2.0 Biodiversity Terminology, the Global and National Context, and Biodiversity and Agriculture

In this chapter, we review the literature to define important biodiversity concepts, provide the global and national context to the biodiversity debate, and outline general relationships between agriculture and biodiversity.

2.1 Biodiversity Terminology

The burgeoning discipline of conservation biology, the rise of environmentalism and the spate of international, national, regional and local activity in conserving biodiversity over the past three decades, have spawned a large literature with terms and concepts that are unfamiliar to and perhaps regarded with suspicion by cotton growers and others in the industry. The aim of this section is to define the principal terms and briefly explain the pivotal concepts. This will assist those in the cotton industry to better understand the information presented and recommendations in subsequent chapters of this report.

Table 2.1 lists definitions of key terms that are used throughout this report. Often there are variations in how these terms are defined by different organisations, but the differences are minor. We regard 'biological diversity' and 'biodiversity' as synonymous and accept the following definition (ANZECC 1996):

> *The variety of life forms: the different plants, animals and micro-organisms, the genes they contain, and the ecosystems they form. It is usually considered at three levels: genetic diversity, species diversity and ecosystem diversity.*

Another term employed extensively throughout the report is 'ecoregion'. An ecoregion is a recurring pattern of ecosystems associated with characteristic combinations of soil and landform that characterise that region (Brunckhorst 2000). At ecoregion boundaries, new combinations of regional climate, soils and landform produce a different set of ecosystems (Forman 1995). The flora, fauna and ecosystems that characterise an ecoregion tend to differ from the biodiversity of other ecoregions. Thackway and Cresswell (1995) compiled the *Interim Biogeographic Regionalisation of Australia* (IBRA) to classify ecoregions (often erroneously called 'bioregions' – see Brunckhorst 2000) across the continent. Through consideration of multiple data sets of ecosystem and landscape characteristics and development in partnership with State and local resource management agencies, the IBRA has gained broad acceptance (Brunckhorst 2000).

Table 2.1 also defines the terms 'ecological community,' 'ecosystem,' 'in-situ conservation,' 'ex-situ conservation,' 'habitat,' 'protected area,' 'minimum viable population' and 'threatening process'. Where definitions of other terms have been provided from several different sources, Table 2.1 indicates whether or not the definitions are considered to be equivalent. In the conservation biology literature, 'long-term' refers to a time scale of hundreds of generations of the organism in question, which is sufficient time for populations of the species to evolve into new species (Soule 1980).

Table 2.1. Definition of key biodiversity terms used in this report

Term	Convention on Biological Diversity (Anon. 1992a)	National Strategy for the Conservation of Australia's Biological Diversity (ANZECC 1996)	NSW Biodiversity Strategy (NSW NPWS 1999)	Definitions considered to be equivalent (Y or N)
Biological diversity or biodiversity	Means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems [Biological diversity].	The variety of life forms: the different plants, animals and micro-organisms, the genes they contain, and the ecosystems they form. It is usually considered at three levels: genetic diversity, species diversity and ecosystem diversity [Biological diversity].	The variety of life forms, the different plants and animals and micro-organisms, the genes they contain and the ecosystems they form [Biodiversity].	Y
Ecological community			An assemblage of species occupying a particular area.	
Ecosystem	Means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.	A dynamic complex of plant, animal, fungal, and microorganism communities and the associated non-living environment interacting as an ecological unit.	Communities of organisms and their physical environment interacting as a unit.	Y
In-situ conservation	Means the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties	Conserving species within their natural habitat.	Within the natural location.	Y
Ex-situ conservation	Means the conservation of components of biological diversity outside their natural habitats.	Conservation of species outside their natural habitat; for example, in zoos, botanic gardens and seed banks.	Outside of the natural location.	Y
Habitat	Means the place or type of site where an organism or population naturally occurs.	The place or type of site in which an organism naturally occurs.	The living space of a species or community, providing a particular set of environmental conditions.	Y
Protected area	Means a geographically defined area which is designated or regulated and managed to achieve specific conservation objectives.		An area of land and/or sea especially dedicated to the protection and maintenance of biodiversity, and of natural and associated cultural resources, and managed through legal	Y

			or other effective means.	
Minimum viable population		The minimum number of individuals of a species in a given locality that could be expected to survive in the long-term.		
Threatening process			Processes such as habitat disturbance or destruction or pollution that threaten the survival, abundance or evolutionary development of a species, population or ecological community.	

