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Environmental Issues in Australia

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Abstract

Australia is a mineral-rich country with low and variable rainfall and, hence, biological productivity, as well as a predominately coastal population. Since European settlement in 1788, a range of landscape impacts, species introductions, and freshwater conflicts have led to serious environmental issues. Contemporary drivers of environmental change include population growth and associated development; water use for food production; resource extraction by the fishery, forestry, mining, and oil and gas industries; and climate change. A range of international agreements have influenced domestic environmental policy, culminating in Australia's foremost piece of environmental legislation, the Commonwealth Environment Protection and Biodiversity Conservation Act 1999. Despite sound legislative instruments and policy intentions, a range of contemporary environmental issues associated with coal seam gas extraction, freshwater allocation, fisheries, and climate change illustrate that shortcomings in resolving environmental issues and obstacles remain with regard to improving the status of the environment. Given the increasing pressures on the environment, greater oversight and efficient enforcement are needed, particularly given population projections and plans for economic development.

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1. INTRODUCTION

Human activity is having a significant and escalating impact on the global environment, reducing the resilience and capacity of ecosystems for delivery of vital ecosystem services, including provision of food and water and protection from natural disasters (1, 2). Transgressing planetary boundaries associated with the Earth's biophysical subsystems or processes may be deleterious or even catastrophic owing to the risk of crossing thresholds that will trigger nonlinear, abrupt environmental change (3). Many environmental threats and impacts are linked to growing human populations; the global population now exceeds seven billion people and is tracking toward nine billion by 2050 (4).

Most environmental issues arise as a result of human-induced habitat modification, resource use, and waste disposal. Examples include air and water pollution, impacts on biodiversity as a result of direct (e.g., hunting and fishing) or indirect activities (habitat clearing, pesticide use), and reduction of freshwater flows as a result of diversion (irrigation) or storage (dams) for human use. Despite increased global awareness of the need for conservation, declines in habitat and biodiversity are continuing, and many conservation challenges are linked to increasing population and associated development pressures (5, 6). Protection and availability of freshwater for natural and human uses is an escalating conflict, and movement of species around the world has also led to a range of environmental issues (5). Climate change compounds many issues, particularly those involving freshwater, food security, coastal management, and biodiversity conservation (7, 8).

Although issues of resource depletion and scarcity existed in many preindustrial civilizations, the emergence of the modern environmental movement in the 1960s shaped the current international framework and the policy and legislative response nationally (9, 10). To solve or manage environmental issues in the Anthropocene (11) will require new approaches and, most likely, significant compromise between resource use and conservation (3, 12). Some countries may be addressing local or regional environmental issues, but issues such as anthropogenic climate change are global environmental challenges, and solutions will require international cooperation.

Here we examine a range of contemporary environmental issues in Australia, a country that is at the forefront of environmental management but has considerable ongoing environmental challenges (6, 13, 14). Through Australian examples, we explore the trade-offs between human

uses of environmental goods and services and the preservation of resilient, functioning natural environments (marine, terrestrial, and freshwater) as well as the institutional, policy, and legal responses to those challenges.

To provide background for these challenges in current environmental management, we summarize the dominant features and current status of the Australian environment before explaining how environmental management is governed (Section 2). We explore a range of current marine and terrestrial environmental issues (Section 3) and identify trends from these and other examples (Section 4). We describe a range of policy innovations that may improve environmental outcomes and conclude with prospects for environmental management in Australia (Section 5).

2. THE AUSTRALIAN ENVIRONMENT

2.1. Overview

Australia is a single-country island continent sitting in the middle of its own continental plate. This means that little to no renewal of terrestrial rock strata has occurred via volcanic activity, and erosion is the main landscape formation process (5). Most soils are millions of years old, some have high levels of salt, and all are considered infertile by world standards (15). Australia is the driest inhabited continent, with much of the continent considered desert (5, 14). These low-productivity soils, coupled with low rainfall, have resulted in a nutrient-poor landscape with low levels of vegetation biomass over the majority of the continent (5, 16). Despite this low fertility, Australia is considered mega-diverse, with unique biodiversity resulting from its evolutionary history related to the separation from Gondwana (5).

Human-induced changes to the environment, including species depletion owing to hunting and altered fire regimes, occurred following the first arrival of humans (~50,000 BCE) (17, 18), but these impacts accelerated following European settlement in 1788 because of the introduction of northern hemisphere agricultural and land-use practices (5). The early years of European settlement saw a dramatic reduction in the indigenous population; large-scale land clearing; and impacts on the native fauna as a result of early species introductions such as cats, foxes, and rabbits (17). These changes, as well as poor soils and limited freshwater, have undermined environmental quality in many regions.

Australia's biodiversity is both rich and unique: Between 7% and 10% of all species on Earth occur in Australia, totaling an estimated 566,398 species (19). However, historical management of these riches has not prevented substantial losses. Less than 10% of pre-1750 vegetation remains in the intensive use zones of southeastern and southwestern Australia (5, 14). Native vegetation loss continues at a rate of nearly 1 million ha annually in Australia (14). Terrestrial and freshwater ecosystems have suffered high rates of species extinctions and extensive degradation since European settlement (6, 14, 20); at least 23 birds, 4 frogs, and 27 mammal species have become extinct, the last accounting for more than one-third of all contemporary mammal extinctions worldwide (17).

The consequences of past environmental management in Australia continue to cause concern to some land users and managers. The historical introductions of animals and weeds, widespread land clearing, drainage of wetlands, overexploitation of fish stocks, and pollution continue to influence the health of land and freshwater terrestrial systems (14, 20, 21) despite policies and resource management techniques that now prohibit or minimize such actions (14). Approximately 16% of Australia's terrestrial area is protected (22), but many reserves are small and isolated, and key ecosystems and species are underrepresented (14, 23).

Australia's 60,000-km coastline spans tropical waters in the north to cool temperate waters off Tasmania and the sub-Antarctic islands. Australia's exclusive economic zone is more than

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~8.1 million km^2 (excluding Australian Antarctic Territory). Its marine ecosystems are considered globally significant, as they include many rare, endemic, and commercially important species (24–26). Important coral reefs occur in northeastern and northwestern Australia, with the Great Barrier Reef being notable for its World Heritage listing (27). Australia is bounded to the east and west by poleward-flowing boundary currents that move nutrient-poor tropical waters southward (28). Thus, as on land, marine Australia is considered a low-productivity environment (26, 28).

Australia's current population is heavily concentrated along the coast, as approximately 85% of its 23 million citizens live within 50 km of the coast (29). Coastal stressors associated with coastal development, such as habitat clearance, pollution, and sedimentation, have modified the environment in many areas (e.g., 30). The nearshore region that was historically exploited by commercial fisheries now faces additional pressures from recreational fishers, the oil and gas industries, and marine tourism enterprises (see Section 3).

Although no extinctions in Australian marine waters are known, loss of coastal habitats, such as saltmarsh, mangrove, and sea grasses, is significant (29), as are regional declines in iconic marine fauna including sea turtles, marine mammals, and seabirds (26). Marine protected areas (MPAs) protect between 0.3% and 13% of state waters; if the proposed marine plans for Commonwealth waters are implemented, Australia will protect ~36% of its marine jurisdiction in MPAs and ~13% in no-take marine reserves (31). Significant regional gaps exist in the present reserve coverage, even in biologically sensitive areas (31, 32).

