustainable Development Directorate

Current listing status	Scientific name	Common name	Listing change 2015–16 to 2018–19	Relevant threatening processes (derived from Action Plans or Conservation Advice documents)
Critically Endangered	*Anthochaera phrygia*	Regent Honeyeater	2019: Listed as Critically Endangered in line with Commonwealth status	• Clearing, fragmentation and degradation of woodland dominated by Box Ironbark • Competition at suitable breeding sites and high rates of nest predation
Critically Endangered	*Lathamus discolor*	Swift Parrot	2019: Recommended to be listed as Critically Endangered in line with Commonwealth status	• Habitat loss and alteration across the mainland and Tasmanian range • Fire • Collision mortality • Competition for resources within altered habitats • Psittacine Beak and Feather Disease • Illegal wildlife capture and trading
Critically Endangered	*Pseudophryne pengilleyi*	Northern Corroboree Frog	2019: Recommended to be listed as Critically Endangered in line with Commonwealth status	• Disease (amphibian chytrid fungus *Batrachochytrium dendrobatidis*) • Fire • Climate change • Feral animals • Weeds • Habitat disturbance and degradation
Critically Endangered (locally extinct)	*Litoria castanea*	Yellow-spotted Bell Frog	2019: Recommended to be listed as Critically Endangered in line with Commonwealth status	• Amphibian chytrid fungus • Infection from myxosporean parasites • Habitat loss and degradation through clearing, trampling, fragmentation, altered hydrology, salinity • Small population sizes and population fragmentation • Chemicals • Climate change (temperature increase, extreme weather events and droughts)
Critically Endangered	*Caladenia actensis*	Canberra Spider Orchid	2019: Recommended to be listed as Critically Endangered in line with Commonwealth status	• Climate change • Disturbance such as trampling, grazing, development and maintenance of infrastructure, and bushfire • Disease • Low genetic diversity • Life history traits: short flowering period, dependence on a single subfamily of wasps for pollination and an important association with soil fungi
Critically Endangered	*Corunastylis ectopa*	Brindabella Midge Orchid	2019: Recommended to be listed as Critically Endangered in line with Commonwealth status	• Severely restricted distribution (one population) • Life cycle traits (period of dormancy when its presence is not evident, short flowering period, and association with soil fungi) • High sensitivity to disturbance such as erosion, roadworks, shrub growth and weed invasion, herbicides • Illegal collection

Current listing status	Scientific name	Common name	Listing change 2015–16 to 2018–19	Relevant threatening processes (derived from Action Plans or Conservation Advice documents)
Critically Endangered	*Pterostylis oreophila*	Kiandra Greenhood	2019: Recommended to be listed as Critically Endangered in line with Commonwealth status	National: • Grazing and trampling • Altered hydrology due to the impacts of grazing • Soil disturbance by rooting by feral pigs and trampling • Weed invasion • Inappropriate land management including Inappropriate fire regimes • Plant collection Namadgi: • Invasive animals leading to overgrazing, soil disturbance and erosion • Weeds
Endangered	*Rostratula australis*	Australian Painted Snipe	2019: Recommended to be listed as Endangered in line with Commonwealth status	• The loss and degradation of wetlands, through drainage and the diversion of water for agriculture and reservoirs In NSW, the threats are summarised as: • Drainage of breeding sites in wetlands (particularly in the Murray-Darling Basin) • Reduced water quality from siltation and pollution • Predation by foxes and feral cats • Use of herbicides, insecticides and other chemicals near wetlands • Grazing and associated frequent burning of wetlands • Exotic weeds and invasive native plants degrading wetland habitat • Poor understanding of the species' breeding ecology
Endangered	*Botaurus poiciloptilus*	Australasian Bittern	2019: Recommended to be listed as Endangered in line with Commonwealth status	• The loss or alteration of wetland habitats due to clearing for urban and agricultural development • Predation by introduced vertebrate pests such as foxes and cats • The primary purpose of urban wetlands (stormwater control) resulting in fluctuating water levels • Reduced water quality as a result of increasing salinity, siltation and pollution
Endangered	*Petrogale penicillata*	Brush-tailed Rock-wallaby	Nil	• Historical hunting • Introduced predators (primarily, the red fox) • Introduced herbivores increase competition (primarily, the feral goat) • Bushfire and drought • Uncontrolled human disturbance • Hydatid disease
Endangered	*Dasyurus viverrinus*	Eastern Quoll	2019: Recommended to be listed as Endangered in line with Commonwealth status	National: • Predation by feral cats, red foxes and dogs • Disease • Non-target poisoning associated with 1080 and rodent control programs • Road mortality • Extreme weather events associated with climate change

Current listing status	Scientific name	Common name	Listing change 2015–16 to 2018–19	Relevant threatening processes (derived from Action Plans or Conservation Advice documents)
Endangered	*Isoodon obesulus obesulus*	Southern Brown Bandicoot (Eastern)	2019: Recommended to be listed as Endangered in line with Commonwealth status	National: • Predation by foxes, feral and domestic cats and to a lesser extent dogs • Habitat loss, fragmentation and degradation • Too frequent and extensive burning • Road mortality • Climate change adversely affecting habitat quality • Displacement by high rabbit densities • Disease, possibly toxoplasmosis • Timber harvesting • Reduced genetic diversity • Poisoning associated with control of non-native predators
Endangered	*Pseudomys fumeus*	Smoky Mouse	Nil	• Vegetation clearance (loss and fragmentation of habitat) • Inappropriate fire regimes • Predation (primarily by fox and cat) • Climate change
Endangered	*Tympanocryptis pinguicolla*	Grassland Earless Dragon	Nil	• Loss, fragmentation and degradation of grassland habitat (urban development, agriculture) • Bushfire/inappropriate fire regimes • Weed invasion • Climate change • More frequent drought • Loss of genetic diversity • Cultivation and pasture improvement • Overgrazing (kangaroos, rabbits, stock) or short mowing • Development of excessive vegetation biomass • Predation by cats, dogs and foxes • Increased predation by native animals
Endangered	*Maccullochella macquariensis*	Trout Cod	Nil	• Habitat modification (sedimentation, cold water pollution, clearing or degradation of riparian vegetation) • River regulation (reduced flows downstream of dams, inappropriate flow timing) • Barriers to fish passage • Overfishing • Sedimentation • Reduction in water quality • Alien species • Climate change • Hybridisation and reduced genetic diversity
Endangered	*Bidyanus bidyanus*	Silver Perch	Nil	• River regulation (reduction of water flow downstream of dams) • Barriers to fish passage • Introduced species and disease • Habitat modification • Reduction in water quality • Sedimentation • Historical overfishing • Climate change

Current listing status	Scientific name	Common name	Listing change 2015–16 to 2018–19	Relevant threatening processes (derived from Action Plans or Conservation Advice documents)
Endangered	*Macquaria australasica*	Macquarie Perch	Nil	• Habitat modification • Dams causing alterations to natural flows, movement barriers, and releasing colder hypoxic water (cold water pollution) • Sedimentation of streams and reservoirs resulting in decline of habitat quality and quantity, reducing availability of prey, and smothering eggs and preventing their lodgement • River regulation causing reduced flows and flow at inappropriate time of year • Barriers to fish passage for feeding or breeding habitat due to construction of dams, weirs and road crossings • Overfishing • Reduction in water quality (including pollutant discharges, changes to thermal regimes, and sedimentation) • Alien species (e.g. Brown Trout, Rainbow Trout, Carp, Goldfish, Redfin Perch, Eastern Gambusia, and Oriental Weatherloach) • Climate change • Fire • Low genetic diversity • Reduction in spawning habitat availability • Predation by birds (primarily cormorants)
Endangered	*Synemon plana*	Golden Sun Moth	Nil	• Loss, fragmentation and degradation of grassland habitat • Weed invasion (dilution of food plants and altering grassland structure) • Bushfire or inappropriate fire regimes • Herbage mass extremes • Cultivation and pasture improvement • Herbicides and pesticides • Excess nutrients • Shading (by buildings and planted trees) • Altered drainage • Climate change
Endangered	*Gentiana baeuerlenii*	Baeuerlen's Gentian	Nil	• Land clearing and grazing, particularly in times of drought
Endangered	*Prasophyllum petilum*	Tarengo Leek Orchid	Nil	• Restricted range and population size (one population) • Vulnerable to environmental change and localised disturbance • Disturbance by Sulphur-Crested Cockatoos • Competition or overcrowding from native and non-native species • Climate change
Endangered	*Rutidosis leptorrynchoides*	Button Wrinklewort	Nil	• Habitat loss from agriculture and urban development • Small sites are particularly vulnerable to localised disturbance (human activity, roadside maintenance, waste dumping, inappropriate mowing, parking vehicles) • Weed invasion • Shading and competition with understorey and shrub vegetation • Heavy stock grazing • Erosion of genetic diversity • More frequent drought

Current listing status	Scientific name	Common name	Listing change 2015–16 to 2018–19	Relevant threatening processes (derived from Action Plans or Conservation Advice documents)
Endangered	*Swainsona recta*	Small Purple Pea	Nil	• Loss, degradation and fragmentation of habitat (as a result of urban development and agriculture) • Small, fragmented populations are vulnerable to localised disturbance and stochastic events including climate change, browsing, invasive plants, inappropriate fire regimes, and browsing • Reduced genetic diversity
Endangered	*Muehlenbeckia tuggeranong*	Tuggeranong Lignum	Nil	• The species ability to sexually reproduce appears to be very limited – the plants are predominantly dioecious and only one female plant is known to exist • Likely low genetic diversity • Physical disturbance (recreational activity, periodic flooding, bushfire, grazing by macropods) • Weeds
Endangered	*Lepidium ginninderrense*	Ginninderra Peppercress	Nil	• Habitat loss from urban development • Habitat degradation associated with land management and / or visitor activities • Disturbance to the existing drainage patterns
Endangered	*Bossiaea grayi*	Murrumbidgee Bossiaea	Nil	• Population range reduction and further fragmentation of populations • Dieback (unknown cause) • Weed infestation • Mechanical disturbance associated with forest harvesting
Vulnerable	*Melanodryas cucullata cucullata*	Hooded Robin	Nil	• Loss and modification of grassy woodland habitat • Loss of perching sites essential for foraging (removal of timber and litter) • High levels of nest predation • Inappropriate fire regimes • Predation by feral and/or uncontrolled domestic animals (foxes, dogs and cats) • Invasion of key habitats by introduced pasture and weeds • Uncontrolled grazing by livestock • Clearing of both living and dead trees • Rural tree dieback
Vulnerable	*Polytelis swainsonii*	Superb Parrot	Nil	• Habitat loss • Climate change • Nest competition • Secondary/potential threats: urbanisation, vehicle strike, predation, poisoning, illegal trade, Psittacine beak and feather disease
Vulnerable	*Climacteris picumnus victoriae*	Brown Treecreeper	Nil	• Decline in quality and quantity of woodland habitat • Removal of fallen timber and litter and inappropriate fire regimes • Predation by feral and/or uncontrolled domestic animals (foxes, dogs and cats) • Invasion of key habitats by introduced pasture and weeds • Uncontrolled grazing by livestock • Clearing of both living and dead trees • Rural tree dieback

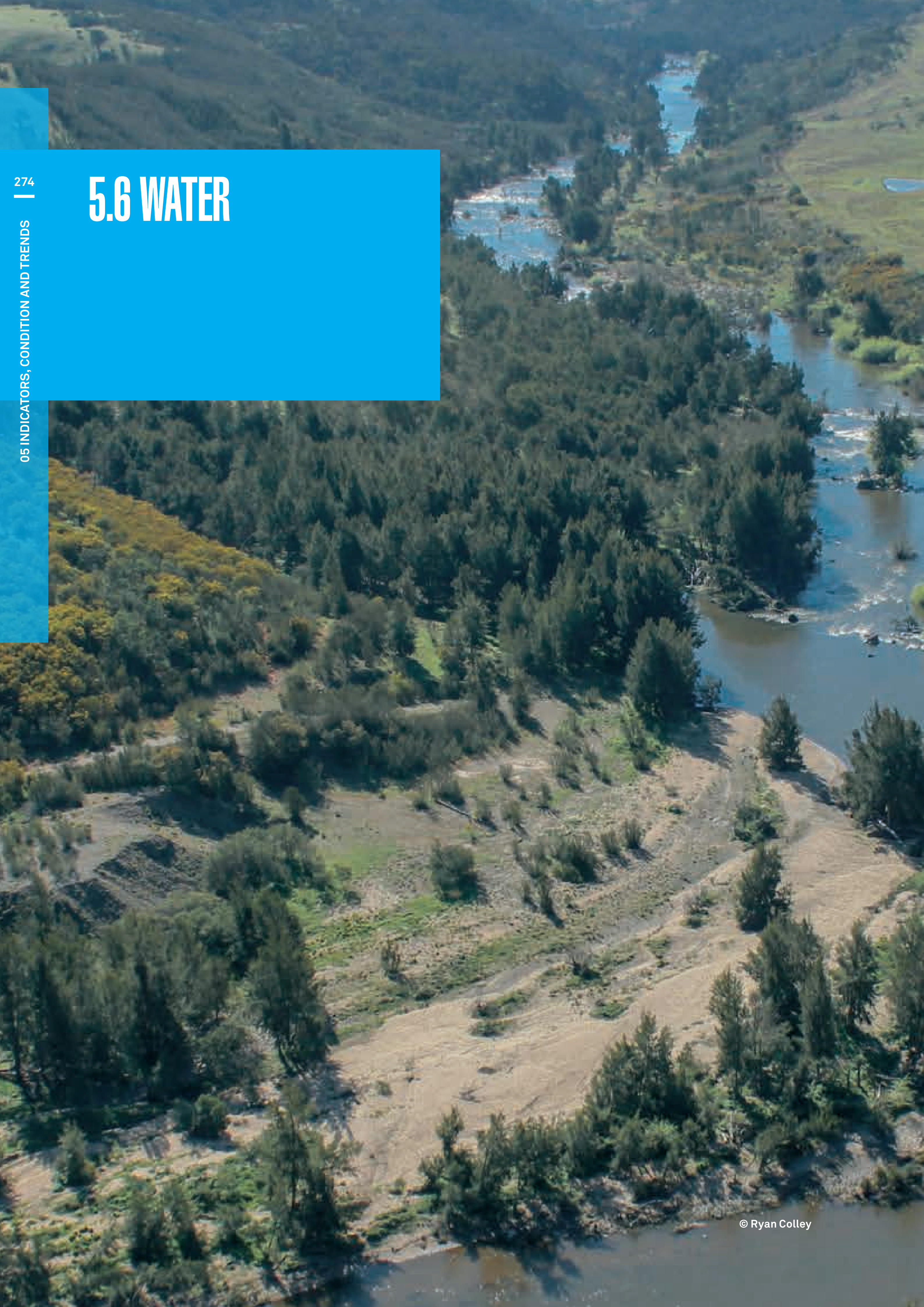
Current listing status	Scientific name	Common name	Listing change 2015–16 to 2018–19	Relevant threatening processes (derived from Action Plans or Conservation Advice documents)
Vulnerable	*Grantiella picta*	Painted Honeyeater	Nil	• Habitat loss through clearing of breeding and non-breeding habitat • Habitat degradation by grazing of livestock, native macropods and rabbits and lack of recruitment • Removal of mistletoe from trees on rural land and in production forests • Competition with the aggressive Noisy Miner • Nest predation by overabundant Pied Currawongs, Pied and Grey Butcherbirds, and crows and ravens
Vulnerable	*Daphoenositta chrysoptera*	Varied Sittella	Nil	• Decline in the quantity and quality of woodland habitat • Tree clearing, small-scale clearing for fence lines and road verges, tidying up on farms, firewood collection • Rural tree decline • Loss of paddock trees • Overgrazing • Fragmentation of habitat • Invasive weeds
Vulnerable	*Lalage tricolor*	White-winged Triller	Nil	• Decline in the quality and quantity of woodland habitat • Removal of fallen timber and overgrazing leading to a loss of complexity
Vulnerable	*Hieraaetus morphnoides*	Little Eagle	Nil	• Decline in the quality and quantity of woodland habitat • Urbanisation and associated human activity • Increased competition for food and nest sites with Wedge-tailed Eagles • Use of pindone for rabbit control (potential)
Vulnerable	*Calyptorhynchus lathami lathami*	Glossy Black-cockatoo	Nil	• Degradation, loss and fragmentation of foraging and breeding habitat • The loss of canopy seed banks of feed trees by clearing or regular burning, as well as poor regeneration of these trees due to grazing, • Predation and competition for nest hollows (potential) • Illegal harvesting (potential) • Climate change
Vulnerable	*Petroica boodang*	Scarlet Robin	Nil	• Open forest/woodland habitat loss and degradation • Predation (native and non-native species) • Climate change • Competition (e.g. noisy miners)
Vulnerable	*Dasyurus maculatus maculatus*	Spotted-tailed Quoll	Nil	• Habitat loss, fragmentation and degradation • Competition and predation • Poisoning • Killing by humans
Vulnerable	*Mastacomys fuscus mordicus*	Broad-toothed Rat (mainland)	2019: Recommended to be listed as Vulnerable in line with Commonwealth status	National: • Climate change • Too frequent burning • Habitat loss, fragmentation and degradation due to feral herbivores • Weed invasion • Competition with native rodents for food • Predation by foxes and feral cats

Current listing status	Scientific name	Common name	Listing change 2015–16 to 2018–19	Relevant threatening processes (derived from Action Plans or Conservation Advice documents)
Vulnerable	*Petauroides volans*	Greater Glider	2019: Recommended to be listed as Vulnerable in line with Commonwealth status	National: • Habitat loss, fragmentation through clearing • Inappropriate fire regimes • Climate change reducing habitat suitability
Vulnerable	*Phascolarctos cinereus*	Koala (Qld/ NSW/ACT population)	2019: Recommended to be listed as Vulnerable in line with Commonwealth status	National: • Loss and fragmentation of habitat • Vehicle strike • Disease • Predation by dogs • Drought and incidences of extreme heat are also known to cause significant mortality, and post-drought recovery may be substantially impaired by other threatening factors
Vulnerable	*Pseudomys novaehollandiae*	New Holland Mouse	2019: Recommended to be listed as Vulnerable in line with Commonwealth status (presumed extinct in the ACT prior to reintroduction to Mulligans Sanctuary)	National: • Inappropriate fire regimes • Predation by feral cat and red foxes • Habitat loss, fragmentation, and degradation • Lower rainfall and more frequent droughts related to climate change
Vulnerable	*Pteropus poliocephalus*	Grey-headed Flying-fox	2019: Recommended to be listed as Vulnerable in line with Commonwealth status	• Entrapment in fine gauge netting loosely draped over backyard fruit trees • Loss of foraging and roosting habitat through clearance of vegetation for development or agriculture • Climate change
Vulnerable (locally extinct)	*Litoria raniformis*	Southern Bell Frog	2019: Recommended to be listed as Vulnerable in line with Commonwealth status	National: • Habitat loss and degradation • Barriers to movement • Predation • Disease • Exposure to biocides
Vulnerable	*Litoria verreauxii alpina*	Alpine Tree Frog	2019: Recommended to be listed as Vulnerable in line with Commonwealth status	National: • Infection with amphibian chytrid fungus • Trampling by feral horses and cattle • Invasion of alpine bogs and fens by pest species • Weeds • Pollution • Changes to natural water flows • Climate change including increased UV-B radiation • Habitat loss through fire, construction and development

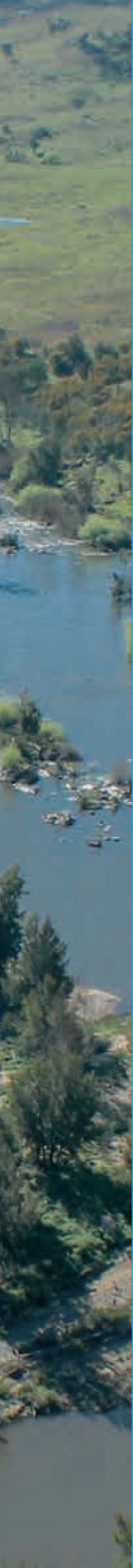
Current listing status	Scientific name	Common name	Listing change 2015–16 to 2018–19	Relevant threatening processes (derived from Action Plans or Conservation Advice documents)
Vulnerable (locally extinct)	*Litoria aurea*	Green and Golden Bell Frog	2019: Recommended to be listed as Vulnerable in line with Commonwealth status	National: • Habitat destruction, degradation and fragmentation • Changes to the structure and diversity of aquatic vegetation • Predation of eggs and tadpoles by plague minnow and, to a lesser extent, European Carp, Goldfish, Brown Trout and Rainbow Trout • Infection with amphibian chytrid fungus • Changes to hydrology, including inappropriate opening of coastal lagoon estuaries and changes to flow/flooding regimes of streams and wetlands • Changes to water quality • Intensification of public access to habitat
Vulnerable	*Aprasia parapulchella*	Pink-tailed Worm-lizard	Nil	• Loss and fragmentation of habitat by urban development and associated infrastructure • Incompatible and inadequate land management practices, including fertilizer application, overgrazing and the spread of invasive weeds • Inappropriate fire regimes • Removal of loose surface rock • Predation (by native and exotic species) • Build-up of vegetation biomass and leaf litter altering thermoregulatory opportunities
Vulnerable	*Delma impar*	Striped Legless Lizard	Nil	• Loss and fragmentation of habitat through clearing of native grasslands for urban, industrial and infrastructure development and for agricultural purposes • Modification and degradation of native grassland habitat through incompatible and inadequate land management practices, weed invasion • Other potential effects of urbanisation, including increased incidence of predation and frequency of fires • Climate change
Vulnerable	*Gadopsis bispinosus*	Two-spined Blackfish	Nil	• Habitat modification • River regulation • Barriers to fish passage • Sedimentation • Reduction in water quality • Introduction of alien species • Climate change • Fire • Reduction in spawning habitat availability
Vulnerable	*Euastacus armatus*	Murray River Crayfish	Nil	• Overfishing • Removal of riparian vegetation • Sedimentation • River regulation • Residential development • Reduction in water quality • Fires • Invasive species and disease • Climate change
Vulnerable	*Perunga ochracea*	Perunga Grasshopper	Nil	• Loss, fragmentation and degradation of grassland habitat • Climate change

Current listing status	Scientific name	Common name	Listing change 2015–16 to 2018–19	Relevant threatening processes (derived from Action Plans or Conservation Advice documents)
Vulnerable	*Eucalyptus aggregata*	Black Gum	2019: Recommended to be listed as Vulnerable in line with Commonwealth status	• Mortality as a result of habitat clearance • Suppression of gene flow due to habitat fragmentation • Lack of recruitment and genetic hybridisation
Vulnerable	*Pomaderris pallida*	Pale Pomaderris	2019: Recommended to be listed as Vulnerable in line with Commonwealth status	National: • Rural residential development, weed competition (particularly blackberry) and browsing by feral goats, inappropriate fire regimes • Increasing fragmentation and loss of remnants NSW: • Browsing by other feral animals including deer, goats and potentially horses and grazing by livestock and kangaroos • Sediment runoff from fire trails • Flood damage in smaller riparian populations where frequent flooding may disrupt the lifecycle to the extent that the soil seedbank may be affected • Low genetic diversity in isolated small populations that are likely to be at higher risk of loss from stochastic events • Lack of knowledge regarding dormancy thresholds, seed vigour and seedling and plant performance for this species
Vulnerable	*Thesium australe*	Austral Toadflax	2019: Recommended to be listed as Vulnerable in line with Commonwealth status	• Small populations and numbers make them susceptible to impacts • Heavy grazing • Development of dense shrub or tree cover • Loss and degradation of habitat and/or populations • Weed invasion
Regionally Conservation Dependent	*Bettongia gaimardi*	Eastern Bettong	Nil	National: • Predation by foxes (and feral cats) • Habitat clearing/fragmentation of its dry forest and woodland habitat • Habitat degradation and competition from livestock/introduced herbivores including overgrazing by livestock and rabbits • Inappropriate fire regimes • Viral or other diseases • Climate change

5.6 WATER



© Ryan Colley



Section contents

Water in the ACT

Catchment Health Indicator Program (CHIP) 2015 to 2018

- **67** reaches assessed across 3 ACT catchments
- **42%** in good to excellent overall condition, 57% fair
- **25%** with good to excellent macroinvertebrate condition, 49% fair, 26% poor to degraded
- **14%** had good to excellent riparian condition, 37% fair, 48% poor to degraded
- condition is strongly influenced by land use

Native fish

- **30%** native species typically account for less than 30% of fish abundance and 20% of fish biomass in the Murrumbidgee River
- population increases for Two Spined Blackfish, Macquarie Perch and Murray Cod
- population decline for trout cod
- **270,000** native fish stocked to lakes and ponds between 2015 and 2019

River flows

- annual flows well below the long-term average in 2017 and 2018
- Murrumbidgee River flows greater downstream of the ACT
- environmental flow requirements met downstream of storage reservoirs

Water quality

- turbidity guideline exceedances high for the Murrumbidgee River (2015 to 2017)
- except for nitrogen, water quality is comparable upstream and downstream of the ACT

Water quality CHIP results

- **35%** reaches in excellent condition
- **62%** reaches in good condition
- **3%** reaches in fair condition

Recreational water quality

- nearly all lake and river sites experienced closures due to enterococci
- enterococci main cause of closures in Lake Ginninderra
- blue-green algae main cause of closures for Lake Tuggeranong and Lake Burley Griffin
- Lake Tuggeranong closed for most of the 2018–19 recreational swim season

Indicator assessment

Indicator	Status	Condition	Trend	Data quality
W1: Aquatic ecosystem health	Aquatic ecosystem health is variable across the ACT and strongly influenced by land use. Aquatic health is mostly good in conservation areas, but condition is poorer in urban and rural areas. The impact of land use is particularly evident for assessments of macroinvertebrate and riparian condition. Dry conditions in the region are also having an impact on aquatic health. Alien fish populations are high for the Murrumbidgee River with native fish accounting for less than 30% of fish abundance and 20% of biomass.	Fair	?	● ● ● High
W2: River flows	All river flows were well below the long-term average in 2017 and 2018. A continuation of these conditions will have consequences for the ecosystem health and amenity of rivers in the ACT. All discharges downstream of storage reservoirs met the environmental flow requirement; this took place despite the significantly reduced rainfall and river flows in 2017 and 2018.	Fair	↓	● ● ● High
W3: Water quality	Water quality was generally good for the reporting period, including for sites in urban and rural areas. Water quality results may reflect the decreased rainfall for most of the reporting period. However, turbidity remains an issue following high rainfall events. Water quality in the Murrumbidgee River is comparable upstream and downstream of the ACT indicating minimal water quality impacts in the region.	Good	↑	● ● ● High
W4: Recreational water quality	Recreation water quality is poor in the ACT for both lakes and rivers. Nearly every monitored recreation site experienced closures due to the exceedance of enterococci guidelines, and blue-green algae has required extended closures in Canberra's lakes. Lake Tuggeranong was closed for most of the 2018–19 recreational swim season due to poor recreational water quality.	Poor	↓	● ● ● High

Indicator assessment legend

Condition

- **Good** = Environmental condition is healthy across the ACT, **OR** pressure likely to have negligible impact on environmental condition/human health.
- **Fair** = Environmental condition is neither positive or negative and may be variable across the ACT, OR pressure likely to have limited impact on environmental condition/human health.
- **Poor** = Environmental condition is under significant stress, OR pressure likely to have significant impact on environmental condition/ human health.
- **Unknown** = Data is insufficient to make an assessment of status and trends.
- **NA** = Assessments of status, trends and data quality are not appropriate for the indicator.