2.2 Biodiversity – the Global and National Context

The United Nations Conference on Environment and Development (UNCED, also known as the 'Earth Summit') held in Rio de Janeiro in June 1992, resulted in five major agreements on global environmental issues. The most important in the present context was the *United Nations Convention on Biological Diversity* (Anon. 1992a). This Convention which Australia signed at the Earth Summit, along with 156 other Member States, defined an international framework and outlined the principal strategies by which Contracting Parties should ensure biodiversity conservation within their jurisdiction and minimise environmental impacts within and beyond their jurisdiction. The Convention is a formal treaty binding on the Contracting Parties. In Australia, subsequent federal and state legislation and policies and strategies for biodiversity conservation are a direct consequence of the Commonwealth's ratification of the Convention.

The conservation principles and strategies embodied in the *United Nations Convention on Biological Diversity* are outlined in Appendix 1. The Convention acknowledged the intrinsic and utilitarian values of biodiversity, and the importance of biodiversity in maintaining the life sustaining systems ('ecosystem services') of the biosphere. The Convention (Anon. 1992a):

- noted with concern the global loss of biodiversity as a result of human activities;
- identified the need to protect biodiversity primarily through *in situ* means, through the conservation and recovery of ecosystems, natural habitats and viable populations of species; and
- recognised the need to identify, anticipate and avoid the processes and activities that otherwise threaten biodiversity ('threatening processes').

The Convention required Contracting Parties to (Anon. 1992a):

- develop national strategies for the conservation and sustainable use of biodiversity;
- integrate conservation and sustainable use of biodiversity, as far as possible and appropriate;
- establish and manage a system of protected areas and other special areas (e.g. reserves under private ownership) for biodiversity conservation;
- ensure biodiversity conservation *in situ* by taking appropriate measures across all tenures, not just within protected areas and other special conservation areas;
- manage the threats to biodiversity posed by exotic species (by avoiding their introduction) and human activities;
- ensure the protection of threatened species through regulation; and
- provide financial and other appropriate social and economic incentives for *in situ* biodiversity conservation.

Australia recognised the importance of biodiversity conservation when the Council of Australian Governments (COAG) adopted the *National Strategy for the Conservation of Australia's Biological Diversity* (ANZECC 1996). In 2000, the Australian and New Zealand Environment and Conservation Council (ANZECC), which comprises the environment ministers of New Zealand, Papua New Guinea, and all States and Territories of Australia and the Commonwealth, commissioned a progress report on the implementation of the *National Strategy*. The report found that whilst significant advances had been made since 1996, several objectives had not been achieved. Accordingly, the Commonwealth developed a set of objectives and targets for ten priority outcomes for the Commonwealth, States and Territories to pursue between 2001 and 2005 (ANZECC 2001). The priority actions were:

1. protect and restore native vegetation and terrestrial ecosystems;
2. protect and restore freshwater ecosystems;
3. protect and restore marine and estuarine ecosystems;
4. control invasive species;
5. mitigate dryland salinity;
6. promote ecologically sustainable grazing;
7. minimise impacts of climate change on biodiversity;
8. maintain and record indigenous peoples' ethnobiological knowledge;
9. improve scientific knowledge and access to information; and
10. introduce institutional reform.

Action 7.3.1 of the *National Strategy* called upon State and Territory governments to development complementary biodiversity strategies. Accordingly, the New South Wales Government released its *NSW Biodiversity Strategy* in 1999 (NSW NPWS 1999). The *NSW Strategy* consisted of 143 actions grouped under five headings:

1. community consultation, involvement and ownership (actions 1-12);
2. conservation and protection of biodiversity (actions 13-32);
3. threatening processes and their management (actions 33-54);
4. natural resource management (actions 55-112); and
5. improving our knowledge (actions 113-143).

2.2.1 Human Impacts on Biodiversity

Scientists and environmentalists have focussed increasingly on biodiversity over the past two decades. This has been due to mounting interest and concern about the impact of human development on the local and global environment, the realisation that the variability of life on Earth has and will continue to decline, and that by ignoring human impacts on the global environment and biodiversity, we may ultimately severely reduce our own welfare and that of future generations (Heywood and Baste 1996). Lack of knowledge of the diversity, variability and functional roles of plants, animals, micro-organisms and the ecosystems in which they occur, only heightens scientific concern about the uncertainty of the long-term consequences of human impacts. Even today we are not certain to an order of magnitude how many species occupy the planet. A working figure of 13 million was accepted in the United Nations Environment Program's *Global Biodiversity Assessment* (Heywood 1996), only about an eighth of which have so far been formally (scientifically) described and given species names (e.g. *Eucalyptus populnea* for bimble or poplar box).

Biodiversity is important to humans for four fundamental reasons: (1) ecosystem (life support) processes, (2) ethics, (3) aesthetics and culture, and (4) economics (SEAC 1996).

