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Review of the impacts of red meat production and alternative sources of protein on biodiversity

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Abstract

All food production systems are under pressure to comply with societal expectations that the food is not only of good nutritional value but is sustainably produced. The reputation of the Australian red-meat industry is intrinsically tied to the policies and management practices of former generations of producers and policy makers, as well as current unsustainable practices evident in some other parts of the world. Meat & Livestock Australia has invested considerably in environmental issues such as biodiversity, and has sought to review its performance vis-à-vis other protein producing industries in biodiversity management.

This review compares the performance of the red meat industry against white meat, plant-protein and other protein production systems through a review of over 500 peer reviewed and other scientific sources. The review finds that taking into account the past legacy of red-meat production systems, the industry labours to compete with highly regulated, indoor intensive industries such as chicken-meat and pork against a range of pressures upon biodiversity. However, the review also finds that management practices developed by the red-meat industry in recent years can vastly improve the industry's performance. Recommendations for industry level policy and investment and principles and guidelines for enterprise level management that will enhance the capacity of the red meat sector to further act responsibly are outlined.

Executive Summary

Introduction

The beef and sheep industries in Australia have been critical in the development and shaping of Australia from the time of the First Fleet. They have played a significant role in the economic fortunes of the nation in the past and continue to make a major contribution, particularly in the export market. They have also played an important role in the psyche of Australia and in defining the character of the Australian ‘outback’ culture, as well as helping shape the typical Australian diet. The Australian meat and lamb industries continue to grow on increasing demand domestically and internationally for red-meat. National dietary guidelines indicate that 3-4 serves of lean red meat a week can provide easily digestible and high quality protein, as well as a range of important and accessible nutrients such as iron, zinc and Vitamin B_{12}.

In addition to being an important economic and cultural force, the beef and sheep industries have left a lasting impact on the biodiversity of Australia. This ranges from the direct impacts of land clearing for conversion to exotic pastures, overgrazing (particularly in drought conditions) and trampling to indirect impacts such as the introduction of environmental weeds, changes to fire regimes, altered hydrological flows and major impacts on soil (e.g. loss of soil and biological crusts, erosion, compaction). Because the grazing industry covers such a large area of Australia, these impacts are widespread and obvious to many.

The major protein alternatives to beef and sheep meat consumed in Australia are chicken, pork, eggs, dairy products and fish. Emerging industries include goats (mainly exports) and kangaroos, which currently contribute a small proportion to the economy. Each of these industries also impact on biodiversity, sometimes in similar and sometimes in very different ways to the red-meat industry.

Purpose of this study

Meat & Livestock Australia (MLA) has sought to gather the most accurate, scientifically robust information to establish the evidence base for its performance in respect to biodiversity management. This is to inform better land management, enlighten public debate and help shape future conservation programs. To meet these aims, this project is intended to:

- ➢ Review the literature to establish the impacts – positive and negative, historical and current, direct and indirect – of the beef and sheep meat industries on Australia’s biodiversity (aquatic and terrestrial);
- ➢ Identify any significant gaps in the literature as areas for further research;
- ➢ As far as possible, compare the biodiversity impact of red meat production systems with other major alternative dietary protein production systems in Australia, and, in particular, industry approaches to conservation; and
- ➢ Make recommendations for future investment and activity:

What we did

Ten protein sources were selected from an original list of around 30 for a comparative analysis of their impacts on biodiversity. They can be characterised both in terms of their food classification (red meat, white meat, plant-based and other) and in terms of the intensification of production system (high density, intensive and extensive - in order of intensity from highest to lowest):

Protein source	High density	Intensive	Extensive
Red meat			
Cattle	Feedlots	High Input pasture	Low Input pasture
Sheep	Feedlots	High Input pasture	Low Input pasture
Kangaroo	-	-	Native populations
Goat (TBC)	-	High Input pasture	Low Input pasture
White meat			
Poultry	Battery	Free range	-
Pigs	Feedlots	Free range	-
Fish	Aquaculture*	-	Native populations
Plant-based			
Grains, legumes & pulses	-	High Input cropping	-
Other			
Eggs	Battery	Free range	-
Dairy	Feedlots	High Input pasture	-
* includes both terrestrial and sea-based fish farming			

The analysis was largely based on an extensive review of the literature, using a pressure-state-response framework to analyse the findings. As no standard approach to classifying threats and threatening processes is available, and because protein sources are related to a particular set of impacts on biodiversity, the following list of broad pressures was developed for use in this report:

I. Vegetation clearance and modification
II. Altered fire regimes
III. Altered grazing regimes
IV. Altered hydrology
V. Trampling and soil compaction
VI. Invasive species
VII. Pollution
VIII. Disease and pathogens
IX. Climate change
X. 'Other' pressures

What we found

For many industries, drawing a direct link between production systems and actual loss of biodiversity is challenging, if not impossible. Industries rarely interact with landscapes and ecosystems in isolation to other anthropocentric activity. It is far easier to measure the contribution to a pressure than it is to accurately apportion responsibility to the outcomes of that pressure. The following table attempts to capture the potential relative contribution of ten different protein sources to various pressures on biodiversity outlined in this report. While the Table can be used to make comparisons between industries, the authors urge caution against this as it can have the perverse outcome of giving some industries an unwarranted sense of assent that they may divert their attention away from the collective responsibility for protecting biodiversity and ecosystems. By the same token, comparisons may also lead to the impression that those industries with a higher impact are not sustainable or are inadequately responding. The practices of the red-meat industry now are not the practices that lead to the high impact that industry has had in the past.

Protein source	Potential relative contribution to pressure on biodiversity										Response Presence of inter-vention	
	Vegetation clearance	Altered fire regime	Altered grazing regime	Altered hydrology	Trampling & compaction	Invasive species	Pollution (air, water, land)	Disease & pathogens	Climate change	Direct loss of biota	Regu lation	BMP
Beef (ext)	H	H	H	H	H	H	M	L	H	L	M	M
Beef (feedlot)	M	L	M	M	L	L	M	M	M	L	H	H
Lamb (ext)[C]	M	M	M	L	M	M	L	L	L	L	M	M
Lamb (feedlot)	L	L	L	L	L	L	L	L	L	L	H	M
Goat	L	L	M	L	L	L	L	L	L	L	M	L
Kangaroo	L	L	M	L	L	L	L	L	L	L	M	L
Pork (indoor)	L	L	L	L	L	L	M	M	L	L	H	M
Pork (outdoor)	L	L	L	L	L	L	L	L	L	L	H	M
Chicken (indoor)	L	L	L	L	L	L	M	M	L	L	H	M
Chicken (outdoor)	L	L	L	L	L	L	L	L	L	L	H	M
Fish (wild catch)	L	L	L	L	H[O]	L	L	L	L	H[W]	H	M
Fish (aquaculture)	L	L	L	M	L	M	M	M	L	L	H	M
Plant-based	M	M	L	H	M	M	M	L	L	L	M	M
Dairy	M	M	M	M	M	M	M	L	M	L	H	H
Eggs (indoor)	L	L	L	L	L	L	M	M	L	L	H	M
Eggs (outdoor)	L	L	L	L	L	L	L	L	L	L	H	M

Relative pressure = Contribution relative to other protein sources
H = high; M = medium; L = low
[O] Ocean floor dragging
[W] Wild catch/harvest
BMP = Industry driven Best Management Practice

Responses

In response to the documented and potential impacts on biodiversity, the beef and sheep meat industries have implemented a broad range of initiatives including research into sustainable land management practices and how the industry can minimise the impacts on biodiversity. It has instigated a number of training and education initiatives, developed codes of practice, monitoring systems management guidelines which increasingly include environmental considerations, and seen changes to land and water management practices. In parallel with these initiatives, governments have introduced a range of legislation and regulations, supported research and training programs, as well as provided a number of incentives for improved management and restoration of landscapes.

Recommendations for the red meat industry

This report includes a range of recommendations for the red meat industry at both the industry and enterprise levels.

Themes for industry level recommendations include:

- Improve conversion efficiency
- Reduce the hoof print
- Match land use to land capability
- Embed a biodiversity culture into grazing (demythologise biodiversity)
- Breakdown institutional silos
- Acknowledge and reward good management
- Collaborate
- Contribute to national monitoring efforts

Themes for enterprise level recommendations cover planning, on-ground management and monitoring. Examples of these are listed below, with further details provided in the main body of the report.

Planning

- Develop a vision and set clear goals (personal and financial) for the property
- Develop, implement and update a property management plan that incorporates biodiversity conservation as a core component
- Develop a risk management plan, particularly for use in drought and economic down-times

On-ground management

- Match stocking rate to carrying capacity
- Keep Total Grazing Pressure within the sustainable capacity of the property
- Manage both the animal and pasture component of the enterprise
- Use a strategic approach to grazing management, including the use of spelling
- Utilise perennial pastures
- Keep soils healthy and in good condition
- Maintain ground cover above 60% - 70%
- Set aside at least 10-15% of the property as core areas for biodiversity conservation
- Keep weeds and feral animals in check

Monitoring

- Monitor the impacts of management on production and biodiversity goals and incorporate results into new practices

Definitions

Alternatives (NHMRC 2003)

Alternatives refers to other protein-rich foods, such as eggs, liver and kidney, shellfish, legumes, nuts and nut pastes, and certain seeds, such as sunflower and sesame seeds.

Biodiversity

The variety of life, its composition, structure and function, at a range of scales.

Extensive

Industries that utilise native vegetation as the resource base and have relatively low stocking rates. Principally corresponds to the rangelands and savannas in the centre and the north of Australia (covering around two-thirds of the country), but also on native pastures in south-eastern Australia. External inputs to these systems are low or zero.

High density

Industries that keep animals, birds, reptiles, fish or crustaceans in close quarters with predominantly introduced water and feeding (as opposed to grazing).

Intensive

Industries where native vegetation has been cleared and converted to another land use, principally exotic pastures or crops. Pastures are often irrigated and fertilisers added to accelerate plant growth.

Meat

Most people use the term 'meat' to refer to animal flesh, mostly skeletal muscle. However, Food Standards Australia and New Zealand has a broader definition that also includes offal ('meat other than meat flesh' e.g. brain, liver, kidney, tripe).

Red Meat (MLA)

In Australia, the term ‘red meat’ is used by the meat industry to refer to meat from cattle, sheep and goat (i.e. beef, veal, lamb, mutton and goat meat). It does not include meat from pigs (e.g. pork, ham, bacon) or kangaroo. In many other parts of the world, including the US, UK and Europe, the term ‘red meat’ includes pig meat.

Red meat (NHMRC 2003)

Red meat refers to the muscle meat from cattle, sheep, goat and kangaroo. It does not include pork, ham or bacon; in other parts of the world—such as the United States, the United Kingdom and Europe—red meat includes pig meat.

Total grazing pressure (Fisher et al. 2005)

The combined grazing pressure exerted by all stock – domestic and wild, native and feral – on the vegetation, soil and water resources of rangeland landscapes.

Contents

Tables, figures and boxes

List of Tables

List of Figures

List of Boxes

1 Background

1.1 *Protein production and nutritional factors*

This section starts with a general introduction to the science of nutrition and human health, to set the context for the discussion on protein and other nutritional factors. While this may seem out of place in a report on biodiversity and food production, the basis for comparing the impacts of different food sources is the protein they provide for human consumption. As outlined below, consumers base their choice of products such as red and white meat on a range of nutritional information, which is much broader than protein, with factors such as the level of saturated fat an important consideration. As it is the 'protein package' that consumers are interested in, and that protein producers (especially red meat) market their product on, the intention of this section is to compare the range of nutrition that different 'protein' sources provide. While the impact of different protein sources on the environment has not played a major role in consumer choice or nutritional guidelines, this appears to be changing due to concern about climate change impacts and general sustainability issues. A reflection of this trend is the inclusion of environmental sustainability in the dietary guidelines that are currently being revised by the National Health and Medical Research Council. In the future it is likely therefore that consumers will not only be basing their choices on the type of nutritional information covered in this section, but also on the impact of different protein sources on the environment. This is the focus of the main body of this report.

The field of human nutrition and associated literature is large, complex and can sometimes be challenging to penetrate given the terminology and concepts involved. Information ranges from detailed studies on the nutritional benefits of individual nutrients, to long-term, multi-factoral studies such as the widely cited Nurses' Health Study conducted by the Harvard Medical School (e.g. Lu et al. 2007). This study, which had an initial focus on the long-term consequences of oral contraception, started collecting dietary information in 1980 and is now going into a third phase. Depending on the nature and design of the studies undertaken and the type of analysis used in nutritional studies, a wide variety of results about benefits and impacts can be obtained, which can sometimes be inconsistent and even conflicting. The claims and counter-claims that this can lead to, particularly on the internet and increasingly on supermarket shelves, can be confusing to the general public in terms of the best nutritional choices.

The main points where there is general agreement on nutrition and general health include: that a varied diet of fresh, unprocessed, nutritious food is optimum for good health; that exercise is an essential component of a health regime; that modest alcohol consumption is advised; plenty of water should be consumed; and that a diet high in saturated fats, salt and/or sugar is a recipe for poor health. These broad recommendations are reflected in 'The Dietary Guidelines for Australian Adults' (NHMRC 2003; Box 1) which incorporates the 'Australian Guide to Healthy Eating', a poster-like illustration that shows the core food groups that individuals are advised to eat on a daily basis (Department of Health and Family Services 1998).

There is also some agreement in the field of nutrition that a restricted calorie intake, up to a point, may increase life expectancy, although this may not occur in all cases. Some debate surrounds the selection of the 'variety of nutritious foods' individuals are advised to eat. For example, Shrapnel and Baghurst (2007) note that while meat and plant-based foods are in the same core food group in the ‘Australian Guide to Healthy Eating’, simply substituting a portion of a plant-based food for a portion of meat will not provide the same benefits in terms of certain nutrients. These observations highlight that different proportions of different food-types are required to meet daily nutritional needs (NHMRC 2003), and demonstrate some of the complexities faced by consumers.

Box 1: Recommendations to promote good health and good nutrition for adult Australians

Enjoy a wide variety of nutritious foods.

- Eat plenty of vegetables, legumes and fruits.
- Eat plenty of cereals (including breads, rice, pasta and noodles), preferably wholegrain.
- Include lean meat, fish, poultry and/or alternatives.
- Include milks, yogurts, cheeses and/or alternatives. Reduced-fat varieties should be chosen, where possible.
- Drink plenty of water.

Take care to:

- Limit saturated fat and moderate total fat intake.
- Choose foods low in salt.
- Limit your alcohol intake if you choose to drink.
- Consume only moderate amounts of sugars and foods containing added sugars.

Prevent weight gain: be physically active and eat according to your energy needs.
Care for your food: prepare and store it safely.
Encourage and support breastfeeding.

Published in ‘The Dietary Guidelines for Australian Adults’ (NHMRC 2003)

Consumer preference can change over time due to a range of factors including information on nutrition, exposures to the diet of other cultures and the price of food. Figure 1, for example, shows that per capita consumption of chicken has increased dramatically between 1960 and 2006, whereas beef and veal have remained relatively constant. Market research commissioned in 2004 by Meat & Livestock Australia showed that the amount of fat on red meat is a major influence on what is purchased by consumers, with over 70% purchasing lean meat (Human Nutrition Program report, Chapter 15). Dang (2007) demonstrated that the past two decades has been a time of significant change in the consumer's perspective on food—what they eat, how they eat, and even why they eat. Two key consumer trends were identified - a significant increase in the understanding of food as a preventative health tool and the increasing concern for the integrity of the food we eat.

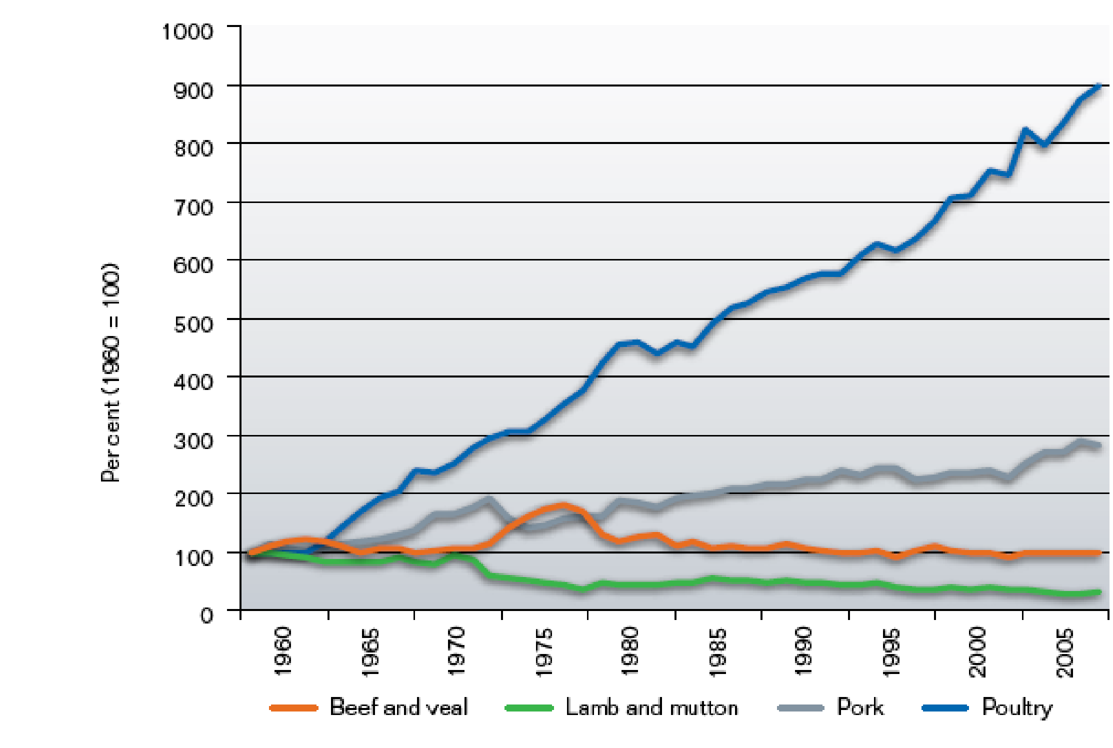

Figure 1: Australia's per capita consumption of meat 1960-2006 (Source: Garnaut 2008)

The focus of this report is the impact of red meat and other major protein sources on Australia's biodiversity – both terrestrial and aquatic. Protein is essential to human health. It is an indispensable requirement for the growth and maintenance of any living creature, with every cell in our body needing protein for metabolism. While essential, protein is however, one of many nutrients that are critical to the functioning of the human body. The uptake and utilisation of these different nutrients can be affected by a range of factors such as age, gender, weight, physical activity and how much sunlight a person receives. This has led, for example, to different dietary guidelines for children, adults and elderly Australians by the NHMRC. As new information comes to light, recommendations on the daily intake of different nutrients can also change (NHMRC 2006). This variability can make it challenging to make generalisations about nutrition and can lead to some of the confusion about nutrition identified earlier.

While the protein composition of different food sources is therefore important to compare, so is the 'package' that the protein comes in (and with) when considering what is essential to good nutrition. Some of the other nutritional factors related to protein-sources that have received attention in recent years include minimising the level of saturated fats, as well as ensuring an adequate intake of nutrients such as long-chain omega-3 essential fatty acids, vitamins (e.g. D and B12), iron, zinc and anti-oxidants (e.g. Williams 2007). The NHMRC (2003) Dietary Guidelines for Australian Adults documents the nutrient content per 100g of a range of protein sources including lean meats, fish, poultry and alternatives such as eggs, soybeans and almonds (Table 1). This enables a comparison of the nutrients in a range of products available to Australian consumers. Of the options described, lean red meat provides quality protein, the best source of bio-available iron, substantial amounts of Vitamin B12 and zinc and a relatively low percentage of dietary fat. Pork and poultry contain equivalent amounts of protein, but substantially less iron, zinc and Vitamin B12. Skinless chicken has a higher total fat content per 100g than lean lamb and beef, while lean pork has the lowest level by a small margin.

Emerging sources of protein not covered in Table 1, such as kangaroo meat, are promoted as having a range of nutritional benefits. For example, recent studies demonstrate that kangaroo meat has a very low fat content (Beilken and Tume 2008). According to the industry web-site, which cites a number of sources, kangaroo meat is also a particularly rich source of protein, iron and zinc, as well as being an important source of several B-group vitamins and omega-3 fatty acids (http://www.macromeats-gourmetgame.com.au/Nutrition/Amazing NutritionFacts.aspx; accessed 6/6/2009). Goat meat is another emerging industry in Australia (Foster 2009). Identifying its nutritional benefits under local conditions is the subject of current research funded by Meat & Livestock Australia. Elsewhere, goat meat has been shown to be low in fat and cholesterol and high in iron and zinc.

The health benefits of fish are widely promoted. According to NHMRC (2003), fish contains amounts of protein equivalent to red meats, pork and poultry, but markedly lower levels of bio-available iron and zinc than red meat. Depending on the species, Vitamin B12 can be similar or higher than red meat, with the fat content also varying. Oily fish in particular are a very rich source of long-chain omega-3 fatty acids, which have been shown to provide specific health benefits. These are also found in some other muscle meats, but at considerably lower levels (NHMRC 2003). Recent research based on a dietary recall approach, which included updated information on the composition of long-chain omega-3 fatty acids, estimated that up to 50% of these nutrients could be provided by meat sources (Howe et al. 2006). Eggs are another alternative source of protein than muscle meats, having around two-thirds of the level per 100g (Table 1). They are a good source of Vitamin B12, and provide substantial amounts of iron and zinc, although the iron is not bio-available.