Trend

- ↑ Improving
- ↓ Deteriorating
- – Stable
- ? Unclear
- **NA** = Assessments of status, trends and data quality are not appropriate for the indicator.

Data quality

- ● ● ● **High** = Adequate high-quality evidence and high level of consensus
- ● ● ○ **Moderate** = Limited evidence or limited consensus
- ● ○ ○ **Low** = Evidence and consensus too low to make an assessment
- ○ ○ ○ **NA** = Assessments of status, trends and data quality are not appropriate for the indicator.

Key actions

That the ACT Government:

ACTION 1: identify opportunities to develop water-sensitive urban design measures to reduce the impact of urban land use on aquatic ecosystems.

ACTION 2: re-establish riparian vegetation in both urban and rural areas to improve habitat and protect lakes and waterways from pollutant run-off.

ACTION 3: establish a government reporting framework for the assessment of aquatic ecosystem health. This should include the selection of key monitoring sites that provide comprehensive coverage of land use types, sub-catchments and ecosystems across the ACT; incorporate work undertaken for the Catchment Health Indicator Program; incorporate all relevant condition parameters; and produce public reports at appropriate intervals to provide meaningful assessments.

ACTION 4: produce an annual recreational water quality report that includes monitoring results, investigations into the main sources of pollutants, recommended actions to improve water quality; and assessments of management effectiveness.

ACTION 5: increase fish-stocking programs to maintain fish populations in Canberra's lakes and ponds.

ACTION 6: identify opportunities to collaborate with the NSW Government on management activities to improve aquatic ecosystem health upstream and downstream of the ACT, including the management of native and alien fish, re-establishing riparian zones and reducing catchment erosion.

ACTION 7: seek to increase water releases to the upper Murrumbidgee River under the Snowy 2.0 project to improve aquatic ecosystem health in the Murrumbidgee River.

Main findings

Aquatic ecosystem health 2015 to 2018

The main pressures on aquatic ecosystem condition in the ACT are land use impacts, modified river flows, and climate change.

This is the first ACT State of the Environment report to use data from the Catchment Health Indicator Program (CHIP). The program assessed 67 reaches in the Ginninderra, Molonglo and Southern ACT catchments.

38 (57%) reaches were in fair condition across the 3 catchments, 26 (39%) were in good condition. Only 2 reaches were found to be in excellent condition and 1 was assessed as poor.

Aquatic condition is strongly influenced by land use with reaches in urban and rural areas in poorer health than those in conservation and protected lands.

The Southern ACT catchment had the highest proportion of reaches in good to excellent condition with 15 out of the 26 reaches assessed.

The presence of some good condition reaches in urban areas shows that healthy aquatic ecosystems can be supported with effective management and water-sensitive urban design.

Macroinvertebrate condition 2015 to 2018

Only 25% of reaches assessed were found to have good to excellent macroinvertebrate condition, 26% were found to be in poor to degraded condition, with 49% classed as fair.

The Southern ACT and Molonglo catchments had the most reaches with healthy macroinvertebrate communities.

Macroinvertebrate condition was strongly linked to land use but also likely influenced by the mostly dry conditions over the assessment period.

Riparian condition

Only 14% of reaches were assessed as having good to excellent riparian condition, 37% were found to be in fair condition and 48% were assessed as poor to degraded.

Urban and rural areas generally had fair to degraded riparian condition due to vegetation clearing. However, there were also some fair and poor reaches in conservation and protected areas.

The replanting of native species in cleared riparian zones and the removal of weed species would greatly improve aquatic health and the amenity of aquatic ecosystems for the ACT community.

Native fish

There are positive trends for some populations of native fish including the Two Spined Blackfish and Macquarie Perch in the Cotter River, and Murray Cod in some sections of the Murrumbidgee River.

Negative native fish population trends include a decline of Trout Cod following the cessation of conservation stocking by the NSW Government in the Upper Murrumbidgee Catchment, and low populations of Golden Perch in the upper reaches of the Murrumbidgee River.

Alien fish species are common in the ACT, with native fish typically accounting for less than 30% of total fish abundance and less than 20% of total fish biomass in the Murrumbidgee River. The dominance of alien species in the Murrumbidgee River is mainly due to high numbers of carp.

The proportion of native fish abundance is higher in the Cotter River, accounting for over 70% of the total abundance and between 45% and 70% of the total biomass between 2014 and 2019.

Alien fish species are having an impact on native fish in the ACT, competing for food and habitat resources, spreading disease and modifying habitat.

Between 2015 and 2019, over 162,000 Golden Perch and 107,000 Murray Cod were stocked in Canberra's lakes and larger ponds.

The presence of Murray Cod and Golden Perch in Canberra's urban lakes and ponds is dependent on stocking.

River flows 2015 to 2018

For the Murrumbidgee and Molonglo rivers, annual discharges were well below the long-term average in 2017 and 2018. These years followed two consecutive years of annual discharges higher than long-term average flows (2015 and 2016).

Discharges for the Cotter River and Paddys River also had annual discharges that were well below the long-term average in 2017 and 2018 with only 2016 above the long-term average.

Annual discharges were lowest in 2018 due to the lack of rainfall: the annual discharge in Paddys River was just 7% of the long-term average; the Molonglo River 15%; Murrumbidgee at Lobbs Hole 17%; Murrumbidgee at Halls Crossing 19%; and Cotter River 24%.

These reduced discharges have consequences for ecosystem health as well as the amenity of the ACT's waterways.

Annual discharges for the Murrumbidgee River leaving the ACT were much higher than those upstream of the region. The ACT's additions to Murrumbidgee River flows are vital for downstream ecosystem health and water supply, particularly during low flow periods.

All discharges downstream of storage reservoirs met the environmental flow requirement; this took place despite the significantly reduced rainfall and river flows in 2017 and 2018.

Water Quality 2015 to 2018

Water quality guidelines were met for nearly all monitoring samples taken in the Murrumbidgee River for pH, electrical conductivity and dissolved oxygen.

Turbidity guideline exceedances were for high for the Murrumbidgee River for the years 2015 to 2017. Exceedances in 2018 were lower than other years and are likely related to reduced rainfall and catchment run-off.

Except for nitrogen, water quality in the Murrumbidgee River is comparable upstream and downstream of the ACT, with turbidity slightly improving as the river moves though the region.

For assessments undertaken as part of the CHIP, water quality was found to be excellent for 35% of reaches and good for 62%, with only 2 reaches assessed as fair condition.

All catchments had the majority of their reaches in good to excellent condition for water quality. The Southern ACT catchment had 62% of reaches in excellent condition.

Although the ACT's water quality was generally good, nitrogen concentrations are much higher in the Murrumbidgee River downstream of the Lower Molonglo Water Quality Control Centre.

Water quality condition is linked to land use with the majority of reaches in excellent condition on conservation and protected land.

Despite the added pressures imposed by urban and rural land uses, water quality was still good in these areas, with some reaches attaining excellent condition ratings. This assessment demonstrates the effectiveness of water quality management in some urban areas, particularly as a result of constructed wetlands and other water-sensitive design approaches.

Water quality results may also reflect the decreased rainfall for most of the reporting period. Dry conditions decreased the amount of pollutants entering waterways from rainfall run-off.

Recreational water quality 2016–17 to 2018–19

Nearly every monitored recreation site experienced closures due to the exceedance of enterococci (faecal coliform bacteria) guidelines.	Blue-green algae is the main cause of recreation closures for Lake Tuggeranong and Lake Burley Griffin.
When compared to the other urban lakes, Lake Ginninderra is the only lake where enterococci is the main cause of recreation closures and had the highest number of closures due to enterococci each year.	Lake Tuggeranong had the highest number of blue-green algae closures in 2016–17 and 2018–19 and was closed for most of the 2018–19 recreational swim season.
Murrumbidgee River had a high number of site closures for enterococci.	The Molonglo River was the only river to have recreation closures due to blue-green algae.
Enterococci results for Paddys River are a concern with substantial periods of closure for the single site monitored.	To reduce the number and duration of recreational closures, there needs to be improved management and interception of run-off in urban areas, and the re-establishment of riparian vegetation in both urban and rural areas.

Spotted Marsh Frog. Source: Ryan Colley.

INTRODUCTION

Healthy aquatic ecosystems are essential to the ACT's biodiversity, urban community, and agriculture. Aquatic ecosystems, and their riparian and floodplain lands, provide many environmental benefits and are habitat for both aquatic and terrestrial species. They provide ecosystem services such as the supply of water resources, water purification and nutrient cycling, and are important places for culture, recreation and social interaction.

This section provides an assessment of aquatic ecosystems and water quality in the ACT. The following indicators are assessed:

- Indicator W1: Aquatic ecosystem health
- Indicator W2: River flows
- Indicator W3: Water quality
- Indicator W4: Recreational water quality

Threatened aquatic biodiversity is discussed in section **5.5 Biodiversity**. Water resources and consumption are discussed in section **5.2 Human settlements**.

Assessments of the ACT's groundwater systems are not included in this report. Groundwater is a minor component of total water use in the ACT, and typically restricted to non-potable supply. There is also a lack of comprehensive data on groundwater resources and quality data in the ACT making difficult to assess their condition. The ACT's *State of the Environment 2015* report concluded that groundwater availability and quality were likely to be good in the ACT.[1] It was also concluded that the volume of groundwater extraction was far less than the recharge volume for aquifers.

Aquatic ecosystems in the ACT

The main rivers in the ACT region are shown in Figure 1, these are:

- Murrumbidgee River, which is the largest river flowing through the region and the second longest river in Australia. The river originates in the alpine area to the south of the ACT and is heavily influenced by water diversions from the Snowy Mountains Scheme. All rivers and creeks in the ACT drain into the Murrumbidgee River.
- Molonglo and Queanbeyan rivers, which originate to the south-east of the ACT and drain through Lake Burley Griffin before flowing into the Murrumbidgee River. The Queanbeyan River supplies water to the Googong Reservoir.
- Cotter River, which has a protected catchment and provides high-quality water to three reservoirs: Corin, Bendora and Cotter. The river originates in the Brindabella Mountains before flowing into the Murrumbidgee River.
- Gudgenby, Naas, and Paddys rivers are also significant rivers in the region.

Canberra has three constructed lakes – Lake Burley Griffin, Lake Ginninderra and Lake Tuggeranong – and numerous constructed ponds and wetlands. These lakes provide habitat for biodiversity, water pollution control, improve aesthetics and heat mitigation, and are sites for a range of recreational opportunities.

The ACT also has the Ramsar-listed Ginini Flats Wetland Complex in the Namadgi National Park, and 12 nationally important wetlands listed in the *Directory of Important Wetlands in Australia* (Figure 2).[2] High Country Bogs and Associated Fens was added to the endangered category of the ACT Threatened Ecological Communities List in February 2019.

1 Office of the Commissioner for Sustainability and the Environment, 2015, *ACT State of the Environment Report 2015*, ACT Government, Canberra.
2 Environment Australia, 2001, *A Directory of Important Wetlands in Australia*, Third edition, Australian Government, Canberra, found at www.environment.gov.au/resource/directory-important-wetlands-australia, accessed August 2019.

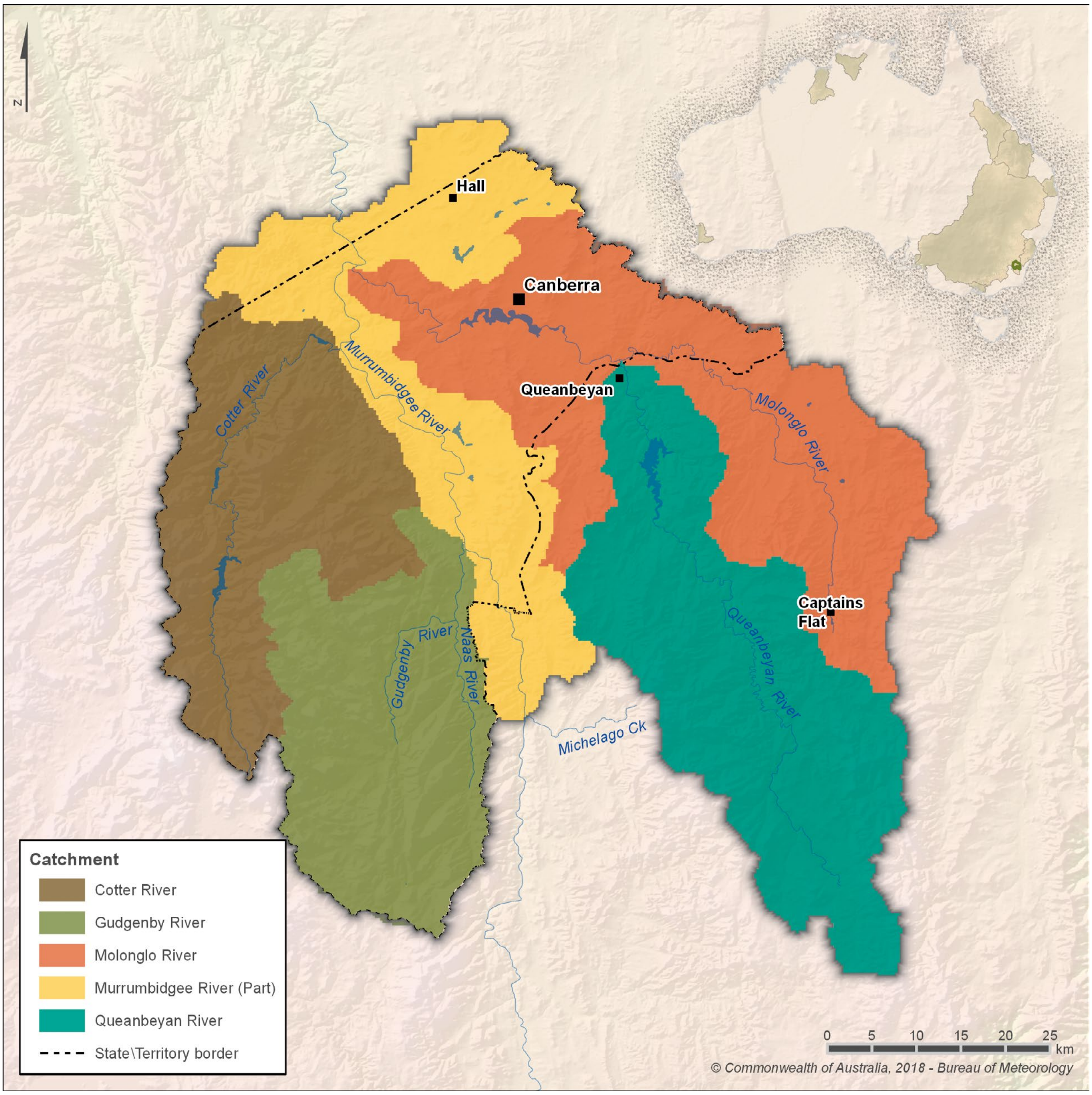


Figure 1:
Catchments and main rivers in the ACT region

Source: Bureau of Meteorology

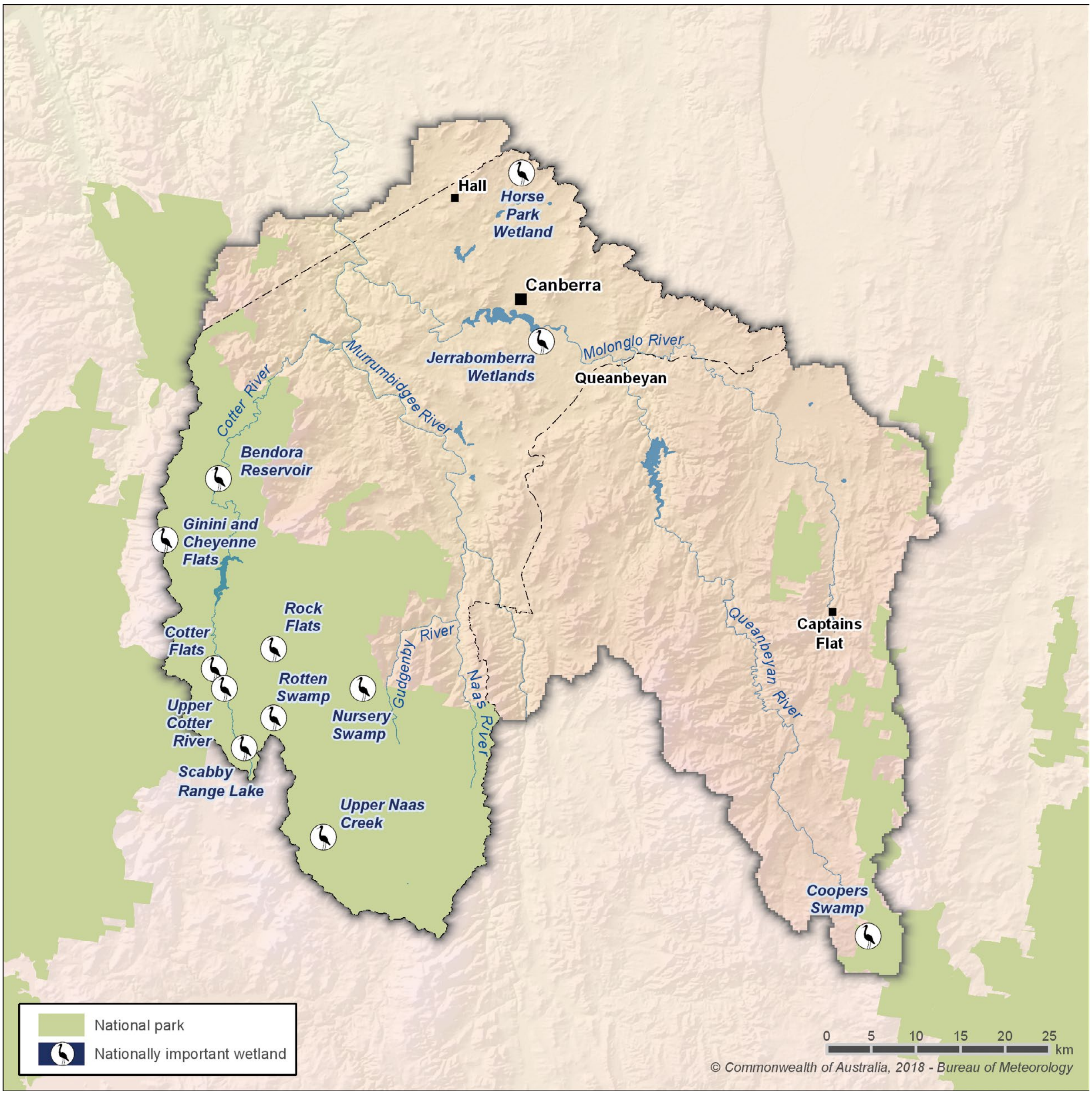


Figure 2:
Significant wetlands in the Canberra region

Source: Bureau of Meteorology

Pressures on aquatic ecosystems

There are many pressures on the ACT's aquatic ecosystems including changes in land use types, degradation of water quality, loss of riparian and other catchment vegetation, the alteration of natural flow regimes, modified river channels, streamflow diversion, fire, introduced species, and recreational fishing. Many of these pressures are rarely localised, with impacts usually affecting downstream ecosystem health. In the case of significant impacts, river degradation can be extensive. For example, the impacts of storage dams and their associated flow alteration on rivers can occur over extensive distances (see *Case study: Impact of the Snowy Mountains Scheme on the Murrumbidgee River*). This means that for those river systems that originate in NSW (Murrumbidgee and Molonglo Rivers), their condition within the ACT is highly influenced by upstream catchment conditions and management.

The main pressures on aquatic ecosystems are discussed below.

Land use and habitat loss

The clearance of vegetation and degradation of soils associated with modified landscapes such as urban and agricultural areas can significantly impact aquatic ecosystem health. Modified landscapes increase the pollutant and sediment loads entering waterways and alter hydrology through changes to natural drainage and river channels. The construction of large impervious surfaces in urban areas also increases surface run-off which can pollute waterways with fertilisers and other chemicals, organic matter, salts, soil, oil and sewage effluent.

The clearance and degradation of riparian zones has resulted in the loss of crucial habitat (including instream woody debris and terrestrial habitat) and functions such as shading, channel protection and food resources. Riparian condition has also been affected by loss of connectivity and the introduction of exotic species such as willow trees (see riparian connectivity in section **5.5 Biodiversity**).

Agricultural production can also have significant impacts on aquatic ecosystems. For example, native vegetation clearance for cropping and grazing has led to increased soil erosion and the potential for chemicals and animal waste to enter waterways. These compromise water quality through sedimentation, elevated nutrients, and the introduction of potentially toxic chemicals. Forestry activities can also impact on aquatic ecosystems, particularly through erosion and increased run-off following harvesting operations and the introduction of roads.

River flows

Water reservoirs and weirs cause significant alteration to the timing and volume of natural flow regimes and are barriers to the movement of fish and other species. Changes to natural flows are particularly detrimental for species with life-cycle stages that are intimately linked to seasonal flow changes. In addition to flow alteration, reservoirs can cause thermal pollution through the release of cold water which can impact on biodiversity. Other impacts on river flows include channel modifications to prevent the duration and frequency of flooding. Any alteration to river flows can change the natural morphology of rivers.

The impacts of modified flow regimes are compounded by the occurrence of drought. Extended periods of reduced flows can lead to increased water temperatures (especially where riparian vegetation has been cleared), degraded water quality and increased risk of algal blooms. These have negative consequences for biodiversity and agriculture (stock animals). Extended dry conditions can also result in habitat loss and depleted biodiversity on the edges of water systems.

Fire

Bushfires remove vegetation cover, exposing and altering the structure of soils and increasing the risk of significant erosion. Consequently, rainfall and run-off after bushfires can deposit large volumes of sediment and ash into aquatic ecosystems. These deposits degrade water quality by increasing turbidity and nutrient concentrations, and can reduce dissolved oxygen concentrations causing the loss of fish and macroinvertebrates. Large amounts of sediment and ash can also smother instream habitat.

Severe fires can also result in the loss of riparian vegetation and the habitat, shading and food resources that this vegetation provides.

In addition to biodiversity impacts, fires that occur in drinking-water catchments can have consequences for domestic water supply. These include increased water treatment costs and reductions in water yields due to increased uptake by regenerating vegetation.

Climate change

Climate change exacerbates existing pressures on aquatic ecosystems. Reduced rainfall (including snowfall), hotter temperatures and increased evapotranspiration (see section **5.1 Climate change**) all have severe consequences, including:

- reduced river flows and reduced wetland inundation
- reduced deep water habitat refuges
- higher water temperatures and lower dissolved oxygen concentrations
- extended dry periods punctuated by severe storms which result in large nutrient, sediment and other pollutant pulses
- increased algal blooms, and
- more frequent and severe bushfires which compromise water quality and riparian vegetation.

Although the aquatic species of the ACT are well-adapted to extremes of floods and droughts, these events are projected to intensify under climate change, pushing some species and communities beyond their ability to adapt. In the long term, the pressures of climate change on freshwater ecosystems could lead to significant and long-lasting changes in the species present in rivers, lakes and wetlands in the ACT.

DATA TRENDS

Indicator W1: Aquatic ecosystem health

This indicator focuses on the health of rivers and streams in the ACT. Although some urban wetland and lake sites contribute to the ecosystem health assessments presented, these do not allow comprehensive assessments of Canberra's urban lakes and wetlands.

There are also no available assessments of wetland condition in the ACT. However, upland bogs and fens are included in the Conservation Effectiveness Monitoring Program being undertaken by the ACT Government (see section **5.5 Biodiversity**).[3] This monitoring program will provide data on the condition of these wetlands in the future.

This indicator also includes assessments of native fish and macroinvertebrates. These provide an indication of the health of aquatic ecosystems and demonstrate the biological impacts of degraded habitat, changes to flows and water quality, and the impacts of invasive aquatic species.

ASSESSING ACT'S AQUATIC HEALTH – THE CATCHMENT HEALTH INDICATOR PROGRAM (CHIP)

This is the first ACT State of the Environment report to use data from CHIP.[4] The program provides a score of catchment health in the ACT region using data collected by Waterwatch volunteers and staff. Assessments include monthly water quality data, macroinvertebrate (water bugs) abundance and diversity collected twice a year from key sites, and riparian vegetation assessments conducted every two years. When combined for an individual stretch of waterway (a reach), these data produce a score that indicates the overall health of that reach. A reach only receives a score if the minimum data requirement is met.

Assessments are accompanied by a report card supplied by the local Waterwatch coordinator to provide expert knowledge on condition results and possible issues. The report cards ensure that vitally important context is provided by the coordinators who know the underlying geology, hydrology, land use and history of the catchments. These considerations must be considered when using and interpreting the CHIP.

In 2018, CHIP produced 96 reach report cards informed by 232 site surveys. These were conducted by over 200 volunteers and included 2,081 water quality surveys, 192 macroinvertebrate surveys and 220 riparian condition surveys.

The total area surveyed by CHIP is more than 11,400 square kilometres and includes 5 catchments: Southern ACT catchment (26 reaches); Molonglo catchment (26 reaches); Ginninderra catchment (15 reaches); Cooma region (23 reaches); and the Yass catchment (6 reaches). Information on these catchments are provided in annual CHIP reports.

The use of CHIP data in the ACT State of the Environment report

Because this is the first inclusion of CHIP data in state of the environment reporting, the results can be seen as baseline data. Future State of the Environment reports will use this baseline data to assess changes in aquatic ecosystem health in response to changing conditions and management activities; they will also present data on the average CHIP score (condition) for reaches over a 4-year period aligned to the State of the Environment reporting periods. This approach is considered to be more accurate than comparisons of annual data which often represent short-term changes rather than actual trends in condition. This 2019 report uses average scores for the 2015 to 2018 period.

CHIP results for the Cooma region and Yass catchment are not presented in this report because they are situated almost entirely in NSW. However, for catchments in the ACT that include NSW lands (Molonglo and Ginninderra), all reaches in the catchment are included.