Contemporary drivers of environmental change that contribute to environmental degradation include (*a*) population growth and associated development; (*b*) food production, including erosion, dryland salinity, and fertilizer and water use; (*c*) resource extraction and use, such as that by fisheries, forestry, mining, and oil and gas development; and (*d*) climate change. The status of Australian terrestrial, freshwater, and marine species, habitats, and ecosystems is summarized in a range of comprehensive and sectoral reports (see the sidebar titled Environmental Reporting in Australia).

2.2. Climate Variability and Change in Australia

Climate variability is a major environmental driver in Australia that indirectly contributes to a range of stressors. Much of the continent is strongly influenced by large-scale drivers of global climate variability, such as the El Niño-Southern Oscillation and the Indian Ocean Dipole (34–36).

ENVIRONMENTAL REPORTING IN AUSTRALIA

Environmental reporting occurs in several forms. National State of the Environment reporting is legislatively mandated by the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (33) and provides information about environmental and heritage conditions as well as trends and pressures for the Australian continent, surrounding seas, and Australia's external territories. Assessments occur every five years (**http://www.environment.gov.au/topics/science-and-research/state-environment-reporting**). The fourth report, issued in 2011 (14), identifies climate variability and change, population growth, and economic growth as the principal drivers of Australia's current and future environment. Additional specialty (e.g., marine and terrestrial) reporting also occurs nationally (e.g., Climate Change Report cards, **http://www.oceanclimatechange.org.au**, **http://terrestrialclimatechange.org.au**), regionally [e.g., Queensland healthy waterways (**http://www.healthywaterways.org**)], and locally [e.g., Derwent estuary (**http://www.derwentestuary.org.au**)].

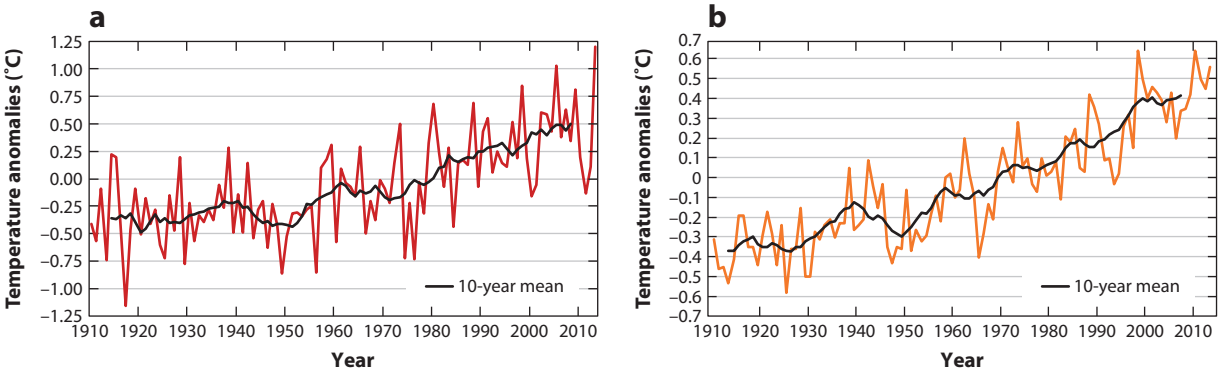

Figure 1

Annual mean temperature anomalies for Australia (compared with the 1961–1990 average): (*a*) land surface temperatures and (*b*) sea surface temperatures. The black line shows the 10-year moving average. Figure adapted from **http://www.bom.gov.au/climate/current/annual/aus/2013**.

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Recurring drought contributes to soil erosion and degradation of freshwater-dependent ecosystems in areas where human uses of water conflict with environmental requirements. Arid regions of Australia have highly variable rainfall and runoff from year to year, with standard deviations of approximately 60–100% or more of the long-term mean (37).

As the driest inhabited continent, Australia's natural and human systems are also particularly vulnerable to the effects of climate change (7, 38). The impacts of climate change may exacerbate or ameliorate some of the environmental issues on land (39) and in the ocean (40). Climate change will also influence the effectiveness and costs of responses to some of the other environmental issues described in Section 3. Australian average surface temperatures rose by nearly 1°C between 1910 and 2009 (38). Warming was modest in the early part of this period, declined slightly between 1935 and 1950, and then rapidly increased. The decade 2000–2009 was the warmest on record, and 2013 was the warmest single year since comprehensive record keeping began in 1910 (41) (**Figure 1**). Rainfall changes are also associated with climate variability and change, although long-term trends are more difficult to distinguish than those for temperature, given the large natural variability across regions and over time. During recent decades, cool season (April to November) rainfall has largely decreased in the southwest and southeast when compared with natural variability. Winter season rainfall in the southwest of Western Australia has declined by approximately 15% since the mid-1970s (42, 43). Climate models project that, by 2030, average annual temperatures across Australia are likely to warm by an additional 1°C (above 1990 temperatures), with warming of 0.7–0.9°C in coastal areas and 1–1.2°C inland (38). Further drying is likely in southern areas of Australia and the southwest (44), whereas future changes in summer tropical rainfall in northern Australia remain highly uncertain (38, 43).

Climate-related terrestrial impacts have already been reported in a wide range of species, including changes in the distribution of birds (45), local abundance of koalas (46), breeding phenology of seabirds (47), sex ratios of lizards (48), and heat-related mortalities of bats and cockatoos (49, 50). Climate change is also affecting the oceans around Australia, with seas warming in most areas (**Figure 1**) (26, 43). Average marine climate zones have shifted more than 200 km south along the northeast Australian coast and approximately 100 km along the northwest coast (51). The rate of warming is faster in southeast Australia, owing in part to the ~350-km poleward advance of the East Australia Current (52, 53). Based on elevated rates of ocean warming, southwest and

southeast Australia are recognized as global warming hotspots (53–56), and climate impacts are likely to be most rapid in these regions (56). Habitat-related climate impacts are more prevalent in the waters of northern Australia (21), whereas species distribution changes have been more prevalent in southern waters (55, 57, 58).

Many observed ecological changes in Australian waters have been associated with ocean warming, although it remains difficult to separate the impacts of interacting nonclimate stressors, including habitat degradation, coastal pollution, and fisheries. In one case in which separation has been possible, on the Great Barrier Reef, 10% of the observed 50% decline in coral cover has been attributed to coral bleaching during periods of elevated temperature and the remainder to cyclones and predators (59). Rates of sea level rise vary around Australia; in some places sea level rise coupled with storm surge is contributing to coastal erosion and loss or landward retreat of coastal habitats (29, 60), and in the future it may threaten a range of coastal infrastructure (e.g., 29, 61).

2.3. Environmental Management in Australia

Appropriate governance arrangements are critical to the resolution of environmental disputes and issues. Here we describe the governance framework for environmental decision making, including the institutional, legal, and policy factors that influence current approaches.

2.3.1. Institutional arrangements for environmental governance. Both historical approaches to, and current trends in, environmental management and protection are deeply influenced by Australia's constitutional arrangements (9, 62). Australia has a federal governance structure, and the Constitution of Australia dictates the roles of the Commonwealth vis-à-vis the Australian states. The Australian Constitution does not give the federal government express power to legislate with respect to the environment, and this has meant that the states have had historical responsibility for the development and implementation of policy and law regulating resource exploitation, conservation, and environmental protection.