1. Biodiversity underpins the essential ecological processes that make life on earth possible and that are often taken for granted (SEAC 1996). Healthy functioning ecosystems comprised of myriad organisms are responsible for the quality of the atmosphere, climatic regulation, fresh water, soil formation, nutrient cycling, and

waste breakdown (often called ‘ecosystem services’). Biodiversity is essential for controlling pest plants, animals and diseases, for pollinating crops and for providing food, clothing and many kinds of raw materials.

2. Some people believe that all species or organisms have an inherent right to exist (SEAC 1996). Others believe that biodiversity belongs to the future as well as to the present, and no species or generation has the right to sequester biodiversity for their exclusive use or to squander it. This concept of intergenerational equity is one of the principles of ecologically sustainable development (COAG 1992).

3. Biodiversity can have intrinsic values such as beauty, tranquillity and isolation for people (SEAC 1996). Many Australians place high values on native plants and animals, contributing to our sense of cultural identity, as well as providing outdoor recreation opportunities. Biodiversity is also important to some for spiritual enrichment or renewal.

4. Some elements of biodiversity also have economic value and generate wealth (SEAC 1996). Australian plants, animals and ecosystems attract tourists and provide food, medicines and other pharmaceutical products, energy and building materials. In 1998-99, the commercial fishing industry supported an estimated production value of almost $2 billion (Williams et al. 2001). The annual turnover of industries based on other native plant and animal products (excluding forestry) in recent years has exceeded $1.25 billion (Williams et al. 2001). Tourists to six protected areas in 1991-92 spent more than $2 billion (SEAC 1996). The value of pollination to Australian agriculture has been estimated as $1.2 billion per annum (Anon. 2002f). Biodiversity prospecting for new chemicals for industry and medicine is also attracting attention.

The challenge for Australians, and indeed the global community, is to balance the exploitation and destruction of biodiversity on the one hand with its perpetuation, to ensure that human welfare now and in the future is not compromised. This is no easy matter, however, due to the many value judgements and the diversity of private and public interests involved, as well as the incomplete nature of biodiversity science and its poor predictive power to inform decision making.

2.3 Biodiversity and Agriculture

Given the dominance of humans, no part of the world can be considered truly ‘undisturbed’ (Heywood and Baste 1996). Indeed, most biodiversity now exists in human-dominated ecosystems. The world-wide impacts of agriculture, forestry and fisheries, habitat destruction, exotic introductions of plants, animals and diseases, pollution, and global change threaten the survival of species and populations, the health and productivity of ecosystems and the ecological integrity of human-modified ecosystems. However, the picture is seldom simple and human impacts on ecosystems can have positive, negative or neutral effects on different elements of biodiversity all at once (McNeely et al. 1996). The direct (proximate) mechanisms affecting current levels of global biodiversity, as identified in the *Global Biodiversity Strategy* (WRI et al. 1992), are:

- human exploitation of wild living resources;
- expansion of agriculture, forestry and aquaculture;

- habitat loss and fragmentation;
- indirect negative effects of species introduced by humans;
- indirect positive effects of species introduced by humans;
- pollution of soil, water and atmosphere; and
- global climate change.

The indirect (ultimate) and arguably more significant mechanisms affecting global biodiversity are (McNeely et al. 1996):

- the growth of the human population;
- natural resource consumption patterns;
- global trade;
- economic systems and policies that fail to value the environment and its resources; and
- inequity in the ownership, management and flow of benefits from both the use and conservation of biological and other natural resources.

Biodiversity and humans have had a close and mutually supportive relationship for tens of thousands of years (with the conspicuous exceptions of the human-induced megafaunal extinctions and the recent rise of humans to global dominance). Human activities have helped create substantial genetic and species diversity and have increased the diversity of biological communities through resource management practices and the domestication of plants and animals (McNeely et al. 1996). Many traditional resource management practices have supported the maintenance of species and genetic diversity, often leading to increases in those species of greatest interest to people. Low-input agricultural systems have long been important sources and custodians of biodiversity. More recently, however, in the rise of humans to global dominance, biotic impoverishment – the loss of the characteristic biological diversity in a region – has been an almost universal consequence. Western commercial agriculture has led to considerable marginalisation of the landscape. Surface irrigation schemes, for example, can transform landscapes into a laser-levelled agricultural mosaic of a few crop species and varieties, displacing numerous native ecosystems such as native grasslands, shrub thickets, scattered trees, woodland, riparian vegetation and ephemeral wetlands.