Many plant proteins are low in one of the essential amino acids required by the human body. For instance, grains tend to be short of lysine whilst pulses are short of methionine. An exception to this is soybeans, which contain all the essential amino acids and are considered a high quality protein. It has been calculated that the human body is able to digest 92 percent of the protein found in meat and 91 percent of that found in soybeans (Schaafsma 2000), although the overall level of protein per unit weight is lower in soybeans (Table 1). To help ensure that vegetarians or vegans don't miss out on essential amino acids, plant proteins are combined, such as consuming both grains and pulses over the course of the day.

The NHMRC (2003) reports that for vegetarians, these foods together with cereal foods, can provide most, but not all, the nutrients provided by meats, fish and poultry. Other key nutrients such as Vitamin B12 are available from eggs and dairy products, but are not naturally provided by plant-based sources. Consequently, for vegans or 'strict vegetarians' (who do not eat animal products), these nutrients need to be supplied by supplements or fortified foods. The ability of the body to convert plant-based sources of short chain omega-3 fatty acids into the nutritionally beneficial long-chain omega-3 fatty acids is turning out to be more complex than expected (Bishop-Weston 2009). Consequently, fortified foods or supplements containing these nutrients may also be required for vegetarians. In the next few years, plants that have been genetically engineered to produce omega-3 oil could provide an alternative plant-based source of this important nutrient (Green 2004; http://www.csiro.au/science/ Omega-3-oils-in-grains.html; accessed 6/6/2009). Like the

NHMRC, other general nutrition advice available to the general public such as Better Health Victoria (http://www.betterhealth.vic.gov.au/bhcv2/bhcarticles.nsf/pages/Vegetarian_eating?Open. Document accessed 6/6/09), advises that well-planned vegan and vegetarian diets are appropriate for all stages of a person's life, although do not recommend strict vegetarian diets for young children.

While it is likely that other sources of information will list different figures than Table 1, especially for nutrients that vary with species such as the fat content of fish, it provides a useful comparison about nutritional factors across some common protein sources in the Australian context. The information provided in this section of the report demonstrates that the choice of protein brings with it a diverse range of other nutritional benefits, which vary considerably from source to source. It is these benefits, as well as other considerations such as the environmental impact or ethical dimensions of the nutritional choices they make, that individuals have to make for themselves and their families.

Table 1: Nutrient content per 100g of a range of protein sources including lean meats, fish, poultry and alternatives such as eggs, soybeans and almonds

	Energy (kJ)	Protein (g)	Iron (mg)	Zinc (mg)	Vitamin B_{12} (µg)
Lean beef	450	21.6	2.40	3.6	2.50
Lean lamb	501	20.4	2.30	3.4	0.96
Lean pork	438	21.6	1.00	2.2	0.70
Fresh flathead	395	21.1	0.20	0.6	1.50
Canned red salmon	815	21.9	1.20	0.9	4.00
Skinless chicken	466	20.4	0.95	1.4	0.41
Liver—lamb	680	21.4	9.40	4.3	84.00
Eggs	632	13.2	1.80	0.9	1.10
Soybeans (dry-cooked)	537	13.5	2.20	1.6	–
Canned baked beans	285	4.6	1.60	0.5	–
Almonds	2455	20.0	3.50	3.6	–

	Total fat (g)	Saturated fat (g)	Mono-unsaturated (g)	Poly-unsaturated (g)	Total n-3 (g)
Lean beef	1.8	0.87	0.82	0.21	0.07
Lean lamb	4.2	1.35	1.41	0.34	0.13
Lean pork	1.7	0.50	0.51	0.36	0.04
Fresh flathead	1.0	0.36	0.29	0.52	0.43
Canned red salmon	12.0	2.21	2.46	2.69	2.50
Skinless chicken	3.3	0.92	1.37	0.39	0.04
Liver—lamb	7.5	2.20	2.00	1.30	1.13
Eggs	10.9	3.10	4.30	1.00	0.06
Soybeans (dry-cooked)	7.7	1.10	1.20	4.80	0.17
Canned baked beans	0.5	0.10	0.10	0.30	0.03
Almonds	55.3	3.55	36.05	13.10	–

(Source NHMRC 2003). n-3 refers to Omega-3 fatty acids.

1.2 *Public interest in the environmental performance*

The search for sustainable forms of food production has been the focus of attention among agriculturalists for well over a century (Conford 2001; Howard 1943). Much of the concern was initially based around the pursuit of maintaining soil fertility as a means of reversing declining production levels (Howard 1972; 1946). Indeed, early connections between agricultural sustainability and biodiversity were found to lie in the soil, with claims that soil biota such as mycorrhizae and bacteria acted as a bridge to support the health of crops, livestock and mankind (Howard 1972). Such findings had been observed in Asian agricultural practices that had ensured the earth in China is still young (King 1911). While much of this focus was to stimulate the development and growth of organic farming (Conford 2001), it branched into more conventional forms of agriculture, largely based around replenishing soil properties through the use of agricultural chemicals (Harwood 1990; Liebhardt et al. 1989).

The loss of soil has also acted as a major impetus for agricultural attention to issues of sustainability for close to a century. The wind erosion event, the Dustbowl, on 14 April 1935 in the USA, and similar events in Australia around that time, spawned the creation of Soil Conservation Services in the United States (Helms 1992), Australia (O'Campbell 1980) and elsewhere across the globe (Hurni 1999).

The public's interest in agriculture's struggle for sustainability came to prominence following the publication of A Silent Spring (Carson 1963), which brought to light the issue of excessive use of chemicals, namely pesticides, in agriculture. Carson broadened the perceptions of agriculture's ties beyond soil resources to embrace water and watersheds, and doubtless because of this her publication has been recognised by many as the platform for the environmental movement (Beyl 1992). The very term movement is contestable from a sociological perspective (Benford and Snow 2000) and the notion that all public anxiety about the environmental performance of agriculture (or any other complex issue) could possibly be captured by a single movement seems unlikely (McDonald 2002), however the groundswell of public concern has been palpable for over two decades in Australia (Stringer and Anderson 2001) and has spawned both public and participative responses through collective action such as Landcare (Vanclay and Lawrence 1995; Campbell and Seipen 1994).

Increased public interest in the environmental performance of agriculture has been shown to have had limited influence on producers' decisions and adoption of more sustainable farming systems (Stiefel 1999). However, indirect public influence can be seen in the policies and programs of both government (OECD 2002; Stringer and Anderson 2001) and industry organisations (Productivity Commission 2007). In Australia, where producers associated with most agricultural industries are subject to compulsory levies to support research and development activities, industry organisations responsible for the investment of these levies each have some proportion of their portfolio directed towards sustainable agriculture (Price 1994). By way of example, Table 2 shows the environmental investment levels of a range of Australian industries.

Caution should be exercised in interpreting Table 2, particularly in light of biodiversity considerations. Not all investment in natural resource management has a biodiversity benefit, nor reflects smart investment in conservation (Possingham 2008; 2001). That said, a proportion of the NRM investment in all cases includes some investment specifically related to biodiversity. This is discussed in greater detail later in this review specifically in the context of the responses related to those industries involved in protein production.

Table 2: Natural resource management (NRM) investment by Australia's rural R&D funding bodies (2005)

Industry body	NRM R&D ($million)	R&D Expenditure ($million)	% NRM
Australian Egg Corporation		1.55	0.0
Australian Pork Limited	0.70	6.45	10.9
Sugar R&D Corporation	1.00	7.02	14.2
Forest & Wood Products R&D Corp	1.20	7.07	17.0
Cotton R&D Corporation	2.50	11.11	22.5
Grape & Wine R&D Corporation	2.00	15.08	13.3
Land & Water Australia	16.00	18.15	88.2
Fisheries R&D Corporation	15.90	25.57	62.2
Dairy Australia Limited	2.00	28.65	7.0
Horticultural Australia Limited	19.40	59.97	32.3
Meat & Livestock Australia Limited	6.06	62.60	9.7
Aus Wool Innovation Limited	8.40	65.72	12.8
Grains R&D Corporation	23.00	106.36	21.6

Source: Day (2005)

2 Project Objectives

2.1 Meat & Livestock Australia's expectations

Meat & Livestock Australia (MLA) is a significant investor in sustainable agriculture, including the development and improvement of grazing systems designed to minimise or reverse the impact of meat production on biodiversity (MLA 2006). MLA seeks to gather the most accurate, scientifically robust information to establish the evidence base for its performance, inform better land management, enlighten public debate and help shape future conservation programs.

To meet these aims, MLA has engaged the services of Kiri-ganai Research Pty Ltd to undertake a consultancy to:

- Review the literature to establish the impacts – positive and negative, historical and current, direct and indirect – of the beef and sheep meat industries on Australia's biodiversity (aquatic and terrestrial);
- Identify any significant gaps in the literature as areas for further research;
- As far as possible, compare the biodiversity impact of red meat production systems with other major alternative dietary protein production systems in Australia, and, in particular, industry approaches to conservation; and
- Make recommendations for:
    i. practical industry-wide and enterprise-level monitoring of biodiversity values and conservation management in livestock production systems;
    ii. industry and enterprise-level policies, strategies and practices that advance biodiversity conservation while maintaining or enhancing productivity and profitability in red meat production systems;
    iii. approaches to improve producers' capacity to contribute to production and conservation goals; and
    iv. processes to improve the capacity of the red meat industry to contribute to conservation science and public policy for biodiversity outcomes.

The research team associated with this study includes Professor Jann Williams, one of Australia's leading ecologists and biodiversity researchers, and Dr Richard Price, a prominent environmental research leader, sociologist and political scientist. The combination of these skills is intended to ensure that MLA's desire for scientifically robust analysis is met and that the integrity of the research is not compromised by factors other than those needed to underpin continuous improvement in biodiversity management across protein production systems.

3 Methodology

3.1 *Scope and selection process*

This study focuses on Australian protein production systems, although as discussed on several occasions throughout this report, the Australian literature on the impact of some of these production systems is scarce and often non-existent.

Although Australia is often stereotyped as a harsh environment for agriculture (ABS 2003), its production systems are extremely diverse for both protein and non-protein based food sources. Table 3 summarises the key Australian protein production systems and their characteristics, and this is used as the basis for the comparative analysis undertaken in this review. The protein sources are divided into four classes: red meat, white meat, plant-based and other (mainly dairy and eggs). The red and white meat classes both include introduced domesticated and native animals, while the plant-based crops are all introduced. Meat production associated with dairy cows (e.g. veal and ‘dairy beef’), is not covered in this report because it is a relatively minor industry. Although there have been calls to enhance the growth of native food industries as a means of matching highly evolved animal (Foster 2009; Wilson and Edwards 2008) and plant (Foster 2009; Clarke 2007) systems with Australia’s landscapes, native systems play only a small role in Australian agriculture at this point in time (Foster 2009; Stirzaker et al 2000).

3.2 Literature review

The analysis undertaken in this review is based on the contemporary literature concerning the industries listed in Table 3 and about biodiversity condition of Australian landscapes (including terrestrial and aquatic features). While the scope of this project limited to Australia, most of the literature is of necessity Australian. That said, the scarcity of biodiversity impact studies for many industries in Australia, and in particular the non-red meat industries, has meant reliance on overseas literature where its relevance can be translated to the context of this review.

In all, several hundred publications were reviewed, with precedence given to peer-reviewed scientific literature or official statistics in the public domain. Again, however, the authors found that the paucity of biodiversity impact studies meant some reliance on the grey literature, including industry publications and conference papers where these were presented by researchers related to the field of biodiversity.

The paucity of literature reflects the fledgling interest in studies that aim to integrate biodiversity into agriculture systems. Much of the biodiversity literature in agricultural landscapes has focused on the patches of native vegetation that remain in the landscape, rather than examining biodiversity as part of the farming system. This is starting to change through programs such as Land, Water & Wool and Grain & Graze.

Table 3: Summary of protein sources in Australia

PROTEIN SOURCE	POPULATION	AREA OCCUPIED (Variable units)	CONSUMPTION (unit/person/year)	GROSS VALUE OF PRODUCTION
Red meat				
Beef	27.3 million (2007-2008) (ABS 2009a)	332 million hectares (2007); 87,000 cattle properties (MLA), 41,640 specialising in beef cattle (2008) (Fletcher et al. 2009)	35.6 kg (2007-08)	$7.6 billion (2007-08) (including live cattle sales)
Sheep	45.96 million (2007)	134 million hectares (2007); 47,000 sheep properties (MLA), 11 148 specialising in sheep, including wool producers (2008) (Fletcher et al. 2009)	11.4 kg (lamb) 2.7 kg (mutton) (2007-08)	$2.2 billion (2007-08)
Kangaroos and wallabies	25 million (2002) 2.6 million (slaughtered) (2004) (variable depending on quotas)	The harvested species overlap with the distribution of cattle and sheep, so covers a large area (no commercial harvesting in NT)	17,421 tonnes in total went to domestic human consumption (2007) (Foster 2009) Estimated < 0.25 kg eaten per person per year (May 11 issue of Time Magazine)	$44.05 million (paid to shooters at meat processing plants) (Foster 2009)
Goat	1.35 million (slaughtered); 753,000 exported (Foster 2009)	2 million hectares (TAP 2008)	800-1000 tonnes domestic consumption in total; > 95% exported (Foster 2009)	$57.2 million in meat sales (Foster 2009)
Rabbit (farmed)	262,000 (2006-2007) (Foster 2009)	43 farms (average of 297 breeding does) (Foster 2009)	324 tonnes of meat produced in total (2006-2007) (Foster 2009)	$2.59 million (2006-2007) (Foster 2009)
Camel	1,000,000 (feral) 5-6000 (commercial harvest) (Edwards *et al*. 2008)	330 million hectares (Edwards *et al*. 2008)	1000 camels harvested for domestic human consumption, 3600-4600 for pet food; 400 exported (Edwards *et al*. 2008)	$683,000 (Foster 2009)
Buffalo	60,000 (feral) 13,600 (2006) (Foster 2009)	67 farms (2006) (Foster 2009)	Estimated restaurant trade (2006) was 29 tonnes (Foster 2009)	$4.9 million (Foster 2009)
White meat				
Chicken	93 million (2002) 470 million (processed) (2007)	NA	35.9 kg (2007-08)	$1.3 billion (2007)

PROTEIN SOURCE	POPULATION	AREA OCCUPIED (Variable units)	CONSUMPTION (unit/person/year)	GROSS VALUE OF PRODUCTION
Duck	4,493 (slaughtered) (2004)			$34.2 million (2004)
Turkey	3,050 (slaughtered) (2004)			$43 million (2004)
Goose	Approx 5,000 (processed)			
Emu	6,258 (slaughtered) (2004)	41 farms (2006) (Foster 2009)	88.7 tonnes <u>in total</u> (2007) (Foster 2009)	$1.34 million (Foster 2009)
Exotic*	18,747 (slaughtered) (2004)			$9.1 million (2004)
Pig	2.18 million (2008)	2,914 farms (2002) (Average 114 sows)	24.7 kg (2008)	$880 million (2007)
Game pigs	Between 13 and 23 million (feral) (DEH 2004) 155000 (slaughtered) (Foster 2009)	Cover round 38% of Australia (feral.org.au)	20 tonnes domestic consumption; 1818 tonnes exported (Foster 2009)	$10.77 million (Foster 2009)
Crocodile	NA (farmed)	14 crocodile farms in northern Australia (Foster 2009)	88.59 tonnes total (2006-2007) (Foster 2009)	$8.95 million (Foster 2009) – principally the sale of skins
Fish & Seafood**		NA	23.2 kg (2005)	$2.18 billion (2007)
Plant-based				
Soy	34733 Tonnes (2008)	14,885 hectares (2008)		
Other cereals	25.7 million Tonnes (2008)	21 million hectares (2008)	99.2 kg (2005)	7.5 billion (2008)
Tree nuts	65,410 Tonnes (2005)		43,000 tonnes/year (2008)	$160 million (2005)
Other				
Dairy				
cows	1.7 million (2007 – 08) 9.2 billion litres of milk	3.2 million hectares (2001)	104 litres (milk) 12 kg (cheese)	$4.6 billion (farmgate) $11.5 billion (wholesale)
sheep/goats	500,000 litres in 2006/2007 (sheep) (Foster 2009); 4.8 million litres of milk (goat)	NA	60% yoghurt, 40% cheese (sheep) (Foster 2009); 60% cheese; 35% whole milk/yoghurt; 5% powder & tablets (goat) (Foster 2009)	$4.1 million (goat)
Eggs - chicken	15.2 million hens 236.4 million eggs (2006/07)	NA	7.1 kg (2005)	$398 million (2007)

* pheasant, quail, pigeon, ostrich
** prawns, lobster, squid, octopus, shellfish

3.3 Journal selection

Part of the project brief called for the results to be published in a reputable, scientifically peer-reviewed journal. The project team recommends that Animal Production Science, published by CSIRO Publishing, is the most suitable journal for MLA's purposes. This journal crosses the range of scientific and social-science interests as well as the range of industries covered in this report.

3.4 Analysis

To enable a standardised comparative analysis to be undertaken, a common set of descriptors is used for each of the protein sources listed in Table 2 to depict the relationship between the production of the protein source, its impacts and the industry responses with specific regard to biodiversity. These descriptors include:

i. Pressures and impacts on biodiversity
   - a) nature of impact
     i.e. the physical manifestation of the impact
   - b) root cause of impact
     i.e. the impetus / degradation factor
   - c) extent of impact
     i.e. the size and or cost of the impact
   - d) significance of impact
     i.e. overall impact, including the flow-on affects

ii. Responses
   i.e. how the industry is responding through management, rehabilitation of R&D investment

iii. Monitoring mechanisms
   i.e. how the industry measures its ongoing performance in respect to biodiversity

iv. Effectiveness of responses
   i.e. condition improvement / reversal of trends in biodiversity impact status

v. Public perceptions
   i.e. how the public views the industry and its impacts on biodiversity (rightly or wrongly)

3.5 The type and extent of protein sources used in this study

Ten protein sources were selected out of the list in Table 3 for a comparative analysis of their impacts on biodiversity. They can be characterised both in terms of their food classification (red meat, white meat, plant-based and other) and in terms of the intensification of production system (high density, intensive and extensive - in order of intensity from highest to lowest) (Table 4).

In 2007–08, approximately 54% of Australia's total land area was managed by agricultural businesses (ABS 2009b). This equates to around 4.15 million square kilometres, or 415 million hectares. The management of these vast areas therefore has a major bearing on biodiversity in Australia. Grazing land for domestic cattle, sheep and dairy accounted for 87% of land managed by agricultural businesses. This included both grazing on improved pasture

(16% of agricultural land use) and other grazing land (71% of agricultural land use). Other agricultural land use included 8% for cropping, some of which is used to feed animals for meat production especially in high density systems. Figure 2 provides a visual image of the area that the different land uses cover, with native grazing and modified pastures represented by the light cream and tan colours respectively.

Table 4: Intensity of the production system associated with selected sources of protein

Protein source	High density	Intensive	Extensive
Red meat			
Beef	Feedlots	High Input pasture	Low Input pasture
Lamb	Feedlots	High Input pasture	Low Input pasture
Kangaroo	-	-	Native populations
Goat (TBC)	-	High Input pasture	Low Input pasture
White meat			
Poultry	Battery	Free range	-
Pigs	Feedlots	Free range	-
Fish	Aquaculture*	-	Native populations
Plant-based			
Grains, legumes & pulses	-	High Input cropping	-
Other			
Eggs	Battery	Free range	-
Dairy	Feedlots	High Input pasture	-

* includes both terrestrial and sea-based fish farming

The kangaroos and goats used as protein sources are from wild sources, being native and feral respectively. They cover large areas of Australia’s land area (see sections following for details), principally in semi-arid areas, and overlap in geographic distribution with cattle and sheep. High density feedlots and battery hen production facilities are mostly found in coastal areas, with a concentration around northern New South Wales and South-eastern Queensland for cattle feedlots.

The fisheries analysed in this report cover both wild and farmed populations, both marine and freshwater. For the purposes of this report, the industry comprises the commercial sector covering the high seas – generally between 3 and 200 nautical miles from the Australian coast – the coastal zone – within 3 nautical miles – and inland fishing and aquaculture. The aquaculture sector is highly intensive and has grown rapidly to the point that it now accounts for one-third of the value of the Australian fishing industry (ABARE 2008).