It is important to note that the site selection used for CHIP has a significant influence on the overall number of reaches assigned to a particular condition score. For example, having a high proportion of survey

3 Brawata, R., B. Stevenson and J. Seddon, 2017, *Conservation Effectiveness Monitoring Program: An Overview*, Environment, Planning and Sustainable Development Directorate, ACT Government, Canberra.

4 Upper Murrumbidgee Waterwatch, 2018, *Catchment Health Indicator Program 2018*, Waterwatch, Canberra.

sites in urban areas will likely mean a higher total of sites in poorer condition categories. Consequently, although figures on the number of reaches in each condition category may be useful for an overview of CHIP results, they should be viewed with caution. It is more appropriate to compare changes in individual reach condition over time, than to make comparisons between different reaches and catchments.

Information on reaches used for CHIP assessments, including individual condition scores, characteristics and location, and the main pressures affecting condition, can be found in annual CHIP reports.[5]

Overall aquatic ecosystem condition – the Catchment Health Indicator Program

Overall condition was assessed for 67 reaches in the Ginninderra, Molonglo and Southern ACT catchments, with scores averaged for the 2015 to 2018 period.

For the total reaches assessed, 38 (57%) were in fair condition across the 3 catchments and 26 (39%) were in good condition (Figures 3 and 4). Only 2 reaches were found to be in excellent condition and 1 was assessed as poor. Aquatic condition is strongly influenced by land use with reaches in fair condition mostly in urban and rural areas, and those in good and excellent condition mostly on conservation and protected lands.

Only 2 of the 15 reaches assessed in the Ginninderra catchment were in good condition, the rest were classed as fair. For the 26 Molonglo catchment reaches, 11 were found to be in good condition and 15 were classed as fair. The Southern ACT catchment had the highest proportion of reaches in good to excellent condition with 15 out of the 26 reaches assessed (58%). It was also the only catchment with excellent condition scores, although this was only achieved for 2 reaches. The higher proportion of good and excellent condition reaches is mainly due to the catchment having large areas of conservation and protected lands with unmodified landscapes. For urban and rural areas in the Southern ACT catchment, 10 reaches were classed as fair and 1 as poor.

These results show that aquatic ecosystem condition is variable across the ACT. Although results are strongly linked to land use, the presence of some reaches in good condition in urban areas shows that healthy aquatic ecosystems can be supported with effective management and water-sensitive design.

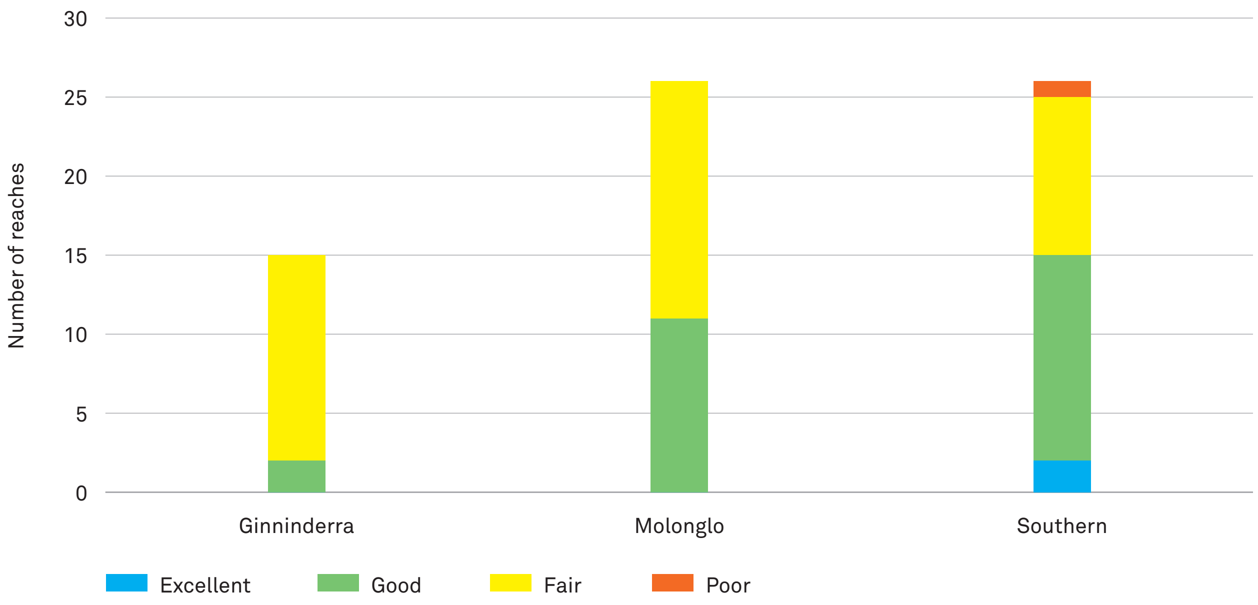


Figure 3: Average Catchment Health Indicator Program score for catchment reaches, 2015 to 2018.

Data sourced from: Upper Murrumbidgee Waterwatch.

5 Upper Murrumbidgee Waterwatch, 2018, *Catchment Health Indicator Program 2018*, Waterwatch, Canberra.

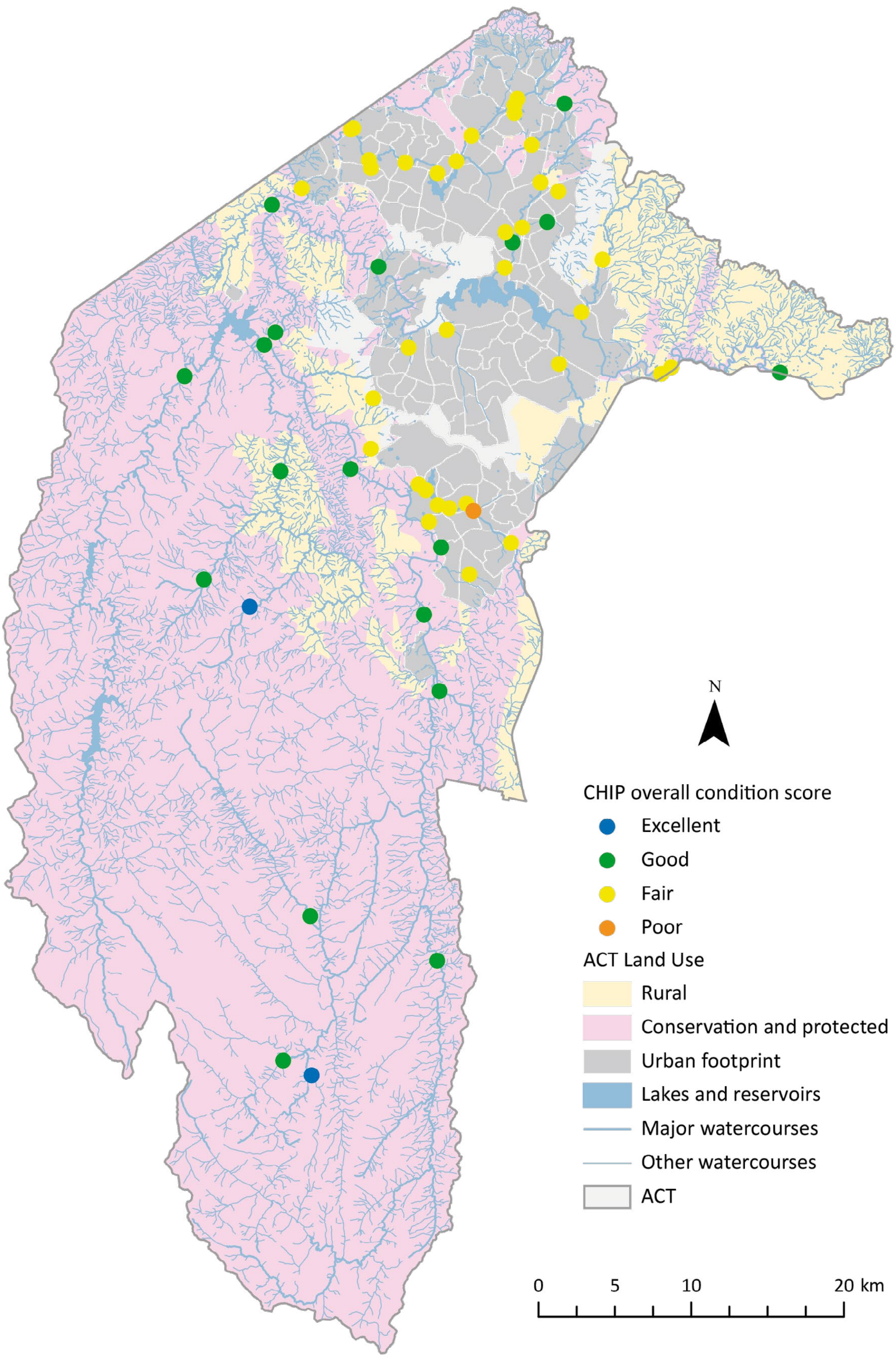


Figure 4:

Average Catchment Health Indicator Program score for catchment reaches, 2015 to 2018.

Data sourced from: Upper Murrumbidgee Waterwatch.

Note: Each dot represents the condition of a reach. NSW sites are not shown.

Macroinvertebrate condition – Catchment Health Indicator Program

Aquatic macroinvertebrates are a diverse group of insects, crustaceans and molluscs that include dragonflies, stoneflies, snails, yabbies, water boatmen and worms. They are relatively sedentary and spend at least part of their life in aquatic ecosystems. Macroinvertebrates are critical to aquatic ecosystem health because they are an important food source for fish and other species such as platypus, and are critical to ecosystem processes such as nutrient cycling.

Because macroinvertebrates are widespread, easy to sample and sensitive to a range of pressures, they are routinely used as indicators of the condition of aquatic systems and their surrounding catchments. Land use change, aquatic and riparian habitat modification, water pollution, and river regulation all affect macroinvertebrate community health.

The CHIP assesses macroinvertebrate community health for each reach using the results of 2 annual surveys from key sites. The assessment methodology can be found in the 2018 CHIP report.[6]

Macroinvertebrate condition was assessed for 65 reaches in the Ginninderra, Molonglo and Southern ACT catchments, with scores averaged for the 2015 to 2018 period. For the 65 reaches assessed, 26% were found to be in poor to degraded condition, with 49% classed as fair (Figures 5 and 6). Only 25% of reaches assessed were found to have good to excellent macroinvertebrate condition. The Ginninderra catchment had no reaches with good macroinvertebrate condition, the Molonglo catchment had 8 reaches, and the Southern ACT catchment had 5 reaches classed as good and 3 as excellent.

The CHIP scores for macroinvertebrate condition are strongly linked to land use, with urban and rural areas generally having fair to poor condition. In such areas, high levels of pollution, alteration to natural flows and loss of riparian vegetation are likely to have had a negative effect on macroinvertebrate communities. Macroinvertebrate results are also likely influenced by the mostly dry conditions over the assessment period, with reduced flows affecting the diversity and abundance of macroinvertebrates (see section **5.1 Climate Change**).

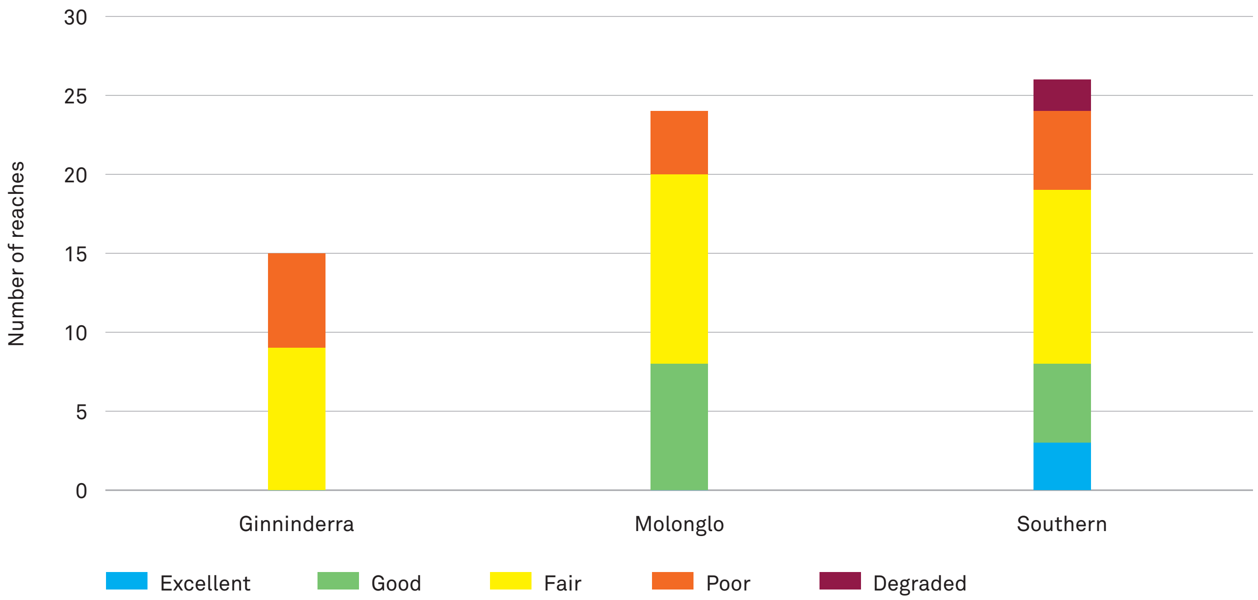


Figure 5:
Average Catchment Health Indicator Program macroinvertebrate score for catchment reaches, 2015 to 2018.

Data sourced from: Upper Murrumbidgee Waterwatch.

6 Upper Murrumbidgee Waterwatch, 2018, *Catchment Health Indicator Program 2018*, Waterwatch, Canberra.

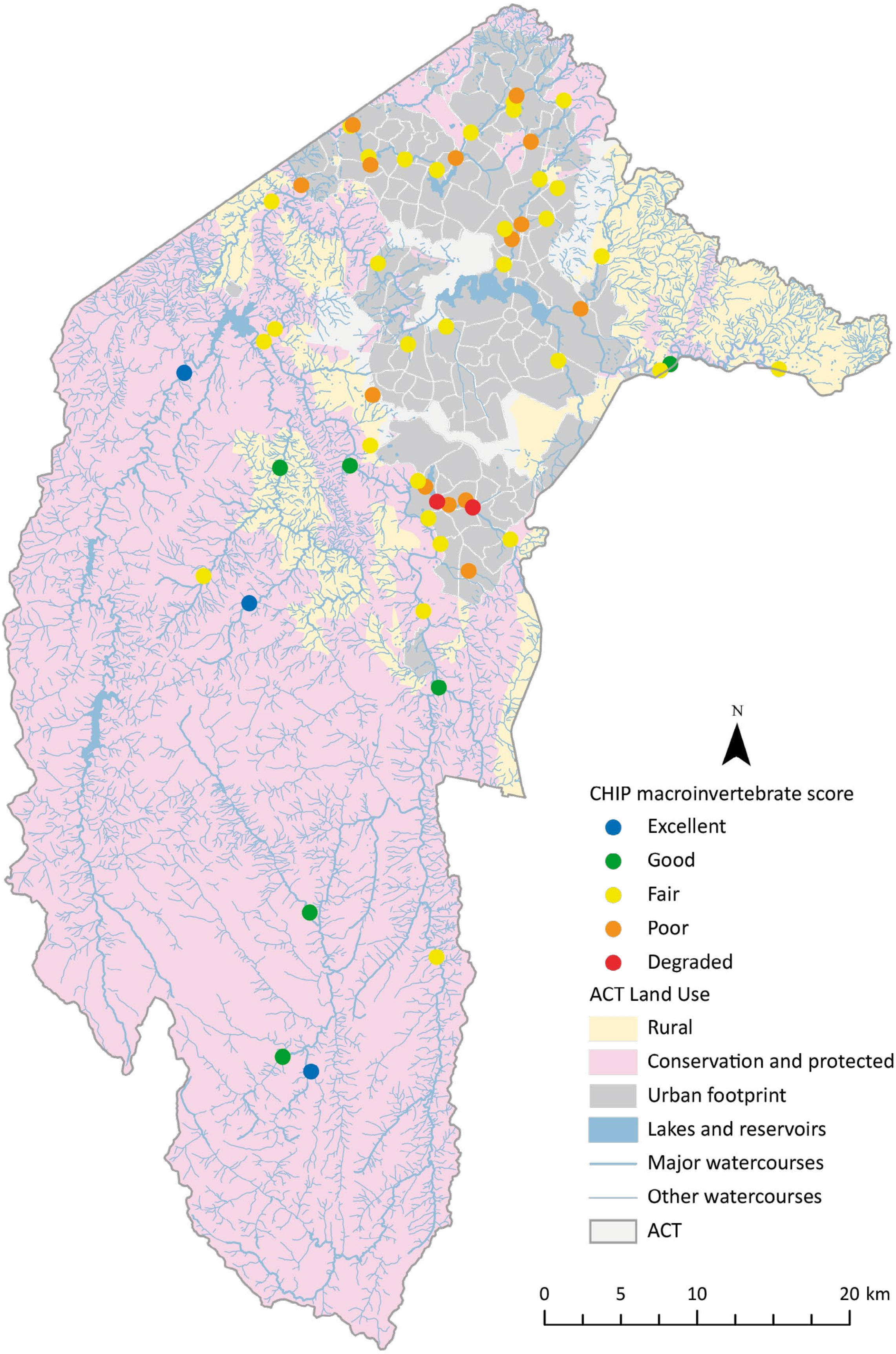


Figure 6:

Average Catchment Health Indicator Program macroinvertebrate score for catchment reaches, 2015 to 2018.

Data sourced from: Upper Murrumbidgee Waterwatch.

Note: Each dot represents the condition of a reach. NSW sites are not shown.

Riparian condition – Catchment Health Indicator Program

The riparian zone is the land and vegetation that fringe aquatic ecosystems. They are vital for aquatic health as these zones provide habitat, stable banks, shade, buffers and filters for incoming run-off, reducing sediments, nutrients and pollutants, and food for aquatic species. The loss and degradation of riparian zones compromises both aquatic and terrestrial biodiversity. Riparian zones are particularly important during drought periods, providing refuge for terrestrial species and helping to reduce the impacts of low flows on aquatic systems. Riparian vegetation is often the only native vegetation remaining in heavily modified landscapes, making them vital wildlife corridors. The health of riparian zones is often dependent on river flows with many riparian species requiring regular flooding for regeneration. Changes to natural flow regimes and the increased occurrence of drought has significantly reduced the flooding of riparian zones, leading to a decline in riparian vegetation health. Information on riparian connectivity can be found in section **5.5 Biodiversity**.

The CHIP assesses riparian condition for each reach with surveys conducted every 2 years. The assessment methodology can be found in the 2018 CHIP report.[7] It should be noted that the current riparian assessment methodology results in poor scores for sites without extensive tree canopy cover. Consequently, riparian condition assessments for naturally treeless ecosystems such as swamps, bogs and fens, are unlikely to reflect their true condition. The riparian condition methodology is being reviewed to improve assessments of naturally treeless ecosystems.

Riparian condition was assessed for 67 reaches in the Ginninderra, Molonglo and Southern ACT catchments. Only 14% of reaches were assessed as having good to excellent riparian condition, 37% were found to be in fair condition and 48% were assessed as poor to degraded (Figures 7 and 8). The Ginninderra catchment had no reaches with good riparian condition, the Molonglo catchment had 5 reaches, and the Southern ACT catchment had 4 reaches classed as good and 1 as excellent.

As with overall CHIP scores and macroinvertebrates, riparian condition is strongly linked to land use, with urban and rural areas generally having fair to degraded condition due to vegetation clearing. However, there were also fair and poor reaches in conservation and protected areas demonstrating that riparian health can be degraded regardless of land use due to impacts of changed flow regimes and pest plants. However, some of these lower scores also may reflect the methodology used.

The restoration of riparian health is perhaps the most easily achievable of actions required to improve aquatic ecosystem condition. The replanting of native species in cleared riparian zones and the removal of weed species would greatly improve aquatic health and the amenity of aquatic ecosystems for the ACT community.

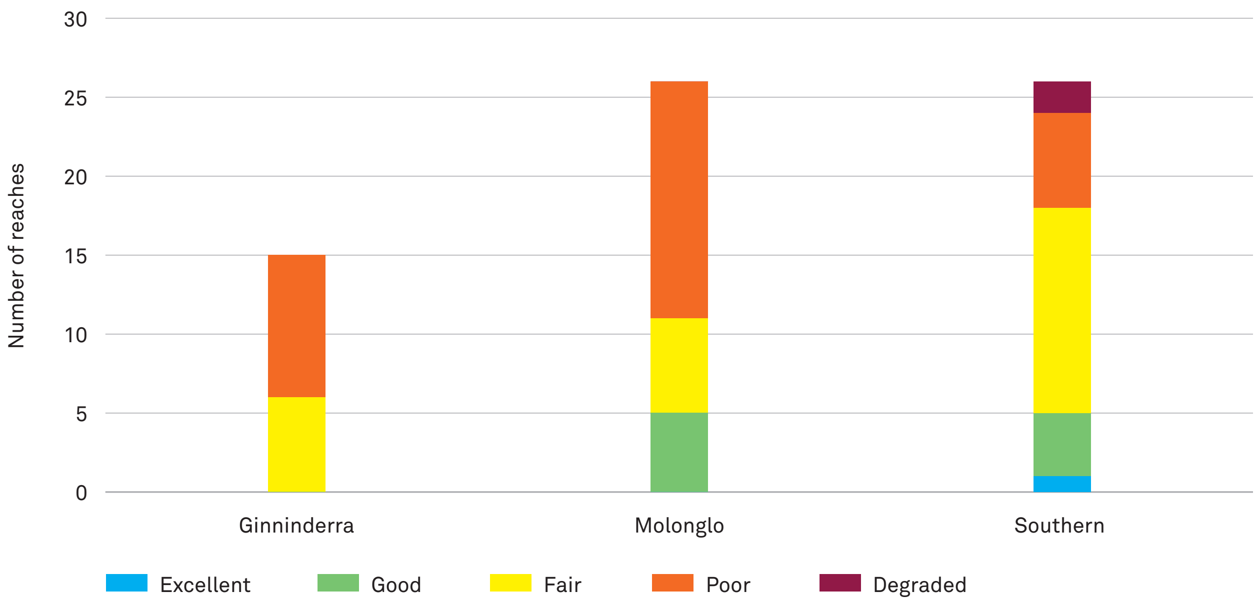


Figure 7:
Catchment Health Indicator Program riparian score for catchment reaches, 2018.

Data sourced from: Upper Murrumbidgee Waterwatch.

7 Upper Murrumbidgee Waterwatch, 2018, *Catchment Health Indicator Program 2018*, Waterwatch, Canberra.

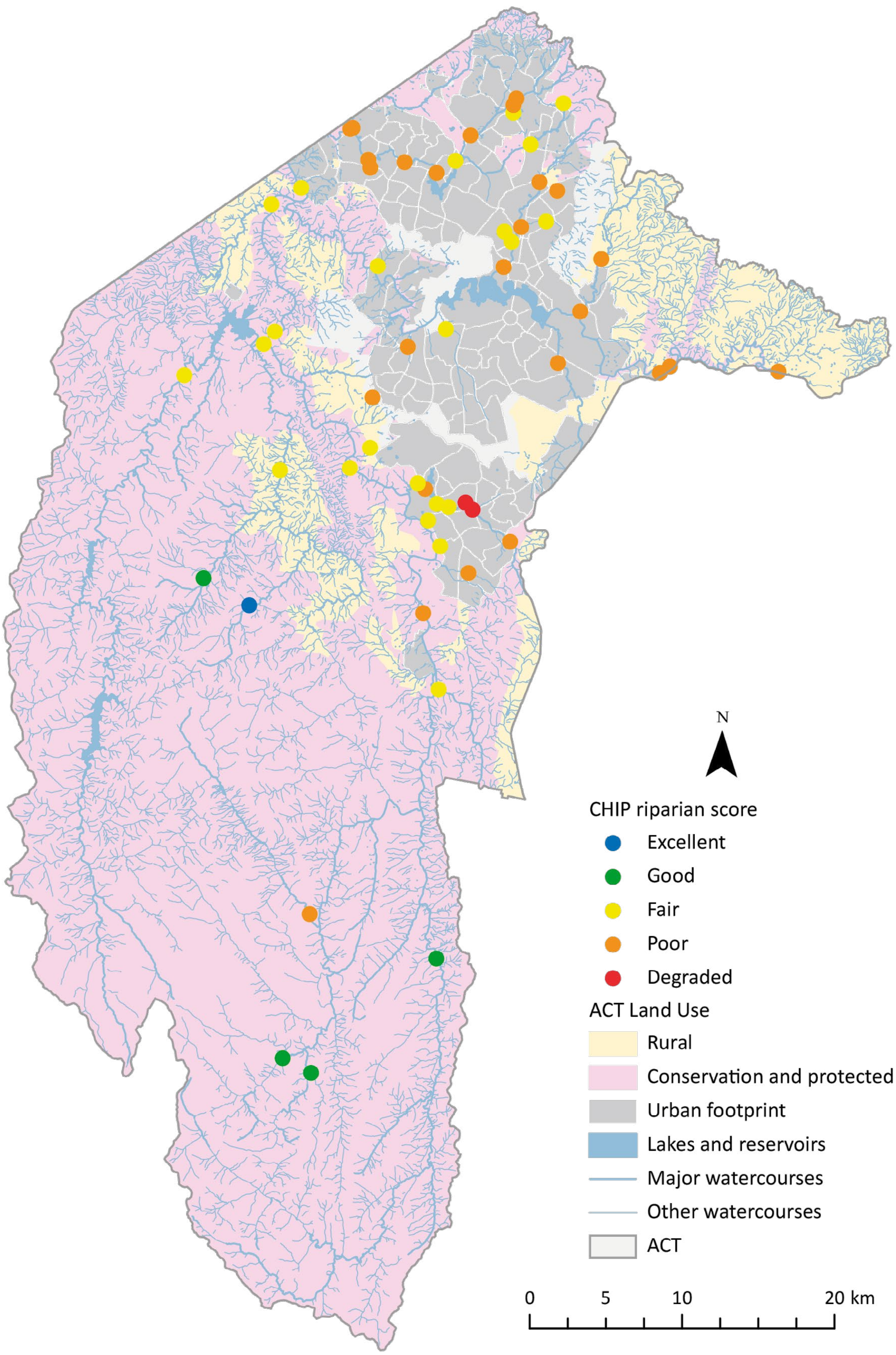


Figure 8:

Catchment Health Indicator Program riparian score for catchment reaches, 2018.

Data sourced from: Upper Murrumbidgee Waterwatch.

Note: Each dot represents the condition of a reach. NSW sites are not shown.