The current western practice of isolating biodiversity management from productive human endeavours is a very recent phenomenon and scientifically unfounded (McNeely et al. 1996). Traditionally, biodiversity has been conserved and utilised as an integral part of natural resource management and productive endeavour. While the active protection of large areas of the characteristic biodiversity of regions by governments will continue to play an important role in biodiversity management, even more important will be steps to safeguard or reintroduce native biodiversity and integrate it within productive landscapes.

The following sections address the impacts of human activities on terrestrial and aquatic biodiversity, with particular reference to agriculture in inland eastern Australia. Recent emphasis has largely focused on the threats posed by human activities on biodiversity, both locally (Williams et al. 2001) and globally (Heywood 1996), so most of the information presented concerns negative impacts associated with agricultural activities. While cotton crops generally only occupy a small proportion (< 5%) of cotton growing catchments in eastern Australia, the catchments in which cotton is grown have numerous issues in relation to the impacts of agriculture on native biodiversity. Therefore, while the cotton industry is not responsible for the overall state of biodiversity conservation in cotton growing catchments, the industry will continue to come under intense scrutiny, along with the rest of the agricultural sector, in these catchments. Despite its small land base, the industry will have to contend with the overall state of biodiversity and its conservation in cotton growing catchments.

There is little information available on the habitat value of farming landscapes for native biodiversity. Generally the value of heavily developed cropping landscapes has been assumed to be close to nil, with all the focus on the fragmented remnants of native vegetation. The accuracy of this assumption will be discussed further in Chapter 4.

2.3.1 Terrestrial biodiversity

The three principal threats to native terrestrial biodiversity in Australia are:

1. habitat loss as a result of vegetation clearance;
2. habitat modification (for instance, as a result of grazing and cultivation); and
3. exotic species introductions.

The clearance of native vegetation remains the single most significant threat to terrestrial biodiversity in Australia (SEAC 1996). Only four countries (Brazil, Indonesia, Democratic Republic of Congo and Bolivia) exceed Australia’s rate of clearance of native vegetation (Williams et al. 2001). The rate of land clearance has accelerated over time with as much land cleared in the past 50 years as in the 150 years before 1945. In 1999, the NSW and Queensland governments alone granted permits to clear almost three quarters of a million hectares of vegetation. Most of this recent clearing has occurred in the same ecoregions in which cotton is grown, although much of the clearing has not been for cotton production per se.

Land clearance results in the loss of native plant species and the destruction of habitat. Williams (2001) stated that 1000-2000 individual birds permanently lose their habitat for every 100 ha of woodland that is cleared, while the clearing of mallee for wheat farming kills, on average, more than 85% of the resident reptiles and more than 200 individual reptiles per hectare. Habitat modification through thinning, grazing and cultivation also destroys native biodiversity, as well as favouring species tolerant of human disturbance regimes at the expense of species sensitive to human activities. Since European settlement, Australia has lost about 40% of its total forest area, and nearly 70% of all native vegetation has been removed or significantly modified by human activity (SEAC 1996). Agriculture and grazing have been responsible for 90% of the plant extinctions in Australia to date, and threaten the survival of the majority of Australia’s endangered terrestrial vertebrates (SEAC 1996).

In addition to the outright and more or less immediate destruction of native plants and animals as a result of vegetation clearance and modification, a less well appreciated consequence is the ‘extinction debt’ that ultimately results from these activities (EPA 1997). The number of species that live in an area is partly a function of the area of the habitat. These species-area relationships have been documented by biogeographers and ecologists for over 150 years (Krebs 1985, Begon et al. 1986). As area of habitat increases, so to does the number of species living in the area. Conversely, the more habitat that is cleared, the more species that will eventually go extinct in the remaining habitat. Extinction debt refers to the fact that species are not lost from the remnants instantaneously; rather, species losses but take from days and weeks to centuries or millennia to occur. Recher (1999) predicted an extinction spasm of up to half the terrestrial species of Australian birds over the next century as a result of habitat changes to date, unless management changes substantially. Comparable predictions of a world-wide mass extinction of plants and animals as a result of global deforestation have been made by Myers (1979) and Wilson (1985). Wilson (1995) observed that:

> *The one process ongoing … [today] that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats. This is the folly that our descendants are least likely to forgive.*

Evidence of local extinctions is emerging. Local and regional extinctions of woodland birds are known from the longer-settled or more thoroughly cleared agricultural districts of the Mt Lofty Ranges, Victoria, Western Australian Wheatbelt, New England Tablelands and Sydney region (Ford et al. 2001). A number of woodland bird species typical of the wheat-sheep regions are now threatened, and others only survive in abundance in the northern, less-modified and more recently developed parts of inland eastern Australia. Declines and species extinctions are expected to continue in the more recently developed parts of the eastern cropping zone, as extinction processes play out. The number of extinctions and declines of native plants and animals witnessed to date is a small fraction of the ultimate number of extinctions that will occur as a result of land clearance and habitat modification already undertaken. Further clearing and habitat modification will exacerbate the ultimate losses. For this reason, many scientists have called for the cessation of clearing of native vegetation across southern and eastern Australia (e.g. Robinson and Traill 1996, Recher 1999, Ford et al. 2001).