The federal government has used other constitutional heads of legislative power, such as the external affairs, corporations, and interstate trade or commerce powers, to enact measures aimed at fulfilling Australia's international treaty obligations and resolving management issues that have cross-border implications. The High Court of Australia has interpreted these powers so broadly that the Commonwealth could enact wide-ranging environmental laws, but successive governments have preferred a policy of cooperative federalism (9, 63). Roles and responsibilities for environmental matters are allocated between the federal and state governments along the lines articulated in the 1992 Inter-Governmental Agreement on the Environment (IGAE) (64). The IGAE laid the foundation for Australia's foremost piece of environmental legislation, the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (33). The EPBC Act establishes a process for Commonwealth environmental impact assessment with respect to proposals undertaken by the Commonwealth or activities likely to have a significant impact on one of nine listed matters of national environmental significance, namely, world heritage places, national heritage places, wetlands of international importance, listed threatened species and ecological communities, migratory species, Commonwealth marine areas, Great Barrier Reef Marine Park, nuclear actions, and water resources with respect to coal seam gas (CSG) and coal mining developments. To reduce overlap and streamline approval processes, the EPBC Act provides for the negotiation of bilateral agreements with states and territories. Assessment bilaterals accord full faith and credit to the state or territory assessment process but leave the final decision on approval to the Federal Environment Minister (33, section 47). Approval bilaterals effectively delegate Commonwealth decision making over the matter to the states (33, section 46) and are thus strongly opposed by

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environmentalists concerned about states acting for short-term state economic gain at the expense of nationally important environmental values (65). All jurisdictions have assessment bilaterals, but currently only one approval bilateral, related to management of the Sydney Opera House, exists. The EPBC Act also established the Commonwealth's approach to the listing and protection of vulnerable, threatened, and endangered species and ecological communities—both terrestrial and marine—and the establishment and management of Commonwealth reserves.

Absent from the Australian Constitution is any reference to the third tier of government—local government. In an increasingly decentralized and polycentric environmental governance landscape (10), local governments carry significant responsibility for a wide range of environmental decisions and duties. However, as creatures of state government enactment, they have no independent status or sources of revenue. This fiscal imbalance can lead to inconsistencies in the quality of environmental oversight and regulation and means that many functions that are formally delegated to local government, such as land use planning and management, may not be performed adequately (66, 67).

The governance framework that emerges from these constitutional, legislative, and fiscal arrangements is multilayered, complex, and often either duplicative or poorly coordinated. This has resulted in criticisms that excessive "green tape" unnecessarily hinders resource and other economically important development (68, 69). As discussed in Section 4, the current response to these shortcomings is to wind back legislative protections rather than to address the issues of overlap, delays, and fragmentation.

2.3.2. Sources of Australian environmental policy. The Australian Constitution is silent with respect to any right to a clean or healthy environment, so Australia's overarching environmental duties derive from international agreements, including both binding treaties and aspirational documents such as the Rio Declaration. Australia is a signatory to all major multilateral environmental agreements and many regional and bilateral treaties (**http://www.dfat.gov.au/environment/treaties.html**). These cover a wide range of subject matter, including world heritage protection, transboundary movement of hazardous waste, ozone depletion, climate change, conservation of biological diversity, marine pollution, migratory birds, wetlands, various hazardous chemicals, and whaling. Although many of the obligations contained in these agreements are nonbinding, collectively they provide a strong normative framework for Australia's national system of environmental protection (10, 62).

2.3.3. Current approaches to environmental management. Along with Australia's federal structure, the major factor that influences environmental protection measures is the legal system's protection of private property rights. There have been inroads into the historical reluctance to interfere with the use of private property with the aim of preventing environmental nuisance or protecting species or resources, but the assumption persists that any curtailment of the right to use and enjoy private property should be compensated (9, 70). This limits the range of measures governments are willing to introduce. Perhaps the strongest example of this is the historical "right" of farmers to clear land for agricultural purposes, to stock their land at whatever levels they wish, to extract ground or riverine water for irrigation, and to apply chemicals without regard to the impacts of runoff. Each of these claimed "rights" has been modified by legislation to a greater or lesser degree, but efforts to impose sustainable limits on land and water use or to take an integrated catchment approach to natural resource management must often grapple with political opposition from farmers' advocacy groups (71).

The dominant approach to conserving land for biodiversity, or other natural values, has thus historically focused on the acquisition and reservation of public land. The National Reserve

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System (NRS) remains the key element of national conservation policy. When Australia ratified the 1992 Convention on Biological Diversity (CBD), it undertook to reserve 17% of its bioregions by 2020. The Terrestrial NRS currently includes more than 10,000 protected areas, covering 16.52% of Australia's land area (**http://www.environment.gov.au/topics/land/national-reserve-system**); these protected areas are chosen on the basis of the criteria of comprehensiveness, adequacy, and representativeness (72). All states and territories have legislation establishing reserves broadly reflecting the protected area categories of the International Union for the Conservation of Nature (IUCN) (73), including wilderness areas managed to protect wilderness values, national parks for conservation and recreation, and a range of other classifications that incorporate sustainable uses of natural resources. In addition, many local government planning schemes or other statutory instruments contain provisions supporting the identification and protection of high-conservation-value land (9, 74).

The NRS also contains indigenous and private land. The NRS includes 52 Indigenous Protected Areas comprising more than 26 million ha—more than one-third of the entire system (75). Private land is protected using contractual instruments such as conservation covenants that run in perpetuity. As in other countries, land trusts have emerged in recent years as a major force in conservation. For example, the estate of the Australian Wildlife Conservancy includes 23 sanctuaries covering more than 3 million ha, and the Bush Heritage Trust has more than 35 reserves covering nearly 1 million ha. Complementing the terrestrial reserve estate, the Commonwealth formally declared a national representative network of marine protected areas in 2012, although these boundaries are currently subject to review.

3. RECENT ENVIRONMENTAL ISSUES

In this section we describe four recent Australian environmental controversies, with a focus on the policy or legislative setting for resolving or promoting the conflict. These examples address freshwater resource management, fisheries conflicts, mining and CSG extraction, and climate policy. We selected these examples because they illustrate the diverse range of contemporary environmental challenges. We have not attempted to cover all the issues in Australia and acknowledge that conflicts over forestry, groundwater pollution, invasive species management, hunting and grazing in national parks, coastal development, wind farm placement, biodiversity offsets, urban sustainability, and fire management are also prevalent (e.g., 23). We touch on some of these additional issues in Section 4, in which general trends across a range of environmental issues are elucidated.

3.1. Freshwater Allocation and Storage in a Dry Landscape

Freshwater is one of Australia's most valuable natural resources. Tensions over the best use of water resources have played out in a range of contexts over Australia's European settlement history and have influenced the course of Australian politics and constitutional law. The competing demands of irrigation or hydroelectricity generation and the natural values of river systems have dominated these conflicts (76).