Native fish

The distribution and abundance of native fish is highly dependent on the condition of aquatic ecosystems. Pressures on native fish include:

- alteration and reduction of natural flow regimes
- structures such as dams, road crossing and weirs that create barriers to the movement of fish
- degraded habitat including loss of riparian vegetation
- invasive fish species which place pressure on native fish through predation, competition for habitat and resources, disease and habitat modification
- degraded water quality, and
- recreational fishing, particularly unregulated (unlicensed) fishing, which impact on species already affected by other pressures.

The ACT Government undertakes fish surveys in Cotter River above Cotter Reservoir, the Murrumbidgee River and selected urban lakes. Main findings for the distribution and abundance of fish species include:

Cotter River

- The data shows a strong population of Two Spined Blackfish in the Namadgi National Park above Cotter Reservoir.
- The recovery of Two Spined Blackfish following the 2003 bushfires and Millennium Drought. This recovery has been supported by environmental flows from dams.
- Evidence of an expansion of Macquarie Perch upstream of Cotter Reservoir following the construction of a fishway at Vanities Crossing in 2001.
- The population of Macquarie Perch has been supported by the translocation of fish from Cataract Reservoir as part of a genetic rescue project.

Murrumbidgee River

- The decline of Trout Cod following the cessation of conservation stocking by the NSW Government in the Upper Murrumbidgee Catchment.
- Murray Cod have shown an increase above Redrocks Gorge.
- Downstream of Redrocks Gorge, the Murray Cod population shows recovery from a decline after the Millennium Drought.
- Golden Perch were found to have low population levels in the upper reaches, and populations in the lower reaches were at moderate detection levels showing a small increase after the Millennium Drought.
- The Golden Perch population is likely to be dependent on connectivity with populations downstream of the ACT. This is dependent on the occurrence of sufficient flows at the right time of year.

Urban lakes

- Murray Cod and Golden Perch are stocked to Canberra’s urban lakes and selected ponds. However, they generally do not breed in these environments and so require ongoing stocking to maintain populations.
- Successful reproduction of smaller native species, such as Carp Gudgeon, is common in urban lakes and ponds.

Native fish abundance and biomass

Fish surveys in the Murrumbidgee and Cotter Rivers show that alien species are common in the ACT. For the Murrumbidgee River, native fish typically account for less than 30% of total fish abundance (Figure 9). The biomass (a measurement of the relative size of species) of native fish is even lower in the Murrumbidgee River in comparison to exotic species, typically accounting for less than 20% of total fish biomass (Figure 10). The dominance of alien species in the Murrumbidgee River is mainly due to high numbers of carp. Native abundance and biomass in the Murrumbidgee River have increased in some recent years with the expansion of Murray Cod populations in 2010, and occasional years of high recruitment producing large numbers of juvenile Murray Cod.[8]

8 Biomass is influenced by the size of introduced fish such as carp, rainbow trout and brown trout which are often much larger than native species. Abundance and biomass can also be influenced by the numbers of schooling species or juvenile recruitment as compared to larger-bodied species and adults.

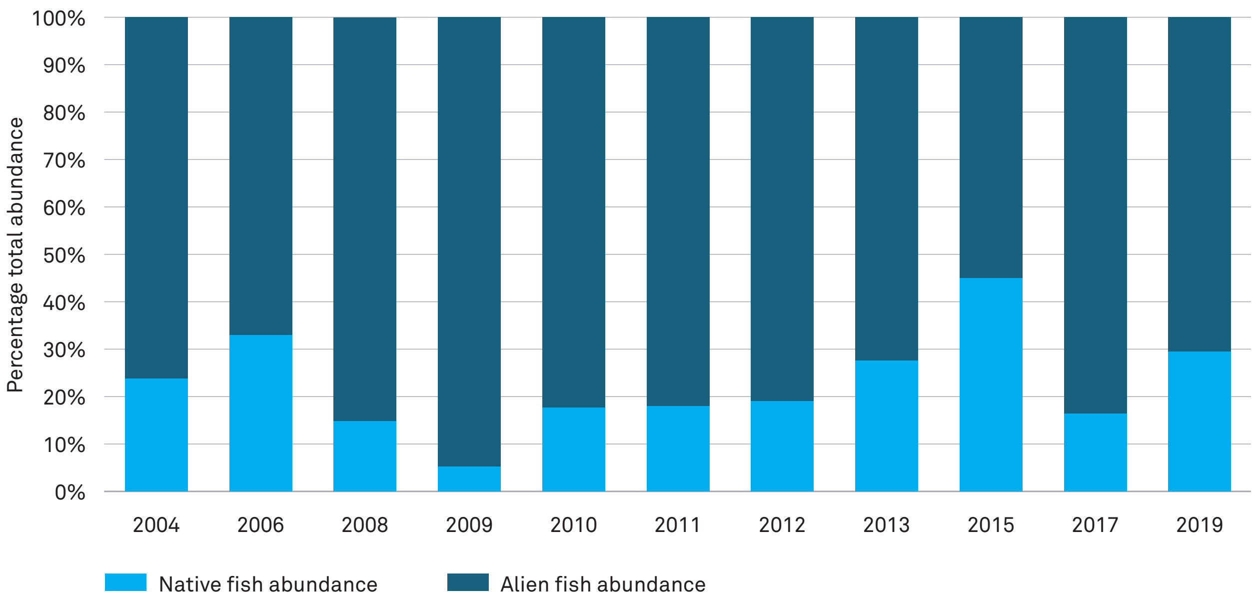


Figure 9:
Abundance of native and alien fish species in the Murrumbidgee River, 2004 to 2019.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

Note: Fish surveys are not undertaken for every year.

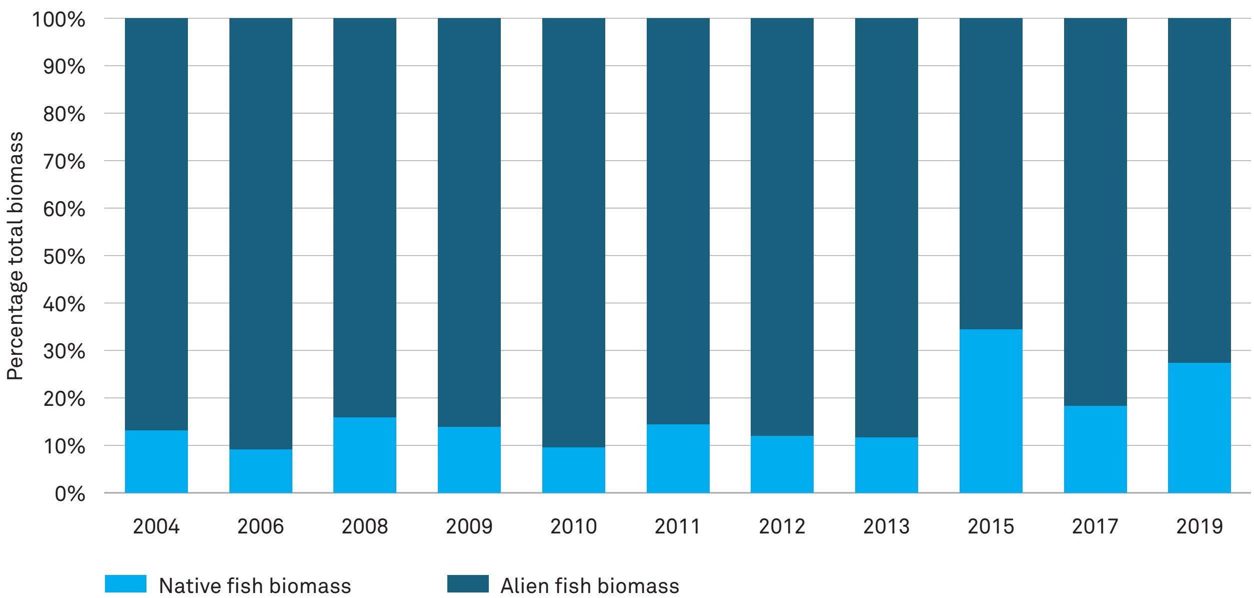


Figure 10:
Biomass of native and alien fish species in the Murrumbidgee River, 2004 to 2019.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

Note: Fish surveys are not undertaken for every year.

The proportion of native fish abundance is higher in the Cotter River, accounting for over 70% of the total abundance between 2014 and 2019 (Figure 11). Biomass is more variable with native species accounting for between 45% and 70% of the total biomass over the same period (Figure 12).

Native fish abundance in the Cotter River has increased since a low in 2005 during the Millennium Drought. This increase is also generally shown for biomass in the Cotter River, although there was a significant decrease in native fish biomass in 2011 and 2012 due to consecutive large flood events that impacted on breeding seasons. These results show that river flow is a significant driver of changes in native and alien fish abundance and biomass in the Cotter River. In addition to flow, recreational fishing pressure is likely to be reducing the population of alien species in the reach between Bendora and Cotter reservoirs.

Although native fish abundance and biomass is higher in the Cotter River compared to the Murrumbidgee River, results for both rivers demonstrate that alien species are impacting on native fish in the ACT. River modification has created favourable conditions for alien species to thrive. The greater biomass of alien species has significant implications for native fish communities, particularly in relation to competition for food and habitat resources, as well as the spread of disease and habitat availability.

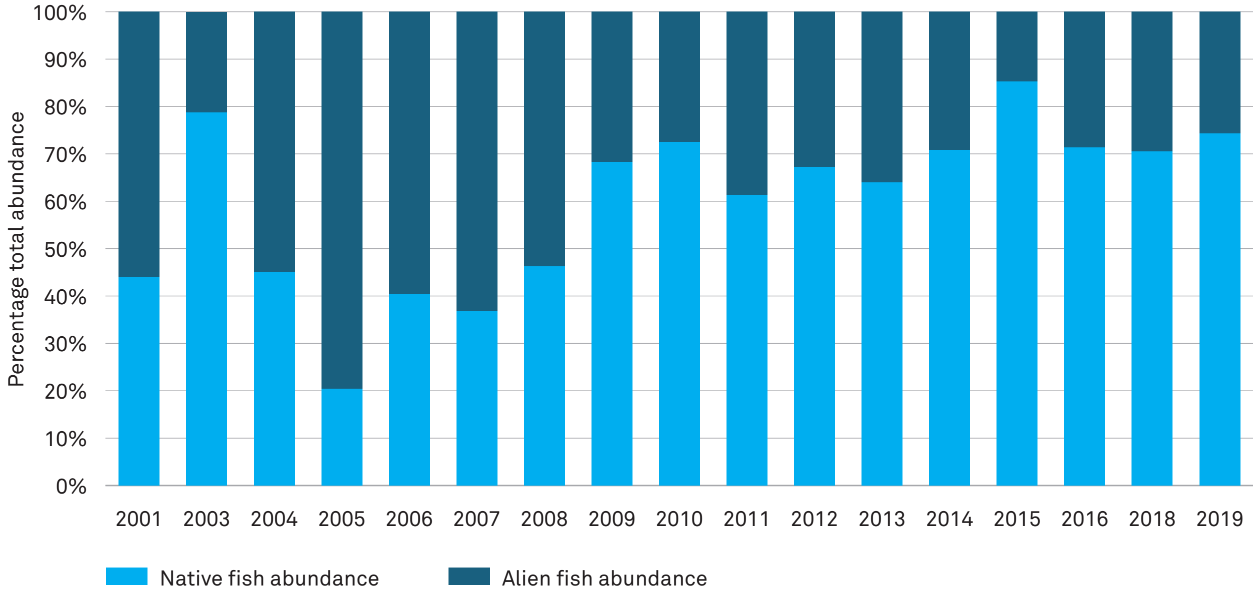


Figure 11:
Abundance of native and alien fish species in the Cotter River, 2001 to 2019.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

Note: Fish surveys are not undertaken for every year.

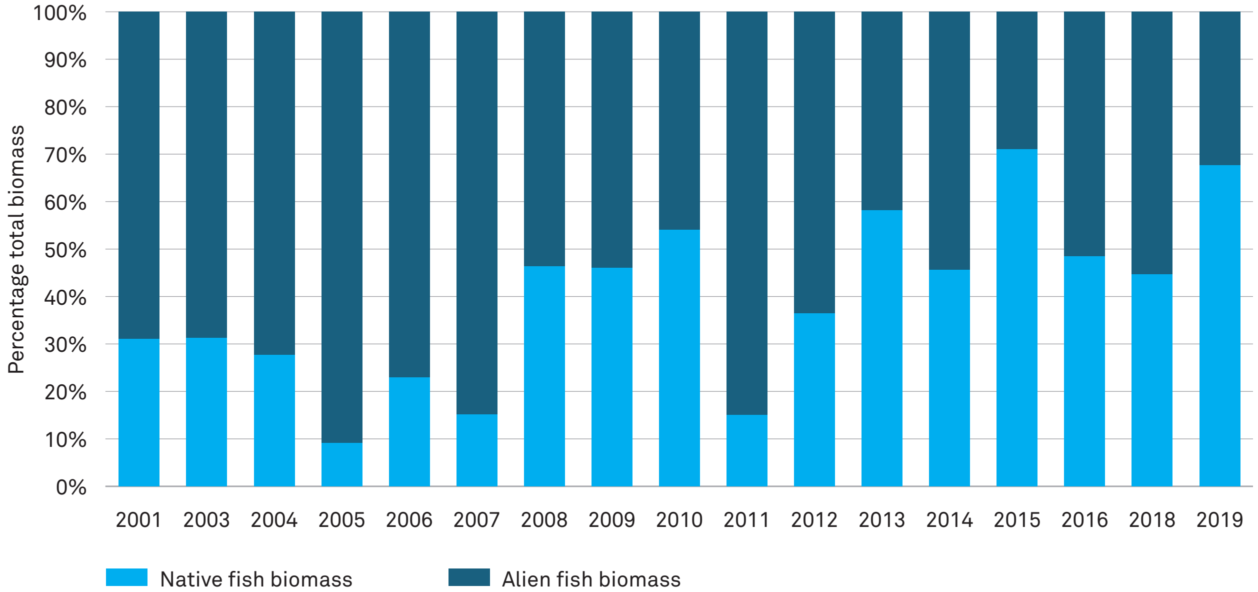


Figure 12:
Biomass of native and alien fish species in the Cotter River, 2001 to 2019.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

Note: Fish surveys are not undertaken for every year.

Native fish stocking

The ACT Government stocks juvenile Murray Cod and Golden Perch into Canberra's lakes and larger ponds including Lake Burley Griffin (funded by the National Capital Authority), Lake Ginninderra, Lake Tuggeranong, the Yerrabi in Gungahlin, Upper Stranger, Point Hut, West Belconnen and Coombs ponds. Stocking is undertaken to provide recreational fishing and to increase the abundance of native species. The lakes and ponds do not provide the required environmental conditions for the successful breeding of Murray Cod and Golden Perch and so populations must be maintained by regular stocking. Stocking of urban lakes and ponds also aims to reduce the angling pressure on natural riverine populations, such as the Murrumbidgee fish population.

Between 2015 and 2019, over 162,000 Golden Perch and 107,000 Murray Cod were stocked to Canberra's lakes and larger ponds (Figure 13). Canberra's lakes account for over 80% of the total fish stocked in the ACT with Lake Burley Griffin receiving over half the fish stocked to the lakes. This is because of the size of the lakes which require more fish to meet the target stocking rate of 200 fingerlings per hectare.

Upper Stranger Pond was stocked for the first time in 2017 with Golden Perch and Murray Cod stocked at high densities after carp were removed. Four ponds in the new Coombs suburb area were also stocked in 2017 to complement a research project on the effects of lake drawdown.

The success of stocking is reliant on fish releases at appropriate intervals with sufficient numbers of fingerlings. Inappropriate stocking levels increases the risk of negative changes to fish population structures.

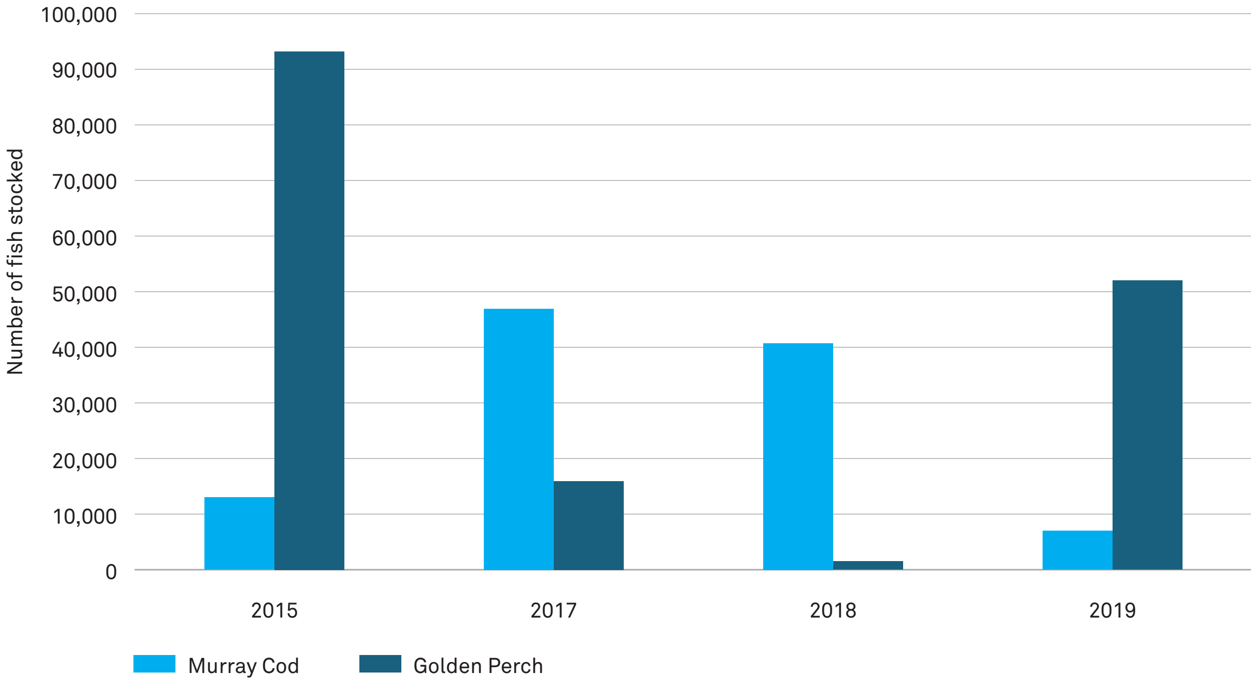


Figure 13:
Number of Murray Cod and Golden Perch stocked to Canberra lakes and ponds, 2015 to 2019.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

BARRIERS TO FISH PASSAGE IN THE ACT

Connected waterways are critical for the survival of native fish. Structures such as dams, weirs and road crossings create barriers that can prevent fish passage. Native fish move within and between waterways to breed and to locate critical resources such as food, shelter, nursery sites and spawning grounds. Native fish species can also utilise different parts of river systems for different life cycle stages. For example, the Murray Cod (*Maccullochella peelii*) and Golden Perch (*Macquaria ambigua*) usually travel upstream to find suitable breeding areas. Barriers that prevent fish passage can also cause populations to become isolated, which can lead to inbreeding and loss of genetic diversity.[9]

An assessment of constructed barriers to fish passage in the ACT conservation estate found:

- A total of 234 potential barriers to fish passage.
- Seven of these barriers were beneficial barriers that restricted the movement of pest fish species, preventing competition and the spread of disease.
- Eighteen sites were assessed as significant barriers to fish movement, 6 sites had a medium level of blockage and 70 sites had a low level of blockage and/or were in low quality aquatic habitat.
- Of the total of 234 potential barriers, 133 were assessed as not preventing the movement of native fish.[10]

These findings show that there are numerous constructed barriers to fish passage in the ACT. The remediation or removal of barriers, particularly those assessed as significantly restricting the movement of native fish, will improve the connectivity of ACT waterways.

Indicator W2: River flows

The ecological condition and functioning of rivers are strongly linked to natural flow regimes. A flow regime is the timing, size and duration of river flow events. It is a key driver of river and floodplain wetland ecosystems, influencing river morphology, biodiversity, and the processes that sustain aquatic ecosystems. Modification of natural flow regimes may affect biodiversity, alter riverine habitat, and facilitate the invasion of exotic species. Aquatic plant and animal species have evolved life histories directly in response to the natural flow regimes. Healthy river flows are also required to support human activities and needs such as domestic water supply, irrigation and recreation opportunities.

In the ACT, natural flows have been altered by water resource development such as the presence of dams and other barriers, regulation of flow, diversion or extraction of in-stream flows, and channel modification. Rainfall interception for farm dams can also impact on natural flows but this is minimal in the ACT with farm dams estimated to reduce run-off to surface water by approximately 1%.[11]

Land use also influences river flows; for example, highly urbanised catchments and cleared agricultural lands can quickly increase river flows due greater rainfall run-off. Other impacts on river flow include fire and plantation forestry. These activities can both increase and decrease flows through the removal of vegetation which increases rainfall run-off, and regeneration which increases the uptake of water.

The natural flows in ACT rivers are highly variable, characterised by generally dry conditions punctuated by wet years which replenish water storages and river systems. Flows also vary seasonally with higher flows usually occurring in the winter and spring months.

9 Pavlova, A. et al., 2017, Severe Consequences of Habitat Fragmentation on Genetic Diversity of an Endangered Australian Freshwater Fish: A Call for Assisted Gene Flow, *Evolutionary Applications* 10(6): 531–550.
10 Unpublished study conducted by the Environment, Planning and Sustainable Development Directorate.
11 Kalisch, D. and R. Argent, 2019, *Integrated Water Accounts for the Canberra Region 2013–14 to 2016–17*, Australian Bureau of Statistics and the Bureau of Meteorology, Canberra.

River discharge is measured at gauging stations throughout the ACT. Annual data is presented for the 2015 to 2018 period only. For the Murrumbidgee River, annual discharges were well below the long-term average in 2017 and 2018 for gauging stations located upstream and downstream of the ACT (Figures 14 and 15). This followed two consecutive years of annual discharges higher than long-term average flows from 2015 to 2016. This trend in annual discharge relative to long-term flows was also evident for the Molonglo River (Figure 16).

Discharges for the Cotter River and Paddys River also had annual discharges that were well below the long-term average in 2017 and 2018 (Figures 17 and 18). But unlike the Murrumbidgee and Molonglo rivers, only annual discharges in 2016 were above the long-term average.

Annual discharges were lowest in 2018 due to the lack of rainfall (see section **5.1 Climate Change**). This resulted in annual discharges significantly lower than long-term averages. For example, the annual discharge in Paddys River was just 7% of the long-term average; Molonglo River 15%; Murrumbidgee at Lobbs Hole 17%; Murrumbidgee at Halls Crossing 19%; and Cotter River 24%.

These reduced discharges have consequences for ecosystem health as well as the amenity of the ACT's waterways. The low rainfall and river flows in the ACT's drinking-water catchments has also impacted on the ACT's water resources (see section **5.2 Human settlements – Water resources**)

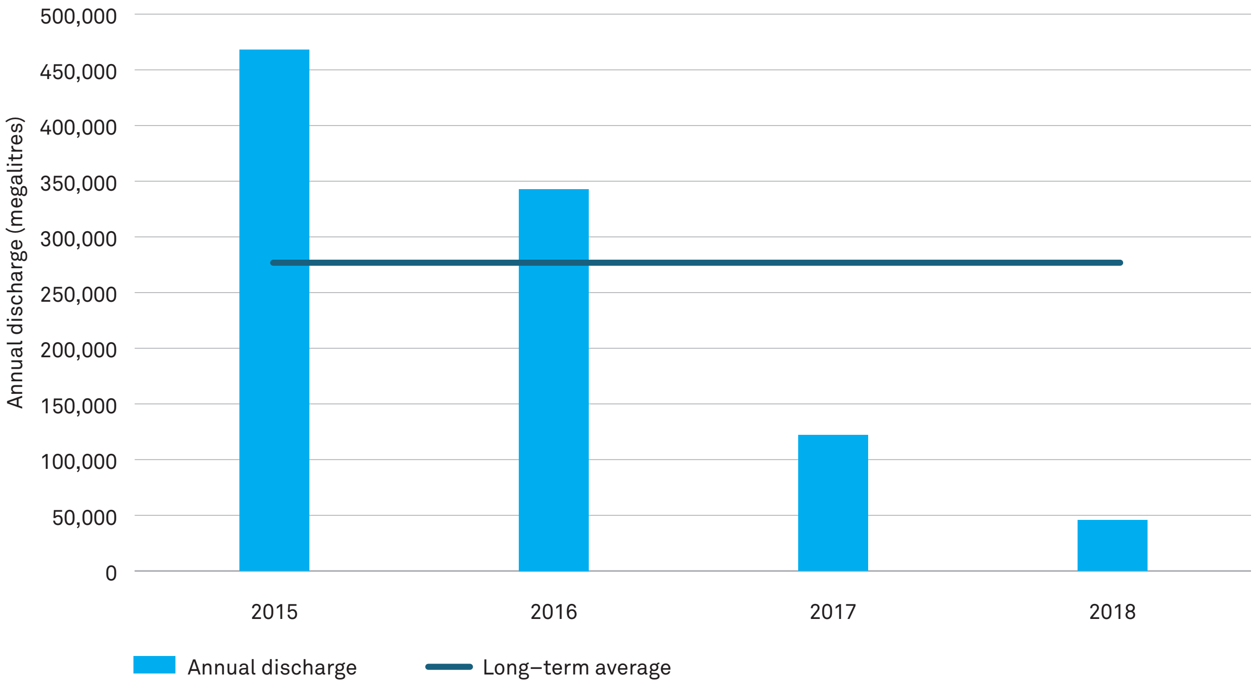


Figure 14:
Annual discharge for the Murrumbidgee River at Lobbs Hole, 2011 to 2018.
Data sourced from: Environment, Planning and Sustainable Development Directorate.