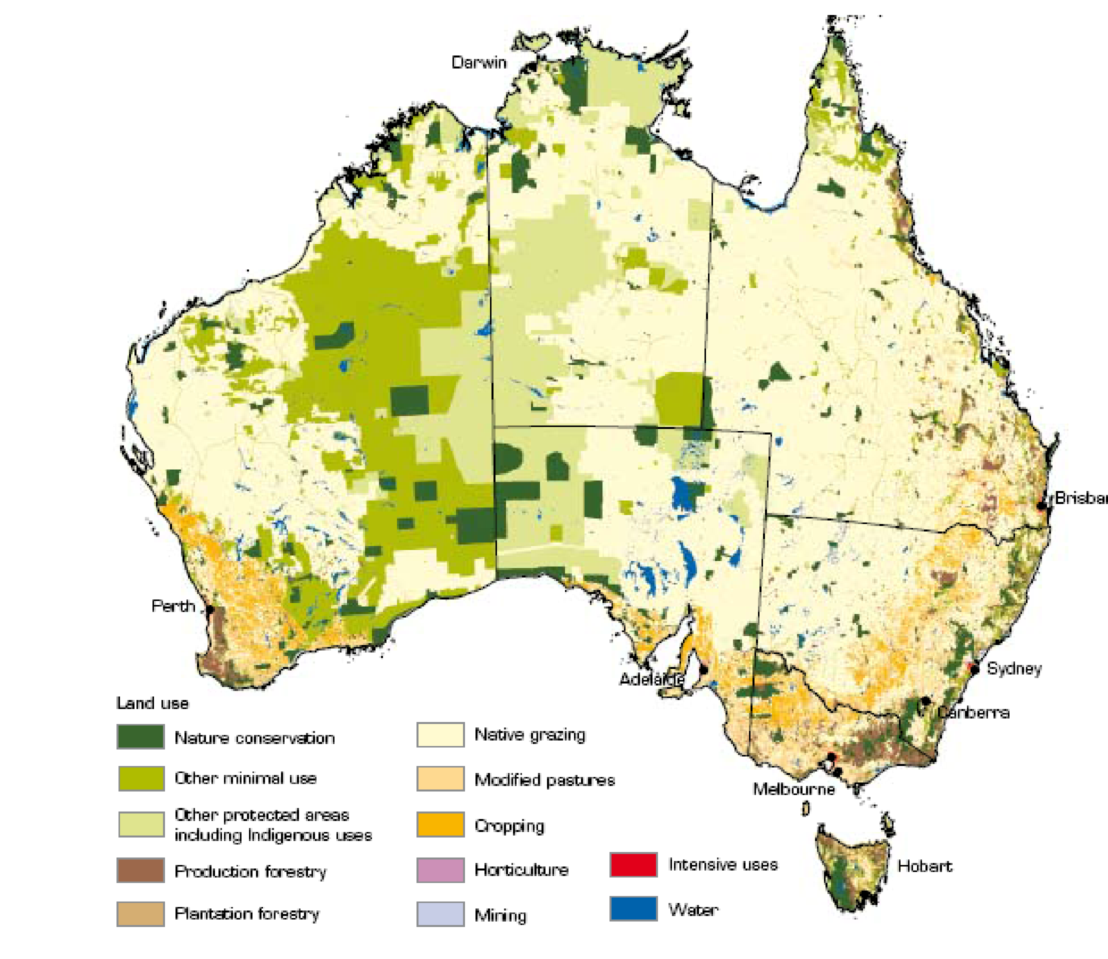

Figure 2: A 2000-2001 national-scale land use map illustrating the broad distribution of pastures and crops across Australia (Source: NLWRA 2008)

3.6 Classifying impacts on biodiversity

The research and policy sectors that focus on the conservation and management of biodiversity largely use a threat-based approach to classifying impacts. Within this framework, different classifications have been developed to describe impacts on biodiversity. For example, Auld and Keith (2009) provide a simple classification of five general types of threats to biodiversity to assist the integration of science and management. They argue that a clear understanding of the cause and effect of threats, combined with adaptive management strategies for amelioration, is needed to manage all types of threats. Coutts-Smith et al (2007) developed a threat hierarchy for their study on pest animals and biodiversity, noting that a standardised system to describing threats would improve the assessment and direct comparison of threats.

Government agencies at the state and national level, as well as international organisations such as the International Union for the Conservation of Nature (IUCN) develop and maintain lists of threatened species and ecosystems, as well as processes that threaten biodiversity. Common categories are used across many of these organisations, including ‘extinct in the wild’, ‘endangered’, ‘threatened’, ‘vulnerable’ and ‘least concern’. These categories are used to compare and contrast the status and trends of species and ecosystems, with policies and programs often focusing on the endangered and threatened categories. In turn, these categories have been used to categorise threatening processes, such as the work on the Australian flora by Burgman et al. (2007) that compiled information on all federally listed endangered and critically endangered species in 2004. Using this data, the contribution of different threatening processes to past, present and future declines of different plant species were assessed.

As no standard approach to classifying threats and threatening processes is available, and because protein sources are related to a particular set of impacts on biodiversity, the following list of broad pressures was developed for use in this report:

- Vegetation clearance and modification
- Altered fire regimes
- Altered grazing regimes
- Altered hydrology
- Trampling and soil compaction
- Invasive species
- Pollution
- Disease and pathogens
- Climate change
- ‘Other’ pressures, including direct decline of biota from harvesting

The list is based on a range of literature on biodiversity impacts (e.g. Williams et al. 2001, NLWRA 2002, Beeton et al. 2006, Steinfeld et al. 2006, Burgman et al. 2007, Auld and Keith 2009). These broad pressures lead to a number of direct impacts on biodiversity, which are described in association with each broad pressure below. In turn, these impacts are the basis for describing the state of biodiversity (potential and actual) in the separate sections that follow on each protein source. Many of the pressures interact with each other, as noted below. Where these interactions have a major impact on biodiversity, they are referred to in the text.

3.7 Pressure-State-Response model

Describing the pressures and impacts on biodiversity is an essential first step. The Pressure-State-Response (PSR) framework provides a broader context for assessing the pressures that various activities place on biodiversity. The PSR approach was developed by the OECD and is now widely used. The model considers that human activities exert pressures on the environment that affect its quality and the quantity of natural resources (state). Society then responds to these changes through environmental, general economic and sectoral policies, and through changes in awareness and behaviour or activities (societal response). Often, decisions are targeted not at the original pressures, but at the symptoms exhibited by the changed state. Without considering the pressures, and the driving forces behind them, such measures are almost always doomed to failure.

In Australia the PSR model, and variations on it, are used in State of the Environment reporting by governments at the local, state and national level. "Indicators" are the essential components of these models, but often data is lacking to demonstrate trends over time

(Williams et al. 2001). For this report, the Pressure-State-Response model is used for each protein source. The list of pressures for each protein source will vary, but all are based on the aggregate set in Table 5. Formal indicators have not been developed, but where possible, data collected on trends over time is used to illustrate patterns. Often this data comes from surrogates of biodiversity, such as the amount of native vegetation cleared.

The broad pressures identified for this project are often common across different protein sources. For example, vegetation clearance and modification is related to the beef, sheep and dairy industries for pasture production and a number of protein sources which are associated with grain production for both animal and human consumption. Rather than describing these pressures for each of the protein sources where they have a major impact, they are described only once in the next major section of the report. The pressures described in this manner, and the industries they relate to, are listed in Table 5. If there are particular examples of pressures that are specific to only one or two protein sources, they are covered in the 'Other' category. These include the killing of dingoes to protect livestock, which is largely associated with the sheep industry.

Table 5: Pressures of biodiversity by different protein sources

Broad pressure	Protein sources
Vegetation clearance and modification	Beef, sheep and dairy industries for pasture production; Grain production for intensive enterprises and feedlots (dairy, cattle, sheep, pigs, chickens); Grains and legumes grown for human consumption. Potential minor clearing for pork and chicken high density facilities.
Altered fire regimes	Beef, sheep, goats and dairy
Altered grazing regimes	Beef, sheep, goats, dairy and kangaroos
Altered hydrology	Beef, sheep, dairy, pork, chicken, eggs
Trampling and compaction	Beef, sheep, dairy, pork
Invasive species	Weeds – beef, sheep and dairy; Escaped organisms – fisheries.
Pollution (water, soil and air)	All protein sources, except kangaroos
Disease and pathogens	Pork, chickens and eggs, fisheries
Climate change	All protein sources, to varying degrees
Direct decline from harvest	Fishing, kangaroos

3.8 Historical versus current and future pressures on biodiversity

It has been argued that in Australia most of the pressures and impacts on biodiversity related to agriculture have occurred in the past, when our understanding of impacts was less and some laws made land clearing obligatory to help the development of the country. These past pressures often have a lasting legacy that will continue for decades to come, even with remedial action. This response is often referred to as an extinction debt, a concept introduced by Tilman (1994) and refined and tested since (e.g. Loehle and Li 1996, Cogger et al 2003, Helm et al. 2006, Mac Nally et al. 2009, Possingham 2009). Consequently, despite identifying some encouraging signs at local to regional scales, Beeton et al. (2006) indicated that biodiversity continues to be in serious decline in many parts of Australia. Examples of the ongoing declines of species have been reported by several authors, particularly for birds and mammals in the rural landscapes of south-eastern Australia (Ford et al. 2001, Radford et al. 2005, Mac Nally et al. 2009), even where areas have been revegetated (Vesk and Mac Nally 2006).

Studies such as Lunt and Spooner (2005) have highlighted the over-riding influence of land-use history in creating past, current and future patterns of biodiversity across a range of spatial scales in south-eastern Australia. They argue that the more we know about the history of landscapes, the better we will be able to understand, describe, predict and manage patterns of remnant woodland vegetation and associated biota.

Burgman et al. (2007), analysing data on endangered flora, found that land clearance for agriculture (grazing and cropping) and urbanization have been the primary causes of range contractions and habitat loss in the past, and are responsible for the current status of the majority of threatened Australian plants. In the future, Burgman et al. (2007) argued many species are at risk from demographic and environmental uncertainty alone, which is often related to the legacy of management practices such as vegetation clearance. These examples demonstrate that both historical and current land use management have ongoing impacts on biodiversity and cannot always be easily separated, even when management actions have improved and remediation activities are in place.

Past and current land use has led to the creation of new ecosystems with a different combination of species than those found in natural systems (Bridgewater 1990). There is ongoing debate in the ecological community about the value of these systems and how much resources should be allocated to them compared to less modified systems (Hobbs et al. 2006).

3.9 The danger of generalising patterns – grazing as an example

The impacts of grazing on biodiversity will vary depending on its intensity (e.g. stocking rate), frequency and season – in other words, depending on the grazing regime (Williams 2005). This is similar to the concept of fire regimes, which was introduced by Gill (1975) and is widely used in the ecological literature (e.g. Bradstock et al. 2002). As noted by Lunt (2005) grazing ecology must be recognised as a complex field, in which outcomes will vary depending upon the ecosystem in question and the grazing regime being implemented. Despite the increased understanding that using grazing regimes as a framework would have, this term has not been commonly used in conservation studies in Australia. Many of these refer to the broad impacts of 'grazing' rather than more specific descriptions, leading to the perception that it is 'grazing' that places pressures on biodiversity, rather than particular grazing regimes (BHA 2009).

The detailed section that follows on the pressures and impacts associated with grazing regimes illustrates the range of different vegetation types and management styles where studies have been undertaken. Responses of native systems to grazing regimes and other land uses often vary between sites. Using historical ecology as a framework, Lunt and Spooner (2005) give examples where remnant vegetation in South-eastern Australia has been pushed into multiple states, each conserving (or promoting) different subsets of the original biota and ecosystem processes. As a consequence, the authors state that management objectives and advice need to be tailored to the state of the remnant. For example, remnants in cemeteries, which have been subject to little or no grazing, cannot be managed in the same way as more heavily grazed remnants in forest or conservation reserves. Grazing impacts on biodiversity have been demonstrated to vary across the landscape in semi-arid and savanna landscapes, with patterns varying on different soil types in northern Australia and in different vegetation types in South Australia (e.g. the Bounceback Program).

Because of the looseness in the description of the grazing regime being studied, and sometimes the lack of information on the type of stock that was involved, careful consideration must be used before generalising impacts from one study to another or one vegetation type to another.

3.10 Pressures often work in tandem and over time

While Table 5 and many reports on biodiversity conservation and management list and analyse pressures on an individual basis, it is clear that most species are threatened by a number of interacting factors. This was a key issue to emerge from the analysis by Burgman et al. (2007) of endangered Australian plants. They referred to this phenomenon as 'threat syndromes', which formalises the understanding that it is often the combined effect of a range of pressures that has an impact on biodiversity. Hobbs (2001), for example, identified synergisms between habitat fragmentation, grazing by livestock and invasion of remnants in south-western Australia by exotic plants and animals.

Interactions between multiple factors that impact on the state of biodiversity have also been identified through recent research in northern Australia. This attributes the declines in both birds and mammals, as well as changes in landscape function (Franklin et al. 2005, Woinarski et al. 2005, Woinarski et al. 2007) to factors such as the breakdown of traditional aboriginal land management and the concurrent impacts of altered fire and grazing regimes, changes to water availability and flow and the presence of feral animals and weeds (Woinarski and Ash 2002). Interactions between grazing and fertiliser impacts on native plant diversity have also recently been quantified in south-eastern Australia (Reseigh et al. 2003, Dorrough et al. 2006).

Not only do pressures on biodiversity often work in tandem, the cumulative impacts of different pressures over time are also important to consider (Lunt and Spooner 2005). Fleishman and Mac Nally (2007), for example, argue that examining changes of land cover and species patterns over time is important because shifts can confound detection of systematic responses to impacts such as fragmentation. These interactions in space and time can make it challenging to tease apart the main causal factors and the solutions needed to address them. They will be revisited in the sections on individual protein sources and towards the end of the report.

4 Broad pressures on biodiversity

The focus of this report is on the impact of red meat production on biodiversity. The definition of red meat used by Meat & Livestock Australia includes cattle, sheep and goats. Following the NHMRC (2003), we have included kangaroos in the definition. Red meat production systems involve a number of pressures on biodiversity (Table 5). These pressures, and their direct and indirect impacts on biodiversity, are described in the following section. Where relevant, information is also included on pressures associated with other protein sources (see Table 3). This section provides essential information for the section on the state of biodiversity for individual protein sources. This will include an examination of the responses of a range of stakeholders to the pressures on, and state of biodiversity for different protein sources.

4.1 Vegetation clearance and modification

Throughout the world, the development of agriculture has resulted in the rapid transformation of continuous ecosystems to landscapes dominated by crops and pastures, within which small remnants of the original vegetation are retained. In 1999 it was estimated that the countries with the highest annual rate of vegetation clearance, which included Australia, converted at least 8 million hectares of natural ecosystems to other land uses (Williams 2001). When figures like this are repeated on an annual basis, the global impacts of vegetation clearance and modification are clear. In addition to land cleared directly for pasture production, feedlots rely on grain and legume crops to feed livestock (predominantly cattle), with approximately 34% of the world’s cropland now used to produce feed grains and legumes for livestock (Steinfeld et al. 2006). In Australia, the chicken, beef and pork feedlot sectors are heavily dependent on grain as the main feed ingredient. The beef and dairy industries now represent more than 50 per cent of feed use in Australia. The beef feedlot industry is the largest user of grain by volume, followed by chicken and pork (Scott 2008). When examining the impacts of red meat and other protein sources on biodiversity therefore, clearing for pastures and grains needs to be considered.

The majority of clearing in Australia has occurred in southern and eastern Australia, with the south-west of the continent being particularly affected. Of an estimated total cover of over 24.693 million ha in south-western Australia, about 20.124 million ha have been cleared (George et al. 1996). It is commonly thought that most of the native vegetation cleared in Australia occurred last century and early this century. This is not the case (Glanznig 1995). In the period 1945-1995 as much land was cleared as in the 150 years before 1945. Extensive clearing for agriculture occurred in the 1960s and 1970s and significant clearing was still taking place in the 1990’s. Data reported in Graetz (1998) suggest that early clearing of native vegetation in Australia was principally for cropping; with clearing for pastures increasing in importance from the 1950s on. These data indicate that annual rates of clearing peaked in the 1970s, when extensive areas were cleared in south west Western Australia and Queensland for grain production and in Queensland for pasture improvement. Even the most detailed study of land cover change for its time (Barson et al 2000) was only able to attribute change to broad categories such as agriculture and grazing.

These national estimates of clearing give a useful overview of patterns in vegetation clearance and land use change. Teasing apart the relative contribution of cattle, sheep, dairy and crops to rates of clearance at a regional level however can be challenging. Studies such as Seabrook et al. (2007) provide some insights into patterns of clearing over time, but also demonstrate the complexity of the drivers that affect the mix of enterprises on a farm. The authors show changes in the area of crops over time in the Brigalow country where the study was conducted, but were unable to graph the area cleared for sheep and cattle enterprises. It would take considerable effort to draw out the details of the type of agricultural enterprise that native vegetation was originally cleared for in the range of studies such as this, assuming the information was available in the first place.

Publications such as Glanznig (1995), which was written when native vegetation clearance was high on the agenda, lists rates of clearing on a state-by-state basis rather than by enterprise. The series of reports produced by the National Land & Water Resources Audit in 2001 and 2002 give some indication of potential clearing by enterprise type, by presenting information on trends in area under improved pastures and crops since 1950 (NLWRA 2002a) and the area of sown pasture by state (NLWRA 2002b). Both of these publications suggest that around 30 million hectares had been cleared for sown pastures (for both sheep and cattle grazing) and around 25 million hectares for crops by mid-1995. This compares to an area of 21.9 million hectares sown to winter crops in 2009 (ABARE 2009).

At a more detailed level, state-based reports prepared for the NLWRA give a snapshot of land use at a particular time, including the amount of land used for cropping and improved pastures, and hence how much vegetation was cleared (e.g. Beeston et al. 2001). Whether or not this was the original reason for clearing however is not recorded. The annual report produced by the State Landcover and Trees Study (SLATS) in Queensland provides the most detailed information on rates of clearing and the underlying drivers. For example, in 2006-2007 it was reported that clearing to pasture remained the single major replacement cover, making up 93% of State woody vegetation clearing for that year (Department of Natural Resources and Water 2008). For the purposes of this report, the current distribution of cattle and sheep industries in the intensive land use zone, where most native vegetation has been cleared, gives some guidance about the regions that have been cleared for red meat production. These are concentrated in inland Queensland and NSW for cattle, and NSW, Victoria and Western Australia for sheep (Fletcher et al. 2009).

There are multiple direct impacts of broad-scale vegetation clearance and modification on biodiversity, as indicated in Table 5. These include: loss of deep rooted perennial trees and shrubs, leading to habitat loss; increased habitat fragmentation, leaving small patches, scattered trees and reduced connectivity; reduced ground cover; reduced canopy cover (and altered micro-climates); potential for increased invasion of environmental weeds; increased soil compaction and greenhouse gas emissions (contributing to climate change) and reduced riparian vegetation. These direct impacts can have flow on effects that also can negatively affect biodiversity, such as potential changes in regional climate and increased soil salinity levels and erosion events that can impact on aquatic ecosystems. These impacts are described below, and where appropriate, in other parts of the report.

Because of the range of impacts associated with the broad-scale clearing of native vegetation for agriculture (cropping and grazing), it has been identified as the most serious pressure affecting biodiversity in Australia (Glanznig 1995, Williams et al. 2001, Morgan 2001, NLWRA 2002). Figure 3 illustrates that while the total area of land cleared (green bars) in Australia has declined between 1973 and 2004, millions of hectares of native vegetation have been replaced by other land uses over this 30 year period. Recent commentary suggests that new pressures are starting to eclipse clearance of vegetation in terms of their impacts (Beeton et al. 2006, Burgman et al. 2007). While overall rates of clearing appear to be declining (Figure 3), the legacy of past clearing and ongoing clearance – both broad-scale and through less obvious mechanisms as lack of regeneration due to grazing (Williams et al. 2001) – still represents a major pressure on biodiversity.

In recent years Queensland has had the highest rates of clearing in Australia (mostly for pasture production), and has been the focus of considerable attention (Glanznig 1995, Fensham et al. 1998, Rolfe 2002, Williams et al. 2001). For example, permits to clear a total of 1,079,297 ha of leasehold land including 684,967 ha of virgin bush and 391,730 ha of regrowth and invasive woody weeds were granted in Queensland in 1994 (Glanznig 1995). Changes to legislation in Queensland, which brought an end to broad-scale clearing in December 2006, have reduced the rate of clearing. The Department of Natural Resources and Water (2008) report showed that based on satellite imagery, the clearing of native vegetation in Queensland has dropped by 37 per cent, down from 375 000 ha/year in 2005–06, to 235 000 ha/year in 2006–07. The report also shows greenhouse gas emissions are down from 41.24 to 31.55 megatonnes.