The damming of the Snowy River (**Figure 2**) in the 1930s for Australia's first hydroelectric scheme met with little public opposition, but there has been strong advocacy in recent years to restore environmental flows to the river (77). The decision to flood Lake Pedder in Tasmania's remote Southwest National Park in the 1970s prompted the establishment of the world's first Green political party, the United Tasmania Group. Despite a national campaign to prevent the expansion of the Middle Gordon Hydro-Power scheme, the flooding of Lake Pedder proceeded in 1973 (**Figure 2**). In the 1980s, the Tasmanian government's proposal to construct a dam on

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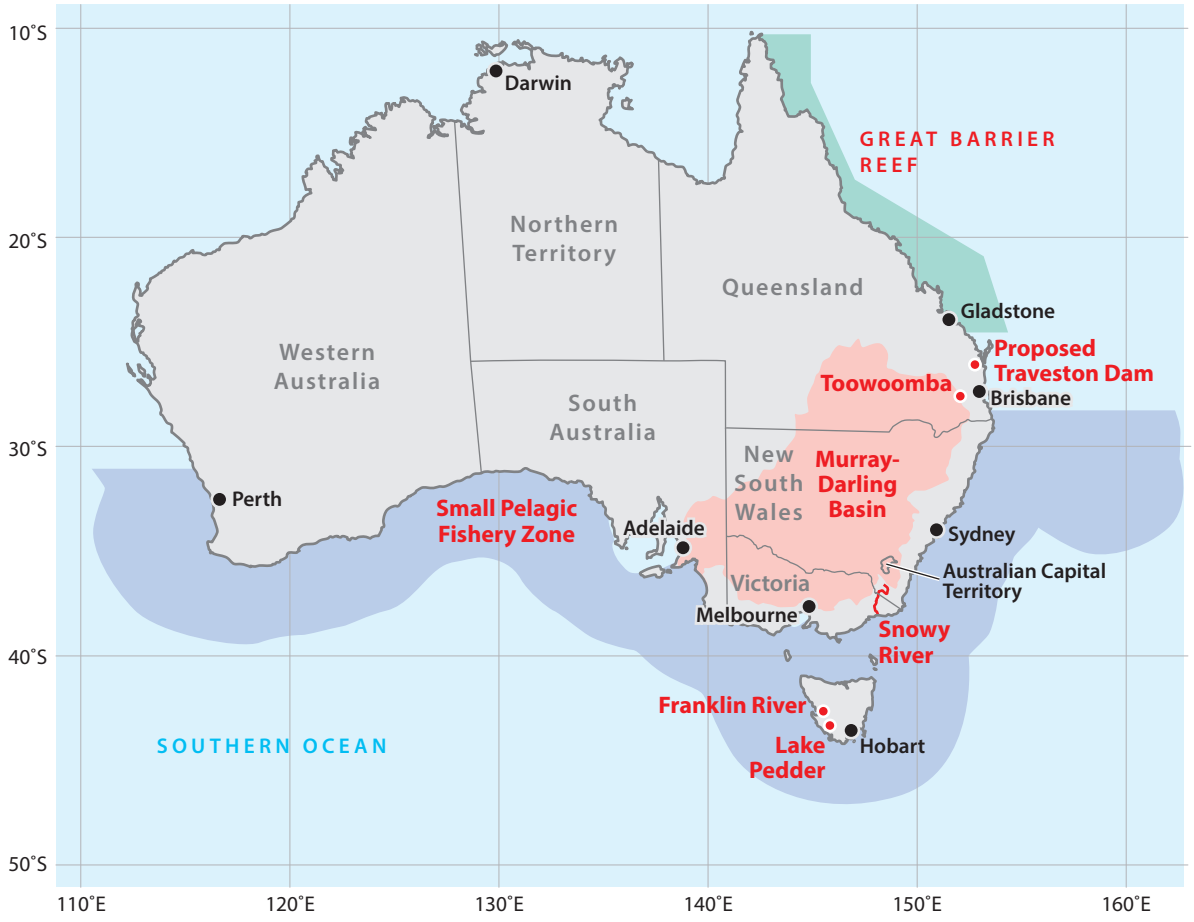

Figure 2

Locations of historical (Lake Pedder, Franklin River, proposed Traveston Dam) and ongoing (Great Barrier Reef, Murray-Darling Basin, Small Pelagic Fishery Zone) environmental conflict in Australia.

the Franklin River (**Figure 2**) led to national political action, a change of federal government, a High Court of Australia challenge that expanded the Commonwealth's constitutional rights over environmental matters, and the emergence of the Green Party as a significant political force in Australia (63, 78).

As it is a dry continent, drought is a recurring condition in Australia, but no drought has been as widespread as the millennium drought from the late 1990s to 2010. This extended dry period affected Australia's most populous cities—Sydney, Melbourne, Brisbane, Adelaide, and Perth—as well as the Murray-Darling Basin (**Figure 2**) and the wheat belt of southwest Western Australia (79). More than AU$4.5 billion in drought relief was provided by state and federal governments to farmers during this period. Despite the breaking of the drought in 2010, climate change portends a future of further water scarcity in south and southwest Australia (80, 81), so the responses to the millennium drought deserve closer attention. These include major reforms to water law at the state and national level and both demand- and supply-side measures to safeguard urban water supplies.

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3.1.1. Water law reform. Agriculture accounts for more than two-thirds of Australia's water consumption (79). A history of overallocation of water licenses for irrigation in southeast Australia has resulted in significant deterioration of inland freshwater ecosystems and dependent species (14), as well as inadequate water security for rural users. The waters of the Murray-Darling Basin are the most contested in Australia. Spanning the states of Queensland, New South Wales, Victoria, and South Australia and the Australian Capital Territory, the Basin supports Australia's major irrigated agricultural regions as well as provides the urban water supply for many major cities and towns, including the South Australian capital of Adelaide. The lack of cooperation between all affected jurisdictions, or a legally enforceable management framework, has exacerbated conflicts between environmental and consumptive uses (82). During the worst of the millennium drought, there was no flow at all from the Murray River mouth, with consequential impacts on estuarine fishes and the Ramsar Convention–listed wetlands dependent upon its flows (24).

Although national water reform was agreed to in 1994 (83), it took a further decade and Australia's worst-ever drought for the National Water Initiative to receive broad endorsement (84, 85). The reforms introduce national- and state-level water planning arrangements that address overallocation and ensure minimum environmental flows for the river systems. They incorporate mechanisms by which to adjust water entitlements in response to changes in resource availability (by shifting from entitlement to a specified volume of water to entitlement to a share in the available supply). In some cases, the guarantee of minimum environmental flows has required a federal government buyback of water rights or properties. Water rights have also been separated from property in land, enabling them to be traded and allocated to their highest value use and thereby enhancing the capacity for property owners to make choices about future land uses (86, 87).

3.1.2. Urban water supply. As well as placing unprecedented pressure on rural water users, the millennium drought raised serious urban water security concerns for Australia's populated eastern seaboard. The response of state governments involved a mix of supply- and demand-side management. On the supply side, Queensland established the SEQ water grid, a network of 535 km of pipe connecting the major storage dams in the southeast of the state (88). Construction of a new storage dam in Queensland was also proposed but ultimately vetoed by the Commonwealth because of its likely impacts on a range of nationally listed threatened or endangered species (89). The town of Toowoomba held a referendum in which residents rejected a plan to use recycled sewer water, although some water recycling eventually occurred (90). Desalination plants have been constructed in New South Wales, Queensland, South Australia, Victoria, and Western Australia. Operation of the Queensland plant, however, has been placed on hold indefinitely because heavy rain in 2009 and flooding in 2011 replenished the major water supply dams in the populous southeast of the state.