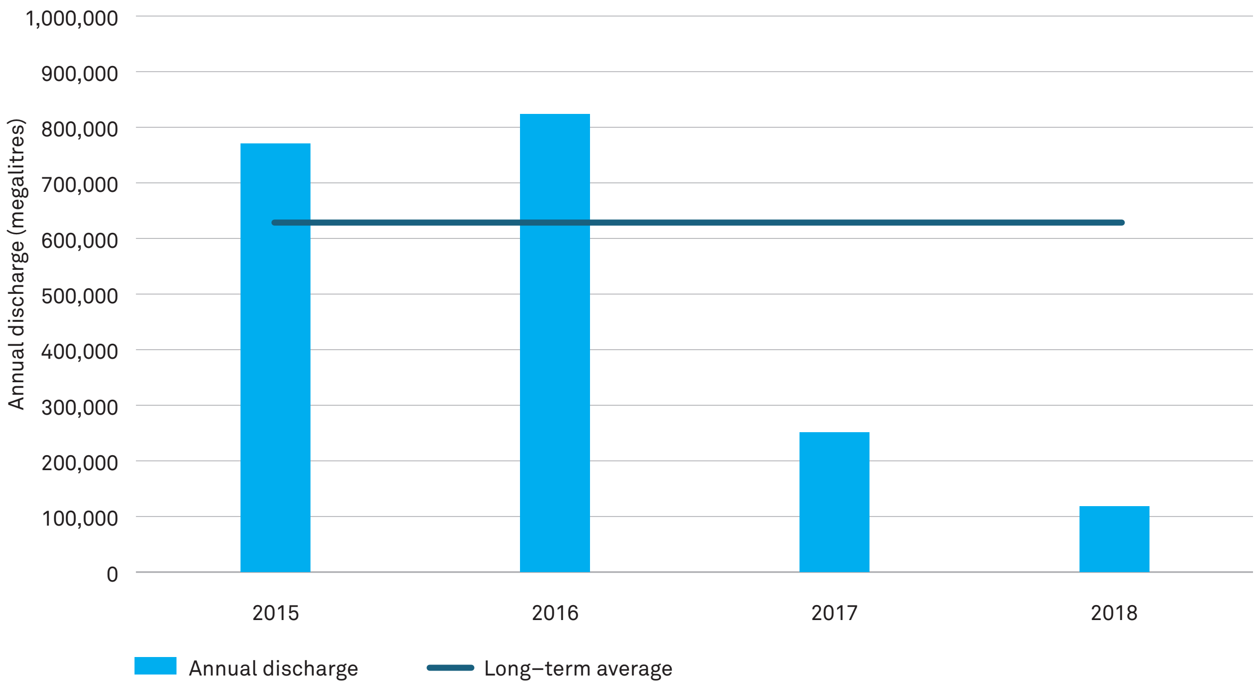


Figure 15:
Annual discharge for the Murrumbidgee River at Halls Crossing, 2011 to 2018.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

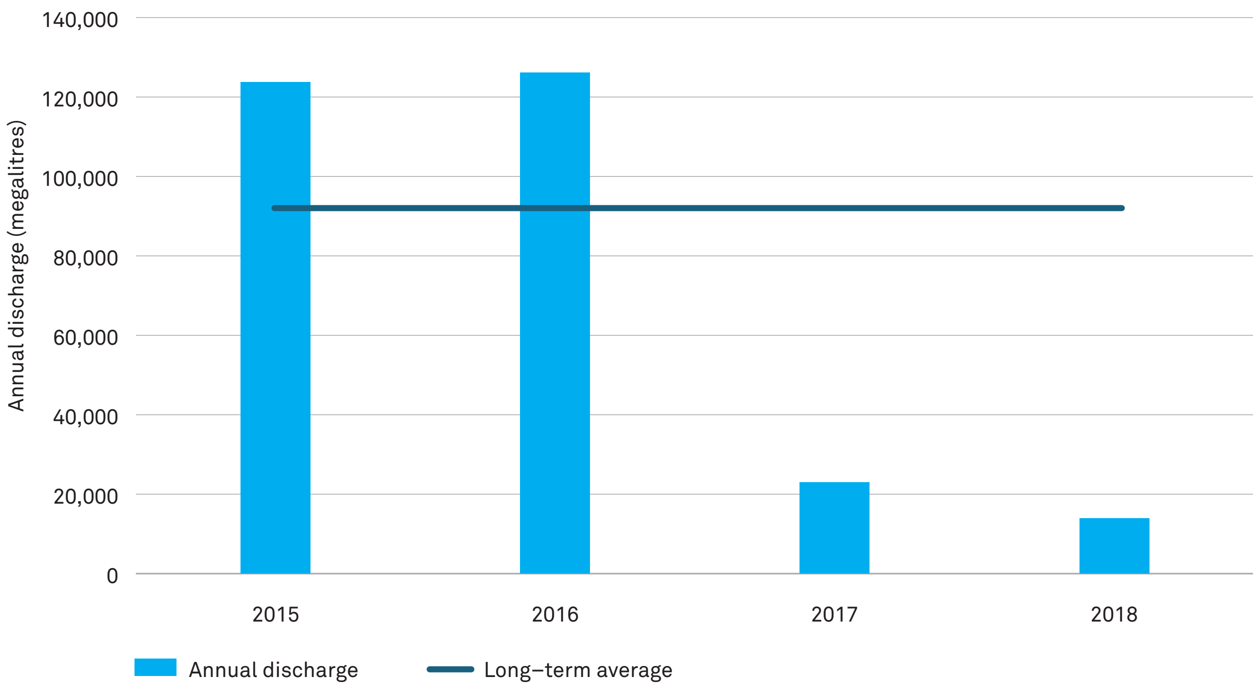


Figure 16:
Annual discharge for the Molonglo River at Oaks Estate, 2011 to 2018.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

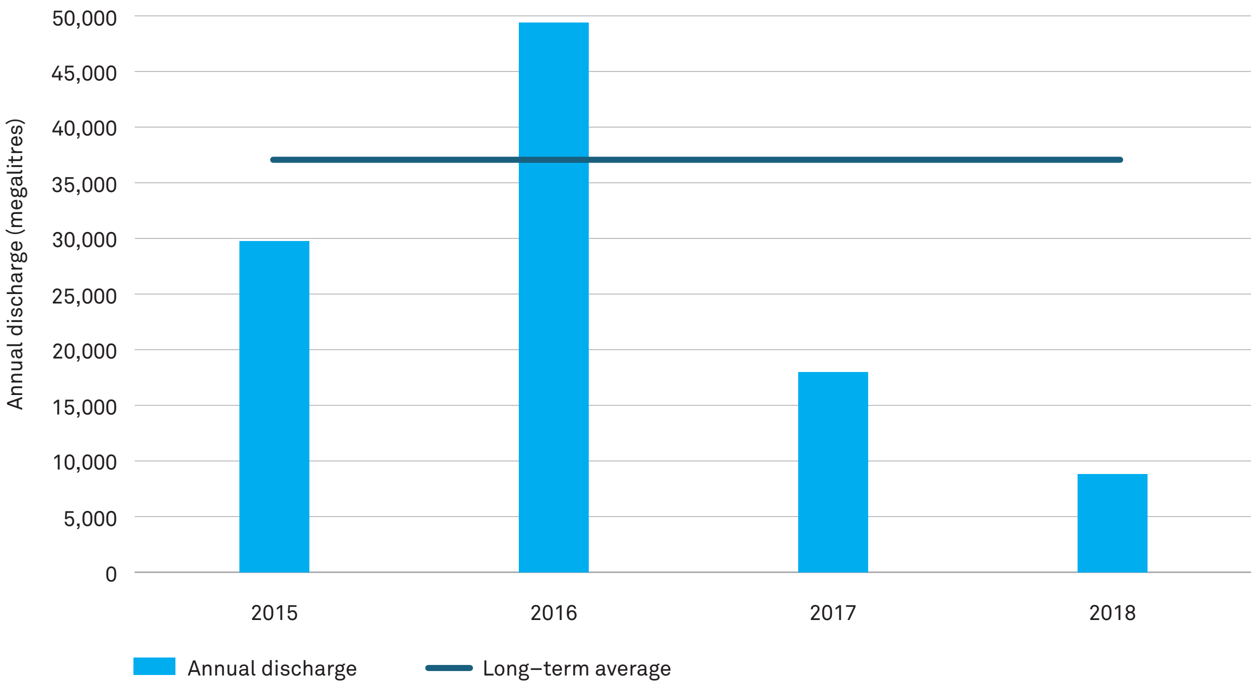


Figure 17:
Annual discharge for the Cotter River at Gingera, 2011 to 2018.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

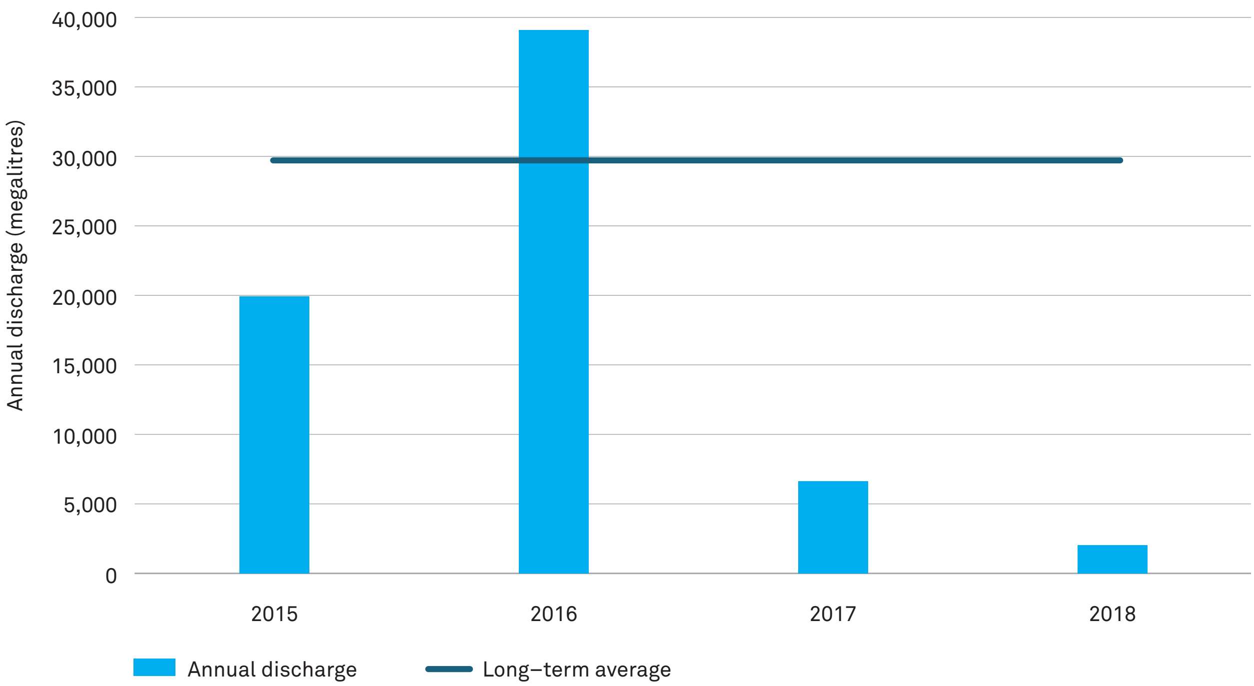


Figure 18:
Annual discharge for Paddys River at Riverlea, 2011 to 2018.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

Water flows entering and leaving the ACT

To ensure that the ACT is not having a detrimental effect on ecosystem health and water supply downstream of the region, it is important that the volume of water leaving the ACT via the Murrumbidgee River should be comparable to that entering the region. Over the 2015 to 2018 period, annual discharges for the Murrumbidgee River leaving the ACT were much higher than those upstream of the region (Figure 19). This occurred despite the significantly reduced river flows in 2017 and 2018. Reasons for increased discharges include contributions from the Cotter River and Molonglo River, as well as discharges of treated effluent from the Lower Molonglo Water Quality Control Centre.

These results show that the ACT's additions to Murrumbidgee River flows are vital for downstream ecosystem health and water supply, particularly during low flow periods.

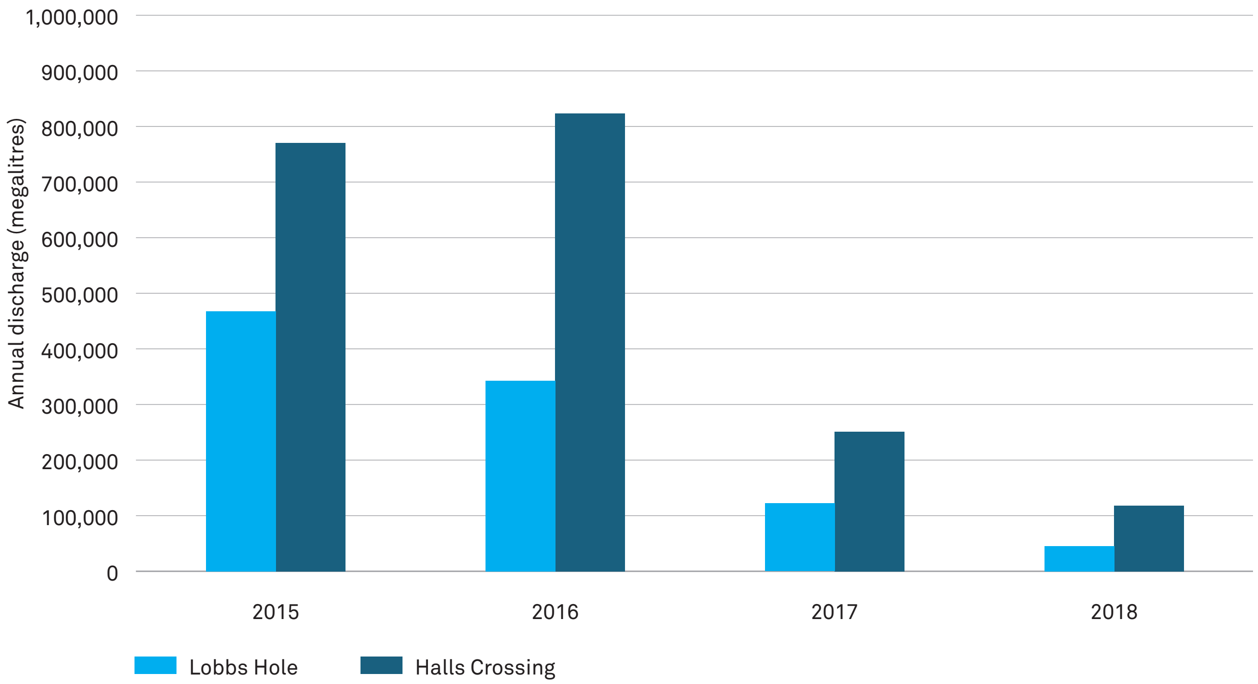


Figure 19:
Comparison of annual discharge for the Murrumbidgee River flowing into the ACT (Lobbs Hole) and leaving the ACT (Halls Crossing), 2015 to 2018.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

Environmental flows

Environmental flows describe the quantity and timing of water required to maintain the health of aquatic ecosystems affected by water resource development. In the ACT, environmental flow requirements are specified in the Environmental Flow Guidelines, an instrument under the *Water Resources Act 2007*.[12]

In heavily used river systems, such as water supply catchments, environmental flows can be delivered in ways that protect specific components of the flow regime, to help keep stream ecosystems healthy, or to provide conditions required for aquatic fauna life histories (such as fish breeding). Environmental flows can be provided through releases and spills from reservoirs (for example, the Cotter, Murrumbidgee and Queanbeyan rivers) and through restrictions on the amount of water that can be withdrawn.

Over the 2015 to 2018 period, all discharges downstream of storage reservoirs met the environmental flow requirement, including discharges below the Cotter Dam (Figure 20), Bendora Dam (Figure 21), Corin Dam (Figure 22) and Googong Dam (Figure 23). Environmental flow requirements were met despite the significantly reduced rainfall and river flows in 2017 and 2018. For the Cotter, Corin and Googong dams, downstream flows greatly exceeded environmental requirements.

12 *Water Resources Act* 2007 (ACT), found at https://www.legislation.act.gov.au/a/2007-19/, accessed 20 October 2019.

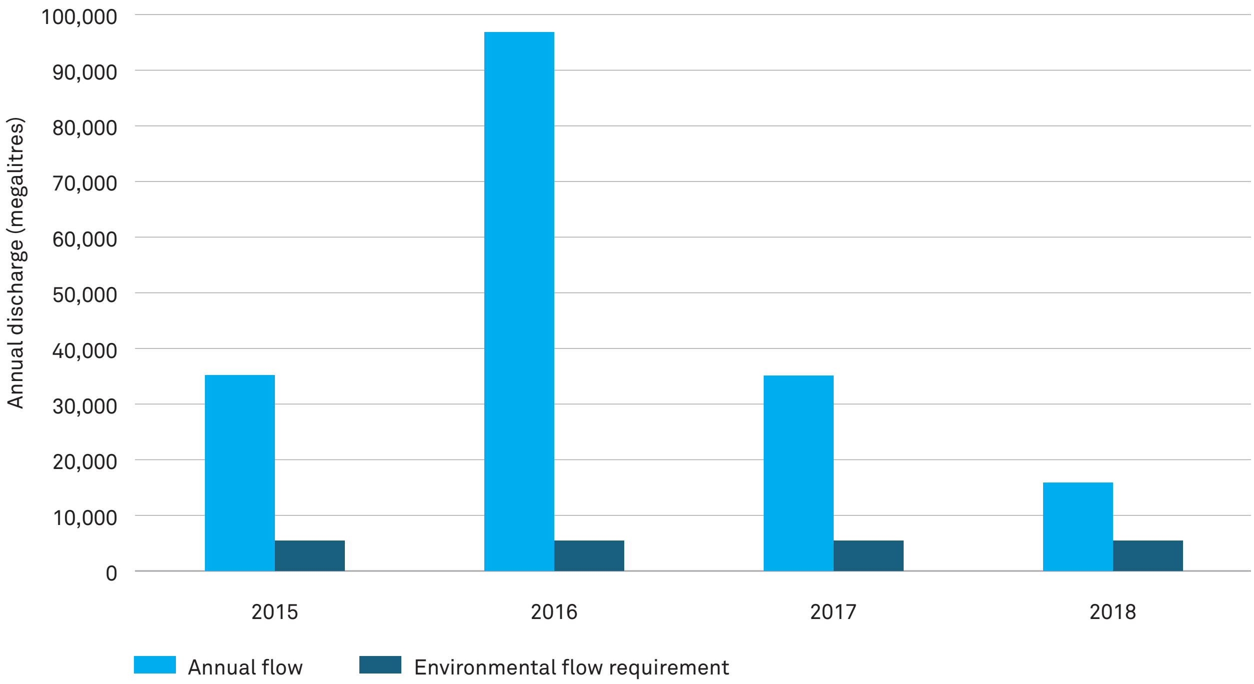


Figure 20:
Annual discharge below Cotter Dam, 2015 to 2018.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

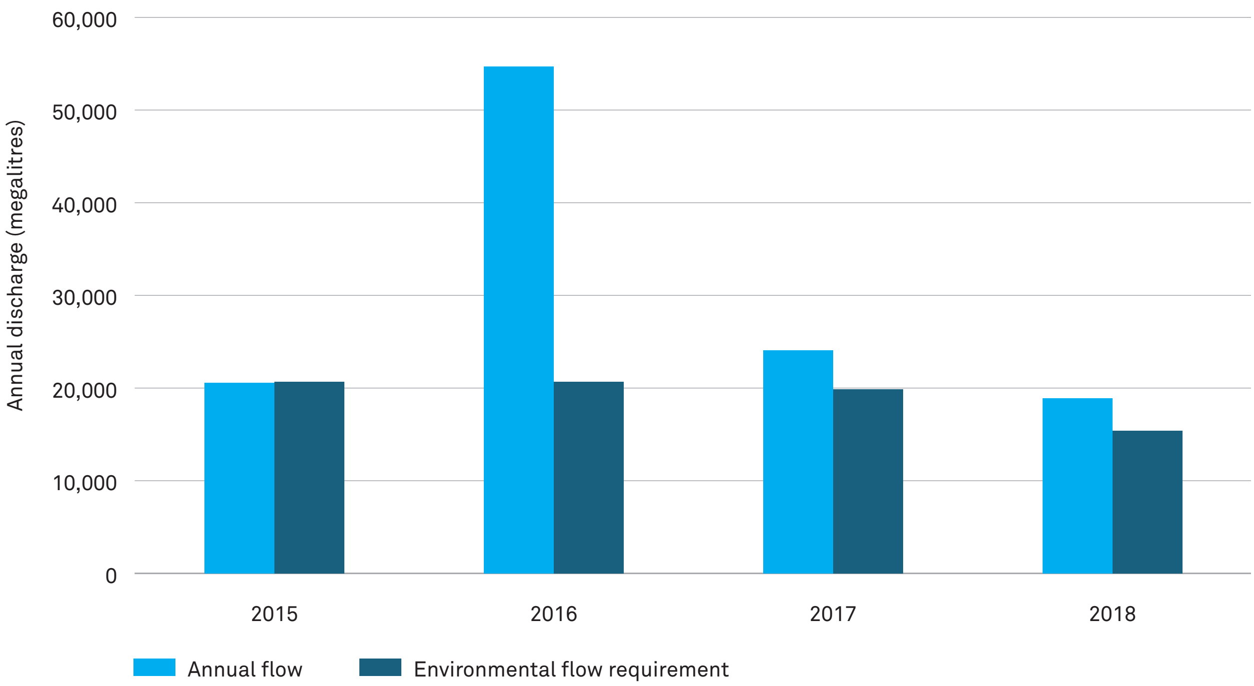


Figure 21:
Annual discharge below Bendora Dam, 2015 to 2018.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

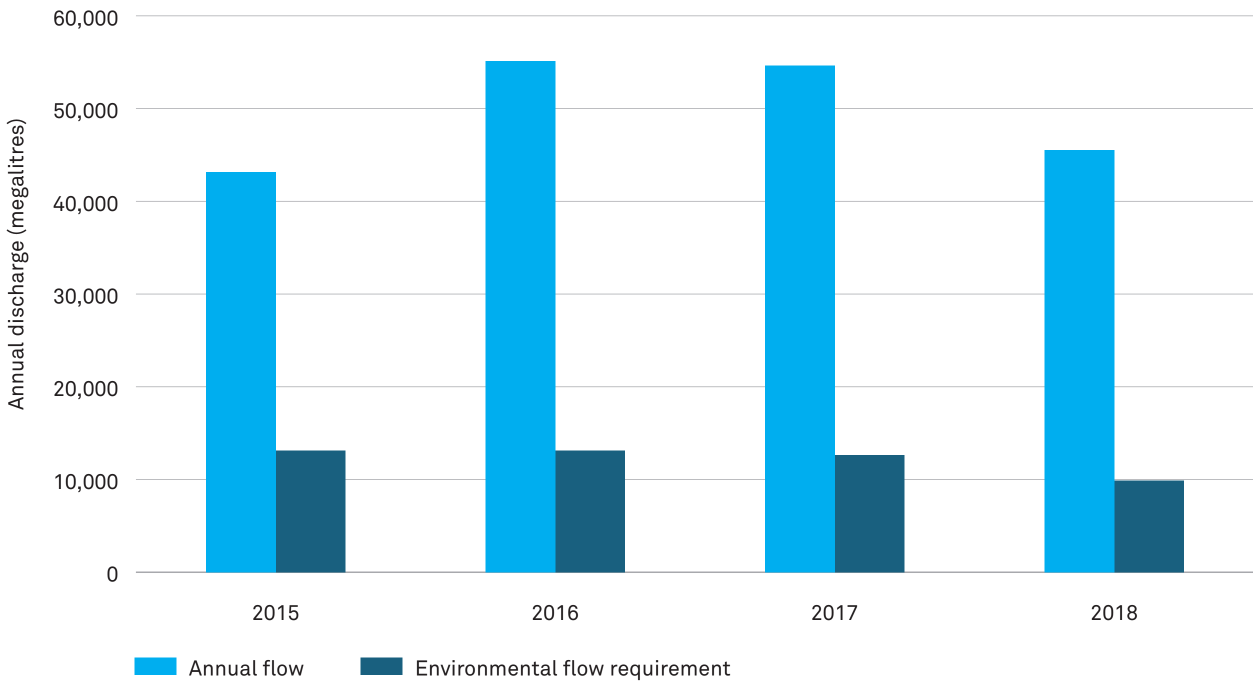


Figure 22:
Annual discharge below Corin Dam, 2015 to 2018.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

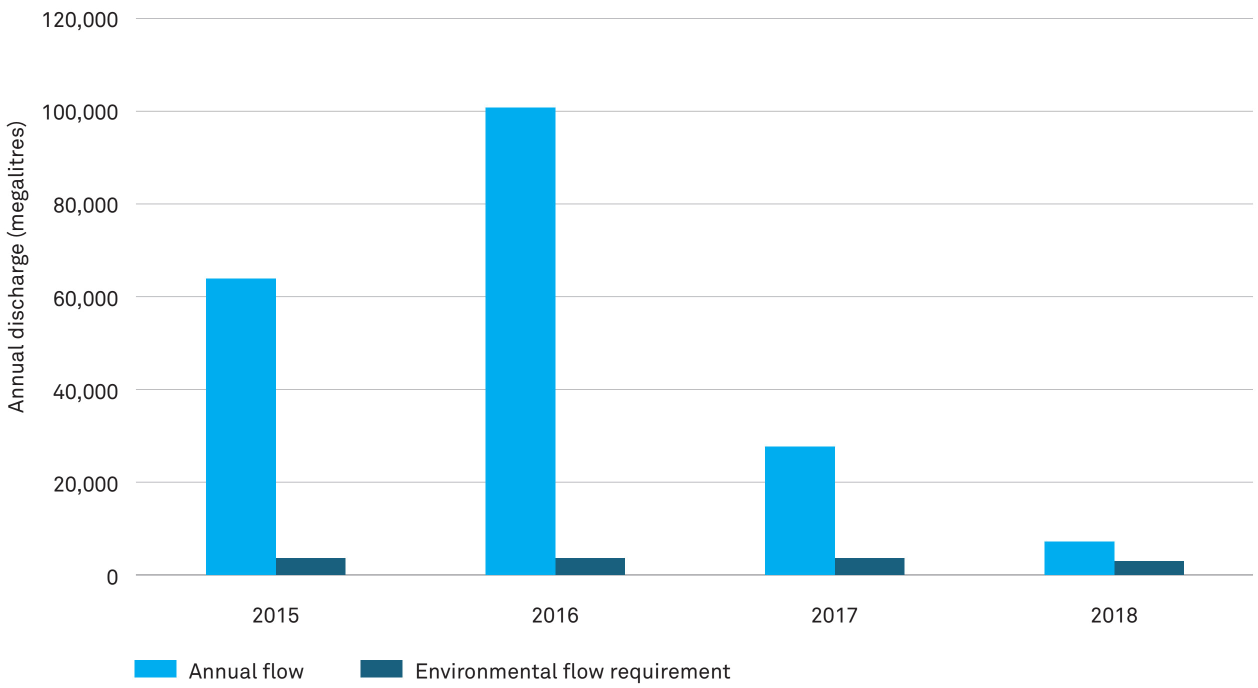


Figure 23:
Annual discharge below Googong Dam, 2015 to 2018.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

CASE STUDY:
IMPACT OF THE SNOWY MOUNTAINS SCHEME ON THE MURRUMBIDGEE RIVER

Completed in 1960 as part of the Snowy Mountains Scheme, Tantangara Dam captures flows from the upper Murrumbidgee River and diverts them to Eucumbene Dam for hydroelectricity and irrigation. Since Tantangra Dam came into operation, around 99% of the Murrumbidgee River flows have been diverted to Eucumbene.