An important consequence of species-area relationships is the implication for the efficacy of protected areas (i.e. national parks and equivalent reserves) in conserving a region's biodiversity. Since ecological processes transcend land tenure boundaries, protected areas can only ever conserve a fraction of the original species pool in a region while they cover a relatively small proportion of the region or of the native habitats in the region. The fraction is a function of the amount of native habitat remaining in the region and the proportion of the remaining habitat within the reserve system. Importantly, the rate of extinction increases as a function of the area of habitat that has already been destroyed (Tilman et al. 1994). For instance, destruction of 1% of habitat causes the extinction of eight times more species if 90% versus 20% of a region has already been destroyed (McNeely et al. 1996). Ironically, the protected area network is least extensive and least representative of pre-European habitats in the most heavily cleared and altered regions of Australia, namely the wheat-sheep belt. In other words, society has invested least in conservation in the regions where conservation efforts will be most important to stem the extinction spasm underway. This represents an opportunity for the agricultural industries to negotiate alternative futures with the rest of society to the pending mass extinctions within the agricultural heartlands of Australia.

Exotic organisms are the other major threat to native terrestrial biodiversity in Australia (Williams et al. 2001). Conservation agencies ranked exotic animals as the process threatening biodiversity in more ecoregions (53%) throughout Australia than any other (SEAC 1996). The rapid and widespread extinction of many species of Australian mammal of intermediate size (in the critical weight range of 0.035-5.5 kg) since European settlement is partly or largely attributable to predation by the European fox (*Vulpes vulpes*) (Morton 1990, Short and Smith 1994, SEAC 1996). The competition, predation and habitat alteration of a large number of other exotic animals are important threatening processes for a range of native plant and animal species (SEAC 1996).

Introduced plant species account for 15% of the total Australian flora (SEAC 1996). Exotic plants (weeds) are responsible for changes to the structure, species composition, fire frequency and abundance of native communities (SEAC 1996) in addition to being a significant economic cost to agriculture. The disturbance regimes associated with cropping and grazing (mechanical and chemical destruction of vegetation, selective grazing, physical disturbance of soil and nutrient enrichment) favour a wide range of weeds. Weeds are considered the fourth most widespread process threatening biodiversity in Australia by conservation agencies after introduced animals, livestock grazing and cropping. Weeds are thought to have contributed to the extinction of four native plants in Australia and threaten the survival of 57 other plant species as well as some bird and reptile species (SEAC 1996).

Given the importance of exotic animals and plants as threatening processes to native biodiversity and farmers' experience in managing weeds and feral animals, here, too, there are opportunities to offer a land stewardship service to the wider community.

2.3.2 Aquatic biodiversity

The main threats to aquatic and riparian biodiversity in inland waters and to groundwater dependent ecosystems in cotton growing areas in eastern Australia are (Ball et al. 2001):

1. water extraction;
2. developments that impact on water resources and the biota associated with wetlands and groundwater dependent ecosystems; and
3. the introduction and spread of exotic species.

The principal threats arising from catchment development are the grazing of wetlands and riparian vegetation, increasing catchment salinity and salt loads in waterways, eutrophication and blue-green algal blooms, and agricultural pesticide pollution. The greatest loss and degradation of wetlands and impacts on flowing waters in Australia have occurred in agricultural districts (SEAC 1996). The specific environmental impacts of irrigated cotton production of most concern are (SEAC 1996):

1. the large scale water use in areas of limited water availability:
2. off-site pesticide impacts; and
3. the potential for nitrate leaching to groundwater.

Intensive development of river systems in the Murray Darling Basin for irrigation has resulted in water extractions exceeding sustainable yields (Ball et al. 2001, NL&WRA 2001d) in all of the cotton growing catchments in NSW. This means that the amount of water extraction is jeopardising an acceptable level of aquatic ecosystem health (Ball et al. 2001). Estimates of sustainable yield have not been made for Queensland rivers (Ball et al. 2001). Over the last 20 years, the area of irrigated land has almost doubled in NSW and Qld, but has remained relatively constant in most other states and territories (Ball et al. 2001). Diversions were capped in Basin states at 1993-94 levels of development in Basin states, with the exception of Queensland which is in the process of implementing a cap on diversions. Water extraction is close to exceeding the cap in most NSW river systems. In the Murray-Darling Basin, between 95 and 100% of the surface water use is for irrigation and rural (domestic and livestock) use. Cotton accounted for 12% of total irrigation water use in Australia in 1996-97 (Ball et al. 2001).