Southeast Queensland adopted the most sophisticated, and arguably the most effective, approach to reduce water demand (91). The three-pronged strategy combined an extensive public awareness and education campaign; subsidies for installation of water storage tanks and water-saving appliances, showerheads, and toilets; and severe water restrictions backed up by stiff penalties for noncompliance. The effect was to reduce consumption, per capita, from 700 L/(person·day) in the 1990s to 140 L/(person·day) during the years 2007–2008, with a peak reduction to 112 L/(person·day) during the peak of the drought. These behavioral changes were not sustained when water restrictions were completely removed following the breaking of the drought, although per capita consumption remains considerably lower than during the 1990s.

3.1.3. Future of water allocation in Australia. Although the water reforms of the first decade of the twenty-first century have addressed historical problems of overallocation and misuse, water

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CONDITIONS WITHOUT ENFORCEMENT MAY BE FUTILE

The Paradise Dam on Queensland's Burnett River was completed in 2005 despite concerns about its impact on the Queensland lungfish, which is listed as vulnerable under the EPBC Act (33). Conditions attached to the Commonwealth approval of the dam required the installation and operation of a fishway "suitable for lungfish," to commence "when the dam becomes operational" (94). An AU$20 million fishway was completed, but drought conditions made it inoperable for all but 13 of the first 43 months of the dam's operation. When the Commonwealth Environment Department (CED) failed to act, a regional environmental group sought civil enforcement of the Commonwealth's conditions in the Federal Court of Australia (94). Despite evidence of the fishway's limited operation, the Federal Court concluded that the condition had been met because the fishway did not need to be operable at all times to be suitable. Monitoring reports have subsequently concluded that negligible numbers of fish use the downstream fishway in nonflood conditions, that large numbers of lungfish are killed or severely injured on the fishway during flood periods, and that the cumulative impact on the fish population is likely to be significant (95, 96). Despite the monitoring results and flooding destroying the fishway in 2011, the CED has stated that the lungfish population will be reassessed only following completion of the ten-year monitoring program (97). Clearly, imposing monitoring and reporting requirements demands institutional commitment to their enforcement if they are to be effective management tools (98).

is likely to remain a source of deep contention in Australian environmental and resource policy. Sustainable diversion limits under the Murray-Darling Basin Plan will be reviewed in 2015, and this is likely to reopen debate on the current compromise between consumptive and environmental allocations. Controversies over dams also persist; for example, the Paradise Dam on the Burnett River in Queensland was completed in 2005 despite community protest and legal action seeking to protect the endangered Queensland lungfish (see the sidebar titled Conditions Without Enforcement May Be Futile). In contrast, along with the ill-fated Traveston Dam proposal in Queensland, a major dam proposal for the Hunter region of the New South Wales mid-coast has been shelved (92). Major supply projects are still likely, however, while in opposition the current federal government expressed support for the construction of up to 100 new dams as part of a plan to promote Northern Australia as a major food production region (93).

3.2. Conflict in Marine Fisheries

Australia's marine capture fisheries supply food to domestic and international markets. Together with marine aquaculture, they focus on high-value species, such as lobsters, pearls, abalone, and prawns (99, 100), and represent an AU$2.2 billion/year industry. Australians consume an average of 26 kg seafood per person per year, well above the global per capita average of 17 kg. Although the depletion of fish stocks and the ecological sustainability of global fisheries are issues of international concern (101, 102), Australia leads the world in the ecological status and management of its fisheries (e.g., 103). Reductions in fishing capacity and strict quota management have led to a decline in the number of overexploited stocks in Australian waters; now only 2 of 111 stocks are so classified (100). Harvest strategies that have been implemented are designed to respond to fluctuations in abundance and allow rebuilding to scientifically agreed-upon reference points, where necessary (104). With regard to the target species, therefore, Australian fisheries are relatively uncontroversial.

However, fishing can directly affect a range of other species. These include nontarget species that are retained for sale (by-product species) and bycatch species that are discarded, including

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iconic species such as seals, turtles, seabirds, and dolphins (105–107). Habitat impacts from contact with fishing gear also occur (108, 109). As a result, much recent attention has been directed to the reduction of bycatch, particularly of iconic seabirds, turtles, and marine mammals, and to minimizing habitat damage (e.g., 110). Australia has also been at the forefront of efforts to minimize impacts on protected species and habitats, with fisheries subject to strict controls and even closures if bycatch limits are exceeded (100).

The management of Australia's Commonwealth fisheries falls under the Fisheries Management Act of 1991 (111), which is administered by the Australian Fisheries Management Authority. Strategic environmental assessments are undertaken for all Commonwealth fisheries under the EPBC Act (33) to provide further scrutiny of the ecosystem impacts of a given fishery. This management framework requires independent stock assessments to set catch levels using prescribed rules along with a comparison of the fishery's management plans against an ecologically sustainable development framework developed by the federal environment agency that considers impacts on nontarget species and habitats (112). This regime adopts ecosystem-based fisheries management (EBFM) rather than single-species management. The shift to EBFM over the past decade was driven by several policy directions and initiatives, including (*a*) a national policy commitment to ecologically sustainable development; (*b*) development of fisheries legislation that incorporates explicit reference to wider ecological impacts of fishing (e.g., 111); (*c*) the inclusion of Commonwealth waters in the EPBC Act's environmental impact assessment requirements; (*d*) Australia's Oceans Policy, which adopted an explicit ecosystem-based approach to management (112); and (*e*) international uptake of EBFM (113). A risk-based management approach (114) has been central to implementing the EBFM approach in Australia in both state and Commonwealth fisheries (112, 115–118). These methods have subsequently been widely applied outside Australia (117). This management system has been recognized internationally as having a rigorous base of scientific research and extensive monitoring and compliance (103), but despite this recognition, a recent high-profile conflict illustrates the fragility of an apparently strong scientific process.

In 2012 a fishing company, Seafish Tasmania Pelagic, applied to register a fishing vessel to catch an agreed and allocated quota of small pelagic fish. The vessel in question was a 142-m Dutch factory trawler, fishing vessel (FV) *Margiris*, and would have become the largest fishing vessel operating in Australian waters. The small pelagic fishery principally targets sardines, blue and jack mackerel, and redbait, which have historically been used for aquaculture food, pet food, and commercial bait. The existing fishery is small; of a total allowable catch of 30,300 tonnes, only 535 tonnes were landed in the 2010–2011 season from five smaller vessels without onboard processing or freezing capability (119). This limited onboard processing capability restricted the area of operations to waters close to land-based processing facilities and rendered catches suitable only for aquaculture feed or bait. Seafish Tasmania Pelagic argued that using a factory freezer vessel would increase the value of this relatively small-scale small-profit fishery without increasing the overall catch limit for the fishery (which was fixed by quota). Onboard processing meant that the factory trawler could range widely throughout the fishery zone (**Figure 2**) and the fish could be processed for human consumption, with the goal of providing low-priced seafood to West Africa (120).

The vessel arrived in Australia in September 2012 and, as required by Australian law, was reflagged as the Australian vessel FV *Abel Tasman*. The intent was to immediately start harvesting the fishing company's quota of almost 18,000 tonnes (approximately half of the total quota allocated in the fishery). Despite the potential economic benefits, the arrival of the vessel in Australian waters led to significant opposition, with major environmental groups joining recreational and game fishers to oppose its operation. The primary concerns included the size of the vessel, the bycatch of marine mammals (especially seals and dolphins), and the potential for localized depletion of

small pelagic fish stocks (119, 120). The blanket opposition of powerful international environment nongovernmental organizations to so-called super trawlers was highly influential, and much of the campaign against the *Abel Tasman* invoked impacts that have been experienced in countries with poorly designed and enforced fisheries management regimes (121).