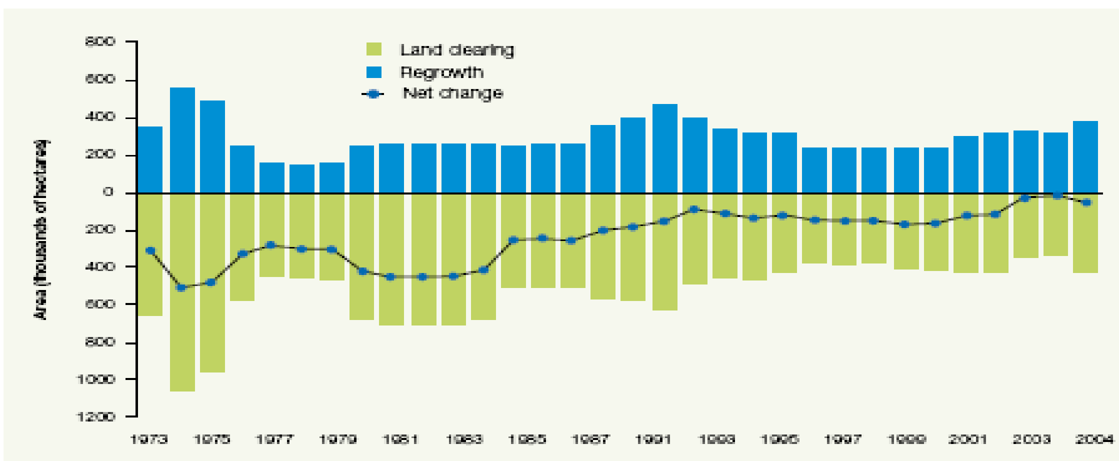

Figure 3: Net forest change in Australia (using forest regrowth and deforestation data) 1973-2004: Source (Beeton et al. 2006). Area (Y axis) is in thousands of hectares.

A study of the social history of land clearing by the Australian Greenhouse Office (AGO 2000), which examined clearing over the period 1970-1990, found that agricultural profit was the primary motivator for land clearing. Profit can be gained in two ways: immediate economic gain from increased production, and future economic gain from increased land values. During the period 1970-1990 both these forms of economic gain were enhanced by a range of financial and institutional incentives for agricultural development, which provided cheap land along with venture capital in the forms of loans or tax concessions. In contrast to these results, Seabrook et al (2007) found that at a regional scale the suitability of soil for agricultural was the main driver for clearing vegetation. Because these results were different from most other studies on landscape change, they concluded that solutions to the over-clearance of native vegetation need to be tailored to the specific regional situations encountered.

Certain ecosystems have been targeted for clearance, due to their value for grazing and cropping. NLWRA (2002c) gives an area of major vegetation groups cleared as a proportion of total clearing in Australia. Using these statistics, it was shown that approximately 31% and

25% respectively of eucalypt woodlands and eucalypt open woodlands had been cleared, accounting for 32% and 13% of all clearing. At a regional level, over 80% of Australia's temperate woodlands have been cleared since European settlement (Olsen et al. 2005), while 99.5% of the original temperate grasslands have been lost (McDougall and Kirkpatrick 1994). Different patterns of clearing leave behind different amounts of remnant native vegetation. McIntyre and Hobbs (1999) developed a framework to describe landscape 'alteration' states, which has been widely adopted by the ecological community.

The four states that are described in the McIntyre and Hobbs (1999) framework are associated with increasing amount of habitat removal and decreasing levels of habitat connectivity (Figure 4) related to vegetation clearance. In intact landscapes (e.g. arid rangelands), less than 10% of the vegetation is removed and the landscape mosaic is, therefore, 'habitat' in various states of modification. At the other extreme are relictual landscapes (e.g. cropping or urban areas) where over 90% of the native vegetation is removed and small areas must survive in a landscape matrix, which may be hostile to the continued persistence of the vegetation. In between these two extreme states are variegated landscapes with 60-90% vegetation cover and fragmented landscapes, which have 10 – 60% cover. Variegated landscapes can be found in all eastern states and result from the grazing of natural grasslands without significant inputs, and from limited amounts of cropping.

As described in the McIntyre and Hobbs (1999) framework, broad-scale vegetation clearance has led to the fragmentation of the landscape, leaving a legacy of remnant vegetation patches, scattered trees and decreased connectivity between patches (Fischer and Lindenmayer 2007). The fragmentation of the landscape caused by broad-scale clearing drives the ongoing loss of a whole host of species – the process of 'extinction debt' continues to deplete plant and animal populations today as a result of activities that occurred some time ago (see section on historical patterns).

It is not only broad-scale clearance of vegetation for pastures and crops that has an impact on biodiversity. The cumulative impact of the clearance of smaller areas of vegetation, including paddock trees, can be considerable. In some landscapes, scattered remnant trees are the only examples of native vegetation left in an area (Reid and Landsberg 2000, Fischer et al. 2009). Many of the trees on private land, in small remnants or scattered across farmland are likely to die in the next 50–100 years even without climate change; given the lack of regeneration (Gibbons & Boak 2002). These trees continue to be cleared in some places, largely as the result of agricultural intensification and development (Carruthers et al. 2004, Mallawaarachchi and Szakiel 2007).

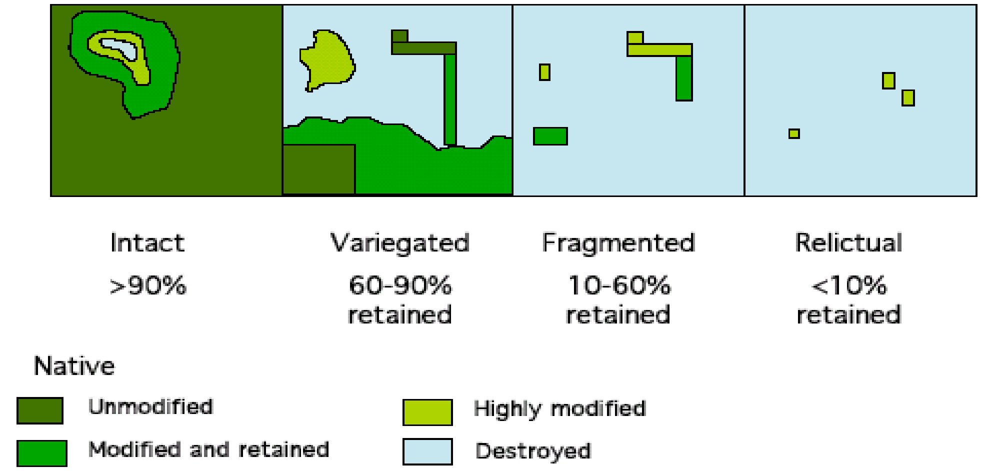

Figure 4: A framework for classifying landscapes based on the description of four landscape alteration 'states' associated with increasing amount of habitat loss and decreasing levels of habitat connectivity. (Source: BRS)

The condition of native vegetation that remains after vegetation has been cleared has a significant impact on biodiversity. Condition refers to the level of naturalness or 'health' of vegetation, and is a major indicator of the capacity of ecosystems to produce goods and services (Williams 2005). It may be assessed from a number of perspectives (e.g. vegetation structure, plant species composition, ecological functionality) using many attributes such as the degree of tree crown dieback, presence of weed species and provision of quality habitat for threatened animals. A special issue of the journal *Ecological Management & Restoration* was dedicated to the mapping of vegetation condition and how this information can be used to assess the health of vegetation (EMR 2006). The condition of vegetation can be affected by ongoing land use such as grazing by stock, incursion of weeds and changes in micro-climate at the edges of remnants. These factors will be addressed elsewhere in the report.

One of the indirect impacts of clearing for agriculture has been the changes in the populations of kangaroos and other native animals in response to the increased availability of productive pastures and crops, the decreased availability of habitat, and in some areas the decreased predation by dingoes and increased access to water (McAlpine et al. 1999). In some cases this has put pressure on the native systems that remain, when kangaroo numbers exceed their carrying capacity (Viggers and Hearn 2005).

Another indirect impact of the clearing of woody vegetation in Australia has fundamentally altered the intimate interplay of terrestrial ecosystems and the hydrological cycle (Walker et al. 1993, George et al. 1996), which has major impacts on both natural systems and human society. Gordon et al. (2003) estimate that the decrease in woody vegetation in Australia over the last 200 years has led to an approximately 10% decrease in water vapour flows from the continent. This, in turn, corresponds to a decrease in annual freshwater flow of almost 340 cubic kilometres, leading to problems such as large-scale dryland salinization (Robins 2004). Other models demonstrate links between broad-scale vegetation clearance, increased temperatures and decreasing rainfall at the regional level (Nair et al. 2007, McAlpine et al. 2007). More recently, Deo et al. (2009) have postulated that land cover change due to vegetation clearance has exacerbated climate extremes in eastern Australia, thus resulting in longer-lasting and more severe droughts. The importance of considering the influence of land cover change on current and future droughts in Australia, and how the impacts can be ameliorated, is emphasised by McAlpine et al. (2009).

Potential erosion from areas that have been cleared for grazing and cropping is another indirect impact of clearing on biodiversity. This is covered in greater detail under the broad pressure related to water pollution. Vegetation clearance will also have an impact on other soil properties such as structure and infiltration rates, thus affecting the soil biota associated with native systems.

4.2 Altered grazing regimes

Asner et al. (2004) in a review of grazing systems and global change noted that managed grazing lands occupy 25% of the global land surface, with the area increasing six-fold between 1700 and 1990. The authors contend that while managed grazing is a spatially diffuse land use and less intensive than cropping, globally it is a major driver of deforestation, woody encroachment and desertification. In Australia, grazing land for domestic cattle, sheep and dairy accounted for 87% of land managed by agricultural businesses (ABS 2009a) in 2008, or around 361 million hectares. This included both grazing on improved pasture (16% of agricultural land use) and other grazing land (71% of agricultural land use). Figure 2 shows that sheep grazing is restricted to southern and eastern Australia, whereas cattle extend into northern and central Australia, being found in most regions except the arid zone. This section introduces the range of impacts on biodiversity that have been associated with grazing, with greater detail provided in the specific protein sources that follow.

Lunt (2005), in a study on grazing impacts on temperate grasslands, describes three major ways grazing animals affect natural ecosystems (Box 2). These processes are not independent, interact considerably and vary in their scale. For example, the build up of nutrients from animals such as sheep is localised, but can have a significant impact on native plant species where it occurs. Increases to soil nitrogen and phosphorus levels in these sites strongly affect plant composition and promote exotic species over native species (Prober et al. 2002). Soil changes caused by the feet of grazing animals affect subsequent plant growth, and reductions in plant cover by herbivory affect soils, as witnessed by scalds and erosion (Lunt 2005). The nature of the impacts will also vary depending on the grazing regime and vegetation type being examined. In this report, the impact of grazing on soils is covered under the pressures 'trampling and soil compaction' and 'water pollution'. Grazing also alters the amount of biomass on a site, which in turn has an impact on fire regimes (see text on 'Altered fire regimes'). In semi-arid and rangeland systems artificial watering points, which are used to spread grazing pressure, can have a major impact on biodiversity. In this report, this is covered under the pressure 'altered hydrology' and demonstrates the connections between different pressures.

Box 2: Three major ways the daily activities of grazing animals affect ecosystems

1. Grazing animals eat plant parts, thereby directly removing vegetation and altering ecological processes within remaining vegetation.
2. The feet of grazing animals directly affect soils, by breaking soil surface crusts, compacting soils and encouraging erosion.
3. Animal wastes (urine, faeces and carcasses) redistribute nutrients within ecosystems. Nutrients consumed in eaten plants are deposited within relatively small parts of the landscape, often at high local concentrations.

Source: Lunt (2005)

Different herbivores graze differently, have different dietary preferences, are different sizes and have different behavioural and social patterns (Beaumont et al. 2000). Cattle, for example, eat plants using their tongues, sheep eat plant parts with their teeth and goats generally browse rather than graze. Different sheep breeds also demonstrate different grazing patterns, with the Dorper breed (used for sheep meat) being less selective than merinos (Brand 2000). Goats have the unique ability to utilise forage resources that cannot be utilised effectively by other ungulates such as sheep or cattle (e.g. thorny plants and species containing high proportions of phenolic compounds (Nastis 1995). Their biology also allows them to access parts of plants and the landscape that other introduced domestic herbivores can't.

All of these factors influence the impact of different herbivores on natural ecosystems and addressing them can increase our understanding of these complex systems (Hunt et al. 2007). To try and standardise the impact of different herbivores, the Dry Sheep Equivalent (DSE) is a unit frequently used to compare the feed requirements of different classes of stock or to assess the carrying capacity and potential productivity of a given farm or area of grazing land. There is some variation in the weight of a dry sheep used in defining a DSE, which usually sits around the amount of feed required by a 45-50 kg wether or non-lactating, non-pregnant ewe to maintain its weight (McLaren 1997). The DSE of different domestic stock varies considerably depending on their energy requirements (McLaren 1997), so it is important to indicate the status of the animals being studied. The DSE of kangaroos is estimated at between 0.2 and 0.7 DSE (SoE 2006). This figure has recently been revised (Olsen and Low 2006), which has implications for studies that compare impacts across different herbivores. While the DSE unit is commonly used as a standard unit of comparison in agriculture, it is still to be widely applied in ecological studies.

Another factor that influences the pressure that grazing regimes have on biodiversity is the palatability of plants to herbivores. This varies significantly, with factors such as the succulence, amount of protein, sugars and fats, and digestibility being important (Valentine 2001). The question of whether herbivory can benefit plants has been the subject of some debate. Belsky (1986), in a review of the evidence that existed at the time, concluded that although herbivores may benefit certain plants by reducing competition or removing senescent tissues, no convincing evidence existed to support the theory that herbivory benefits grazed plants. More recently, the focus has changed to identifying vegetative traits that can be used to identify the response of plants to grazing pressure (Diaz et al. 2001, 2007). These studies found that overall, grazing favoured annual over perennial plants, short plants over tall plants, prostrate over erect plants, and stoloniferous and rosette architecture over tussock architecture. There was, however, no consistent effect of grazing on growth form with climate and the history of herbivory playing an important role in responses.

Certain parts of the landscape, such as riparian zones, are particularly susceptible to grazing pressures (Staton and O'Sullivan 2006). Different plants and ecosystems also respond to grazing differently, with some being very sensitive to grazing by domestic stock and others less so (Lunt et al. 2007). In addition to these factors being important to consider, the effects of grazing on diversity are scale-dependent, with different outcomes observed depending on the scale that is investigated (Lunt 2005). For instance, herbivores may increase diversity at the small-scale (by reducing competition or providing niches for regeneration) but might reduce diversity at larger scales by selectively depleting species that are sensitive to grazing (Landsberg et al. 2002).

As noted earlier in the report in the section on the danger of generalisations, grazing ecology must be treated as a complex field. This is illustrated in the examples given above of the factors that influence grazing patterns. It is important to be able to describe the grazing regime (season, intensity and frequency), as well as the type of herbivores involved, when examining grazing pressures on biodiversity. The absence of a standardised method for describing grazing regimes in grazing studies has greatly constrained attempts to develop a general understanding of grazing impacts on vegetation. This can make it challenging to tease apart the numerous studies that examine the state of biodiversity grazed by domestic stock.

The concept of total grazing pressure (TGP) is mainly used in a rangelands context (Fisher et al. 2004), but could usefully be used across all landscapes that are grazed when documenting the impact of grazing regimes on biodiversity. Fisher et al. (2004) state that 'the improved management of total grazing pressure will ensure the sustainable capacity of rangelands are not exceeded as well as help maintain the proper functioning of ecosystems and survival of native species'. This statement provides a link between the TGP concept and the upper grazing pressure that can be sustained. TGP helps ensure that managers examine the mix of animals that will generate the pressure. This management system requires that all animals contributing to the grazing pressure be controlled, such as domestic, indigenous and feral grazing animals.

A continent-wide analysis of total grazing pressure in relation to Net Primary Productivity (NPP) for the 2006 SoE report compared the grazing pressure of sheep, cattle and kangaroos, based on an estimated kangaroo population of 19 million (SoE 2006). In this study, DSE (Dry Sheep Equivalent) was used as a measure to standardise grazing pressure across different animals. The study found that cattle contributed 66% of TGP, sheep 30% and kangaroos 4%. The report estimated that areas where low NPP and high DSE were found were most at risk from grazing pressure. This equated to an area of around 20,649 km^2. While the analysis was called an interpretation, with the approach used containing several caveats, it gives an indication of the potential contribution of different herbivores to grazing pressure at a national scale.

Because herbivore grazing by cows, sheep, goats and kangaroos (sources of red meat protein) is so widespread in Australia, and because the study of its impacts is a complex area, the location and types of studies undertaken are described here rather than under each protein source. The detail of what these studies report about the state of biodiversity is covered under the separate protein sources.

Ecologists use a range of approaches to study grazing impacts, as different types of studies address different types of questions. The three main approaches identified by Lunt (2005) in southern temperate systems include surveys to compare the effects of different historical regimes, for example by examining areas where stock have been excluded; experiments to compare the effects of contemporary grazing regimes, and experiments to determine how grazing affects ecosystem processes. Surveys are also undertaken to compare contemporary grazing regimes in rangeland and savanna systems (both using on-ground and remote sensing techniques), where properties cover large areas. In recent times, ecologists are starting to develop frameworks that can help study the impact of grazing regimes and improve management of natural systems – particularly in south-eastern Australia (Lunt 2005, Lunt et al. 2007). There have also been calls for better collaboration between ecological and agronomic researchers so that each discipline has a better understanding of how to design grazing systems that meet both production and conservation objectives (Dorrough et al. 2004).

The numerous studies on grazing regime impacts in Australia cluster into geographic areas, which correspond to different vegetation types, histories of land use, current management regimes and where researchers are based (Table 6). Depending on the region, vegetation may have been cleared for pastures or cropping, or pastoral grasses may have been introduced, often becoming environmental weeds. This variation in regional characteristics has an impact on the conclusions drawn from grazing studies and how easily they can be generalised.

Table 6: Geographic patterns in grazing impact studies across Australia and some of the scientists involved

Region	Characteristics of region	Examples of scientists who have worked on grazing impacts
SE Australia	Highly cleared, leaving remnants and scattered trees, minimal regeneration of eucalypts. Some native pastures. Grazing of sheep and cattle.	Lunt, Kirkpatrick, Dorrough, Fischer, Reid, McIntyre, Clarke
SW Western Australia	Highly cleared, leaving remnants and scattered trees, minimal regeneration of eucalypts. No native pastures.	Yates, Ausberg-train, Hobbs
Tropical savannas	Vegetation largely intact, but modified by environmental weeds which impact on fire regimes. Cattle grazing.	Woinarski, Garnett, Fisher, Ash

Region	Characteristics of region	Examples of scientists who have worked on grazing impacts
Semi-arid rangelands, central Australia	Vegetation largely intact, but modified by environmental weeds which impact on fire regimes. Cattle grazing. Artificial waterpoints widespread.	Landsberg et al., Tiver, Ludwig, Noble
Semi-arid rangelands, western NSW and Queensland	Broad-scale clearing for pasture production; Vegetation modified by environmental weeds which impact on fire regimes. Mainly cattle grazing. Artificial waterpoints widespread. Goats part of grazing pressure.	Fensham, McAlpine, McKeon, Hacker
Sub-tropical grassy woodlands	Some clearing, but vegetation largely intact. Variegated landscape (sensu McIntyre and Hobbs). Mainly cattle grazing.	McIntyre, McIvor, House, Chilcott, Martin

4.3 Altered fire regimes

Australian ecosystems have evolved with fire. Fire regimes (season, intensity, frequency and type) show considerable variability across different ecosystems (Gill 1975, Whelan 1995, Anon 1996, Gill et al. 1999, Bradstock et al. 2002, Abbott and Burrows 2003). Indigenous Australians used fire extensively as a management tool (Latz 1995, Dyer et al. 2001). With the permanent settlement of Europeans in Australia, which to them was a very foreign environment, fire regimes changed markedly with major consequences for biodiversity. This can include changes to the composition, abundance and distribution of species, as well as ecological processes such as competition and pollination (see previous references and separate sections on different protein sources for further details). Depending on the timing of rainfall in relation to areas being burnt, altered fire regimes can exacerbate erosion associated with vegetation clearance and overgrazing (Beeton et al. 2006).

The main pressure caused by cattle, sheep and goats on biodiversity associated with altered fire regimes is through changes to the vegetation dynamics through grazing, trampling and weed invasion, all which affect the type and distribution of fuel. Changes to fuel characteristics include removal of plant biomass due to clearing and overgrazing and changes in fuel type and distribution with the spread of exotic pasture species [or grasses], such as buffel grass (Butler and Fairfax 2003, Friedel et al. 2006) and Gamba Grass (Douglas and Setterfield 2005) into natural systems outside of the area of primary intent/use where they then function as weeds. . Fire is also used as a tool by graziers to encourage new growth for cattle and sheep (Dyer et al. 2001, Kirkpatrick and Bridle 2007). Given the extent of grazing lands across Australia, the impacts of red meat production on fire regimes are widespread and cover many ecosystem types. The interactions between fire and grazing, and the potential synergistic effect on biodiversity, are increasingly being studied in the context of pastoral systems (Kutt and Woinarski 2007; Sarah Legge, AWC personal communication).

4.4 Altered hydrology

Altered hydrology has been listed as a pressure associated with a range of protein sources (Table 5) because of its impact on both aquatic and terrestrial biodiversity. There are two major management activities that directly affect water availability – the use of artificial watering points in arid semi-arid systems and changes to environmental flows associated with the use of water for irrigation of pastures or for high density feedlots (stock and grain production). The provision of artificial watering points makes more grazing land available to stock, with subsequent impacts on biodiversity (Landsberg et al. 1997, James et al. 1999, Fensham and Fairfax 2008, Howe and McAlpine 2008). These impacts are discussed in greater detail in Section 5. The change in hydrology associated with the removal of deep-rooted woody species is covered in the section on vegetation clearance.