Apart from reductions in river flows as a result of water extraction, other impacts of the development and regulation of surface water resources on aquatic biodiversity and ecosystems include:

1. modifications to natural flow regimes, resulting in altered seasons of flow;
2. physical and structural changes associated with river regulation and agriculture in floodplain environments, such as channelisation or rivers, construction of levee banks to reduce the area of inundated land, modification of natural drainage patterns and vegetation clearing, leading to an overall reduction in the area and health of wetland ecosystems;
3. water quality impacts such as cold water pollution (which may affect up to 3000 km of NSW rivers alone); and
4. barriers to the movement of fish and alienation of habitat (through dam and weir construction).

Grazing of inland wetlands and riparian vegetation can lead to degradation of aquatic ecosystems (Ball et al. 2001). Riparian vegetation is critical for preventing stream-bank erosion and 'filtering' catchment run-off. It is also important in light limitation of algal blooms and as a source of carbon for streams. Stock access to water ways results in their fouling of water directly with excreta.

Groundwater extraction in Australia grew dramatically between 1985 and 1996-97 due to the cap on surface water extractions in the Murray Darling Basin and the scarcity of surface waters resources in most other areas (Ball et al. 2001). NSW uses more than 60% of the groundwater extracted for irrigation. Groundwater use poses a threat to the survival of groundwater dependent ecosystems along with possible impacts on surface water. However, most sustainable yield estimates for groundwater resources currently do not consider groundwater dependent ecosystems or the impact of groundwater extraction on base flows associated with surface waters, due to ignorance of these phenomena.

The increasing salinity of Australia's catchments and inland waters is a significant threat to the health of aquatic ecosystems (Ball et al. 2001), and irrigation and drinking water supplies. In the Murray Darling Basin, 300 000 ha of land are affected by dryland salinity, with up to 5 million ha at risk. River systems in the Murray-Darling Basin where in-stream salinities are predicted to increase substantially over the next 50-100 years include the Condamine-Balonne and Border Rivers in Qld, and the Lachlan, Bogan, Macquarie, Castlereagh and Namoi Rivers in NSW, all of which support irrigation and cotton growing areas. Nationwide, 80 important wetlands are affected by salinity and this number is expected to rise. Many freshwater riparian habitats and wetlands contain endemic species and communities that are at risk from salinisation. Loss of these communities will reduce the biodiversity of these areas.

Blue-green algae produce toxins that affect humans, livestock and native aquatic flora and fauna (Ball et al. 2001). Blue-green algae occur mostly in storages, lakes, wetlands and waterways that are nutrient enriched and have increased periods of reduced or no flow due to river regulation. For most inland waters, the major source of nutrients is diffuse pollution. Soil eroded into waterways may provide a source of nutrients for decades and therefore algal blooms will continue to occur despite efforts to reduce point and diffuse source pollution. Exceedence of the water quality guidelines for turbidity (an indicator of suspended sediment) and phosphorus is a major or significant issue in most of the cotton growing catchments in eastern Australia (Ball et al. 2001, NL&WRA 2001d).

Possibly the most widespread pollutants in inland surface water resources are agricultural pesticides, with cotton amongst the highest users of pesticides on a per hectare basis (Mawhinney 1998, Ball et al. 2001). Since 1990, the broad spectrum organochlorine insecticide, endosulfan, has been regularly detected in rivers in concentrations lethal to aquatic biota, particularly fish, in cotton growing areas in central and northern NSW. Endosulfan is also highly toxic to aquatic invertebrates, and moderately to highly toxic to birds (Extension Toxicology Network 2002). Since 1990, at least 20 fish kills in NSW rivers have been attributed to pesticides. Endosulfan levels have been decreasing (except in the Darling River) since the early 1990s due to improvements in education, regulatory control, implementation of best management practices and reduced use (Ball et al. 2001). Chlorpyrifos and Dimethoate have also been detected in concentrations exceeding guidelines for the protection of aquatic ecosystems in the Gwydir and Namoi Rivers. Chlorpyrifos is a broad spectrum organophosphate insecticide used principally on cotton in these catchments, and is highly toxic to fish and aquatic invertebrates and moderately to highly toxic to birds (NRA 2000). Dimethoate is a broad spectrum organophosphate insecticide and is toxic to aquatic invertebrates, moderately toxic to fish, and moderately to highly toxic to birds (Extension Toxicology Network 2002).