Revised environmental flow provisions in 2012 increased water releases from Tantangra Dam to the Murrumbidgee River to an average of 26 gigalitres per year. Much of this flow is delivered in spring, but for considerable periods of time there are no water releases from Tantangara Dam. This increased water release only represents 10% of the predicted inflows into Tantangara dam. In contrast, the Snowy River currently receives 21% of its annual discharge as environmental flows.

Modelling of potential river flows in the absence of water diversions shows the impact that Tantangara Dam operation (and downstream river abstractions) has on the Murrumbidgee River. The impact of flow diversion is most noticeable upstream of the ACT. A comparison of actual flows and the modelled flows for the Murrumbidgee River at Mittagang crossing (near Cooma), shows that actual monthly mean flows are much lower than would be expected given catchment rainfall and evaporation (Figure 24). The difference is particularly apparent for the winter and early spring months, with modelled mean August flows nearly 5 times higher than actual flows.

The difference between actual and modelled flows is reduced further downstream at Lobbs Hole (near ACT's southern border) and further still at Halls Crossing (near ACT's northern border) as tributary inflows join the river (Figures 25 and 26). Despite this, differences during peak flow times are significant with a reduction of flows likely to impact on river health and aquatic biodiversity.

The upper Murrumbidgee River below Tantangara Dam still retains areas of high ecological significance and is noted for its importance to threatened native fish and other aquatic communities. All of these values are dependent on flows. The upper Murrumbidgee populations of Murray Cod and Macquarie Perch are listed in their respective species recovery plans as nationally significant. Silver Perch are now extinct in the Murrumbidgee River between Tantangara Dam and the ACT – a lack of connectivity resulting from river regulation is a likely contributor to their demise. Nine other aquatic dependent species are also present, some of which are listed as threatened in State and/or Territory legislation.

In addition to a range of iconic and threatened species, important hydrological processes are threatened by excessive abstraction, such as sediment flushing. The capacity for riverine flows to naturally push these sediments downstream is greatly impaired by reductions in annual discharge. As such, significant sand slugs have been created in the Murrumbidgee River, creating barriers to connectivity and reducing habitat for a range of species, including fish and platypus.

With the Snowy 2.0 project underway, an opportunity exists to improve the environmental outcomes for the upper Murrumbidgee River. Improved environmental flows from Tantangara Dam would greatly enhance the ecological and cultural values for this iconic stretch of river.

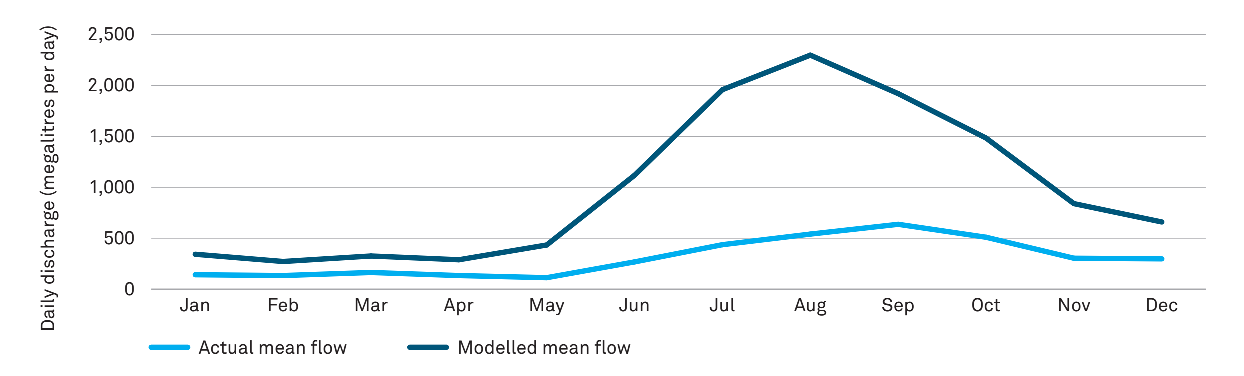


Figure 24:

Modelled and actual flows in the Murrumbidgee River downstream of Tantangara Dam at Mittagang crossing near Cooma.

Date sourced from: Environment, Planning and Sustainable Development Directorate.

Note: Modelled flows are those predicted in the absence of any river regulation or abstraction. The graph shows mean monthly discharge only, upper and lower ranges may vary considerably.

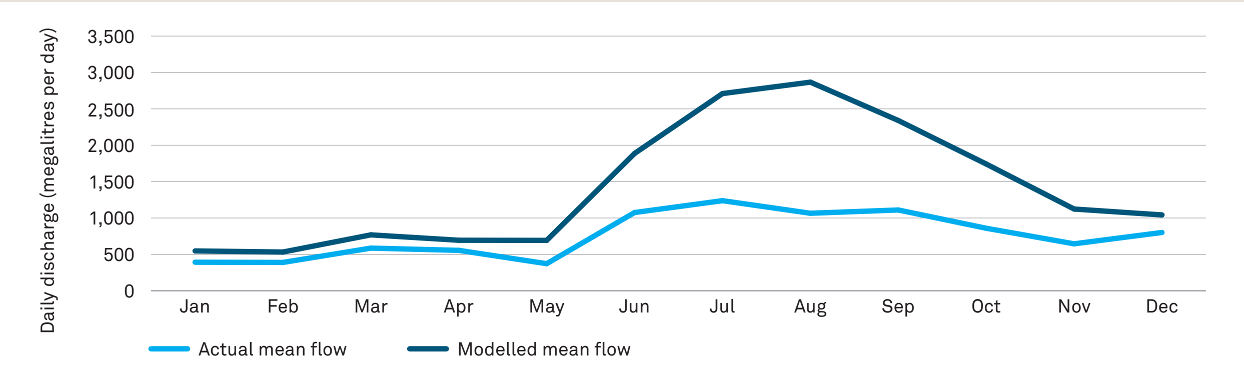


Figure 25:

Modelled and actual flows in the Murrumbidgee River downstream of Tantangara Dam below Lobbs Hole.

Date sourced from: Environment, Planning and Sustainable Development Directorate.

Note: Modelled flows are those predicted in the absence of any river regulation or abstraction. The graph shows mean monthly discharge only, upper and lower ranges may vary considerably.

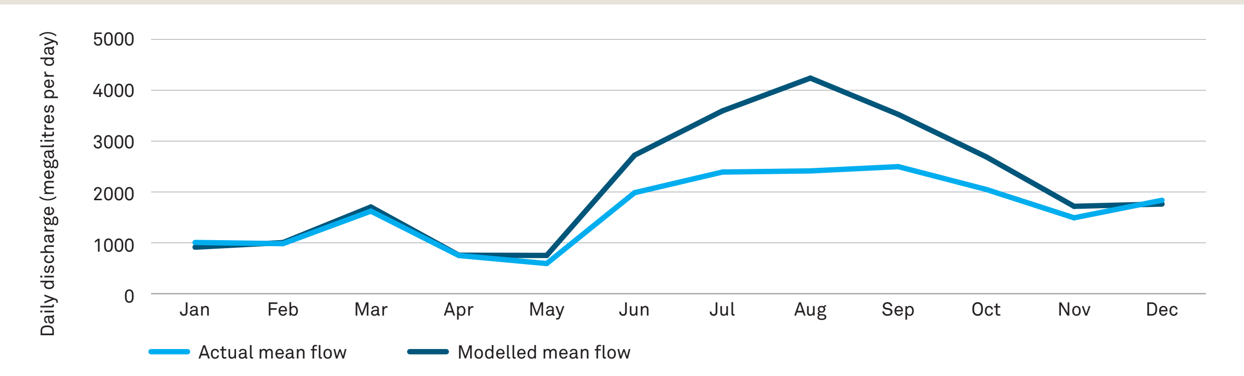


Figure 26:

Modelled and actual flows in the Murrumbidgee River downstream of Tantangara Dam at Halls Crossing.

Date sourced from: Environment, Planning and Sustainable Development Directorate.

Note: Modelled flows are those predicted in the absence of any river regulation or abstraction. The graph shows mean monthly discharge only, upper and lower ranges may vary considerably.

Indicator W3: Water quality

Water quality is critical to the ecosystem services that rivers provide for a range of social, economic and environmental needs. Good water quality is required for drinking water, aquatic ecosystem health and the biodiversity it supports, as well as for recreational and cultural opportunities. Poor water quality can lead to the loss of aquatic species, human illnesses, and the loss amenity from the closure of recreational water bodies and odour. Degraded water quality can also increase the cost of water treatment and prevent agricultural activity.

Water quality is highly sensitive to a range of factors including land use, flow regimes, and the loss of riparian vegetation. Land clearing for agriculture and urbanisation has increased erosion, sedimentation, turbidity and salinity, as well as the increased run-off of a range of pollutants. Agricultural use of chemicals and fertilisers has increased concentrations of nitrogen and phosphorus in waterways, as well as concentrations of herbicides and pesticides. Other pressures on water quality include fire and the impact of invasive species such as carp and willow.

Water pollutants

Sources of water quality pollutants can be broadly classified as point (directly from industry and treatment plants) or diffuse (run-off from catchments). Following significant improvements in the regulation of point source pollution, diffuse sources are the major cause of water pollution. For example, the Canberra urban environment discharges treated sewage effluent from the Lower Molonglo Water Quality Control Centre; however, the high level of wastewater treatment means that pollution from unregulated diffuse sources remains the major cause of poor water quality in the ACT.

The main water quality issues in the ACT are:

- **Turbidity and sedimentation:** erosion is the main cause of turbidity and sediment problems, with significant occurrences following storms and bushfires. Turbidity reduces light penetration affecting the ability of aquatic plants to photosynthesise and impairing animal activities such as predation. At very high levels, suspended sediment can clog and damage fish gills and the filter-feeding apparatus of animals such as mussels. Large-scale sediment deposition can smother river habitats creating shallow flow areas that are subject to greater temperature extremes and the risk of invasion by aquatic weeds.
- **Nutrients:** although nitrogen and phosphorus are essential plant nutrients, elevated concentrations can cause excessive plant growth (eutrophication), including toxic algal blooms. Nutrient enrichment affects aquatic communities by changing species composition and reducing dissolved oxygen concentrations as a result of algal blooms. The major cause of increased nutrient levels is run-off from urban and agricultural catchments, particularly in areas with high fertiliser usage. Point sources of pollution, such as discharges from agriculture, industry and wastewater treatment plants, have also elevated concentrations of phosphorus and nitrogen.
- **Salinity**: the salt concentration of water presents a direct threat to aquatic ecosystems. While some aquatic species tolerate a range of salt concentrations, changes in salinity can kill a wide range of plants and animals. Human settlements are also affected by salinity because it accelerates corrosion and can damage infrastructure, such as roads and bridges. It also affects soil, plant and livestock health and can therefore reduce agricultural productivity. In the ACT, increased electrical conductivity in some areas may be caused by the underlying natural geology of the catchments.
- **Dissolved oxygen:** the concentration of oxygen in the water is important for the maintenance of aquatic organisms. Low oxygen levels can stress fish, which can lead to fungal infections and disease, or result directly in the death of fish and other aquatic species. Dissolved oxygen concentrations are particularly affected by temperature (colder water can hold more dissolved oxygen), and severe declines occur following algal blooms.

EXPERT COMMENTARY: WATER QUALITY IN THE ACT

Dr Fiona Dyer, Associate Professor in Water Science at the Institute for Applied Ecology, University of Canberra.

Water played an integral role in the selection of the site for the city of Canberra. The chosen location provided the water security thought necessary for the nation's capital. It was not just the quantity of water that was important for early Canberrans, it was the quality – the supply of fresh, clean water – that provided a foundation for the growing population. These days, the quality of water in the ACT's rivers, lakes and wetlands varies through time and depends on the waterway in question. Some of the ACT's waterways have pristine water quality, yet others are highly degraded; sometimes our waterways are ideal to swim in, yet at other times they are pose significant health risks.

Around 60% of the ACT is either national park or reserve. This provides waterways in these areas with protection from the effects of human activities and changes in land use. Consequently, the quality of water in these areas is the best possible. Canberrans benefit from this because a significant amount of drinking water is sourced from the Cotter River catchment, which is predominantly within the Namadgi National Park. This water requires minimal treatment which not only keeps the costs to consumer low but has broader benefits through smaller amounts of energy and chemicals used to treat the water.

The greatest risks to water quality in our parks and reserve systems are posed by large bushfires, and bacteria that are introduced through the waste (faeces and urine) of recreational users. These risks increase with the number of people using the parks and poor practices by park visitors. Limiting access to the Cotter catchment is a key strategy for protecting the quality of our drinking water, but similar strategies do not exist for other parts of the natural estate. As Canberra's population increases and there are more people using our parks, the risk to water quality will need to be actively managed.

While the parks and reserves of the ACT generally have excellent water quality, the same cannot be said of streams in urban areas. A concentration of construction and industrial activities, vehicle emissions, bird and animal droppings, leaves and grass clippings, rubbish, fertilizers and areas of degraded land result in pollutants and sediment entering urban waterways. This situation is exacerbated by the piped stormwater drains and hard land surfaces which mean that when it rains, urban streams carry more faster-flowing water compared to corresponding natural streams. Because of this many urban streams have been lined with concrete to ensure that water is moved efficiently away from homes and other infrastructure. The downside of concrete is that the urban streams lack the biological processes that would naturally reduce the concentrations of sediment and other pollutants. These pollutants are passed through our urban stormwater network and end up trapped in ponds and lakes.

Canberra's ponds and lakes play an important role in the treatment of urban stormwater. They were designed to receive stormwater from the surrounding suburbs, and trap nutrients and other pollutants to prevent them from being passed downstream into the Murrumbidgee River. The smaller urban ponds that are spread throughout Canberra's suburbs are very effective at trapping nutrients and other pollutants when the flow in the stormwater network is low. At high flows, we rely on the larger lakes to trap the much greater volumes of water and pollutants which then leads to a range of problems within the lakes.

Canberrans have a strong affinity for our urban lakes and the recreational opportunities they provide. As such, the water quality of these lakes is of particular importance to the community. The water quality in our lakes varies: sometimes, the water quality is good enough for swimming and the lakes provide a great space for Canberrans to cool off and enjoy water-based activities; at other times, the lakes are plagued by water quality problems that include major toxic cyanobacterial (blue-green algae) blooms or high bacteria levels.

While the ability of our lakes to trap nutrients and other pollutants is an important function, the downside is that over time, the pollutants accumulate in the lake and the quality of water declines. Nutrients pose particular problems because high concentrations support the growth of cyanobacteria. In recent years, Lake Burley Griffin, Lake Tuggeranong and Lake Ginninderra have been closed to recreation because of cyanobacterial blooms. Lake Tuggeranong was closed for most of the summer of 2018–2019 because of a particularly severe outbreak of cyanobacteria. The extended closure of Lake Tuggeranong caused a significant loss of amenity to the community. Studies show that high loads of nutrients, particularly phosphorus, delivered to the lake during rainfall events are a major factor contributing to the algal blooms.

The most effective way to prevent cyanobacterial blooms is to reduce the amount of nutrients getting into waterbodies. Prevention will require long-term management of catchments to stop nutrients entering the stormwater drains. This is not just the responsibility of government agencies through the implementation of water-sensitive urban design principles; all Canberrans have an important role in helping to keep our stormwater clean. We can do this by managing our suburban blocks to reduce run-off and prevent leaves, grass clippings and fertilizers from getting into the stormwater network; making sure that we don't wash dirt and other pollutants into the drains; being mindful of where our animal waste is being dropped; and getting involved in community groups who help to look after our small urban parks and reserves to ensure that they function more effectively.

It will take tens of years of best-practice water-sensitive urban design and catchment management for the water quality in the lakes to improve. This is because there is a legacy of trapped nutrients in the bottom of the lake that can support algal blooms into the future. Without improved catchment management, the problems we experience with cyanobacterial blooms will not change.

The water quality challenges faced by our water managers are only going to intensify as Canberra's climate changes. Longer dry spells will leave areas of bare ground susceptible to erosion. Increases in rainfall intensity will result in more sediments, nutrients and pollutants being washed into streams. Longer periods of hot weather combined with higher nutrient concentrations will result in warmer surface water in our lakes leading to extended periods when cyanobacterial blooms can occur. This will be exacerbated by increases in population and urban densification which leads to increases in run-off and the potential for more sediment, nutrients and pollutants to be washed into the stormwater network. These challenges will require strategic investment, careful management and the engagement of the community to ensure the quality of water in our nation's capital is the best it can be.

Blue-green algae on Lake Tuggeranong in 2019. Photo: Alica Tschierchke, University of Canberra.

Water quality – Catchment Health Indicator Program

The CHIP assesses water quality for each reach using the results of monthly surveys from all sites (where possible). The assessment methodology can be found in the 2018 CHIP report.[13] Water quality parameters monitored are pH,[14] electrical conductivity, turbidity, dissolved oxygen, phosphorus and nitrate. These parameters have been widely established as the best indicators of water quality while being relatively easy to measure.

Water quality was assessed for 66 reaches in the Ginninderra, Molonglo and Southern ACT catchments. Water quality was found to be excellent for 35% of reaches and good for 62%, with only 2 reaches assessed as fair condition (Figures 27 and 28). All catchments had the majority of their reaches in good to excellent condition. The Southern ACT catchment had 62% of reaches in excellent condition.

As with all other CHIP parameters, condition is linked to land use with the majority of excellent condition reaches on conservation and protected land. However, despite the added pressures imposed by urban and rural land uses, water quality was still good in these areas, with some reaches attaining excellent condition ratings. These assessments demonstrate the effectiveness of water quality management in some urban areas, particularly as a result of constructed wetlands and other water-sensitive design approaches. Water quality results may also reflect the drier conditions for most of the reporting period. Decreased rainfall reduces the occurrence of urban and rural run-off which are main contributors to water quality decline in the ACT.

Although the ACT's water quality was generally good, nitrogen concentrations are much higher in the Murrumbidgee River downstream of the Lower Molonglo Water Quality Control Centre (LMWQCC), with concentrations second only to the Molonglo River immediately downstream of the LMWQCC.[15] Nitrogen concentrations (measured as nitrate) for the Murrumbidgee River downstream of the LMWQCC ranged from 4–30 mg/l in 2018, compared to around 1 mg/l upstream of the ACT, and an excellent nitrate score for the Murrumbidgee River reach upstream of the LMWQCC discharge. A nitrate concentration of greater than 2.6mg/l is considered to be degraded under Waterwatch condition thresholds.

The high nitrate concentration in the Murrumbidgee River continues downstream of the ACT, particularly during dry periods when the LMWQCC discharge contributes a higher proportion of the total river flows. More information is required on the impacts of the LMWQCC on aquatic ecosystems in the Murrumbidgee River.

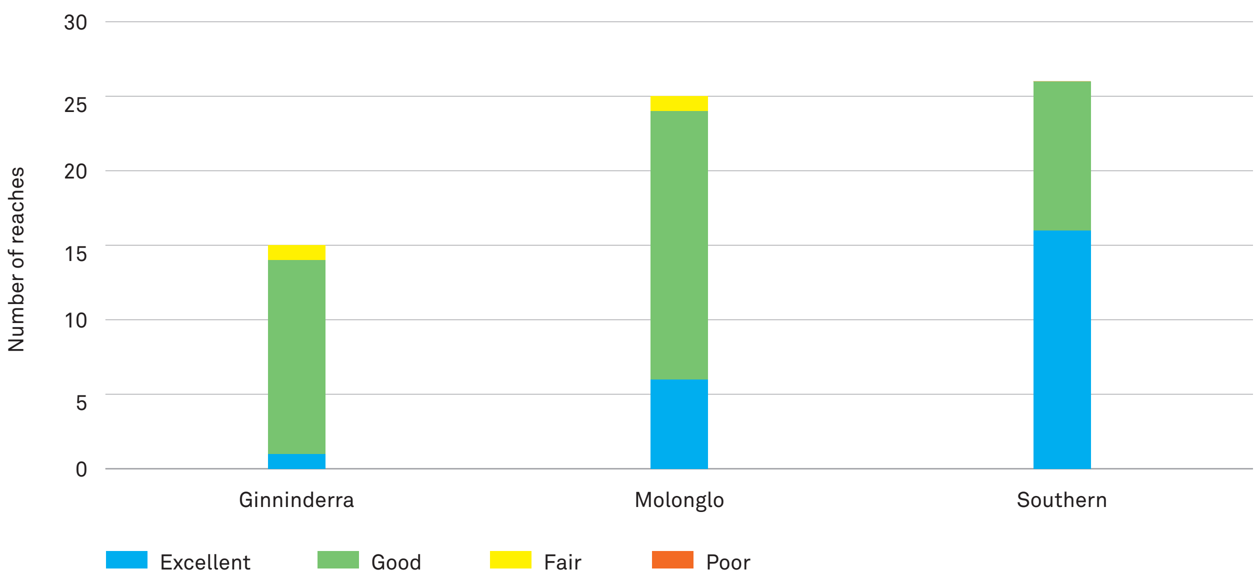


Figure 27:

Average Catchment Health Indicator Program water quality score for catchment reaches, 2015 to 2018.

Data sourced from: Upper Murrumbidgee Waterwatch.

13 Upper Murrumbidgee Waterwatch, 2018, *Catchment Health Indicator Program 2018*, Waterwatch, Canberra.
14 pH is a measure of acidity or alkalinity of water.
15 Murrumbidgee River downstream of the LMWQCC refers to those reaches downstream of the Molonglo River confluence. The Molonglo River receives discharges from the LMWQCC immediately upstream of the confluence with the Murrumbidgee River.

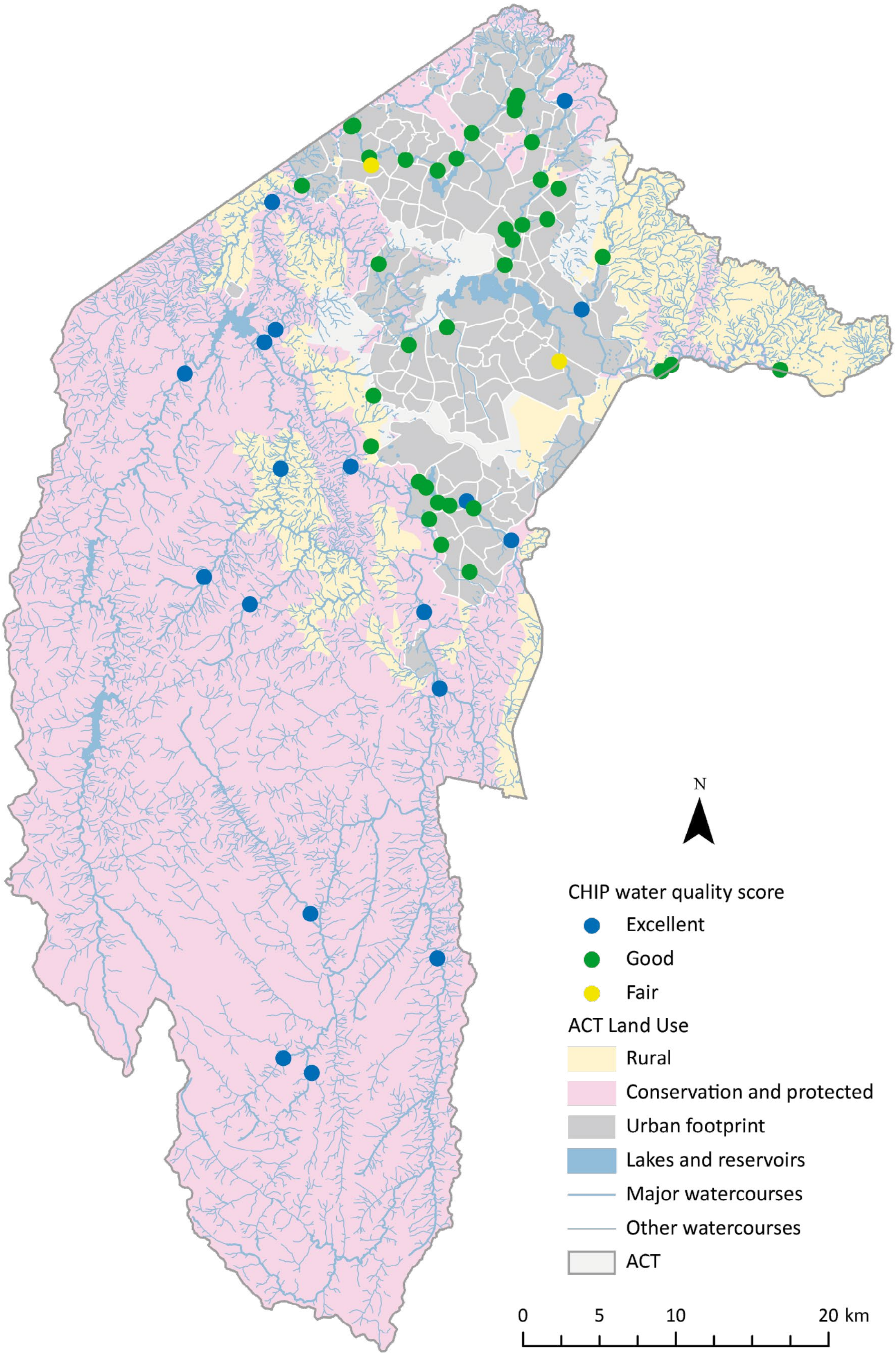


Figure 28:

Average Catchment Health Indicator Program water quality score for catchment reaches, 2015 to 2018.

Data sourced from: Upper Murrumbidgee Waterwatch.

Note: Each dot represents the condition of a reach. NSW sites are not shown.

Water quality entering and leaving the ACT

It is important that the quality of water leaving the ACT via the Murrumbidgee River should be comparable to that entering the region. However, a range of pressures, especially those related to land use, can degrade water quality within the ACT. The impact of the ACT on water quality is determined by comparing ACT Government monitoring results for the Murrumbidgee River at sites upstream and downstream of the ACT. In situ water quality probes measure pH, electrical conductivity, dissolved oxygen (as a percentage of saturation) and turbidity. Phosphorus and nitrogen are not assessed by these probes.

Except for turbidity, monitoring results show that all, or nearly all of water quality samples taken in the Murrumbidgee River met guideline levels over the 2015 to 2018 period. This was for sites upstream and downstream of the ACT. Turbidity guideline exceedances were high for both upstream and downstream sites in the years 2015 to 2017 (Figure 29). Exceedances in 2018 were lower than other years and are likely related to reduced rainfall and catchment run-off. The number of turbidity samples exceeding guideline levels was higher upstream of the ACT for all years except 2016.