Artificial watering points utilise water that is drawn from groundwater systems, with subsequent impacts on groundwater dependent systems such as artesian mound springs. For example, the NSW Scientific Committee identifies major threats to artesian spring communities as the alteration of flow or unsustainable extraction of water from artesian bores reducing flows to the mound springs and trampling and grazing by stock and feral animals such as pigs, goats and rabbits (see http://www.environment.nsw.gov.au/determinations/ArtesianSprings Ecological CommunityEndComListing.htm0). The Committee notes that a number of springs have dried in NSW in the past 100 years due to falling water pressure caused by over-extraction, which has probably caused the extinction of undescribed species of aquatic invertebrates. Because of the pressures caused by pastoralism and feral herbivores, Artesian Spring communities have been listed as an endangered ecological community by both the NSW and Commonwealth governments.

The impact of human activities on environmental flows has received considerable attention across the research and policy community (e.g. the Living Murray Initiative, the National Sustainable Irrigation Program, various environmental flow research programs). Irrigation for pastures and crops utilises water originally destined for the environment. Dairy farms in northern Victoria/southern NSW use 60% of the irrigation supply and thus contribute to environmental issues such as environmental flows in rivers and rising water tables, with the associated impacts on salinity (Ho et al. 2004). In north-western Tasmania, dairy farmers have changed the drainage of their properties to increase access to what was originally low-lying Blackwood swamp-land. As a result, much of the Montague River and its tributaries has been highly modified or straightened (DPIW 2009). The potential impact of such management practices on groundwater is just starting to be examined (Holtz 2009).

High density feedlots draw relatively large amounts of water from nearby rivers or groundwater. When considering the environmental impact of high density animal production, the production of grain also needs to be considered. 38% of the worlds' grains are fed to animals for meat production. It is estimated that it takes 7 kg of grain to produce 1 kg of beef, 4 for pork and 2.5 for chicken (New Scientist 1997).

4.5 Trampling and soil compaction

The impacts of trampling and soil compaction are treated separately from altered grazing regimes because the impact of hard-hoofed herbivores on the soil and vegetation systems of Australia is one of considerable interest and commentary. Hacker and McLeod (2003) contend that under appropriate management, the type of hooves a grazing animal has is not relevant. In the case where damage to soil occurs, this is attributed to overstocking and poor rangeland management. This could be tested by comparing the impact of different management regimes on soil and vegetation characteristics, especially where stock are matched to land capability. The Holistic Management approach to grazing, developed by Alan Savory based on his experience in South Africa, uses trampling by stock as a tool to manage landscapes, aiming to for the stock to eat one-third of the plant, trample one third and leave one third to regenerate (Savory and Butterfield 1999). These examples demonstrate that as with the direct grazing impacts on native vegetation, the impacts of trampling and compaction on soil ecosystems needs to be described in the context of grazing regimes. It would also be informative to tease apart the effects that reduced vegetation cover (through grazing impacts) has on soil characteristics, compared to the direct effects of trampling and soil compaction by the hard-hooves of grazing animals.

Grazing animals can affect soils through mechanical impacts associated with their daily movement, as well as by actively digging to obtain subterranean foodstuffs (e.g. tubers). Reduced ground cover associated with over-grazing can also affect soil condition. The direct impacts of mechanical impacts such as trampling and soil compaction have been identified as decreased soil infiltration and permeability reducing deep drainage; reduced plant root penetration and plant available water; increased potential for erosion (and leakage into waterways); loss of soil nutrients; waterlogging of soil (QDERM 2009); and loss and damage to soil biological crusts. Lunt (2005) points to the accounts at the time of European settlement of the soft, spongy, boggy nature of Australian soils, and the rapid changes to soils that were caused by grazing stock.

Studies such as James et al. (1999), Woinarski and Ash (2002) and Duncan et al. (2007) have demonstrated that certain grazing regimes can cause long-term damage to soil biota. For example, in a review of the effects of watering points in the arid zone on biota, James et al. (1999) noted that heavy traffic by stock breaks up the cryptogamic crust which has two consequences: (1) the nitrogen-fixing action of the cryptogams is disrupted; and (2) the soil surface is loosened allowing wind and water erosion to remove surface layers. The authors continue, stating that while the compaction of the soil surface due to stock traffic is well documented for non-arid regions, there remains little evidence of widespread compaction in the semi-arid rangelands (James et al. 1999) with most impacts restricted along watering points and along tracks. Eldridge’s (1996) work on cryptogamic crusts is cited as an important source for these statements. In more recent studies, it has been demonstrated that livestock tracks around watering points intensify the natural drainage patterns and exacerbate the natural erosion process (Pringle and Landsberg 2004). Howes and McAlpine (2008), in a review of the impact of arid zone watering points on biodiversity, found that soil erosion increases significantly within the first 2–3 km from water as a result of heavy traffic and vegetation stripping, leading to a decline in abundance and richness of palatable forage species.

Yates et al. (2000) cites several studies to support the statement that ‘in Australian rangelands the removal of perennial vegetation cover by livestock grazing and trampling by hard hooves is known to cause loss of litter cover, loss of soil cryptogams, reduced organic carbon, loss of nutrients, loss of soil microtopography, soil compaction, reduced soil water infiltration rates, increased soil surface erosion and consequently loss of ecosystem functions which capture and cycle scarce limiting resources such as water and nutrients'. This commentary set the scene for their study, which examined the impact of sheep grazing on the soil characteristics of fragmented woodlands in south-west Western Australia. This study, which compared a range of properties at grazed and ungrazed sites, found major differences in soil and vegetation characteristics. This included a decline in native perennial cover and an increase in exotic annual cover, reduced litter cover, reduced soil cryptogam cover, loss of surface soil microtopography, increased erosion, changes in the concentrations of soil nutrients, degradation of surface soil structure, reduced soil water infiltration rates and changes in near ground and soil microclimate. Many of these changes are attributable to the hoof action of sheep.

In addition to the variation in impacts of trampling and soil compaction related to stocking rate, certain ecosystems are differentially affected. Riparian areas are particularly susceptible (Jansen and Robertson 2001), with damage in these areas potentially affecting larger scale ecosystem processes such as drainage patterns, nutrient flows, water quality and aquatic species composition.

While trampling effects are important issues for outdoor piggeries (Evans 1990), and to a lesser extent free-range poultry operations (Boardman and Evans 1994), feral pig populations, which constitute a small proportion of total pork production, are a major cause of land soil degradation across areas of Australia (Foster 2009) and are listed as a threatening process in the EPBC Act 1999. Trampling by feral goats, which are also listed under the EPBC Act 1999, has also been identified as having a major impact on vegetation. For example, the NSW Scientific Committee, when making a final determination on feral goats as a threatening process, noted that the removal or destruction of vegetation together with trampling by ungulate herbivores such as goats decreases soil stability and contributes to erosion (http://www.environment.nsw.gov.au/ determinations/FeralGoatsKtp.htm).

4.6 Invasive species

The main invasive species associated with the cattle industry that create pressures on biodiversity are environmental weeds, including what Grice (2006) terms "commercial weeds" – exotic pasture species [or grasses] that spread into natural systems outside of the area of primary intent/use where they then function as weeds. Environmental weeds have been identified as among the most significant and costly environmental threats in Australia (Anon 2007). The impacts of weeds on biodiversity include competition with native species, loss of habitat for fauna and changes to fire and hydrological regimes.

In 1994, Lonsdale published a seminal paper that described the weed and agricultural potential of grasses that had been introduced for pastoralism. Weeds that have been introduced for pasture production can escape into natural systems, competing with native species and potentially altering fire regimes. "Grice (2006) identified seven exotic pasture plants that have environmental impacts as weeds in a range of native ecosystems outside of grazing lands". This term refers to the proportion of plant species that are deliberately introduced and cultivated for commercial gain, despite their potential to invade natural systems. Examples include Buffel grass in semi-arid areas (Friedel et al. 2006, Smyth et al. 2009), species such as Gamba grass in northern Australia (Douglas and Setterfield 2005) and Para grass in the wetlands of north-eastern Australia (Downing 2009). Further details on the impacts of Buffel Grass and Gamba Grass on biodiversity can be found in Section 5 and Box 4.

Martin et al. (2006) focused their attention on the weeds of rangelands, identifying 160 species considered of threat to biodiversity in this region. Most of these plant species were found to have been deliberately introduced for forage or other commercial use (e.g. nursery trade). Among growth forms, shrubs and perennial grasses comprise over 50% of species that pose the greatest risk to rangeland biodiversity (Martin et al. 2006).

4.7 Pollution

The potential impacts of air, water and soil pollution is one of the few pressures that are found across all sources of protein studied in this report. The sources of pollution are both point-source and diverse, cover nutrients, sediments and emissions, and can have impacts on both aquatic and terrestrial biodiversity. The NLWRA (2001a) assessment of selected agricultural practices provided a snapshot of water-borne sediments and nutrients at the turn of the millennium. Pastoral country used for cattle production in northern Australia was found to be the most significant source of sheet erosion, with this region being the area where river suspended sediment loads had most increased. From a near shore and marine perspective, it was found that approximately 90% of suspended sediment loads reaching marine and near shore environments was derived from 20% of agricultural catchments, particularly in coastal regions of Queensland and NSW. The Fitzroy River basin is one of these key catchments, with cattle grazing covering 82% of land use at the time of the assessment (NLWRA 2001b), much of it on cleared land. The erosion from grazing lands, combined with overstocking on farms in the Fitzroy Basin, can lead to transport of eroded material into the Great Barrier Reef in periods of high rainfall (reefED website; and initiative of the Australian Government http://www.reefed.edu.au/home/explorer/hot_topics/ water_quality/human_impacts).

A more recent assessment of the erosion and potential pollution caused by agricultural practices is provided in the 2006 State of the Environment report. It states that Australia's agricultural land uses and practices have caused an increase in erosion through vegetation clearing and total grazing pressure (Beeton et al. 2006). It is reported that the rate of erosion in pasture lands has doubled from the rate under natural conditions, and there has been a fivefold increase for improved pastures. The hard hooves of exotic animals have been identified as a major source of soil degradation in these reports, as well as other studies cited in the sections on trampling and soil compaction. As noted elsewhere in this report, the degree of degradation will depend on the nature of the grazing regime, the climate and the vegetation and soils found in the area being grazed.

Water pollution has many elements, as demonstrated by the numerous indicators identified for this topic in the Queensland Department of the Environment and Resource Management's Land Manager's Monitoring Guide (QDERM 2009). For example, under the heading 'wastewater release', which is only one of several issues addressed, the potential direct impacts are listed as: altered water temperature, increased water nutrient concentrations, increased water faecal and chemical contamination, increased water sediment load, increased plant detritus and debris in waterways and reduced recreational values. Most of these impacts can have detrimental impacts on biodiversity. Wastewater release is associated with high density production of protein sources, such as cattle, pork and chicken feedlots. These industries are highly regulated, so the release of wastewater is a rare event. The dairy industry also has the potential to release wastewater, and dairy farmers are still developing ways to manage their effluent.

The release of nutrients and heavy metals into the environment from wastewater is a key threatening process. Nitrate nitrogen, for example, is soluble in water and so can be easily carried into lakes, wetlands, streams and groundwater. When it is consumed by people or animals, it can be converted into nitrate and cause health problems and even death. Similarly, ammonia and phosphorus which together with nitrogen are the most significant environmental concerns of intensive feedlots (Burkholder et al. 2007; Burgos and Burgos 2006), can contribute to death to a range of life forms (Lehane 1999; Francis-Floyd and Watson 1996). Pollution of waterways by chemicals used in livestock industries (including through manure spread on pastures from high density operations), in particular hormonal growth promotants, have been identified as an area of potential concern for aquatic biodiversity (Williams et al. 2007, Allison 2008).

4.8 Disease and pathogens

Consumers are significantly concerned about pathogens in the environment, particularly in respect to agricultural activity (Powers and Angel 2008). While much of the concern about disease and pathogens is exacerbated by high profile influenza outbreaks such as avian influenza (Lee Ligon 2005) and swine flu (Herring 2009), the spread of disease and pathogens through the environment, particularly via waterways, do pose a threat to biodiversity (ADAS 2007) including to amphibians (Daszak et al 2003) and fish (Langdon 1989). Further details about the potential impacts of disease and pathogens on biodiversity can be found under the relevant protein sources.

4.9 Climate change

The agricultural sector as a whole contributes around 18% of the total greenhouse gas emissions in Australia (Garnaut 2008). The contribution of protein sources to greenhouse gas emissions ranges from the release of carbon into the atmosphere through vegetation clearance, through to methane production by ruminants and management of greenhouse gases such as nitrogen from feedlots. Ruminant animals (cattle, sheep, goats) are the single largest source of Australia's agricultural greenhouse gas emissions (2,861 Gg CO2-e) and alone contribute about 13% of Australia's total national emissions. 97% of the GHG emissions are from enteric (digestive tract) fermentation, with 3% from faeces.

The companion report to this project by FSA Consulting (Wiedemman et al. 2009) covers greenhouse gas emissions associated with a range of protein sources in considerable detail. If a full life-cycle analysis is undertaken, protein sources can also contribute to emissions through the use of various forms of transport, including trucks to get stock to feedlots, abattoirs and markets, as well as the transport that takes live animals and meat products to export markets. With red meat producers increasingly relying on exporting their product (Fletcher et al. 2009), the carbon footprint associated with overseas transport will also contribute to the total tally of greenhouse emissions.

An illustration of how climate change is increasingly perceived as one of the most significant threats to biodiversity is reflected in the National Biodiversity Strategy. This strategy is currently being revised, with a consultation draft out for comment until June 5th, 2009. The vision in the consultation draft is 'Australia's biodiversity is healthy, resilient to climate change and valued for its essential contribution to our existence'. The inclusion of climate change in the vision for biodiversity conservation at the national level is indicative of the growing level of attention and investment this ‘threat’ is receiving. This momentum builds on previous reports at the national level such as Howden et al. (2003) and Dunlop and Brown (2008).

Auld and Keith (2009) refer to climate change as the most pervasive, least understood and least predictable of threatening processes, with impacts on biodiversity that are likely to be many and varied. While climate change represents a significant threat to biodiversity, the key message from ecologists is that it needs to be examined in the context of other ongoing pressures on natural systems and interactive effects considered. For example, Mac Nally et al. (2009) propose that declines in woodland birds in even largest areas of native vegetation in Victoria are exacerbated by climate change.

4.10 ‘Other’ industry-specific pressures

In addition to the previous nine pressures, a range of other pressures are considered where appropriate. These include the direct loss of biodiversity through over-exploitation of native species (direct and by-catch), biotechnology, dingoes and fencing.

Two industries explored in this report deal with the direct harvest of wild biota (kangaroos and fish). Of the two fishing remains the major concern, with evidence of over-fishing in both Australian waters and elsewhere across the globe (Caton and McGloughlin 2005). Although consumer and interest groups hold strong and diverse views about kangaroo culling for meat or for reducing total grazing pressure, concerns about less common species being impacted have been allayed by the scientific community.

Biotechnology presents a number of issues for biodiversity. Although sometimes touted as a technology with the potential to ease pressure on the environment, it can potentially also act to promote monocultures, reduce agricultural species diversity and cross-over and permanently affect the genes of native species (Johnson 2000).

5 Findings: Impacts of individual protein sources

5.1 Red meat protein

5.1.1 Beef

Background

In Australia, cattle are reared predominantly on extensive rangelands and semi-arid areas, which cover around three quarters of the country. Because of geological, topographic and climatic factors, these regions are not suited to any other intensive forms of agriculture such as cropping. In areas that are suited to mixed farming, livestock grazing and grain crop production are complementary and managed in a way that aims to maximise productivity and improve soil health. In 2007–08, 87% of land managed for agricultural businesses was for grazing land for domestic cattle, sheep and dairy cows (ABS 2009b). Of the nearly 87,000 establishments with cattle identified in Box 3, around 41,640 of these were specialised beef cattle farming establishments as of June 2008 (Fletcher et al. 2009).

Grazing industries utilise most of the approximately 415 million hectares in Australia managed for agriculture, with cattle occupying much of this area. For example, beef cattle are grazed over 145.5 million hectares of land in the Northern (Pastoral) Zone which stretches from Cape York, around the gulf and into the Kimberley region. As of 1999, thirty six percent of the pasture in this region was sown or introduced, and 64% of the pasture was native or naturalised (http://www.anra.gov.au/topics/agriculture/beef/region-northern-pastoral-zone.html). While these figures are 10 years old, they indicate the importance of native pastures in northern Australia, particularly in savanna ecosystems. In the southern zone, where more introduced pastures are utilised, cattle production is concentrated in Queensland and NSW. (Fletcher et al. 2009) Cattle breeds vary around Australia depending on the environments they are grazed in and the type of meat being produced. For example, In northern Australia, tropical breeds such as Brahmans are reared on pasture mainly to service the global lean frozen market for blending into hamburgers, while in southern and central Australia European and British breeds (e.g. Angus, Hereford) are reared on pasture to supply lean chilled beef for the domestic market (Thomason 2007).

In addition to the beef cattle industry occupying a significant area of land, it also makes a significant contribution to the Australian economy (Fletcher et al. 2009). Box 3 includes statistics for the beef industry for 2007-2008, demonstrating the significant value of exports (chilled and live cattle) for the industry. Over this period, around 64 per cent of beef produced in Australia was exported, including more than 700 000 live cattle transported mainly to markets in South-East Asia (Fletcher et al. 2009). The agricultural commodity figures released by the Australian Bureau of Statistics for the 2007-2008 financial year (ABS 2009a) reported that the Australian cattle herd reached 27.3 million head as at 30 June 2008. This represents a decline of 3% year-on-year. As a consequence, the national beef herd declined 2%, to 24.8 million head. The capacity for national herd growth was reported to remain very high, with the number of cows and heifers one year and older increasing 5%, to 13.5 million head. This represents 49% of the national herd, which is a record high.

There are currently about 680 accredited cattle feedlots in Australia. The March 2009 quarterly survey of feedlots, produced by the Australian Lot Feeder's Association and MLA, indicated that the total capacity of Australian feedlots increased 5% year-on-year to a record 1.24 million head. Capacity increased 12% in Queensland (633,062 head), but fell by 984 head in NSW (397,538 head). In 2008, Australian grain fed cattle turnoff totalled 2.13 million head, down 11% on 2007's 2.4 million head, and 8% below the record 2.6 million head turned off in 2006. This represents fewer than 10% of the total population of cattle in Australia.

Box 3: Facts and statistics about the Australian beef industry
for the 2007-08 fiscal year

- There are 86,647 establishments with cattle (ABS).
- Australia exported a total of 1,267,704 tonnes cwt of red meat (DAFF).
- Total value of beef exports has increased 13% from A$3.9 billion in 2002-03 to A$4.42 billion in 2007-08 (ABS).
- The top five markets for Australian beef and veal are: Japan, US, Korea, Indonesia and Taiwan
- The total value of the Australian beef chilled export market has increased from A$1.62 billion in 2002-03 to A$2.02 billion in 2007-08, a 25% increase (ABS).
- Australia exported a total of 769,890 live head of cattle, valued at A$540.330 million.
- Since 2002-03 Australian consumers have increased their expenditure on beef by 25% from an estimated A$5.4 billion to A$6.7 billion in 2007-08 (MLA preliminary estimates for 2007-08).

Source: Meat & Livestock Australia

The majority of feedlots are located in south east Queensland and New South Wales, concentrating around the mixed farming areas having access to cattle, grain and other feed sources. Cattle spend varying amounts of time in feedlots depending on the final market they are being prepared for. For example, grain finished beef are cattle that have largely been raised on pastures and are fed for a short period in feedlots – typically 40-70 days (Thomason 2007). Grain fed cattle are kept in feedlots for longer periods, generally between 100-300 days, to produce marbled meat.

A number of agricultural and veterinary chemicals can be used in cattle production in Australia, including in feedlots (Khan et al. 2008, NRS 2008). Hormonal growth promotants (Blackwood 2008) are the chemicals that have received the most attention, both in terms of management, research and policy action (e.g. Williams 2007, Khan et al. 2008) and public concern. These chemicals are used within the feedlot industry, as well as to maintain growth during poor pasture conditions in extensive systems, particularly in northern Australia (Thomason 2007). While studies of the impacts of these chemicals on biodiversity are limited, findings from relevant projects are covered in the section on pollution that follows.

The state of biodiversity

This section examines the findings of research conducted under Australian conditions on the impacts of beef cattle on biodiversity. It should be read in conjunction with Section 4 and Table 5, which describe pressures and impacts (direct and indirect) associated with the cattle and other protein sources. Both sections cover extensive and intensive grazing systems, as well as high density feedlots. Cattle are associated with all the pressures listed in Table 5, often across large areas. Where helpful, sub-headings indicating the broad pressure being reviewed are used in this section. As the state of biodiversity is often related to interactions between pressures, these are sometimes combined under the one heading.

<u>Vegetation clearance and modification</u>

Broad-scale clearing for cattle production has principally occurred in Queensland and NSW, where nearly 70% of the national herd are located (Fletcher et al. 2009). Most publications examining the state of biodiversity related to this pressure focus on the response of native flora and fauna to the fragmentation caused by vegetation clearance. An exception is Cogger et al. (2003), who estimated the number of animals that die as a direct result of clearance activities. The authors reported that between 1997 and 1999 approximately 100 million native mammals, birds and reptiles died each year as a result of the broad-scale clearing of remnant vegetation in Queensland. This figure was based on land clearing rates and information about the abundance and distribution of native species.