The most widespread known pollutants in groundwater are nitrates and agricultural pesticides (Ball et al. 2001). Experience from North America and Europe suggests that groundwater pollution will become more serious in the future. Nitrate contamination of groundwater is widespread throughout Australia, the major causes of diffuse nitrate contamination being over-fertilisation of agricultural land, clearfelling and grazing. Elevated concentrations of nitrate in groundwater for domestic and livestock use are a health risk. Where groundwater discharges to surface waters, nitrate can also cause nutrient enrichment. Diffuse pesticide contamination of groundwater resources is significant in some cotton growing areas in eastern Australia, although the main chemicals detected are atrazine and simazine (Ball et al. 2001) which are not used in cotton.

The introduction of exotic aquatic fauna and flora into Australia has had a major impact on native species and wetland ecosystems (Ball et al. 2001). The most damaging introductions have been aquatic vegetation (weeds) and fish. Thirty-five exotic fish species have become established in inland waters in Australia, with eight identified as having a significant impact on aquatic ecosystems. Competition and predation by introduced fish species have been implicated in the declining populations and distributions of some native fish species. European carp (*Cyprinus carpio*) is particularly invasive, competing with native fish species for resources, degrading stream habitats by disturbing bottom sediments and destroying aquatic plants.

Some 65 species of aquatic plants have become weeds in Australian inland waters. About 15 of these are significant pests and 13 have the potential to become so (SEAC 1996). Water hyacinth (*Eichhornia crassipes*) and salvinia (*Salvinia molesta*) are among Australia's 20 worst environmental weeds and infest stationary and slow-moving inland waters, especially where nutrient levels are high. Both species have the potential for very rapid growth and can choke water ways, altering aquatic ecosystems. As with animal pests, the impacts of exotic weeds often cannot be separated from other impacts, to which the weed invasion may be a response. Changes to wetland habitats through altered water regimes or water quality and through physical disturbance to aquatic habitats and riparian zones can all favour the spread of introduced plants. Nutrient enrichment and removal of riparian vegetation due to agriculture may have facilitated the ingress of these species in some areas.

Another weed to have invaded extensive areas of floodplain in cotton growing catchments is lippia (*Phyla canescens*). Lippia is a mat forming, deep rooted plant that rapidly dries out the soil profile and completely suppresses other herbaceous vegetation. The Murray Darling Basin Lippia Working Group (2002 unpubl.) estimated that over 800 000 ha of floodplain in the Basin is being invaded by this species, causing streambank erosion and downstream water quality problems, lowering carrying capacity of grazing lands, causing deep cracking in infrastructure such as road bases, levees and dam walls, and threatening native biodiversity in native pastures and woodlands on floodplains and ephemeral wetlands. Lippia poses a major threat along the Lachlan River, in the Macquarie Marshes, and throughout the lower Gwydir, Macintyre and Namoi valleys, as well as being widespread in southern Queensland.

As a result of all these threatening processes, inland waters in the eastern states are under considerable pressure, and the condition and extent of many wetlands have decreased substantially (Ball et al. 2001). The 1996 *Australia: State of the Environment Report* (SEAC 1996) found that many species of aquatic animal are endangered, in decline or extinct. Riparian vegetation is seriously degraded in many catchments due to clearing, grazing and salinity (Ball et al. 2001). Many wetlands in the Murray Darling Basin have experienced significant decreases in area due to isolation from floodplains, reduced flows and flooding, increased salinity from groundwater inflows and higher in-stream salinities, drainage modifications, grazing and reclamation, and the introduction and spread of exotic species. In NSW, over the past 15-20 years, many native fish species have experienced a reduction in range and abundance.

2.4 Positive Impacts of Agriculture on Biodiversity

The question of how agriculture enhances biodiversity needs to be considered from two perspectives: from the point of view of the biodiversity that occurred previously in an area, and from the perspective of the sum total of biodiversity (both pre-existing and new elements) in agricultural landscapes.

In terms of the biodiversity that existed in an area prior to agriculture, the disturbance associated with the establishment of extensive and intensive farming and grazing enterprises inevitably results in a diminution in the abundance, extent and diversity of pre-existing ecosystems. This is because the vegetation clearance, wetland drainage, altered river flows, water abstraction, water point multiplication, cultivation, soil disturbance, and introduction of agricultural and horticultural crops, pastures, garden cultivars, planted windbreaks, weed species, and domestic livestock, physically replace, destroy or diminish elements of the pre-existing biota. Empirical biogeographical laws (Section 2.3.1) dictate that the number of pre-existing species will decline commensurate with the extent of destruction and modification of the original habitats, resulting in declines and local extinctions. Therefore the genetic diversity of the pre-existing biota must also decline.