In response to an intense traditional and social media campaign led by international and domestic conservation groups, Green politicians, and recreational fishers, just days prior to the commencement of fishing, the Australian government imposed a moratorium on the operations of this factory trawler by enacting amendments to the EPBC Act that allowed for the declaration of prohibited fishing activities (119). A legal challenge to the legality of the declaration brought by Seafish Tasmania Pelagic in the Federal Court of Australia was unsuccessful (122).

Similar to the protests against the Franklin Dam in the 1980s, the *Abel Tasman* controversy highlights the potential influence of community protest on environmental decision making. In this case, however, this outcome came at the cost of an internationally lauded, evidence-based decision-making framework. Fisheries management involves balancing risks and uncertainty against benefits, with decision makers ideally assessing this risk on the basis of the best available science in combination with social and economic values to derive a precautionary and adaptive management approach to resource use (120). Other apparently well-managed fisheries in Australia must now be considered vulnerable to similar actions, and the seafood industry may need to engage more effectively with the Australian public in support of sustainable fishing.

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3.3. Rapid Growth in Mining and Coal Seam Gas Development

Environmental politics and policy in Australia are increasingly dominated by the dramatic expansion of liquefied natural gas (LNG), coal, and CSG mining and associated export infrastructure, particularly port development. Mining and mineral development has long been a mainstay of the Australian economy, as it dates back to the copper and gold rushes of the nineteenth century and now contributes 8% of gross domestic product and 50% of export value (123). Australia is the world's largest exporter of coal and is expected to be the largest exporter of LNG by 2020.

CSG companies plan to radically increase coal and CSG mining activity over the coming decades, with an estimated investment of AU$50 billion (124, 125). These proposals enjoy strong support from governments in each jurisdiction and nationally, despite concerns about a range of social and environmental impacts. Unlike the iron ore mines of remote Western Australia, these coal and CSG mines are planned for areas that are currently under agricultural production and often close to regional towns (**Figure 3**). Opposition to coal and CSG development has therefore created new alliances between farmers and environmentalists (126).

In Australia, only the surface of the land is owned by the property owner; the state retains title to the mineral wealth located below (62). Property owners may not deny reasonable access to their property once mineral deposits are located under it, although they are entitled to compensation for any impairment of their land use or access as a result of the mining activity. Some farmers oppose mining activities on their property as having uncertain impacts on both the quality and quantity of groundwater resources needed for irrigation and stock watering, as interfering with a way of life that may have been practiced for several generations, and as undermining the social fabric of rural communities (127). The known environmental issues relate to habitat disturbance and fragmentation; the use of reserves, including national parks, for mines or pipelines; the long-term ecological impacts of groundwater extraction and potential contamination; the treatment and disposal of wastewater; and the disposal of the salt by-product from CSG extraction (128, 129). The claims that LNG constitutes a lower-carbon transitional fuel in Australia's shift toward a lower-carbon economy are also questioned, especially in the context of evidence about

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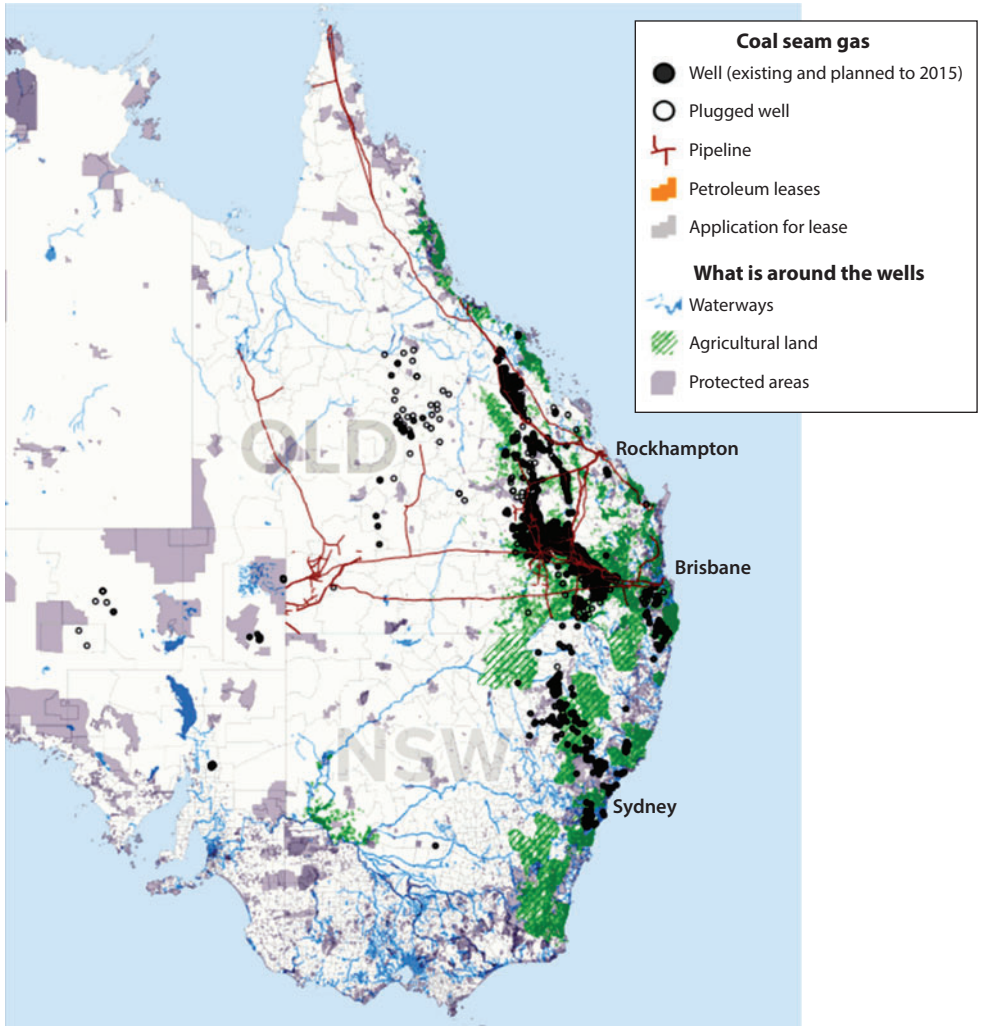

Figure 3

Distribution of coal seam gas activity in Queensland (QLD) and New South Wales (NSW). Figure adapted from **http://www.abc.net.au/news/specials/coal-seam-gas-by-the-numbers/promise**.

higher-than-predicted fugitive emissions (130). Many of these issues have been raised in litigation in New South Wales, but at the time of writing legal action has not reversed any environmental approvals for CSG mining developments (131). Coal and CSG extraction also have significant indirect environmental impacts, particularly major port development along the Queensland coast, including inside the Great Barrier Reef World Heritage area, to accommodate exportation.