The literature on the effects of vegetation clearance on the remnant vegetation that remains, and the fauna that uses it as habitat, is substantial. Many studies describe patterns of fragmentation of remnant vegetation, and what that means for the viability of fauna, with a particular focus on birds and mammals. There are also a growing number of papers on the usefulness of revegetation projects in addressing some of the impacts of decades of vegetation clearance (Munro et al. 2007, Vesk et al. 2008). Overview publications that incorporate relevant research on vegetation clearance and biodiversity conservation include Saunders et al 1987, 1993, Bennett et al. 1998, Saunders and Hobbs 1991, Young and Clarke 2000, McIntyre et al. 2002, Lindenmayer and Fischer 2006, Lindenmayer and Hobbs 2007, and Williams 2005, 2008.

Many of the publications on the state of biodiversity following clearing focus on the landscapes of south-eastern and south-western Victoria. In these regions, clearing of vegetation was often related to sheep, dairy and cropping enterprises, with some cattle in the mix. Where possible, the main focus in this section is research articles in regions where it is likely or certain that vegetation clearance was for cattle production, with the other research covered in the section on sheep-meat. For example, a review by McAlpine et al. (2002), which focused on clearing in semi-arid rangelands in Queensland that are used for cattle production, suggested that if remnant vegetation was cleared to 30% of its original extent there would be a loss of 25-35% of native vertebrate species, with the full impact not seen for another 50-100 years. These conclusions were based on a range of published and unpublished historical and contemporary data, as well as drawing on theoretical work on habitat thresholds for fauna. Less mobile, habitat specialists and rare species were considered to be particularly at risk from a reduction in the extent of native vegetation and loss of connectivity between patches. McIntyre et al. (2002) recommended a number of thresholds for managing grazing landscapes, based on research on cattle properties in south-eastern Queensland. These authors recommended that no more than 30% of native vegetation on a property be cleared for intensive land uses such as introduced pastures as above this threshold it was considered that ecological functions of the landscape appear to be disrupted.

In south-eastern Australia, Radford et al. (2005) provided the first empirical demonstration of landscape-level thresholds in species richness in Australia, using woodland-dependent bird species as a model. A sharp decline in species richness was found in areas with less than 10% vegetation cover, denoting multiple species extinction events. The authors emphasised that these thresholds were the end point of the process of species decline and to maintain viable populations, habitat cover must be maintained well above the threshold level.

Chilcott et al. (2003) identified some of the challenges associated with using thresholds to inform management and policy, finding that the degree of fragmentation examined in the cleared Eucalyptus populnea woodlands of the Queensland Murray-Darling is not constant across scales. They also noted that the effects of current land use change, clearing, grazing and changed fire regimes have not had their full affect on the biodiversity currently represented in these landscapes. The need to consider how climate change may affect thresholds for biodiversity conservation in the future was emphasised, with Chilcott et al (2003) concluding that modifications to the landscape coupled with climate change could result in the loss of species and assemblages from the landscapes, substantial imbalances in landscape water balance and nutrient cycling, invasion of remnants by exotic species, and changes to disturbance regimes.

Some of these changes have already been documented, with studies such as Ludwig and Tongway (2002) finding that clearing native vegetation for cattle production in central Queensland affected the composition and abundance of native plants and animals, as well as soil and water processes. The amount of ground cover was a critical factor affecting rates of run-off and soil loss after clearing, with rates rapidly increasing as cover declined below 40%. Eldridge and Robson (1997) in an experimental study found that run-off rates were greater on ungrazed and unploughed plots, due to the presence of a thin physical soil crust, demonstrating the complexities of these systems. Other studies have examined the interaction between the establishment of exotic grasses and vegetation clearance in semi-arid systems in Queensland where introduced pasture grasses are commonly established after tree clearance (Fairfax and Fensham 2000). This study found that the exotic pastures had more impact on herbaceous plant species diversity than tree clearing per se, cautioning that the small sampling scale made it difficult to detect changes in structure or woody species composition. Fauna were not included in the study.

Martin and McIntyre (2007) were able to disentangle the impacts of clearing and grazing impacts of cattle on woodland birds in south-eastern Australia. Like other studies, they found that the greatest difference in bird assemblages occurred where woody vegetation was removed. Grazing effects were found to have more impact on riparian systems, despite having a similar complement of bird species. Based on their results the authors suggested that any level of commercial livestock grazing is detrimental to some woodland birds, particularly the understorey-dependant species, as they predicted. Nevertheless, provided trees are not cleared, Martin and McIntyre (2007) concluded that a rich and abundant bird fauna can coexist with moderate levels of grazing.

The way vegetation is cleared can have an impact on the state of biodiversity that remains, as does the response of the native vegetation that is cleared. In contrast to vegetation in southern Australia, regrowth of native vegetation commonly develops after clearance in inland Queensland and has particularly hindered pasture development in brigalow lands (Fairfax and Fensham 2000). Pastures with substantial regrowth are often cleared more than once and herbicides are often used to kill woody plants. Blade-ploughing is sometimes used to manage regrowth, where a horizontal blade severs all roots at 30±120 cm depth. Neither of the studies cited above examined the impacts of blade-ploughing on biodiversity, which has been identified as a topic of further research.

The underlying drivers of regrowth (also referred to as "woody weeds") and its management have been the subject of debate for some time (Burrows 2001, Noble and Walker 2006). Clearing is one of many factors associated with regrowth dynamics, which have also been related to fire and grazing regimes, regional climate and global warming (Noble 1997, Eamus et al. 2007). Where regrowth results from clearing, such as in some parts of Queensland, the subsequent growth is also often cleared because of its impact on pasture production. The importance of regrowth for other values such as carbon sequestration and habitat for fauna is increasingly being recognised (Burrows et al. 2002, Bowen et al. 2007).

<u>Altered grazing and fire regimes</u>

> *The question for researchers is no longer 'do herbivores have an effect' but 'why do effects differ?* (adapted from Olff and Ritchie 1998)

In Australia, cattle graze a range of pasture types, from landscapes where the over-storey has been cleared in semi-arid Queensland (often seeded with exotic species such as buffel grass, Fairfax and Fensham 2000), to systems with the over-storey still largely intact, such as the rangeland and savanna landscapes in central and northern Australia (where exotic pasture species are also utilised – see section on 'Invasive species' in this report). Fisher et al. (2004, 2005) developed a framework for organising rangelands into regions with similar total grazing pressure and biodiversity characteristics, and made recommendations for managing both. The 10 Grazing Land Management Zones that were identified in this study provide a useful framework for differentiating regions in the rangelands with different characteristics. In southern Australia, cattle largely graze on landscapes that have been cleared and sown with fertilised, exotic pastures. Interactions occur between grazing regimes and other pressures such as vegetation clearance, invasive species, altered hydrology and altered fire regimes. These will be identified in the report where relevant.

As noted in Section 3, identifying the nature of the grazing regime being studied and the total grazing pressure on a site (including the stock breed and condition), are important aspects of teasing apart the impacts of grazing on biodiversity. Describing the type and condition of vegetation being grazed, as well as the management history where possible, is also an essential element. As this information is often missing, or buried in research and other publications, it would be a worthwhile exercise to pull together as much of this information as could be found for the livestock grazing industry. This is beyond the scope of this review, but would help better understand the interactions between domestic stock grazing and biodiversity in Australia. Section 3 also characterised some of the different grazing environments across Australia and the range of researchers who studied them. Based on this regional approach to grazing studies, the following studies relate to different parts of Australia. These do not equate exactly to the grazing land management zones identified by Fisher et al. (2004, 2005) mentioned previously for the rangelands, but are based on a similar concept.

Overarching the pressures associated with grazing regimes, and the different pressures that interact with them, is the over-riding driver of climate and seasonal events on the condition, productivity and sustainability of grazing lands in Australia. From a production perspective, McKeon et al. (2004) describes eight major degradation and recovery episodes in the Australian rangelands due to grazing pressure and its interaction with climate, particularly extended low rainfall events. The authors describe the manifestations of land and pasture degradation as the loss of desirable perennial grasses and shrubs (for grazing), the resulting increase in soil erosion, soil structural decline and the infestation of woody weeds. Each of these impacts can affect the state of biodiversity in the pastoral system. In addition to operating within the current variable climate, the potential impacts of climate change on biodiversity in the grazing landscapes of the Queensland Murray-Darling have been raised by Chilcott et al. (2003). As noted in the section on biodiversity, these authors reported that modifications to the landscape coupled with climate change could result in the loss of species and assemblages, substantial imbalances in landscape water balance and nutrient cycling, invasion of remnants by exotic species, and changes to disturbance regimes.

Working on cattle properties in the grazing landscapes of south-eastern Queensland, Martin and McIntyre (2007) reported that provided trees are not cleared, a rich and abundant bird fauna can coexist with moderate levels of grazing. Habitats with high levels of grazing were found to result in a species-poor bird assemblage dominated by birds that are increasing in abundance nationally. Despite having similar bird assemblages, the effect of grazing was reported to be stronger in riparian habitat than in adjacent woodland habitat. In the context of this study, grazing intensity (low, medium and high) was characterised by the intactness of grass swards and whether grazing was selective or non-selective. This was based on previous studies that found sward structure and composition in these systems is an indicator of grazing history (McIntyre et al. 2003; McIvor et al. 2005).

The importance of scale in describing and understanding the impacts of livestock on biodiversity was raised in Section 3 and described in relation to vegetation clearance and modification in this section. McIntyre et al. (2003) examined the hypothesis the grazing increased species density at small scales and decreased it at landscape scales, due to the elimination of grazing sensitive species. The hypothesis was not supported, which led to the recommendation that it is desirable for land managers to utilise a range of grazing pressures across the landscape (including no grazing) if their goal is to retain plant diversity.

As described earlier in this report, extensive cattle grazing occurs across the savanna landscapes of northern Australia. While the extinction of medium weight range mammals in the arid zone is well known (Dickman 2007), the savanna landscapes are still regularly referred to as ‘pristine’. This is far from the case. Recent research has shown declines in both birds and mammals across northern Australia, as well as changes in landscape function in response to these and other changes (Franklin et al. 2005, Woinarski et al. 2005, Woinarski et al. 2007). These changes have been attributed to factors such as the breakdown of traditional aboriginal land management and the concurrent impacts of altered fire and grazing regimes, changes to water availability and flow and the presence of feral animals and weeds (Woinarski and Ash 2002).

Trying to tease out the role of grazing impacts from other pressures in these systems can be challenging. As they are part of the overall system being studied, they are perhaps better treated as a ‘threat-syndrome’ (sensu Burgman et al. 2007), although characterising the relative contribution of different pressures can be useful. Kutt and Woinarski (2007), for example, found a variable response to fire and grazing treatments amongst vertebrate groups. Birds responded more to fire effects (9 species – some declining and some increasing at burnt sites), reptiles to grazing effects (6 species – 5 of these demonstrating a decline in grazed sites) and mammals to the interaction (2 species). Five bird species also responded to the interactive effect of fire and grazing. The study demonstrated that although both fire and grazing alone can change the vegetation structure and relative vertebrate species abundance, there was an important interacting influence. Legge et al. (2008) suggest that the interaction between fire and grazing may have been underestimated in the past, given the results of a post-fire study in the Kimberley region.

As recently as a decade ago, faunal responses to grazing regimes in savanna systems had received relatively little attention, whereas the impact on vegetation was relatively well known (Woinarski and Ash 2002). In trying to address this gap, Woinarski and Ash (2002) described complex responses of frogs, birds, mammals and reptiles in northern Queensland to land use and landscape position. The study was located on military lands, where grazing had been removed for over 30 years after a history of 100 years grazing. Many individual bird species showed significant responses to land-use type, with bird species composition was significantly related to both land-use type and landscape position. The richness of the mammal fauna was weakly related to landscape position and not related to land-use type. A few individual mammal species showed significant responses to landscape position and land-use type, but mammal species composition was significantly (albeit weakly) related only to land-use type.

Woinarski and Ash (2002) acknowledged some of the sampling constraints in the study, but concluded the faunal responses were strong enough to attribute, at least partially, the broad-scale changes in biodiversity recently recognized across northern Australia to pastoralism. This land use was considered to lead to a substantial rearrangement of the vertebrate fauna, particularly so for reptiles and those mammals and birds associated with the ground and understorey layers (Woinarski and Ash 2002). Five years later, Kutt and Woinarski (2007) found a more subdued response of bird species to grazing impacts on their own, with only one species being more abundant in ungrazed sites. Both studies demonstrated the importance of understanding the habitat and food requirements of individual species in order to predict the impacts of different management regimes, as well as the complexity of the systems being studied.

Designing experiments to examine the impacts of different grazing management strategies has the potential to deliver clear results. Even so, the complexity and scale of the systems, and the challenges of finding ‘control’ areas that have never been grazed, can also make this approach challenging. The experimental approach has been taken in a study on the impacts of intensifying pastoralism in northern Australia (Fisher et al. 2006). A number of grazing treatments are being examined in large scale plots, with a range biodiversity attributes assessed annually at each site. These include vascular plants, birds, reptiles, small mammals and ants, as well as vegetation structure, ground layer cover and grazing pressure (Fisher et al. 2006).

No effects of the grazing treatments on the sampled biota have emerged after 2 years, which is not unexpected. The black-soil systems being studied are considered to be relatively resilient, and grazing effects must emerge from a background of previous grazing patterns and substantial inter-annual variation (Fisher et al. 2006). The authors therefore emphasise that trials such as this need to be measured over meaningful timeframes (5-10 years) and that it will be important to track the response of individual species to reflect any significant changes in species composition.

Considering the relatively recent nature of studies examining the impact of cattle grazing in northern Australia, and the widespread nature of grazing in these systems, there is some concern amongst ecologists that species may have already been lost from these systems (Woinarski and Ash 2002). As a consequence, differences between sites with contrasting management histories may be more muted.

Semi-arid Queensland is another region where there is a unique combination of vegetation type, land use history and grazing management practices. As noted elsewhere in this report, tree clearing is widespread in these systems, as is the utilisation of exotic pasture grasses (Fairfax and Fensham 2000). Some of the impacts of grazing in these systems were covered in the section on vegetation clearance, as the two often interact. In southern Australia, systems where cattle grazing impacts have been studied include alpine environments, where summer grazing of cattle was practiced for many decades until recently. Wahren et al. (1994), in an analysis of long-term vegetation plots where cattle had been excluded for up to 50 years, identified a number of grazing impacts on vegetation dynamics. In the longest grazed plots, this included a decline in regeneration of several plant species and increased bare ground and loose litter. The responses to grazing varied depending on the vegetation type being studied and the fire history of the sites. The publication on alpine grazing that has received the most recent attention, is the one that tests the hypothesis that ‘grazing prevents blazing’ by Williams et al. (2006). (It doesn’t, by the way). For the general public, the impacts of cattle grazing are summarised in publications such as the Australian Alps Education Kit – Grazing in the Australian Alps (http://www.australianalps.environment.gov.au/learn/grazing.html).

Cattle graze forest and woodland ecosystems in north-eastern NSW as a supplement to farmland grazing. Tasker and Bradstock (2006) studied the impacts of the presence and absence of cattle grazing on forest understorey in these ecosystems, where it is a widespread practice. They compared it with time since logging and wildfire, which are other management practices in the region. In the context of this study, ‘cattle grazing practices’ included frequent low intensity fires that were used by farmers to encourage new growth. Stocking rates were low, about 1 animal for every 4-20 hectares, depending on the vegetation type (Tasker and Bradstock 2006). The authors found that grazed (and burnt) sites had significantly lower vegetation complexity, different dominant understorey species, reduced or absent shrub layers and an open, simplified and more grassy understorey structure than ungrazed sites. While it was not possible to separate out the effects of grazing and low intensity fire, it was considered important to quantify the collective effects of the practices as they are carried out in the real world.

Although only a small section of the landscape, riparian areas are of great importance as habitat for native species, given the higher water and nutrient availability in these areas. These characteristics generally make riparian areas very productive and thus also highly valued for grazing. Riparian systems are particularly susceptible to the impacts of certain grazing regimes, through a combination of both grazing and trampling effects. These impacts can negatively affect vegetation, soil characteristics, water quality, hydrology and the physical characteristics of streams (Jansen et al. 2007a). The susceptibility of riparian zones to grazing was demonstrated by Martin and McIntyre (2007), who found that the impact of cattle on riparian vegetation in south-eastern Queensland was higher on bird species than woodlands close by. In a major study of grazing impacts along the Murrumbidgee River, three quarters of the variation in vegetation condition was explained by five factors: stocking rate, distance upstream, relative periods of paddock rest and grazing, proportion of bank accessible to stock, and the presence of off-river water in the paddock (Jansen and Robertson 2001). These findings were based on a rapid appraisal index for assessing the ecological condition of riparian zones, which has since been widely adapted (Jansen et al. 2007b). Management recommendations based on these results included reduced stocking rates, more off river watering points and resting of paddocks.

In a related study on wetlands associated with the Murrumbidgee River, Jansen and Healey (2003) studied the impact of livestock grazing on the availability of habitat for frogs in wetlands. Using a sample size of 26 wetlands, the study found that frog communities, species richness, and some individual species of frogs declined with increased grazing intensity. Robertson and Rowling (2000), working in the same region, found marked differences in riparian sites with and without livestock. Grazed sites were found to have much lower levels of eucalypt regeneration, different plant species composition and less coarse particulate organic matter and terrestrial fine woody debris. Research such as this form the basis of management guidelines for stock and waterways, such as Staton and O'Sullivan (2006).

The way grazing regimes affect biodiversity is a question encompassing the full complexity of ecosystems, especially when other interacting pressures are involved. The diversity of studies on cattle grazing regimes across a range of different management histories, vegetation types and interacting factors mostly demonstrate changes in the diversity, distribution and/or composition of native plants and animals. Apart from drawing out broad generalisations from these studies, such as the importance of stocking rate, site condition and management history to how biodiversity responds, teasing apart the subtleties of the impacts and interactions on the state of biodiversity is beyond the scope of this review.

Trampling and soil compaction

The hard hooves of exotic animals have been identified as a major source of soil degradation (Yates et al. 2000; Drewry 2006) (see Section 4 for detailed background information on pressures associated with animals with hard hooves). Combined with the loss of soil cover related to over-grazing, in some cases trampling has led to run-off into aquatic systems, with many potential impacts on biodiversity. Greenwood and McKenzie (2001) indicated that all soils under grazed pastures will be compacted to some extent, with compaction of soils likely to be greater in wetter conditions. Riparian zones, which are covered in the section on altered grazing regimes, appear particularly sensitive to trampling (Jansen et al. 2007b).

Studies have demonstrated that stock can cause long-term damage to soil biota (James et al. 1999, Yates et al. 2000, Duncan et al. 2007). The feet of moving grazing animals can exert great pressure on soils (Noble and Tongway 1983). Biological soil crusts, which play an important functional role in vegetation systems (Eldridge and Greene 1994, Eldridge 1996), appear very susceptible to trampling. Chilcott et al. (2003), in a study of cattle grazing in the Queensland Murray-Darling, noted the loss of landscape function such as loss of ground cover, compaction and degradation of soil surface condition (causing excessive water runoff and soil erosion) and the decline in soil biological function.

Hacker and McLeod (2003) contend that under appropriate management, the type of hooves a grazing animal has is not relevant. In the case where damage to soil occurs, this is attributed to overstocking and poor rangeland management. The potential impacts of trampling when used as a tool to improve pasture health in the holistic management grazing system (Savory and Butterfield 1999) is yet to be scientifically studied in the context of biodiversity in Australia.

Altered hydrology

Two main impacts of cattle production systems on biodiversity were identified in Section 4 – artificial watering points and changes to environmental flows associated with the use of water for irrigation of pastures or for high density feedlots (stock and grain production).

The provision of artificial watering points makes more grazing land available to stock, with subsequent impacts on biodiversity (Landsberg et al. 1997, James et al. 1999, Fensham and Fairfax 2008, Howe and McAlpine 2008). Artificial water points, especially in the semi-arid and arid zones have been shown to influence the impacts of grazing by exotic and native herbivores, with native species showing ‘increaser’ and ‘decreaser’ responses depending on how they react to the changes related to grazing. Landsberg et al. (1997) found an inverse correlation between livestock dams and biodiversity and called for a staged closure of artificial watering points on conservation reserves. As noted in Section 4, this work has been quite influential on the management of artificial watering points in the ensuing period.

Recent reviews by Howes and McAlpine (2008) and Fensham and Fairfax (2008) build on and update this research and put it in the context of changes in rangeland management in the intervening decade. Both of these studies indicate that the patterns that native species exhibit in relation to the distance from water can be highly variable. The patterns shown by plants were found to vary depending on factors such as grazing behaviour and forage conditions, the presence of fences, soil type, the salinity of water and climatic variables (Howes and McAlpine 2008), all of which affect the ‘sacrifice zone’ (piosphere) immediately surrounding the water source. Different vegetation types were also found to be more resilient than others, mulga shrublands and Mitchell grasslands the most severely affected by grazing practices. A large degree of uncertainty was still found by these authors surrounding the response of native fauna to the presence of water points.