A residuum of the pre-existing plant and animal populations, however, survives in the fragments of the original ecosystems, as well as in modified, semi-natural areas such as grazed native pastures, and cultivated areas (principally elements of the soil biota). Indeed, some of the pre-existing biota flourish in habitat fragments or under the altered conditions of agro-ecosystems. ‘Increaser’ species benefit from the modified habitats and the reduction in competition from species unable to persist in the modified environment. Their populations increase and they are more abundant in agriculturally modified landscapes than in pre-existing ‘natural’ areas. Native weeds are a good example of these species, for instance the unpalatable wire grasses (e.g. *Aristida ramosa*) and native cypress (*Callitris* spp) that increase in native pastures under domestic livestock grazing and the native weeds that rapidly invade cultivated land (e.g. eastern cotton bush, *Maireana microphylla* and black roly poly, *Sclerolaena muricata*) on the North-West Slopes and Plains of NSW (Lodge et al. 1984; R. Albert, pers. comm. 2002). Eastern grey kangaroos (*Macropus giganteus*), white cockatoos (*Cacatua galerita*) and noisy miners (*Manorina melanocephala*) are classic examples, as well. These examples overshadow the wide range of pre-existing native plants, animals, fungi and microbes that persist and sometimes prosper in agricultural environments, including some threatened species (e.g. koala, *Phascolarctos cinereus,* Smith 1992). The native species that persist or flourish in agricultural landscapes are a subset of those that once occurred, and their relative abundances are likely to be markedly distorted compared to pre-existing patterns.

The biodiversity of an agricultural landscape can also be considered from the perspective of the sum total of ecosystems, species and genes that now occur there. McIntyre et al. (2002) suggested that most pre-existing species may be conserved in mixed farming and grazing landscapes in south-eastern Queensland where intensive agriculture (clearing and cultivation) constitutes 30% of the landscape, low-input grazing constitutes another third of the landscape, 10% of private land is managed for conservation of the original biota, and a regional conservation estate protects those species that cannot be catered for on private land. With the agricultural introductions of exotic species and the invasion of native species from other regions, the biodiversity of such landscapes may be greater than the pre-agricultural condition in terms of the number and evenness of abundance of different ecosystem types, species and genes.

Pimentel et al. (1992) suggested that while national parks and equivalent reserves conserve only a small (< 10%) proportion of terrestrial ecosystems, more biological diversity in terms of numbers of species is likely to exist in agricultural areas and other human-modified ecosystems than in the protected area estate, even though protected areas are the ‘jewels in the crown,’ protecting biodiversity ‘hotspots’. They discussed various agricultural management practices that might contribute to the conservation of total biodiversity in agricultural regions.

The biomass and diversity of consumers and decomposer organisms tend to increase with increased plant biomass, organic matter and soil fertility (Pimentel et al. 1992). Thus, efforts to increase agricultural productivity and retain stubble and trash in fallow for soil conservation are likely to increase the biomass and diversity of animals and detritivores and contribute to biodiversity conservation (Pimentel et al. 1992). Organic matter, for instance, harbours large numbers of arthropod and microbial species, as well as sustaining soil productivity by improving water-holding capacity, providing a source of nutrients and improving soil tilth.

Cropping strategies that increase vegetative diversity through crop rotations, strip cropping and the planting or refuge and trap crops, increase habitat diversity and therefore the likely number and abundance of animal and decomposer species in these areas (Pimentel et al. 1992). Similarly, the planting of shelterbelts and the retention of native vegetation, riparian corridors and uncleared road reserves alongside crops, increases vegetation diversity and the likely diversity of animals.

Broad-spectrum pesticides reduce biological diversity by destroying a wide array of susceptible species while also changing the normal structure and function of the ecosystem (Pimentel et al. 1992). By employing biological controls and other agricultural practices, pesticide use can be reduced while crop yields are maintained or increased. Research in Australian cotton over the past decade has shown that a wide range of non-chemical control methods can be substituted for pesticides. They include host plant resistance, conservation biological control by beneficial arthropods, crop rotations, use of short-season crops, soil and water management, trap and refuge crops, and genetic engineering. Pesticide impacts from cotton production have also been reduced in recent years by the use of new chemicals that are more specific.

Pimentel et al. (1992) concluded that biological diversity in agricultural areas is best conserved by maintaining abundant biomass and plant and habitat diversity, conserving soil and water, and reducing the use of pesticides. Maintenance of this biological diversity is essential for productive agriculture, and ecologically sustainable agriculture is essential for maintaining the biological diversity of agricultural regions.