Community concern over the uncertainty surrounding the connectivity of aquifers, a lack of confidence in the impartiality of industry research into groundwater impacts, and the potential for CSG development in one state to affect aquifers that span multiple jurisdictions prompted the Australian government to amend the EPBC Act in 2013 (132). The amendment introduced a new matter of national environmental significance (MNES) that triggers environmental impact

assessment requirements for the impact of large coal and CSG mining developments on water resources (33, section 24D). The Environment Minister must now consider advice obtained from the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development before deciding on a CSG proposal (133). This requirement is in addition to consideration of other MNESs that the development may affect, such as World or National Heritage places or listed species or ecological communities. The amendment prohibits the Environment Minister from entering into an approval bilateral with respect to this MNES. Given the federal government's strong commitment to delegating environmental decision making to the states and support for expansion of coal and CSG mining, it remains to be seen how this issue will be addressed. Conflict between agrarian and mining interests has the potential to create political tension in Australia over how best to regulate these growing industries.

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3.4. Climate Change and Policy Instruments to Address National Mitigation Efforts

National climate change politics in Australia are highly polarized, and policy has undergone a series of major reversals over the past decade in line with electoral changes in state and national governments. Australia became a signatory to the United Nations Framework Convention on Climate Change in 1992, and the Keating Labor government introduced a National Greenhouse Response Strategy in 1994. This strategy focused on renewable energy and energy efficiency, but implementation was slow. Climate policy under the Howard government from 1996 to 2007 was characterized by a preference for voluntary emissions reduction measures and a reluctance to commit Australia to emissions reduction targets (134). In 1997, the Howard government negotiated a generous 8% increase in Australia's 1990 emissions levels under the Kyoto Protocol—the so-called Australia clause—but then refused to ratify the Protocol. It adopted a no-regrets approach to national climate policy, focusing on voluntary initiatives (135), although it did introduce a national mandatory renewable energy target in 2001 (136).

As a global problem requiring collective solutions, climate change mitigation is rightly viewed as primarily a responsibility of the national government. Yet, during the term of the Howard government, New South Wales introduced the world's first mandatory emissions trading regime (135), the Greenhouse Gas Reduction Scheme (137). The termination of that scheme in 2012 coincided with the introduction of the national carbon price, discussed below, as well as the election of a conservative Liberal government in that state.

Australia ratified the Kyoto Protocol in 2007 following the election of a Labor government under Prime Minister Kevin Rudd, a victory largely attributed to his public commitment to strong action on climate change (135). The Rudd Labor government developed a cap-and-trade Carbon Pollution Reduction Scheme but eventually postponed attempts to enact the scheme in 2010 after the Australian Senate rejected the bill for a second time. Rudd's successor, Julia Gillard, introduced a national carbon pricing scheme in 2012, the Clean Energy Futures Package. Although widely referred to as a carbon tax, the scheme was in fact a cap-and-trade scheme. It required large emitters (emitting more than 250,000 tonnes of CO_2 equivalents per year) to purchase emission permits. The price of permits was initially fixed at AU$23 per tonne and set to rise by 5%/year for the first three years, whereupon it was to be a floating price (138). Revenue from the scheme was used to lower income tax by raising the tax-free threshold, to increase pensions and welfare payments to defray the expected price rises that would flow from the scheme, and to compensate energy-intensive export industries. The scheme also introduced the Carbon Farming Initiative, a voluntary scheme that enabled farmers to generate, through innovative land and livestock management, carbon credits that could then be sold to emitters required to buy permits (139).

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The election of the Liberal-National Coalition to the federal government in September 2013 produced another reversal in Australian climate policy. The promise to repeal the carbon tax was a key factor in the Coalition's electoral success, and one of the first actions of the new government was to abolish the Climate Commission, an independent body established by the Gillard government to communicate reliable and authoritative information about climate change.[1] The new government's "Direct Action" policy consists of the repeal of the carbon tax and its replacement with a multibillion-dollar fund to provide incentives to reduce emissions. Legislation repealing the carbon tax (140) was passed by the House of Representatives and the Senate in July 2014, but the amendments required for the establishment of the Emissions Reduction Fund have yet to be enacted (141). At the international level, Australia's engagement with global climate negotiations has also been curtailed: Australia did not send a ministerial representative to the latest United Nations climate talks in Warsaw (Conference of Parties 19 in November 2013) and has not supported the international Green Climate Fund (**http://www.gcfund.org**).

4. TRENDS IN ENVIRONMENTAL MANAGEMENT

Understanding the trends and implications of environmental drivers is fundamental to ensuring both sustainable uses and appropriate protection of the Australian environment. Strong and diverse interactions exist among climate change, economic growth, and population growth—nationally and globally—that make predictions uncertain. With regard to economic drivers, the relative significance of agriculture and manufacturing for the Australian economy has decreased over the past 100 years, while a steady rise has occurred in the service and mining sectors. Because different industries exert different pressures on the environment, future structural changes in the economy can be expected to yield new environmental impacts (14). As the Australian population grows and per capita income increases, however, more environmental conflicts can be expected. Pressures of urbanization, particularly in the coastal zones of the east and southwest (29), will exert themselves directly through land clearing and indirectly on the adjacent landscape through demands for freshwater, food, building materials, and leisure opportunities. In northeast and northwest Australia, expansion of mining and oil and gas extraction has its own footprint but also leads to new impacts from the construction of new port facilities, including dumping of dredge material and risks of fish disease (142–144).

A relaxation of environmental controls at both state and national levels is facilitating these economic and social drivers of environmental change. For example, the Queensland government introduced new planning provisions in 2013 to permit dredging below the high-water mark to allow for economic development, provided such dredging is appropriately managed (145). A stated aim of the new policy is to minimize the removal or smothering of sea grass beds to avoid impacts on water quality and fishing. The new provisions also permit development of urban areas, tourism, ports and airports, aquaculture, and other activities in areas of high ecological significance (145). Plans for port expansion within Queensland's World Heritage–listed Great Barrier Reef Marine Park have gained federal and state approval despite the concerns of the World Heritage Committee and IUCN. The World Heritage Committee has postponed until mid-2015 a decision on whether to place the Great Barrier Reef on the list of world heritage sites in order to allow the Australian Government to demonstrate that new projects will not affect the reef's values (146). In June 2014, the World Heritage Committee rejected the federal government proposal to excise some of

[1]The Commission was relaunched in September 2013 as the not-for-profit Climate Council, which is funded through public donations (**http://www.climatecouncil.org.au**).

Tasmania's forests from the area added to the World Heritage listing in 2013 and reopen those areas to future logging (147).

Calls for the reduction of so-called green tape at the national level have focused on the requirements of the EPBC Act (69). Complaints about regulatory overlap between the EPBC Act environmental impact assessment requirements and state regimes, protracted approvals processes, and refusals of environmentally sensitive development have led the federal government to propose approval bilaterals with each state and territory (148). These would accredit both the state's assessment process and its final decision on projects affecting matters of national environmental significance, potentially divesting the Commonwealth of its oversight role under the EPBC Act. Given that state governments may be both proponent and assessment agency, or at least have strong economic interests in facilitating local economic development, this conflict of interest may reduce their consideration of environmental risks and prioritize economic gains. Had the Commonwealth deferred to the states in this way in the past, construction of the Franklin Dam and Traveston Dam, logging of the World Heritage North Queensland Wet Tropics, and sand mining on Fraser Island all would have proceeded.

A proposed amendment to the EPBC Act currently before the Federal Parliament would reduce the Commonwealth's role in protecting nationally listed threatened and endangered species. The amendment is a reaction to successful litigation in the Federal Court of Australia, which challenged the validity of Commonwealth approval of a new mine in Tasmania's Tarkine region on the basis that it did not consider an approved conservation advice for the threatened Tasmanian devil, as is required under the Act. The proposed amendment makes clear that no consequences will flow from a failure to consider a conservation advice; that is, the validity of such decisions will not be affected. It would apply to all future decisions and operate retrospectively to validate any previous decision that may not have expressly considered relevant conservation advice (149).