Water quality results for the period 2015 to 2018 show that pH, electrical conductivity, dissolved oxygen and turbidity in the Murrumbidgee River is comparable upstream and downstream of the ACT, with turbidity slightly improving as the river moves though the region. This change suggests that sediment and other particles that cause turbidity are being deposited in the ACT, with a likely impact on ecosystem health and biodiversity. Results also show that turbidity is the main water quality issue for the Murrumbidgee River for the variables assessed. Turbidity was also reported as one of the most serious water quality issues in the ACT's *State of the Environment 2015* report.[16]

However, results for water quality monitoring undertaken for CHIP show that the ACT is increasing nitrogen levels downstream of the LMWQCC (see the **Water quality – Catchment Health Indicator Program** section).

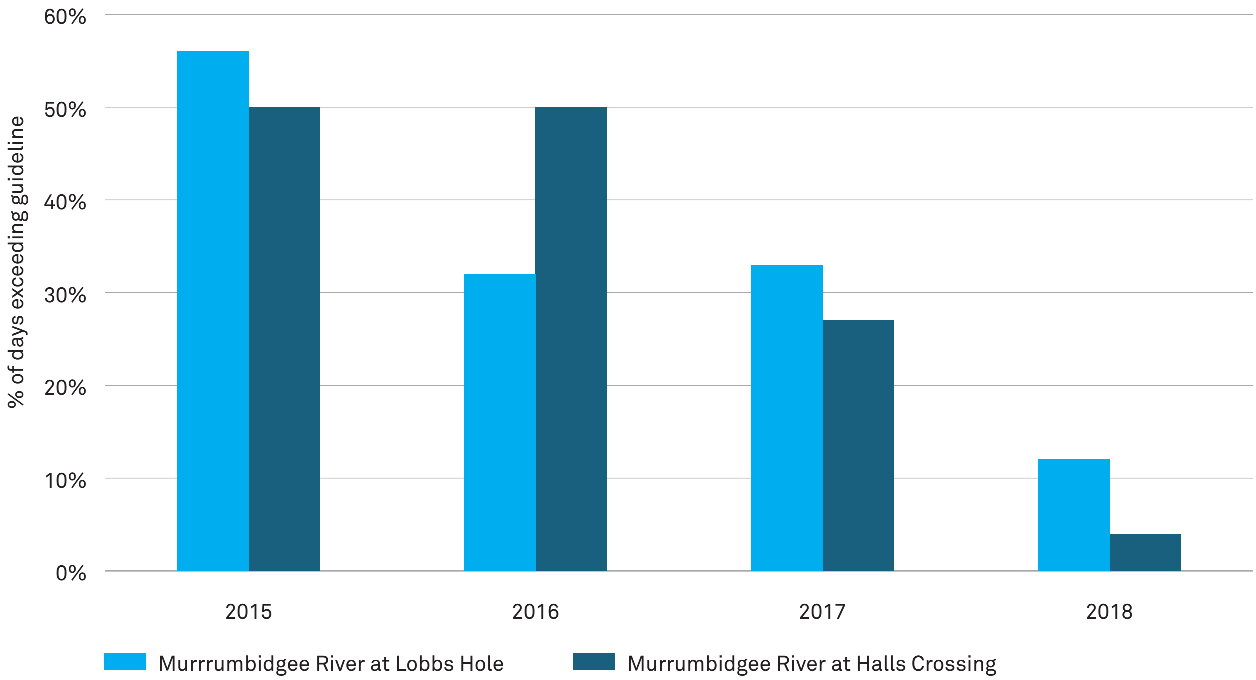


Figure 29:

Percentage of days exceeding the turbidity guideline level for the Murrumbidgee River upstream (Lobbs Hole) and downstream (Halls Crossing) of the ACT, 2015 to 2018.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

16 Office of the Commissioner for Sustainability and the Environment, 2015, *ACT State of the Environment Report 2015*, ACT Government, Canberra.

Indicator W4: Recreational water quality

Recreational water quality refers to the suitability of water for swimming and other activities that involve direct contact with the water. Canberra's lakes and rivers are important for providing amenity and opportunities for recreation. However, the use of lakes and rivers depends on having good recreational water quality.

Assessments of recreational water quality are based on the potentially harmful bacteria known as enterococci and blue-green algae (cyanobacteria). Enterococci, also known as faecal coliform bacteria, are not necessarily a problem for aquatic ecosystems, as they generally serve as food for aquatic organisms without causing them harm. However, the presence of high numbers of faecal coliforms can affect human health when recreational activities involve direct contact with the water. Ingestion of these bacterial pathogens can lead to gastrointestinal illnesses such as diarrhoea. Stormwater run-off is the main source of enterococci, with sewage overflows and releases from damaged pipes also potential sources.

Blue-green algae are naturally present in aquatic ecosystems, but under certain conditions their populations can increase causing a potentially toxic bloom. Low river flows, high temperatures and high levels of nutrients are the primary cause of blue-green algal blooms. Blue-green algae can produce toxins that are harmful to humans and animals when they are swallowed, inhaled, or come into direct contact with the skin. Reactions are variable, depending on the length and type of contact. Common symptoms include irritated skin, flu-like symptoms and gastrointestinal illness resulting in vomiting, diarrhoea, fever and headache.

Recreational water quality monitoring

Recreation water quality monitoring is undertaken in accordance with the ACT Guidelines for Recreational Water Quality across a total of 17 sites in Lake Ginninderra, Lake Tuggeranong and the Murrumbidgee, Paddys and Molonglo rivers.[17] Recreational water quality is also assessed at 10 sites in Lake Burley Griffin by the National Capital Authority.[18] Although the ACT Government is not responsible for the management of Lake Burley Griffin, this data is included because of the important amenity and recreational value of the lake to Canberrans.

Water samples are taken weekly during the recreational swimming season (between approximately October to April) for enterococci and throughout the year for blue-green algae. If samples for enterococci and blue-green algae exceed guideline levels, then a resample is obtained and tested. If two consecutive samples exceed guideline levels, then the site is closed for primary contact. Reopening a recreational site after a closure requires two samples within guideline levels.

The ACT Recreational Water Guidelines were updated in October 2014 and the new exceedance levels were incorporated into monitoring from 2016–17. Due to this change, this report only includes data from 2016–17 onwards.

Results for enterococci monitoring over the 2016–17 to 2018–19 period for are shown in Figure 30. The main trends are:

- nearly every monitored recreation site experienced closures due to the exceedance of enterococci guidelines.
- for lake recreation areas, Lake Ginninderra had the highest number of site closures for each year, although there were slight declines in enterococci closures over the reported period.[19]
- Lake Ginninderra is the only lake where enterococci is the main cause of recreation closures.
- Lake Burley Griffin had the lowest total enterococci closures for Canberra's lakes.
- the Murrumbidgee River had a high number of site closures for enterococci, but this is likely a reflection of the greater number of sites monitored in comparison to other recreation areas.
- enterococci results for Paddys River are a concern with substantial periods of closures for the single site monitored, including for 20 weeks in 2017–18 (the recreational swimming season is typically around 27 weeks), and
- all recreational closures for the Murrumbidgee River and Paddys River were due to enterococci.

17 ACT Health, 2014, ACT Guidelines for Recreational Water Quality, found at https://health.act.gov.au/about-our-health-system/population-health/environmental-monitoring/water-quality

18 National Capital Authority, 2019, Lake Burley Griffin 2018–2019 Recreational Season: Summary of Alerts and Closures, found at https://www.nca.gov.au/national-land/lake-burley-griffin-management/lake-water-quality

19 Total closures are based on results for all monitored sites for each location. Closures for each site occur concurrently and so the data presented does not represent the actual period each location was closed to recreation over the swimming season.

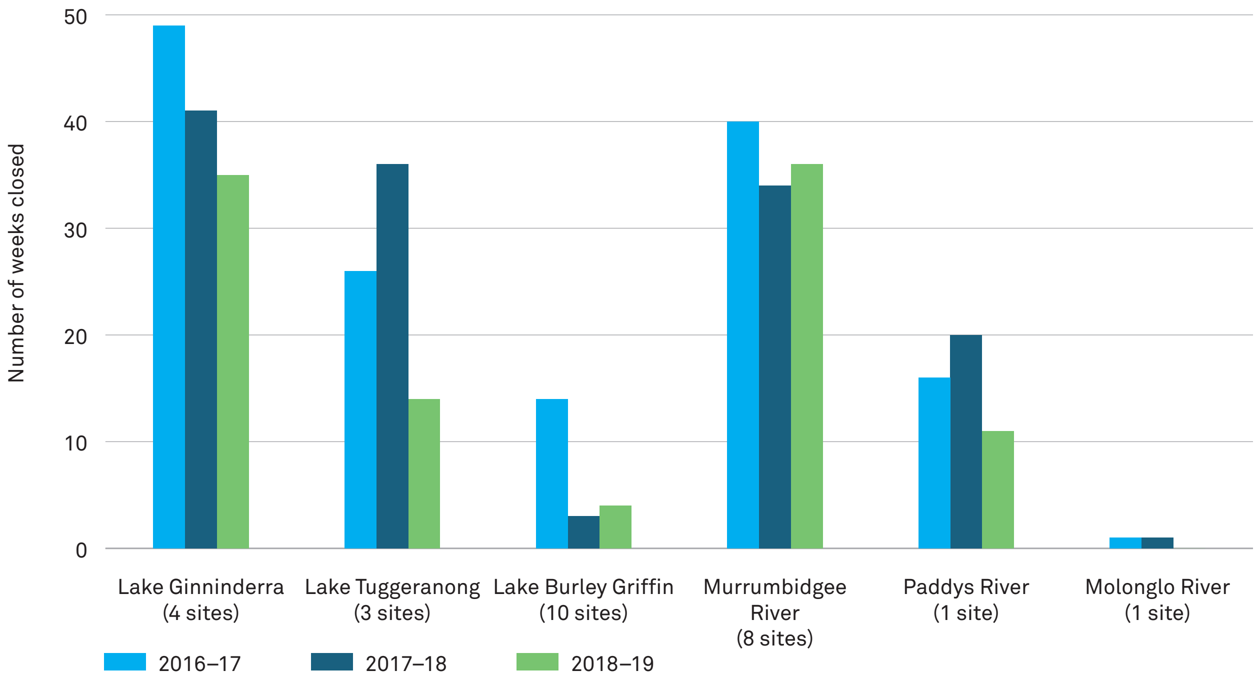


Figure 30:
Total weeks of site closures due to exceedance of enterococci guidelines over the recreational season (October to April), 2016–17 to 2018–19. The number of sites monitored is shown for each recreation area.

Data sourced from: ACT Health and the National Capital Authority.

Notes: Total closures are based on results for all monitored sites for each location. Closures for each site occur concurrently and so the data presented does not represent the actual period each location was closed to recreation over the swimming season.

Results for blue-green algae monitoring over the 2016–17 to 2018–19 period for are shown in Figure 31. The main trends are:

- the principal reason for recreation closures for Lake Tuggeranong and Lake Burley Griffin is blue-green algae.
- Lake Tuggeranong had the highest number of blue-green algae closures in 2016–17 and 2018–19, and Lake Burley Griffin for 2017–18.
- Lake Tuggeranong was closed for most of the 2018–19 recreational swim season due to severe blue-green algal blooms.
- There were no closures due to blue-green algae for Lake Burley Griffin in 2016–17, and
- the Molonglo River was the only river to have recreation closures due to blue-green algae.

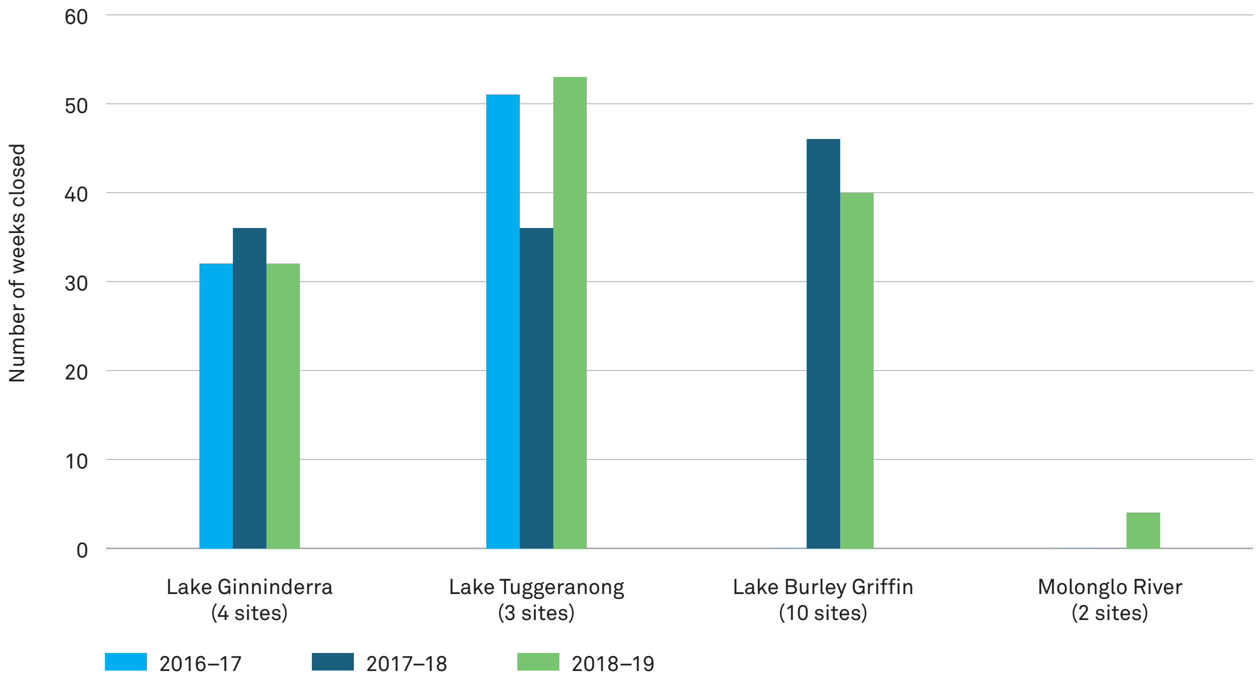


Figure 31:
Total weeks of site closures for exceedance of cyanobacteria guidelines, 2016–17 to 2018–19. The number of sites monitored is shown for each recreation area.

Data sourced from: Transport Canberra and City Services and the National Capital Authority.

Notes: Total closures are based on results for all monitored sites for each location. Closures for each site occur concurrently and so the data presented does not represent the actual period each location was closed to recreation over the swimming season.

The high number of recreational site closures due to enterococci shows that urban and rural run-off is depositing high levels of this bacteria into the ACT's lakes and waterways. To reduce the number and duration of closures, there needs to be improved run-off management and interception in urban areas, and the re-establishment of riparian vegetation in both urban and rural areas (see **Expert commentary: Water quality in the ACT**).

Urban and rural run-off is also the main driver of recreation closures due to blue-green algae. Rainfall run-off transports high amounts of nutrients into lakes and other waterways enabling algal blooms to occur. Consequently, improved run-off management and interception is key to reducing algal blooms in Canberra's lakes. However, the occurrence of algal blooms is also driven by climate factors such as extended dry periods and hotter temperatures. With these conditions set to increase as a result of climate change (see section **5.1: Climate change**), reducing the amount of nutrients in waterways will be required to prevent longer and more frequent recreation closures in the future. The prevention of blue-green algae blooms will not only increase the amenity of the ACT's lakes and waterways, but will also prevent potential impacts on aquatic ecosystems such as fish kills.

DATA GAPS

- Information is poor for groundwater resources and condition, including contamination.
- Little information exists on wetland health.
- Although current monitoring sites provide good coverage of the ACT's urban areas, there needs to be more comprehensive monitoring for aquatic ecosystems in conservation and rural areas to provide a broader picture aquatic health across the region.
- More information is required on the impacts of the LMWQCC on aquatic ecosystems in the Murrumbidgee River, particularly with regard to nitrogen concentrations.

5.7 FIRE

Section contents

Fire in the ACT 2015–2019

Fire occurrence

13,000 hectares burnt with prescribed burns responsible for **96%**

NO large bushfires since 2003

45% of all non-prescribed burn ignitions are deliberatly lit[A]

16% were caused by lightning

10% were caused by accidents

Prescribed burns

Over **12,200** hectares of fuel reduction burns

Fuel reduction burns accounted for **98%** of all prescribed burns

270 hectares burnt for ecological purposes

11 hectares of burning with cultural outcomes

Fire danger

ACT's average and maximum Fire Danger Index have increased

4x increase in Very High Fire Danger days from **11** in 2014–15 to **44** in 2018–19

11 Severe Fire Danger rating days

Climate change expected to increase fire danger

A - Over the period 2004 to April 2019

Indicator assessment

Indicator	Status	Condition	Trend	Data quality
F1: Area burnt in prescribed burns and bushfires	Since 2003, there have been no large bushfires in the ACT. The area of prescribed burns far exceeds that of bushfires, accounting for 94% of the total hectares burnt between 2004 to April 2019, and 96% between 2015 to 2019. Prescribed burns are dominated by fuel reduction activities, with ecological and cultural burns responsible for only 2% of all burning activity between 2015 and April 2019. However, there is a growing recognition of the importance of fire for vegetation, biodiversity and cultural management in the ACT. Arson remains an issue for fire occurrence in the ACT, responsible for 45% of ignitions between 2004 and April 2019, compared to 16% for lightning and 10% for accidents.	Good	−	● ● ● High
F2: Fire risk	Between 2014–15 and 2018–19, climate conditions led to an increase in the average and maximum Fire Danger Index (FDI). There was also an increase in the number of days with a very high Fire Danger Rating (FDR) from 11 days in 2014–15 to 44 in 2018–2019. The 2018–19 fire season had the highest fire danger, with the greatest number of very high and high FDR days, and the highest maximum FDI. Climate change is expected to increase both average and severe FDI in the future.	Fair	↓	● ● ● High

Indicator assessment legend

Condition

- **Good** = Environmental condition is healthy across the ACT, **OR** pressure likely to have negligible impact on environmental condition/human health.
- **Fair** = Environmental condition is neither positive or negative and may be variable across the ACT, OR pressure likely to have limited impact on environmental condition/human health.
- **Poor** = Environmental condition is under significant stress, OR pressure likely to have significant impact on environmental condition/ human health.
- **Unknown** = Data is insufficient to make an assessment of status and trends.
- **NA** = Assessments of status, trends and data quality are not appropriate for the indicator.

Trend

- ↑ Improving
- ↓ Deteriorating
- − Stable
- ? Unclear
- **NA** = Assessments of status, trends and data quality are not appropriate for the indicator.

Data quality

- ● ● ● **High** = Adequate high-quality evidence and high level of consensus
- ● ● ○ **Moderate** = Limited evidence or limited consensus
- ● ○ ○ **Low** = Evidence and consensus too low to make an assessment
- ○ ○ ○ **NA** = Assessments of status, trends and data quality are not appropriate for the indicator.

Key actions

That the ACT Government:

ACTION 1: increase ecological burning to improve the health and biodiversity of native vegetation communities, particularly for grasslands which require more frequent fire.

ACTION 2: increase cultural burning opportunities in partnership with Traditional Custodians and Murumbung Rangers.

ACTION 3: ensure ecosystem and biodiversity outcomes are considered before conducting fuel reduction burns so that ecologically appropriate burning is undertaken.

ACTION 4: in response to increasing fire danger in the ACT, ensure adequate resources are available to reduce the risk of fire impacting on bushfire-prone areas, environmental assets and sensitive ecosystems, and to improve suppression opportunities and effectiveness should a fire occur.

Main findings

Area burnt long-term findings

Since the 2003 bushfires, which burnt an area of 164,000 hectares, there have been no large bushfires in the ACT.

The annual area of vegetation burnt in bushfires since 2003 has mostly been under 100 hectares except for 591 hectares in 2004, 1,474 hectares in 2006, and 443 hectares in 2018.

The area subject to prescribed burning in the ACT has far exceeded that of bushfires accounting for 94% of the 45,000 hectares burnt between 2004 and April 2019.

Area burnt over the reporting period (2015 to 2019)

Over 13,000 hectares were burnt with prescribed burns responsible for 96% (12,540 hectares) of the total area burnt.

There were only two notable bushfires – the 204-hectare Pierces Creek fire in November 2018 caused by an abandoned vehicle being set alight in an act of arson; and the 200-hectare Potters Hill fire in Namadgi National Park in March 2018 caused by a prescribed burn re-ignition.

Fire ignition causes

Most fires in the ACT are deliberately lit. Between 2004 and April 2019, arson accounted for 45% of all non-prescribed burn ignitions in the ACT, compared to 16% for lightning and 10% associated with accidents.

Prescribed burns

Since 2009, fuel reduction burns accounted for 99% (around 31,500 hectares) of all prescribed burns in the ACT.

There is a growing recognition of the importance of fire for vegetation, biodiversity and cultural management in the ACT.

The period 2015 to April 2019 saw a large increase in ecological burning with 270 hectares treated. In addition, 10 hectares were burnt for both cultural and ecological reasons (multiple purpose) and one hectare for cultural purposes only. However, ecological and cultural burns only accounted for 2% of all prescribed burns over the period.

Decisions on fuel reduction burns need to consider ecosystem and biodiversity requirements to ensure ecologically appropriate burning is undertaken.

It is important to develop and maintain a mosaic of burnt and unburnt fuels in strategic locations across the landscape to address both fuel management and biodiversity requirements.

Fire risk 2014–15 to 2018–19

The reporting period saw an increase in the average and maximum Fire Danger Index (FDI), showing a growing trend in potentially more severe fires if they were to occur. Increased FDI also indicates an increasing potential difficulty in fire suppression in the ACT.

The 2018–19 fire season produced the greatest number of very high and high Fire Danger Ratings (FDR) days, and the highest maximum FDI.

The number of days with a very high FDR increased from 11 days in 2014–15 to 44 in 2018–19.

The highest FDR over the period was severe, occurring on 11 days, including 4 days in 2016–17 and 3 days in 2018–19. The highest forecast FDI in the period was 73 in February 2019.

Climate change is expected to increase both average and severe FDI in the future.

INTRODUCTION

This section provides an assessment of the occurrence of fire in the ACT including prescribed burns and bushfires. The occurrence of fire and its impacts is also discussed in sections **5.1 Climate change**, **5.3 Air**, **5.4 Land**, **5.5 Biodiversity**, and **5.6 Water**.

The following indicators are assessed:

- F1: Area burnt in prescribed burns and bushfires
- F2: Fire risk

The ACT has a high risk of bushfires with large areas of forest in the Namadgi National Park, Tidbinbilla Reserve and the Lower Cotter Catchment. This risk extends to the Canberra urban area which is characterised by a mosaic of suburbs and bordering bushland, grassland and forests of the Canberra Nature Park.

Fires are a natural occurrence in the Australian landscape, necessary to maintain the health of many native species and ecosystems. The ACT landscape has evolved with fire and Aboriginal people developed a sophisticated understanding and use of fire to manage land and resources and reduce bushfire risk.[1] More information on the importance of fire to Aboriginal culture in the ACT, including cultural burning for land, biodiversity and heritage management, is in **Chapter 2 Ngunnawal Country**.

Bushfires can have devastating impacts on biodiversity, as well as human settlements and the natural resources communities depend on. Such impacts are mainly the result of changes in fire occurrence and severity. Increased human sources of ignition, the suppression of natural fire to protect human life and assets, and prescribed burning practices for the management of fuel loads can change the natural fire regimes required for biodiversity and ecosystem health. In addition, increased periods of drought and higher temperatures have increased the risk of more frequent and severe fires.

Changes to natural fire regimes and the increasing risk of fire occurrence have many potential social, environmental and economic impacts, such as:

- increased occurrence of severe bushfires pose significant risks to human health through death and injury, and smoke pollution.
- increased property and infrastructure loss, both in rural locations and Canberra's suburbs in bushfire-prone areas.
- changes to ecologically appropriate natural fire regimes can have significant impacts on the composition of vegetation communities and the ecosystems they support.
- post-fire rainfall and runoff can degrade water quality affecting aquatic health and biodiversity.
- degraded water quality in catchments and water storages, leading to increased treatment costs for water supply.
- reduction in streamflow and inflows to water storages due to the increased uptake of water for plant regeneration.
- loss of important heritage, particularly Aboriginal heritage sites, historic sites in rural areas, and damage to landscapes.
- loss of agricultural buildings and infrastructure, crops and animals, and plantation forests, and
- smoke from both bushfires and controlled burns increase air pollution, especially particulate matter and summer smog, which is particularly significant for those with asthma and chronic lung disease.

1 Emergency Services Agency, 2019, *Strategic Bushfire Management Plan 2019–2024*, ACT Government, Canberra.

Increasing bushfire risk in the ACT

Climate change is increasing the risk from bushfires in the ACT. Higher average temperatures, reductions in rainfall, and increased occurrence of severe events such as heatwaves and storms (see section **5.1 Climate change**) have led to more days of elevated fire danger conditions and longer and more severe bushfire seasons in the ACT.

Typically, the ACT bushfire season occurs from the beginning of October until the end of March the following year. However, climate conditions in the ACT are leading to extensions of the fire season. For example, in 2018–19 the bushfire season commenced in September and was extended to the end of April in response to climate conditions, the longest fire season since 2003.

The growth in the ACT's population and extension of urban areas also increases the risk of fire impacting on people and property. Having more people living close to grassland, nature parks or other areas of vegetation means more houses and people within bushfire-prone areas.[2]

Prescribed burning

Prescribed burns are mainly used to reduce fuel loads (surface litter, bark and understorey shrubs). The objective is to reduce the risk of bushfires and potential impacts on people, property, infrastructure, ecosystems and environmental assets such as water catchments. Reduced fuel loads may also improve the effectiveness of fire-suppression activities during bushfire events. Fire-sensitive ecosystems and those still recovering from bushfires are generally excluded from fuel reduction burning.

Ecological burns are undertaken to improve the condition of ecosystems and biodiversity. Ecological burns vary in size, frequency and patchiness to meet biodiversity and ecological outcomes. This is important where species and ecosystems depend on fire for regeneration and regrowth (see *case studies: Grassland Earless Dragon* and *Grassland restoration* in section **5.5 Biodiversity**). Some fuel reduction burns can also have ecological outcomes, for example where vegetation communities are not exposed to fire for extended periods and are outside of their ecologically appropriate natural fire regimes.

Cultural burns are also undertaken in the ACT. The need for cultural burns is determined by Traditional Custodians and Murumbung Rangers to meet cultural objectives for specific locations. The burns are conducted in consultation with Traditional Custodians.

It is important that fuel reduction burns consider ecosystem and biodiversity requirements to ensure ecologically appropriate burning is undertaken. However, this can be difficult where property and asset protection is the main purpose of fuel reduction.