The limited power of sampling designs used in previous studies was also identified as a factor underlying the variable, and sometimes conflicting, responses of native species to grazing associated with watering points (Fensham and Fairfax 2008). These two reviews do not question earlier findings that many native species are disadvantaged by watering points, while a few species benefit. They demonstrate however that no universal pattern can be identified for the response of native plants and animals to the direct impacts of grazing regimes associated with watering points.

The impacts of grazing on soil erosion were found to be more consistent, with levels of erosion increasing significantly within the first 2–3 km from water as a result of heavy traffic and vegetation stripping, resulting in a significant loss of functionality that alters the vegetation dynamics (Howes and McAlpine 2008). This includes a decline in abundance and richness of palatable forage species. Based on their study, Fensham and Fairfax (2008) make a call for further carefully designed studies that concentrate on identifying the role of water-remote areas as grazing-relief refuges and on their potential as havens for those elements of biodiversity that have been suppressed in the landscape at large.

Section 4 also described how artificial watering points utilise water that is drawn from groundwater systems, with subsequent impacts on groundwater dependent systems such as artesian mound springs. Water use for pastoralism has been identified as one of the main pressures on these ecosystems. For example, the NSW Scientific Committee noted that a number of springs have dried in NSW in the past 100 years due to falling water pressure caused by over-extraction, which has probably caused the extinction of undescribed species of aquatic invertebrates (see http://www.environment.nsw.gov.au/determinations/ Artesian Springs Ecological CommunityEndComListing.htm0). Because of the pressures caused by pastoralism and feral herbivores, Artesian Spring communities have been listed as an endangered ecological community by both the NSW and Commonwealth governments.

Pollution

The 2006 State of the Environment report states that Australia's agricultural land uses and practices have caused an increase in erosion through vegetation clearing and total grazing pressure (Beeton et al. 2006). As noted in Section 4, a relationship between grazing and erosion was also reported by the NLWRA (2001a) report on Australian agriculture. The potential for water-borne pollution from cattle production systems is used as the main example in this section, with a brief section at the end on the potential impacts of agricultural chemicals (especially hormonal growth components) on aquatic biodiversity.

The focus on the catchments that flow into the Great Barrier Reef. Extensive clearing in the Great Barrier Reef catchment for cattle grazing, combined with overstocking on farms, can lead to soil erosion and transport of eroded material into the Great Barrier Reef in periods of high rainfall (reefED website; and initiative of the Australian Government http://www.reefed.edu.au/home/explorer/hot_topics/ water_quality/human_impacts). The subsequent impact of sediment inputs on biodiversity in the Great Barrier Reef is not covered in the report.

The Reef Water Quality Partnership (RWQP) formalises ongoing collaboration between Australian and Queensland Government agencies and regional natural resource management bodies of the Great Barrier Reef Catchments, to support the Reef Water Quality Protection Plan (Reef Plan). The priority contaminants of concern are suspended sediments, nutrients (N & P, $N0_X$ as a priority) and pesticides. The RWQP requires modelling framework/s based on the best-available science, for quantifying: concentrations and loads of sediment and nutrients in catchments and receiving waters and trends with time; ecological effects of sediment and nutrients in receiving waters; and influences of changes in land use, land management, climate, and other factors on the above, at spatial and temporal scales relevant to management.

Prosser et al (2002) modelled patterns of soil loss from the Burdekin catchment, concluding that grazing lands contributed around 85% of the sediment load in that region. The leakiness of landscapes and what this means for water quality is another focus of the modelling undertaken in GBR catchments (Bastin et al 2007). While some of this work is not immediately relevant for on-ground management or monitoring, it has the potential to identify areas for improved management or to explore scenarios that examine the leakiness of catchments.

Until recently, there has been a general lack of geospatial land monitoring information available for the catchments that drain into the GBR (Karfs et al. 2009b). Collaborative work has now produced sophisticated monitoring information for assessing land condition at both property and regional scale using remote sensing technologies. For this project, a threshold value of <40% groundcover on the 11-year Landsat GCI time-series 1996-2006 was used for determining persistent bare ground as a surrogate of very poor condition (Karfs et al. 2009b). This threshold was based on the ABCD condition framework developed by Chilcott et al. (2003). Spatially explicit mapping of very poor land condition has now been produced for the Burdekin Dry Tropics region (Karfs et al 2009b), which can be used as a basis for changes to land management. The ability to monitor these changes over time is an important step forward.

O'Reagain et al. (2008) report that major knowledge gaps still exist concerning the relationship between management and runoff in extensive grazing lands. These include how grazing management affects runoff and water quality on the relatively flat, infertile, tertiary sediments, which make up approximately 20% of the Burdekin catchment and how grazing management affects water quality. To test the effects of grazing management on soil and nutrient loss, five 1 ha mini-catchments were established in December 1997 under different grazing strategies on a sedimentary landscape near Charters Towers (O’Reagain et al. 2008). The results from the grazing trials were complex and difficult to interpret, leading the authors to conclude that quantifying water quality outcomes of pasture management via water quality monitoring at the larger catchment scale will always be a long-term task. At a property scale, important findings from the Wambiana trials have been incorporated into guidelines for water quality management (Coughlin et al. 2008). These include the observation that heavy utilisation rates immediately preceding or coinciding with drought can lead to long-lasting pasture damage, despite very light stocking in subsequent years.

These examples demonstrate some of the challenges in understanding and modelling the complexity of the catchments that drain into the Great Barrier Reef, including capturing the role of grazing regimes in sediment flow and subsequent impacts on biodiversity. While there is still much to be understood, improvements in ground cover and riparian zone management are being encouraged to reduce sediment and nutrient flow into areas such as the Fitzroy Basin (Rolfe et al. 2006). While there is broad agreement about the types of management changes required to reduce adverse impacts on water quality, these authors state that there is much less agreement about the impact of specific operations on water quality, the extent of management change needed, and the appropriate mechanisms to achieve that.

As noted above, the section on pollution ends with a brief examination on the potential for agricultural chemicals used on cattle to affect biodiversity in aquatic systems. A review of the impact of steroid hormones from agro-ecosystems on aquatic systems has recently been conducted in Victoria (Allison 2008). While this focused on dairy enterprises, the findings are relevant to other intensive systems such as cattle feedlots. Like other protein-production systems, the author noted the paucity of studies in Australia that examined the impact of agricultural chemicals on aquatic systems. Drawing on the limited number of studies available, he concluded that ‘the work that has been reported on steroid transport from agro-ecosystems clearly shows that there is estrogen and androgen contamination of receiving waters from grazing systems and land onto which feedlot manures and effluents from storage lagoons are applied’. The author also suggested that the hormonal contamination is having physiological impacts on fish in the receiving environments, based on direct evidence from the field. Allison (2008) identified a number of significant knowledge gaps that needed to be addressed to improve the management of these chemicals.

Khan et al. (2008), in a review of chemical contaminants in feedlot wastes, noted that very few of the individual chemical contaminants had been thoroughly investigated. For example, androgenic hormones that are significantly active in feedlot wastes are poorly understood in terms of their fate and environmental implications. Good management of ectoparasiticides was recommended for the prevention of potential ecological implications, particularly towards dung beetles (Khan et al. 2008). The review was undertaken to identify key chemical species that may require consideration in the development of guidelines for feedlot manure and effluent management practices in Australia, which demonstrates the proactive approach being taken by industry.

Invasive species

Exotic pasture species have been extensively utilised in rangeland and savanna systems. These species often become weeds of natural systems, which have a number of influences on biodiversity. Grice (2006) and Martin et al. (2006) developed lists of introduced plants used for pasture that have become environmental weeds. Grice (2006) coined the term “commercial” weeds to describe the proportion of plant species that are deliberately introduced and cultivated for commercial gain, despite their potential to invade natural systems. Several species used for pasture production in cattle enterprises were found on these lists. These include Buffel grass (*Cenchrus ciliaris*) which is widely used as a pasture species in semi-arid environments; and Gamba grass (*Andropogon gayanus*) utilised as a pasture grass in northern Australia and Para grass in north eastern Australia. Forage crops that have become environmental weeds include Leucaena (*Luecaena leucocephala*) in northern Australia and Tagasaste (*Chamaecytisis palmensis*) in the south.

Buffel grass is used as an example in this report of the potential impact of pastures species that become environmental weeds (Box 4). The species plays a major role in production systems in arid and semi-arid Australia and has received considerable attention in the last 2-3 years through the Commonwealth funded ‘Defeating the Weed Menace’ Program. These three different examples given in this section of species introduced for pasture production, have gone on to become environmental weeds and demonstrate some of the complexities of managing these species.

Friedel et al, (2009) have recently developed a set of recommendations aimed at moving forward the apparent deadlock between the importance of buffel grass for production, and the negative impact it can have on the environment. These were based on a study of the costs and benefits of buffel grass across four regions of Australia. The authors felt that a national strategy, supported by state and regional jurisdictions, would enable a systematic approach to management of buffel grass. This should lead to the reduction of negative effects without seriously constraining its production benefits. The important lesson to learn from examples such as buffel grass is how to avoid such situations occurring in the future, through management approaches such as containment (Grice 2006).

Gamba grass is another species that has become a serious environmental weed in the savanna landscapes of the Northern Territory and Queensland. The species (*Andropogon gayanus Kunth.*) was introduced to Northern Australia from Africa in the 1930s as a pasture grass for cattle. It is now considered to be one of Australia’s worst environmental weeds, as well as threatening human health and safety, infrastructure and Indigenous cultural values. The scientific evidence that demonstrates the state of biodiversity following the invasion of this species is listed in the Appendix of 2008 ‘The Gamba Declaration’ (http://www.wwf.org.au/news/gamba-declaration/). This has been signed by numerous scientists and calls for urgent action on banning the species and controlling its impact. The pressures that Gamba grass puts on biodiversity are many, with several endangered and vulnerable species already being seriously affected. Gamba grass reduces tree cover, changes water availability, depletes nutrients and increases greenhouse gas emissions. Research shows that under climate change, gamba fuelled fires will become more frequent, which will increase greenhouse gas emissions.

Leucaena is a deep rooted perennial leguminous tree or shrub with foliage of very high nutritive value for ruminant production (http://www.mla.com.au/TopicHierarchy/InformationCentre/FeedAndPastures/Pasturespecies

/Introducedspecies/Leucaena.htm). It is palatable, nutritious, long-lived and drought-tolerant. In northern Australia, Leucaena is planted in hedgerows with grass sown in the inter-row to form a highly productive and sustainable grass – legume pasture system for cattle grazing. Being deep-rooted, Leucaena is able to exploit soil moisture and remain permanently productive on the heavier clay soils. The species is potentially a serious environmental weed of riparian areas and is also becoming recognised as an important weed in non-coastal areas (DPI 2004). A code of practice has been developed for this species which aims to minimise the risk that commercially grown Leuceana will have on the environment, in addition to the problems the species already causes as an environmental weed (Grice 2006). States such as Queensland have also adopted policies for the containment of the species (DPI 2004).

Box 4: Buffel grass – both friend and foe

Buffel grass (Cenchrus ciliaris) species now covers extensive areas of rangelands in Western Australia, Northern Territory, South Australia, Queensland and New South Wales and has become naturalised in areas near Alice Springs and in western Queensland (Cameron 2004). Tasmania is the only state where it does not occur. Estimates of the area the species and its cultivars occupy vary considerably, ranging between 5 – 50 million hectares (Friedel et al. 2006). This spread has been facilitated by programs of pasture introduction bringing 580 buffel grass accessions from across its natural range to Australia (Hall 2000). Friedel et al. (2009) state that buffel grass is arguably the most important introduced pasture grass in the rangelands, providing great economic benefit to pastoral communities. It is tolerant of drought, fire and heavy grazing and aids the control of soil erosion.

While a considerable amount has been written on the production benefits of Buffel grass, and the financial benefits it brings to pastoralists, relative little has been published on its impacts of biodiversity in arid Australia. Smyth et al (2009) has published one of the few studies of the impact of buffel grass on biodiversity in central Australia. They found that even when cover is low, buffel grass can have a detectable influence on some aspects of community dynamics. Given the evidence from this study and published literature, the authors expected the influence of buffel grass on the diversity of native flora and fauna to increase, particularly if buffel grass expands into land types previously thought unsuited to its environmental needs. In other parts of its range, Fairfax and Fensham (2000) found declines in plant species richness and diversity were substantial when buffel grass was compared to uncleared pastures for brigalow and eucalypt lands. Buffel grass also affects native animals, with Ludwig et al. (2000) reporting a decrease in abundance of Carnaby's skink (*Cryptoblepharus carnabyi*) and the delicate mouse (*Pseudomys delicatulus*) with increasing cover of buffel grass in cleared eucalypt woodlands of central Queensland.

The behaviour of buffel grass can vary widely depending for example on soils, climate, position in the landscape, fire or grazing regimes and time, as well as the particular cultivar (Friedel et al. 2006). Buffel grass can also affect fire regimes itself (Friedel at al. 2006), given its high fuel load compared to native species, with subsequent impacts on native flora and fauna. Friedel at al. (2009) recommended that interventions which focus on delivery should be designed to encourage protection of neighbouring reserves or downstream areas of high environmental value, through, for example, the establishment of buffer zones or through grazing buffel grass pastures prior to seed set.

Martin et al. (2006) believe that because species such as buffel grass has not been included in national prioritisation lists for serious environmental weeds, due to conflicting views regarding the benefits and costs, the opportunities for government funding for research, extension and control activities through programs such as the National Heritage Trust (now CFoC) have been reduced.

The different life forms of the pasture weeds in this section demonstrate the diversity of types that have the potential to impact on natural systems and biodiversity. Lonsdale (1994) identified a series of attributes that can be used to identify species introduced for pasture production that have the potential to become environmental weeds.

A summary of the pressure – state – responses situation for the beef industry is provided in Table 7. A summary of FAO experts' ranking of livestock's role in biodiversity loss is also provided (see Box 5).

Table 7: Pressure – state – response matrix for the cattle industry

Broad pressures on biodiversity	Extent and significance of pressures	State of biodiversity	Root cause	Examples of responses
Vegetation clearance and modification	Widespread (millions of hectares) and of major significance.	Death of animals and plants during clearing; Changed composition and abundance of native plants and animals; Modified vegetation condition; Potential for increased weed invasion in some situations; Reduced quality and quantity of soil organic matter; Changed potential for soil erosion and associated impacts on aquatic biodiversity. Rising watertable (following tree clearing) can lead to soil salinity, waterlogging and/or sodicity and subsequent decreased vegetation condition.	Clearing vegetation to extend the area of exotic pastures (to increase stocking rates) and to provide feed grains. Cost pressures driving the conversion of native pastures to exotic pastures or crops.	Legislation (e.g. Queensland Veg Management Act); Setting aside areas for conservation outcomes; Changed management practices to better utilise native systems (and hence not clear them); Revegetation; Incentive schemes.
Altered fire regimes	Widespread (tens of millions of hectares at least) and major significance.	Changed composition and abundance of native plants and animals; Modified vegetation condition; Potential for increased weed invasion in some situations; Reduced quality and quantity of soil organic matter; Changed potential for soil erosion and associated impacts on aquatic biodiversity.	Burning off to produce 'green pick' (particularly in northern Australia); altered fuel loads due to weeds, overgrazing by stock (reduced fuel load) and "woody weeds".	Changes to burning patterns.
Altered grazing regimes	Widespread ((tens of millions of hectares at least) and major significance.	Loss of understorey diversity, changes in abundance and composition of plant and animal species, expansion of grazing tolerant species and woody thickening.	Overstocking (by not matching stocking rates to carrying capacity); failure to account for total grazing pressure.	R&D programs e.g. SGS, Evergraze, Prograze, Supergraze; Monitoring programs e.g. Vegmachine, Ecograze; Changed management practices such as tactical and cell grazing.

Broad pressures on biodiversity	Extent and significance of pressures	State of biodiversity	Root cause	Examples of responses
Altered hydrology	Widespread and major significance.	Changes in the timing and amount of environmental flows affects aquatic biodiversity and floodplain species; Changes to species composition and abundance at different distances from artificial watering points.	Water extraction for irrigation and feedlots; building artificial watering points to spread grazing pressure; vegetation clearance.	Changed management practices to increase ground cover; closure of watering points in arid and semi-arid systems (Watersmart); reduce water extraction from bores (Great Artesian Basin initiative).
Trampling and soil compaction	Widespread and significant.	Altered nutrient and hydrological cycles that can lead to altered composition and abundance of native species.	Overstocking (by not matching stocking rates to carrying capacity); failure to account for total grazing pressure.	Reduce stocking rates; keeping stock out of riparian zones at critical periods
Environmental weeds	Widespread (tens of millions of hectares) and major significance.	Competition and stress to native vegetation; Changed fauna habitat (food, shelter, access to water, etc); Changed riparian zone affecting buffering capacity and waterway health; Toxic health risk to plants, animals; Altered fire regimes.	Continued use of pastoral species that become environmental weeds; farm machinery dispersing weed propagules.	Contain the spread of species, ban the use of some species; Codes of practice; weed hygiene practices.
Pollution		Death of fish and invertebrates due to reduced dissolved oxygen and toxins released by some algae under bloom conditions; Changed vegetation (aquatic and terrestrial) composition and condition; Increased shellfish contamination; Damage to coral.	Potential leakiness (e.g. nutrients, soil) of extensive, intensive and high density enterprises.	Regulations; settling ponds; Changed management practices such as manure spreading. Codes of practice.
Climate change	Global.	Changes to the composition, abundance and distribution of native plants and animals.	Methane production from ruminants; nitrogen production from feedlots; carbon dioxide emissions from transport and farm machinery.	Responses are covered in the companion MLA report on greenhouse emissions.

Box 5: FAO expert ranking of livestock's role in biodiversity loss

In order to summarise the impact of livestock on biodiversity, the Food and Agricultural Organisation (FAO 2006) invited a number of experts to rank the impacts of livestock according to their extent and severity. The experts found it difficult to be precise when quantifying the loss of biodiversity related to livestock production as they are a result of a complex web of changes, occurring at different levels, each of which is affected by multiple agents and changes over time. In the FAO comparison, extensive production systems equate to those described by the same term in this report. The intensive systems described by the FAO report (FAO 2006) however are a combination of the intensive and high density feedlot categories used in this report. In the FAO analysis, it was found that at a global level the overall cumulative loss from extensive systems to date is much higher than that induced from intensive systems, but that losses induced by intensive systems may well surpass those of extensive systems in the future. One of the mechanisms and associated threats that is not identified in the FAO report, but that is highly relevant in Australia (and no doubt overseas), is overgrazing and the associated decline in the condition of native vegetation. While it is surprising that there is no arrow associated with extensive fishing production systems (e.g. wild fisheries), the Figure provides a useful illustration of the range of impacts on biodiversity associated with livestock.

Expert ranking of livestock- related threats to biodiversity resulting from the different mechanisms and types of production system

Mechanism of livestock sector induced biodiversity loss	Type of livestock production system: Extensive production	Type of livestock production system: Intensive production	Affected level of biodiversity: Intra-species	Affected level of biodiversity: Inter-species	Affected level of biodiversity: Eco-system
Forest fragmentation	↗	↑	●	●	●
Land use intensification	↗	↑		●	
Desertification	→			●	
Forest transition (reversion of former pastures)	↗			●	●
Climate change	↗	↑	●	●	●
Invasive livestock	↘			●	
Plant invasions	↘	→		●	●
Competition with wildlife	↘	↑		●	
Overfishing		↗	●		
Livestock diversity erosion		↑	●		
Toxicity		↑	●		
Habitat pollution	→	↑		●	●

Legend: Relative level and type of threat to biodiversity resulting from the different mechanisms. "Extensive" and "Intensive" refer to the importance of the contributions from both sides of the continuum of livestock production systems.
Red shading indicates the level of past impact
- ■ very strong
- ■ strong
- ■ moderate
- ■ weak

white: no effect
Arrows indicate the direction of current trends
- ↘ decreasing
- → stable
- ↗ increasing
- ↑ rapidly increasing

Source: Steinfeld et al. (2006)

Industry and other responses

There have been a diversity of responses to the pressures on, and state of biodiversity related to the beef cattle industry. These vary across a range of sectors such as government (e.g. legislations and incentives), the cattle and conservation industries and private land managers, and encompass a broad range of responses, including R,D&E, training programs and changed management practices. The aim of Table 8 is to encapsulate the breadth and depth of responses that have been put in place, with some key examples to illustrate them.

Many of the examples in Table 8 involve multiple partners in funding and delivering the responses, particularly in R,D&E programs. Where possible, the response has been listed against the lead partner and/or funder in these programs. The response to impacts on biodiversity are often embedded in larger programs that address a range of issues related to sustainable and profitable land and water management. Examples at the national level include the Grain & Graze R,D&E program (Bridle et al. 2009) and the EDGENetwork Training Program.