A welcome trend in environmental policy is the gradual inclusion of the imperatives of climate change adaptation. Current approaches to project assessment and natural resource management focus on minimizing the adverse impacts of an activity on the environment. As the impacts of climate change manifest in increased erosion, inundation, flooding, drought, and bushfire, decision-making frameworks are also starting to consider whether future environmental change might compromise the economic and social viability of a project (66, 150). Water and agricultural policies now take into account changes in water flows as a consequence of drought and flood; planning laws address the impacts of sea level rise on coastal development (66); and biodiversity conservation strategies establish corridors to facilitate species movements and refugia (151) and consider large-distance translocation of protected species to new habitats (e.g., 152). These trends are still emerging, and in the case of sea level rise, planning guidelines have already been reversed in two states. A comprehensive, strategic, and programmatic review of resource management and conservation regimes is urgently needed to evaluate their effectiveness and adaptability under climate change (29, 98). Better integration of emergency management and traditional sector agencies, such as land use planning and conservation, is likely to be an important feature of these climate-adaptive regimes.

Policy responses to climate change imperatives also illustrate two other trends: the clash between competing environmental policies and the shift toward wider use of market-based instruments for environmental regulation. For example, the expansion of wind farms as a source of renewable energy is under increasing scrutiny because of their potentially deleterious effects on endangered bird populations (153). Residents in areas surrounding wind farms also complain of a range of negative health effects, but no robust science supports their claims (154). This conflict plays out in legal challenges and the withholding of social license for new wind farm projects (155). In another example, the water consumption of blue gum eucalyptus plantations—a previously

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popular form of private-sector carbon sequestration—and their impact on environmental flows and water entitlement holders illustrates the trend toward conflict between environmental values (156).

A shift toward market-based approaches to environmental regulation reflects international trends (157, 158). Mechanisms include the creation and allocation of tradable water and fishing rights and the right to emit CO_2 equivalents (159). The trend toward greater engagement of private actors is also reflected in the recognition of, and incentives for, land stewardship and conservation on private land and demand-side management approaches to urban water security, as discussed in Section 3.2.

5. THE FUTURE OF ENVIRONMENTAL MANAGEMENT IN AUSTRALIA

A range of policy and management innovations emerge from this survey of Australian environmental issues, the wider application and enforcement of which would dramatically improve the status and health of Australia's environmental assets. However, limited information on some ecosystems remains problematic (13). Risk-based management has come to dominate approaches to environmental decision making despite numerous statutory references to the precautionary principle (160). Semiquantitative tools and ecosystem models to support risk-based management as part of implementing the EBFM approach in Australian fisheries have helped address a range of fishing-related impacts (112, 117). Actions have included new management arrangements for sensitive species, including bycatch reduction plans and habitat protection zones. Extension of these marine approaches to terrestrial landscapes deserves serious consideration, but in the absence of sufficient information, use of the precautionary principle is recommended (114). This often requires more conservative choices, so decision makers must continue to evaluate the trade-off between the often high cost of additional data collection and long-term conservative management. Approvals to proceed in the absence of critical information should be accompanied by requirements for monitoring and triggers for action if thresholds are reached (98).

Local and state government approaches to demand-side management of domestic water consumption in response to drought and climate-related warming have generally been successful and serve as a useful lesson for urban water suppliers elsewhere, at least in other developed countries. Although there has been significant progress in addressing urban water security, security of the water supply will continue to challenge Australian settlements. An integrated approach to supply-side management that includes desalination, recycling, reuse, storage, and connectivity will be needed as climate change makes rainfall even more variable in some parts of Australia. This variability will require shifts in social attitudes toward use of recycled water and recognition of environmental flows.

Future challenges lie particularly in adapting to the impacts of climate change. With regard to natural systems, traditional strategies for species-specific protection and protected area reserves are likely to be inadequate under predicted future warming scenarios (161, 162). Environmental policies and ecosystem monitoring targets that do not accommodate changing biological abundance and distribution will not be successful (14, 163). Many species and ecological communities will be unable to adapt autonomously, even with expanded and more connected protected areas (164). Traditional approaches that reduce existing stressors may not be sufficient (165). More intense strategies, such as assisted colonization and ex situ protection, are likely to be invoked despite controversy over their likely effectiveness (162, 166). Clear strategy and a strong commitment to

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developing, testing, and evaluating the full range of responses are needed (167). Decision support tools, for example, to evaluate the optimal time for species interventions, will play an increasingly important role (168). Identification of areas to set aside for future use or movement of species and habitats is now occurring for some regions of Australia (169) and may give rise to new conflicts between development and conservation.

Although tensions between environmental and development objectives will continue, the environmental research community can also contribute to the resolution of trade-offs between apparently beneficial environmental actions. For example, renewable energy generation via wind farms should achieve an ultimate environmental good in reducing greenhouse gas emissions (170), but there are associated environmental costs because of bird strikes (e.g., 153). The development of qualitative and quantitative tools to account for a wide range of environmental, social, and economic objectives can assist decision makers in resolving such trade-offs.

From the examples discussed here, Australia clearly faces both ongoing and new environmental issues. Environmental decision making and stewardship are complicated by historical activities, governance structures, increasing economic and population pressures, and changing societal expectations. Even where scientific support for a particular policy is strong, increasingly sophisticated social networking techniques can lead to unexpected outcomes. Likewise, battles that have led to protection for the environment may be refought and lost in the future. Ongoing vigilance is critical if Australians, and others, are to restore and safeguard environmental quality for future generations.

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SUMMARY POINTS

1. A range of historical and contemporary environmental issues continue to impact biodiversity, landscape integrity, and freshwater resources in Australia.
2. The governance of environmental management and protection is fragmented across three tiers of government and across competing sectoral regimes, with reform proposals focusing on minimization of duplication and reduction of the overall perceived burden of green tape.
3. Significant reforms have occurred in the management and use of freshwater resources, although conflict persists regarding storage, supply, and allocation between natural and human needs.
4. Social activism, including litigation, has been effective in halting a range of potentially harmful environmental activities, even in apparently well-managed resource extraction sectors.
5. Pressure to expand coal and CSG production is leading to conflicts among industry, landowners, and environmentalists; concerns include the integrity of ancient groundwater resources and other potential environmental and social impacts.
6. There is little appetite for wider use of innovative approaches to environmental management that impose heavy financial costs on individuals or groups.
7. The framework for environmental governance has shown signs of fragility in recent years; governments are willing to repeal or amend legislation when it impedes major projects or where social activism exerts strong political pressure.

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FUTURE ISSUES

1. Balancing economic growth, sustainable use of the environment, and biodiversity management, particularly in the coastal zone, will continue to be problematic.
2. Climate change will exacerbate a range of existing issues, and adaptation options that do not lead to increases in conflict are needed.
3. Understanding how public opinions and values influence environmental decision making should lead to better outcomes for resource-based industries.
4. Consideration of how to reduce inefficiencies in environmental regulation without losing regulatory oversight may meet the needs of economic development proponents and conservation-focused parties.
5. Approaches to assessing environmental-social-economic trade-offs and supporting decision making should be developed, tested, and refined.

DISCLOSURE STATEMENT

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