The delivery of the prescribed burn program in the ACT is always limited by seasonal and climatic conditions. Increased temperatures and reduced rainfall in the ACT are making it more difficult to undertake burning activities, particularly in late autumn and spring. The current climate has not only reduced the period suitable for prescribed burns, but has also increased the likelihood of unpredictable weather occurring that may impact prescribed burns already underway.

In addition to prescribed burning, the ACT Government undertakes a range of fuel reduction activities including slashing and mowing, grazing and the physical removal of fuels.

2 Emergency Services Agency, 2019, *Strategic Bushfire Management Plan 2019–2024*, ACT Government, Canberra.

DATA TRENDS

Indicator F1: Area burnt in prescribed burns and bushfires

Since the devastating 2003 bushfires, which burnt an area of 164,000 hectares, there have been no large bushfires in the ACT (Figure 1). The annual area of vegetation burnt in bushfires since 2003 has mostly been under 100 hectares except for 591 hectares in 2004, 1,474 hectares in 2006, and 443 hectares in 2018. Since 2003, the area subject to prescribed burning has far exceeded that of bushfires, accounting for 94% of the 45,000 hectares burnt between 2004 and April 2019.

During the reporting period (2015 to 2019), over 13,000 hectares were burnt in total with prescribed burns responsible for 96% (12,540 hectares) of the total area burnt (Figures 1 and 2). Bushfires burnt around 530 hectares with most fires burning only small areas, with two exceptions: the 204-hectare Pierces Creek fire in November 2018, caused by an abandoned vehicle being set alight in an act of arson; and a fire in Namadgi National Park in March 2018, caused by a prescribed burn re-ignition which burnt around 200 hectares.

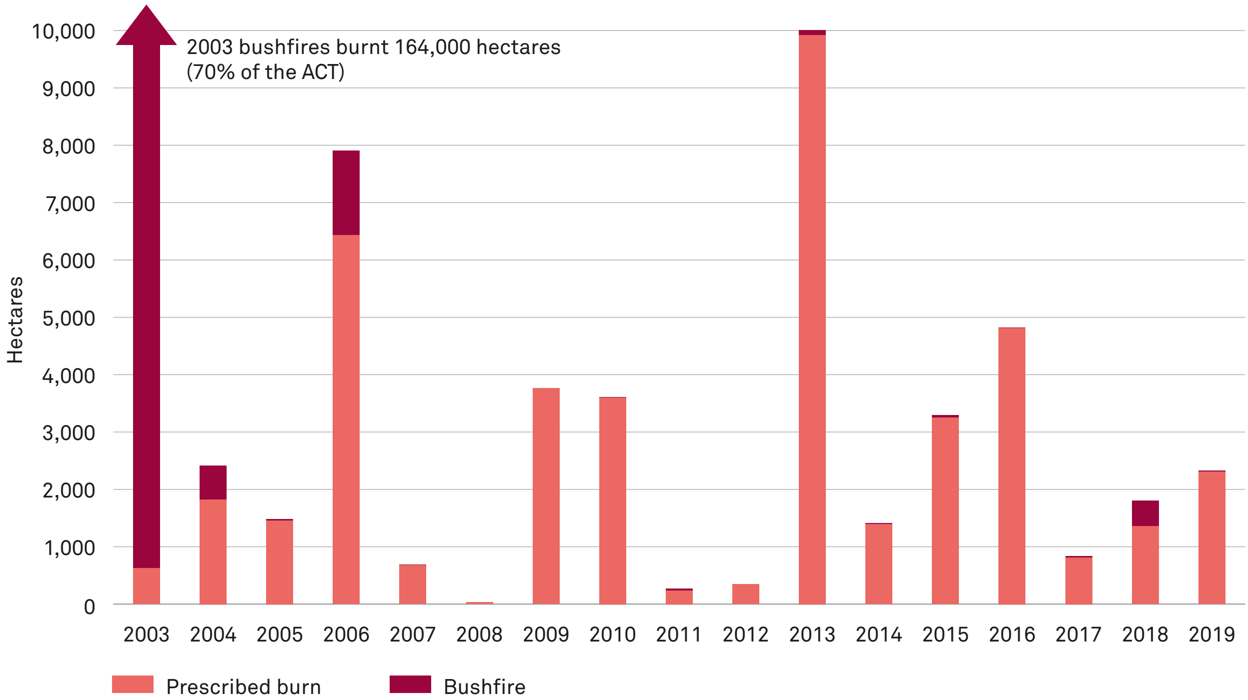


Figure 1:
Area of prescribed burns and bushfires in the ACT, 2003 to April 2019.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

Note: Bushfires include all non-prescribed fire in any vegetation type.

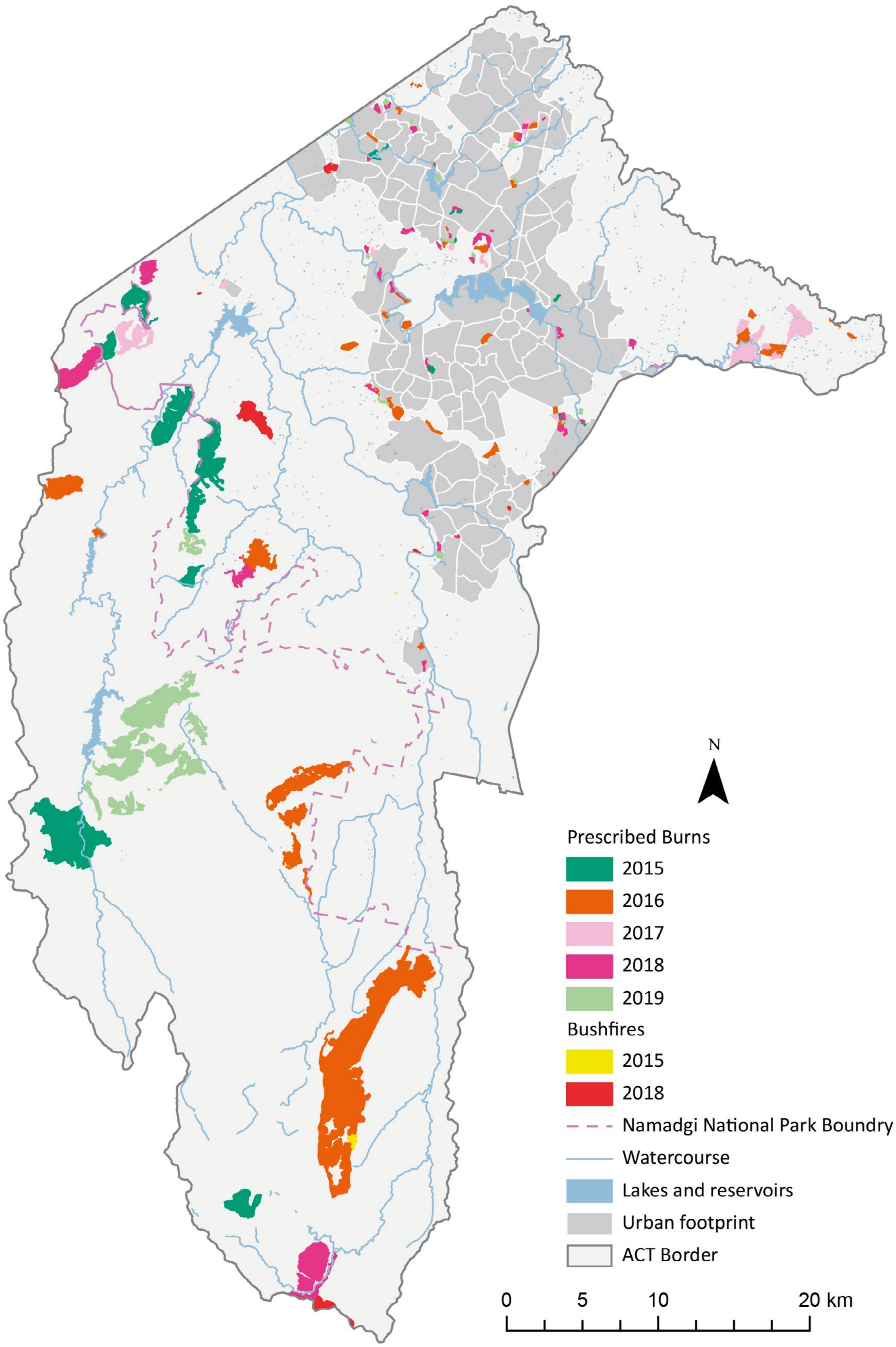


Figure 2:

Area of prescribed fires and bushfires in the ACT, 2015 to April 2019.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

Note: Bushfires include all non-prescribed fire in any vegetation type.

Prescribed burning

The vast majority of prescribed burns in the ACT are undertaken for fuel reduction purposes (Figure 3). Between 2009 and April 2019, fuel reduction burns accounted for 99% (around 31,500 hectares) of all prescribed burns in the ACT.[3]

Ecological and cultural burning has increased in the ACT (Figure 4). The period 2015 to April 2019 saw a large growth in ecological burning with 270 hectares treated, although this only accounted for 2% of all prescribed burns. In addition, 10 hectares were burnt for both cultural and ecological reasons (multiple purpose) and one hectare for cultural purposes only. These results demonstrate the ACT's growing recognition of the importance of fire for vegetation, biodiversity and cultural management.

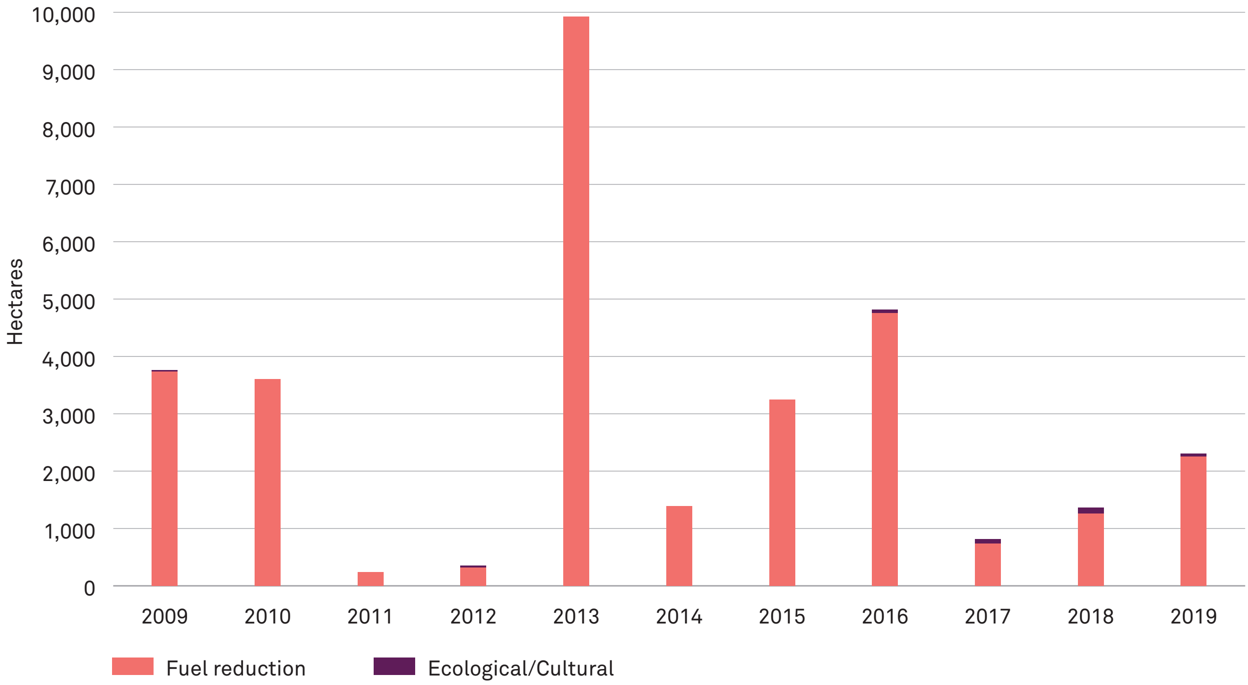


Figure 3:
Area of prescribed burns by purpose in the ACT, 2009 to April 2019.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

Note: 2009 represents the first year of available data for ecological/cultural burns.

3 2009 is the first year of available data for ecological/cultural burns.

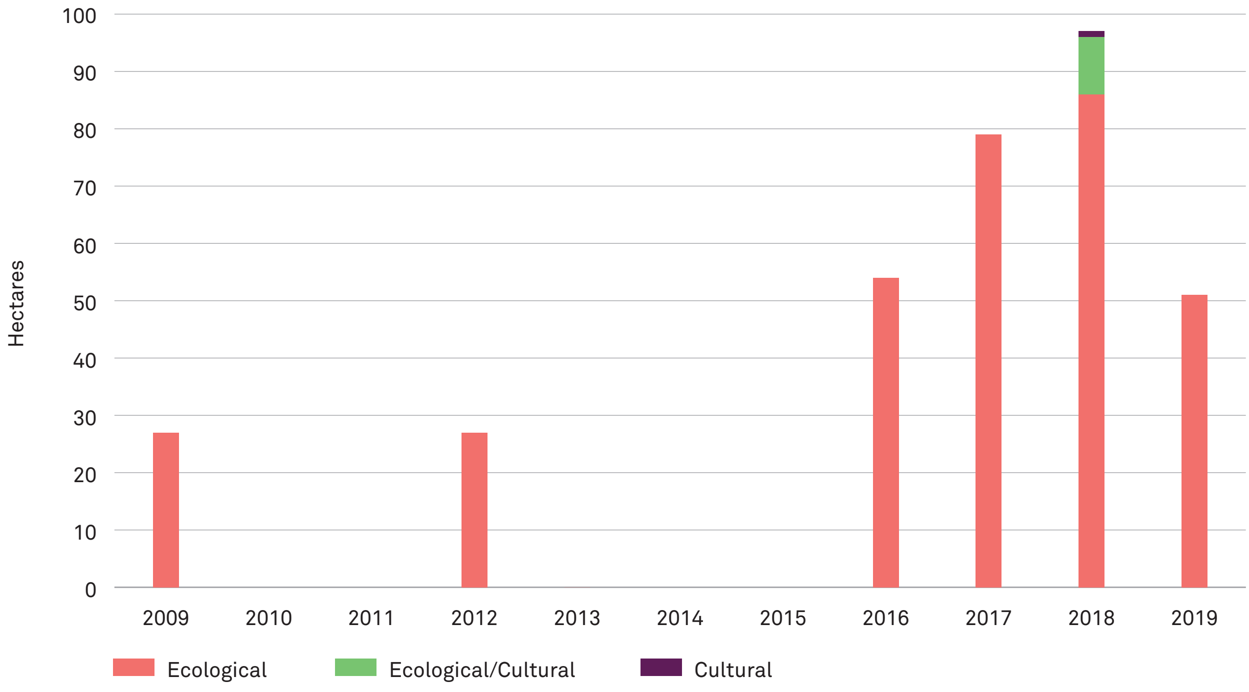


Figure 4:
Area of ecological and cultural prescribed burns in the ACT, 2009 to April 2019.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

Note: 2009 represents the first year of available data for ecological/cultural burns.

Cultural burning. Source: OCSE.

Causes of bushfires

Bushfires are started by natural causes such as lightning, and by human causes. Human-caused ignitions include deliberate acts such as arson and illegal burning-off, as well as through accidents or careless acts. They also include ignitions from power lines, motor vehicles, campfires, motor vehicle accidents and sparks from machinery.

Between 2004 and April 2019, arson accounted for 45% of all non-prescribed burn ignitions in the ACT, compared to 16% for lightning and 10% for accidents (Figure 5). These results show that most fires in the ACT are deliberately lit. For many fires, however, the cause cannot be ascertained with unknown ignition source fires accounting for nearly 30% of the total fires recorded between 2004 and April 2019.

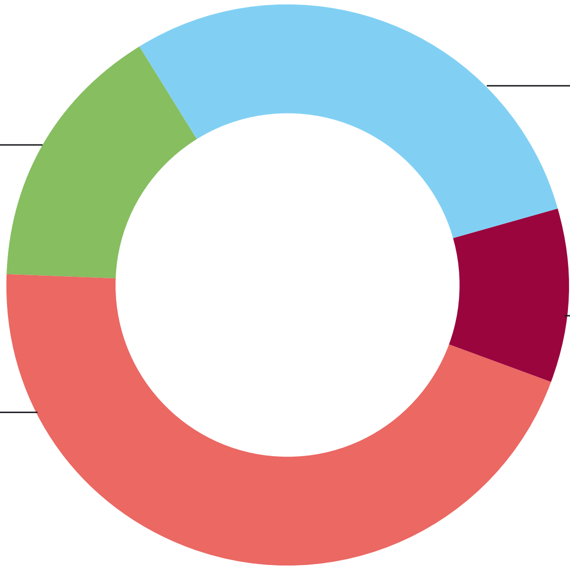


Figure 5:
Ignition sources for all ACT bushfires, 2004 to April 2019.

Data sourced from: Environment, Planning and Sustainable Development Directorate
Note: Bushfires include all non-prescribed fire in any vegetation type. Unknown/other includes one prescribed burn re-ignite in 2018.

Indicator F2: Fire risk

The Fire Danger Index (FDI) assesses the potential severity of bushfire occurrence given the predicted conditions. The FDI reflects the difficulty of suppression should a fire occur, and also the risk to community, property and landscape. FDI is determined by the Bureau of Meteorology based on forecast air temperature, relative humidity and wind speed, along with drought conditions and soil moisture levels. It should be noted that FDI does not reflect the observed conditions on the day, which may differ from those forecasted. The FDI is used to determine the Fire Danger Rating which provides a simplified indication of potential fire consequences (Table 1).

The FDI expresses bushfire potential using a number scale. An FDI of 1 means a very low risk of fire occurring and that it will be easy to control; an FDI of 100 means that fires will have the potential to be so severe that control is virtually impossible. Elevated fire danger conditions (severe, extreme or catastrophic) occur when the FDI is greater than 50. Days of elevated fire danger conditions are not common in the ACT, averaging less than three days a year, usually in January.[4] However, climate change is expected to increase both average and severe FDI in the future.

4 Emergency Services Agency, 2019, *Strategic Bushfire Management Plan 2019–2024*, ACT Government, Canberra.

Table 1:
Fire Danger Index scores and Fire Danger Ratings used for fire risk in the ACT

Fire Danger Index range	Fire Danger Rating
100 – 1,000	6 Catastrophic
75 – 99	5 Extreme
50 – 74	4 Severe
25 – 49	3 Very High
12 – 24	2 High
0 – 11	1 Low–Moderate

Data sourced from: Environment, Planning and Sustainable Development Directorate

Over the 2014–15 to 2018–19 period, the average and maximum FDIs have increased (Figure 6). Whilst this timeframe is too short to suggest an ongoing trend, it does show a growing fire danger in the ACT over the period. The 2018–19 fire season had the highest fire danger over the reporting period, with the greatest number of very high and high days, and the highest maximum FDI.

The data also shows that:

- the number of days with a very high FDR showed the greatest increase over the period, from 11 days in 2014–15 to 44 in 2018–19.
- the highest FDR over the period was severe, occurring on 11 days including 4 days in 2016–17 and 3 days in 2018–19; extreme and catastrophic ratings were not forecast.
- the highest forecast FDI in the period was 73, occurring in February 2019, followed by 72 in January 2019, and 63 occurring in both February 2018 and January 2017, and
- days of high, very high and severe FDR occur most often in January (104 days), followed by December (93 days).

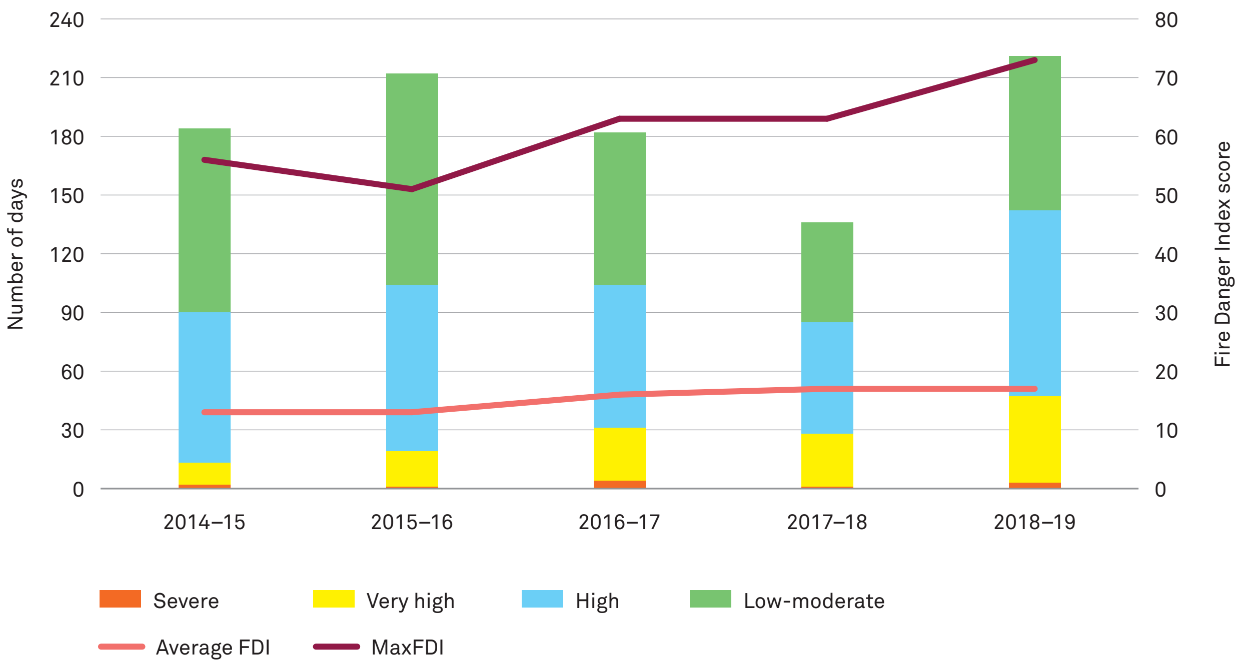


Figure 6:
Number of days in Fire Danger Rating categories, and average and maximum Fire Danger Index scores in the ACT, 2014–15 to 2018–19.

Data sourced from: Environment, Planning and Sustainable Development Directorate.

Note: Only includes data from each fire season which is between 1 October and 30 April, except for 2018–19 which commenced on 1 September.

CASE STUDY
DEVELOPING A RESIDUAL RISK APPROACH TO FIRE MANAGEMENT IN THE ACT

Source: Environment, Planning and Sustainable Development Directorate

The ACT Government is developing a new residual risk approach to inform bushfire management. Residual risk describes the amount of bushfire risk which remains after bushfires and prescribed burning activities have reduced fuel loads. The approach not only informs managers where fuel management activities will have the greatest effect in reducing risk to life, property and the environment, but also enables assessments of the effectiveness of fuel reduction activities already undertaken.

Residual risk is assessed using computer modelling to generate bushfire simulations across the entire ACT and surrounding areas of NSW. These simulations estimate fire behaviour and are based on fuel load changes following prescribed burning and previous bushfires. The potential impacts on life and property that remain after fuel reduction is called the residual risk. If residual risk is 100%, there has been no fire in the landscape and no fuel reduction activities undertaken. This results in a maximum risk of potential fire impacts on life and property. If residual risk is at 50%, the potential risk is reduced by about half.

Whilst it is not possible to completely remove all bushfire risk, the ACT's fuel management program is focused on maintaining a residual risk of between 30% and 50%.

Results for residual risk modelling are shown in Figure 7. The 2003 bushfires reduced the residual risk in the ACT from 85% to 11%. However, as vegetation recovers and fuel loads increase, so does the residual risk. Since the 2003 fires, prescribed burning activities to reduce fuel loads, in both ACT and NSW, have kept the residual risk to below 35%, well within the ACT residual risk target. Based on modelling outcomes, if there is no fuel reduction, residual risk is estimated to increase to over 60% by 2030.

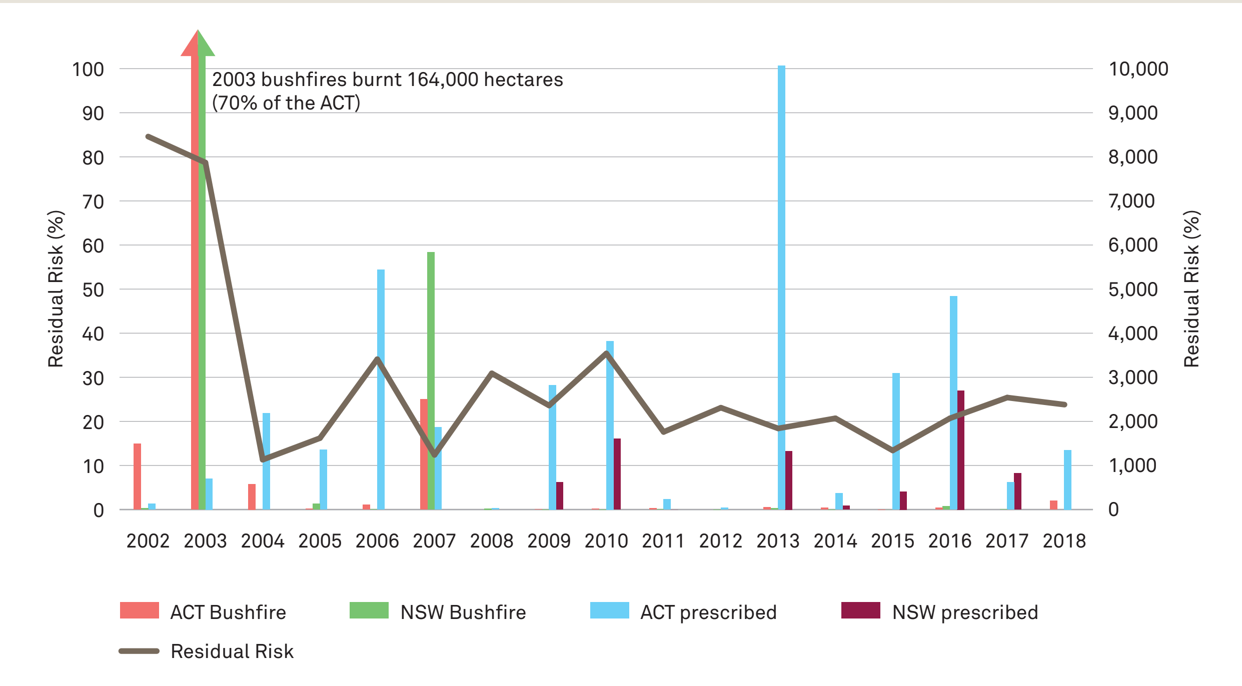


Figure 7:
Fire residual risk and ACT region prescribed burns and bushfires, 2002 to 2018.

Data sourced from: Environment, Planning and Sustainable Development Directorate.