Another example where biodiversity is embedded as part of a larger program is the Grazing Land Management (GLM) Program, which was developed through the MLA EDGEnetwork program (Quirk and McIvor 2003). This program was developed by multiple partners and has been delivered in a number of regions across northern Australia. It is designed to provide 'best practice' information and tools for grazing land management. In the Northern Territory, the program is a partnership between the Northern Territory Cattlemen's Association and the Department of Regional Development, Primary Industry, Fisheries and Resources, funded by the National Landcare Program. The objectives of the program include:

- Improving the understanding of sustainable land management across the region to reduce and prevent land degradation, improve land condition and protect biodiversity.
- Increasing the uptake of outcomes, results and tools from other relevant research projects across Northern Australia involved with improving pastoralists ability to manage grazing and assess risk through training people to use decision support software.
- Delivery of the GLM workshop and provision of advice and follow up support to pastoralists as they apply what they have learnt through the development of an individual property grazing management plan that addresses key production and land management objectives.

In Queensland, the Grazing Land Management Program is delivered at the regional level with the costs of workshops (at least in the Burnett catchment) subsidised through the Australian Government's Caring for our Country Reef Rescue program (Burnett catchment no date).

Programs such as GLM are designed to promote improved land management through the implementation of the following management options (Quirk 2005):

- Assessment of land condition and long-term carrying capacities
- Forage budgeting to ensure
    - ✓ 3P grasses are not grazed out
    - ✓ adequate ground cover at break of season
- Wet season pasture spelling programs

- Improve stock control on key riparian areas
- Key wetlands and waterholes identified and controlled grazing practices implemented
- Spelling and fire to manage woodland density
- Identify key weed infestations, develop plan and implement

While biodiversity is not explicitly mentioned in these management options, their on-ground implementation should lead to improved biodiversity outcomes. There is also no explicit mention of biodiversity in The National Beef Cattle Feedlot Environmental Code of Practice (Meat & Livestock Australia 2000), although adherence to the guidelines associated with issues such as effluent management should minimise the risk of leakage from these systems and subsequent off-site impacts on biodiversity.

Organisations such as Bush Heritage Australia (BHA) and the Australian Wildlife Conservancy purchase properties across Australia to meet their goal to protect and maintain biodiversity over the long-term. Their response to the pressures that cattle place on biodiversity (through grazing and trampling) is to remove domestic stock as soon as possible after properties are purchased, as well as manage other elements of total grazing pressure. The organisation believes that ‘Removing grazing is one of the most important actions to restore the health of habitats and populations of animals” (BHA 2009). BHA is developing partnerships with commercial enterprises that are adjacent to their properties (such as NAPCO) to help them develop biodiversity monitoring programs (Jim Radford, BHA, personal communication) as part of their property management.

There are numerous other responses documented in Table 8, encompassing legislative, research, education and incentive programs, for which it is not possible to go into detail. Fisher et al. (2004) also document a range of responses to the impacts of grazing by domestic stock, feral animals and kangaroos across the 10 land management zones they identified for the rangelands. The most important measure of whether these responses are having a positive impact on biodiversity is through evidence of on-ground change. These will be covered under the sections on monitoring and the effectiveness of responses.

Table 8: Industry and other responses to the state of biodiversity as a result of multiple pressures associated with the cattle industry

Sector/group responding	Broad responses	Example/s of relevant programs and relevant references
Meat & Livestock Australia	R,D&E programs and projects.	Evergraze; Grain & Graze (Bridle et al. 2009); Pigeon Hole project (Fisher 2006); Strategic R&D Plans for Northern Beef, Southern Beef and Feedlots.
	Training and education programs.	EDGENetwork - Grazing Land Management Program (Northern Australia), Managing Living Systems; Prograze (southern Australia). 'Tips & Tools'.
Industry groups	Codes of practice and management guidelines.	National Beef Cattle Feedlot Environmental Code of Practice; National Guidelines for Beef Cattle Feedlots; National Feedlot Accreditation Scheme.
R&D Corporations (other than MLA) e.g. RIRDC, LWA	Fund and/or manage R&D programs; develop and distribute communication products, including management guidelines.	Methane to Markets in Australian Agriculture Program (RIRDC manages as part of an international program); Riparian Lands R&D Program and the Native Vegetation R&D Program (both managed by LWA and set up to address the management of sustainable agricultural landscapes, including biodiversity).
Private land managers (1)	Pasture and biodiversity monitoring, certification/EMS; property management planning; involvement in research.	The Pigeon Hole research project was conducted on a Heytesbury property; NAPCO have ISO14001 certification for the feedlot near Toowoomba; an EMS has been developed by a group of cattle farmers (Gippsland Naturally Pty. Ltd.) and is used as part of their marketing program for their 'Enviromeat' product.
Private land managers (2)	Changed management practices.	Changed management practices include: rotational/ tactical grazing, holistic management (all approaches involve spelling pastures), stock exclusion, weed eradication, planting crop/pasture legumes, use of perennial pastures, monitoring of water tables, fire management, closing artificial watering points; stop or reduce vegetation clearance; nature reserves and other areas set aside for conservation.
Rangelands Australia (Partners include DAFF, Queensland Govt, MLA and the Uni of Queensland).	Developed Australia's only postgraduate coursework programs specifically in Rangeland Management.	Offer a Graduate Certificate, Graduate Diploma and Master in Rangeland Management.

Sector/group responding	Broad responses	Example/s of relevant programs and relevant references
Government: – Commonwealth and State	Legislation, regulations, policies and programs.	• Queensland Vegetation Management Act (1999) (Williams and Price 2008). • Delbessie Agreement (2006) for leasehold land in Queensland. • Regulations and codes of practice for high density feedlots (state level). • *Great Artesian Basin* Sustainability Initiative - a joint Commonwealth/Queensland government *program.* • *Policy on the containment of Leuceana (Queensland).* • *National Residue Survey*
	Research organisations and programs (e.g. CSIRO, Universities, State Primary Industry and Environment Departments); NRM programs (NHT & CFoC); CSIRO.	Biograze, Watersmart, Tropical Savannas CRC (a major R,D&E program in northern Australia with a focus on pastoralism), Projects funded through NHT & CFoC (e.g. the NTCA received funding in 2009); Sustainable Ecosystems (CSIRO) undertakes several research projects in cattle production systems; The CSIRO Water for a Healthy Country Flagship has a Sustainable Grazing Program Great Barrier Reef Catchments Node.
	Best Management Practices.	Cattle grazing in the north and south of Western Australia (e.g. DPI 2005).
	Incentive programs.	Funded through regional NRM organisations or non-profit organisations such as the Tasmanian Land Conservancy.
Regional NRM organisations	On-ground management, training and incentive programs.	Fitzroy Basin Association (as an example) – funds and manages programs such as the Biodiversity Incentive Scheme; Sustainable Landscape Program; Assessing ground cover & Property planning.
Non-profit groups e.g. Bush Heritage Australia	Purchase properties in northern Australia for conservation.	Remove cattle from properties in addition to managing other pressures on biodiversity.
Other sectors/examples	Publications and other communication material. Codes of practice.	Example publications on the potential to integrate conservation and production, including the use of case studies, as part of a profitable farming systems include Mokany et al. 2006, Staton and O'Sullivan 2006, Dorrough et al. 2008, Waters and Hacker 2008. Code of practice for the commercially grown *Leuceana*.

Monitoring

There are several monitoring programs either in place or in preparation for monitoring the impacts of cattle on pasture production, which are conducted across a number of scales (Table 9). Many of these sectors work in partnership to design and deliver these monitoring programs, so in some cases the correct attribution to the major partner in the program may need adjustment!

Some of these monitoring systems have gained wide acceptance in the farming community, such as the ABCD condition framework of Chilcott et al. (2003b) (Karfs et al 2009b), which provides differentiation between grazing land condition classes. This is a fairly simple assessment process designed for rapid assessment, based on photographic references and proformas for recording the condition of pastures and other indicators. The framework has been adopted as part of several different training and monitoring programs, including the Stocktake training package. The level of detail collected about land condition varies with the system used, ranging from simple measures of crown cover of perennial pastures (QDPIF 2006) to measures of pasture and soil condition, as well as tree cover (e.g. Karfs et al. 2009a). Increasing the cover of perennial pastures and improving soil condition can have a number of flow on effects on biodiversity, which would need to be explicitly studied to determine the links between the ABCD approach to monitoring and biodiversity outcomes.

In recent years, a broader approach is being taken to grazing which includes studying and monitoring the impacts on both production and conservation assets, acknowledging that these are intimately linked (Fisher and Kutt 2006). This was necessary because it was found that the techniques being used to describe and monitor pasture/forage production were not always suitable for assessing and measuring the status of biodiversity. Fisher and Kutt (2006) concluded that land condition is, by itself, too blunt an instrument to adequately monitor biodiversity status in savanna rangelands. The authors recommended that the incorporation of additional habitat attributes into site-based condition assessment, as well as the direct assessment of selected biota, would greatly improve information content about potential biodiversity condition.

In Queensland, BioCondition has been developed as an assessment framework that provides a measure of how well a terrestrial ecosystem is functioning for the maintenance of biodiversity values, which requires good botanical and habitat assessment skills (Eyre et al. 2006). Programs such as those set up by Bush Heritage Australia, which are explicitly designed to monitor biodiversity on sites where cattle have been removed, are just starting to get results (Jim Radford, personal communication). It is hoped that partnerships between organisations such as BHA and neighbouring cattle properties will help develop monitoring systems that are straightforward and timely to use, but capture the information necessary to determine patterns in biodiversity over time.

Table 9: Monitoring programs developed by Industry and other sectors that have responded to the pressures on biodiversity identified in this report.

Sector/group responding	Examples of monitoring programs	Scale
Meat & Livestock Australia	Involved in the development of a range of monitoring programs listed below, including the ABCD Monitoring Program.	Multiple
R&D Corporations (other than MLA) e.g. RIRDC, LWA	Rapid riparian assessment tools to measure condition (National Riparian R&D Program, LWA).	Site-based
Private land managers (1)	Pasture and ground-cover monitoring (using a range of techniques depending on where their properties are located); Some biodiversity monitoring being implemented on properties.	Paddock to property scale
Rangelands Australia	Not applicable	Not applicable
Government: – Commonwealth and State	1. ABCD condition monitoring for pastures (QDPI) (part of the GLM program) 2. Vegmachine (through the Tropical Savannas CRC) 3. Ecograze 4. Pastures from Space 5. ACRIS (Australian Rangelands Information System) 6. DPI&F in Queensland conducts Audits of feedlots to ensure operation within licensed conditions, including environmental management (e.g. DPI&F Queensland).	Paddock to regional scale
Regional NRM organisations	Delivery of monitoring programs such as land condition assessment (Karfs et al. 2009a).	Paddock scale
Non-profit conservation groups e.g. BHA & AWC	Development of monitoring systems (e.g. BHA 2008) to examine the impact of management practices on biodiversity on properties that have been purchased and total grazing pressure managed (including the removal of stock). Working with neighbours, such as BHA with NAPCO, to develop monitoring systems for biodiversity on commercial properties.	Site, regional and national.

Effectiveness of responses

Because of the broad range of responses that have been put in place to address the pressures of cattle production systems on terrestrial and aquatic biodiversity (Table 8), selected examples of the effectiveness of the responses are included below. These have been chosen to try and illustrate the diversity of responses and how effective they have been in improving biodiversity outcomes. Whatever the type of response, whether it is legislation, training, incentives, best management practices or research, the ultimate goal is to improved land and water management for both production and biodiversity outcomes. The ways to achieve this are well known and have been written about many times in best practice management guidelines, grazing reviews and other publications referred to in this report. The real challenge is getting them implemented on the ground. This is where studies on the barriers to producers of adopting sustainable management practices become important (McIntyre 2001, Richards 2005, McLeod and McIvor 2006).

One of the major pressures on biodiversity associated with cattle production, especially in Queensland, was clearing of native vegetation. The introduction of legislation to end broad-scale clearing in Queensland, which was largely associated with pastoralism, appears to have been effective, although the way it was implemented has been questioned (Williams and Price 2008). The Department of Natural Resources and Water (2008) report showed that the clearing of native vegetation in Queensland has dropped by 37 per cent, down from 375 000 ha/year in 2005–06, to 235 000 ha/year in 2006–07. As the legislation has only been in place 18 months, the effectiveness in the longer term on vegetation clearance rates will need to be evaluated over time. This will be possible given the annual publication on land cover changes produced as part of the SLATS program in Queensland.

An evaluation of the PROGRAZE program, developed to assist beef cattle and sheep producers improve the quality of grazing management decision making, found strong evidence of practice change by participants particularly, grazing decisions associated with pasture management (Bell and Allen 2000). The implications of these changes for biodiversity outcomes are still to be explored, although some improvements are likely to have occurred. Quirk (2005) identified a number of measures of success to evaluate the Grazing Land Management Program, the most important of which is the implementation of management imperatives and the ongoing assessment of land condition.

Evidence is available in the Gasgoyne region of Western Australia of positive changes in the attitude and behaviour of pastoralists (Watson et al. 2006). The region experienced an increased capacity for change during the period of the project, which was a pilot undertaken as part of the ACRIS. Capacity was assessed in a number of ways including the perceptions of pastoral managers, their confidence in the future, and the financial health of many pastoral businesses and a range of on-ground actions. These on-ground actions include better control of grazing animals, relatively rapid and comprehensive de-stocking during drought conditions and improved landscape and ecosystem management. Much of the improvement in perennial vegetation condition measured in the pilot project occurred during both good seasonal conditions and poor seasonal conditions, which led Watson et al. (2006) to suggest that the negative impact of grazing was not large, except on a minority of sites. The results for perennial grass species and for indicators of landscape function however did not show the same improvement. The purchase by the government of 4 million hectares of pastoral leases for conservation outcomes was seen to increase the potential for biodiversity conservation, as did an increased interest in off-reserve conservation and better control of grazing pressure. While there are a few caveats associated with these findings, they provide an encouraging example of the potential to change if the right resources and programs are put in place.

There are many examples of companies such as NAPCO (http://www.buseco.monash.edu.au/mgt/agribis/energyaward2004.html) and individual cattle producers implementing changes that should have positive impacts on biodiversity. There is still evidence however of current management practices that continue to have a detrimental effect on biodiversity across a range of pressures. Pasture grasses that become weeds such as Gamba grass continue to have major impacts on natural systems in savanna and rangeland landscapes. Overgrazing and its impacts on terrestrial and aquatic biodiversity still occurs. The challenge is to expand the number of producers implementing sustainable management practices, while maintaining (or creating) a profitable farm business.

Perceptions

Overall, grazing by cattle (as part of total grazing pressure) is seen as a threat to biodiversity by a number of groups, either indirectly through land clearing or greenhouse gas emissions, and weeds, or directly through overgrazing and trampling. Groups that consider it a threat include animal liberationists, conservation groups, non-government organisations that purchase private land for biodiversity conservation (e.g. Australian Wildlife Conservancy and Bush Heritage Australia (BHA)) and many ecologists. Information coming from these groups, as well as the mass media, has the potential to influence the broader public and their perceptions. As far as we are aware however, there appears to be no papers published on the perception of the general public towards the environmental impact of cattle production in Australia.

As noted in the section on response to the impacts of cattle grazing on biodiversity, removing domestic stocks from properties they have purchased is a priority for organisations such as BHA. The message this sends to their supporters, as well as more widely, is that grazing by cattle, sheep and other (exotic) herbivores can only be detrimental for biodiversity. This is despite research that shows that biodiversity can coexist with certain grazing regimes in place (e.g. Lunt et al. 2007, McIntyre et al. 2002, Kirkpatrick et al. 2005). Sheep and cattle were also retained on commercial properties purchased for conservation such as the Terrick Terrick National Park in Victoria and the Vale of Belvoir in Tasmania. While in the longer term stock may be removed from these conservation reserves when alternative management strategies are identified, the fact that they had high conservation values after several decades of domestic stock grazing indicates that not all ‘grazing’ is detrimental.

As recently as October (2008) Wilson and Edwards stated that “Hard-hoofed sheep and cattle have caused a great deal of damage to Australia’s land. But now we recognise that they cause damage in another harmful way. They produce large quantities of the greenhouse gas methane and in turn contribute to global warming. In fact, 11% of Australia’s total greenhouse gases come from cattle and sheep.” The fact that kangaroos have different micro-organisms to help them digest food and hence don’t burp methane has led to suggestions that Australians eat more kangaroo meat and the number of cattle and sheep be reduced (Garnaut 2008, Wilson and Edwards 2008).

Animal Liberationists are particularly scathing about the impact of the sheep and cattle industry on the environment, although no other animal-based industries are spared (http://www.animalliberation.org.au/vegconf.php). In summary, it is stated that the extensive cattle and sheep industries in Australia are an environmental disaster, and the more intensive systems used for chicken and sheep are no better if you care about waste (both of grains for animal consumption and manure from the feedlots). Much more detail is provided on the website for those who care to read further. Farmers are not blamed for this predicament; the blame is put fairly and squarely on the shoulders of consumers. If they are not able to stop eating meat, they are encouraged to pay for ‘free range’ meat, which by implication has less impact on the environment.

The main perceptions about the environmental impacts of cattle feedlots relate to the impact of nutrients on groundwater and river quality, soil erosion and the use of grains to feed animals. Concern about these issues has been expressed by the Greens party in Queensland and the Animal Liberation movement.

5.1.2 Sheep meat

Background

Sheep arrived in NSW with the first fleet, and were introduced in Tasmania not long afterwards in 1803 (Kirkpatrick and Bridle 2007). For over 100 years, the fortunes of Australia were closely tied to the wool industry, with most Australian's being familiar with the phrase 'Riding on the sheep's back'. At its peak, over 100 million sheep were farmed in Australia. While the contribution of the wool industry to the Australian economy has declined, it will remain important in the future. Over recent years, sheep meat production has become an increasingly significant driver of developments in the industry (Scott 2008) with the sheep meat industry accounting for 31% of all farms with agricultural activity (MLA 2008). This situation has developed as producers have moved resources away from wool production and into other farm enterprises such as prime lamb, crops and beef cattle. Box 6 provides facts and statistics for the 2007-2008 financial year, indicating the importance of the export industry (both meat and live sheep) for sheep meat producers.

The majority of Australia's 76.9 million sheep (as at June 2008) are located in New South Wales (34 per cent), Western Australia (23 per cent) and Victoria (22 per cent) (Fletcher et al. 2009). The prime lamb industry is concentrated in these states in the higher rainfall regions. Of the 47,296 properties that run sheep, Fletcher et al. (2009) report that as of June 2008, 11,148 farm establishments specialised in sheep, including wool producers. The area operated by farms with lambs and sheep in 2007-2008 was 134 million hectares, or 17% of Australia's land mass (MLA 2008).

Slaughter lamb producers are predominantly located in the Riverina, the Victorian and NSW Murray region, the wheat-sheep zone of NSW, and the high rainfall areas of southern Victoria and eastern South Australia (MLA 2008). Western Australia produces a relatively small amount of meat from sheep, contributing around 11% of the total Australian lamb production in 2007-2008 and around nearly 24% of mutton production (MLA 2008). Approximately 45% of Merino ewes in Australia are mated to produce prime lambs and more than 80% of prime lambs have Merino genetics. Other sheep breeds used for meat production in Australia include the Dorper, which has a different diet selection and grazing behaviour than merinos (Brand 2000). In the southern rangelands of Western Australia, where sheep meat and other enterprises are replacing the traditional merino flocks, new breeds include the Damara sheep (Alchin et al. 2007)

Because of the close link between sheep managed for wool production and sheep managed for meat production, it can be difficult for those outside the industry to tease apart the management practices and impacts of these different products. Where possible, this section aims to separate the impacts of sheep used for wool production and that used for sheep meat (lamb and mutton).

Feedlots are being used increasingly in dryland Australia for the finishing of lambs, and for maintenance of the flock in drought conditions (Dowling and Crossley 2004). Most lamb however produced is still grass-fed with only around 3% grown in feed lots but up to 10% under favourable grain price conditions (Scott 2008). Sheep feedlot systems are different from ones used for cattle. Sheep confinement feeding systems tend to be a value adding activity to bring unfinished lambs up to market specifications when paddock feed is short and operate for a few months of the year rather than all year round. Confinement feeding systems are usually run in conjunction with the rest of the farming system to make the most of commodity prices.

Box 6: Facts and statistics about the Australian sheep-meat industry for the 2007-08 fiscal year

- There are 47,296 properties with sheep (ABS)
- Australian lamb production has continued to expand, reaching a record of 435,392 tonnes cwt in 2007-08 from 329,407 tonnes cwt in 2002-03.
- The top five markets for Australian lamb are the US, Middle East, China, European Union and PNG
- The top five markets for Australian mutton are the Middle East, the US, South Africa, CIS and Taiwan
- The total value of all other lamb export markets for 2007-08 is approximately A$365 million, up from A$202 million in 2002-03.
- Since 2002-03 Australian consumers increased their expenditure on lamb by 37% from A$1.5 billion to A$2.1 billion in 2007-08 (2007-08 MLA preliminary estimates).
- The total value of lamb exports has increased by 49% from A$554 million in 2002-03 to A$824 million in 2007-08 (ABS)
- Australia exported a total of 4.1 million sheep, valued at A$287 million. The principal live sheep export markets include Saudi Arabia, Kuwait, Oman, Bahrain, Jordan, Qatar and the United Arab Emirates in the Middle East.

Source: Meat & Livestock Australia and the Sheepmeat Council of Australia

The state of biodiversity

Vegetation clearance

Widespread clearance of native vegetation for agriculture has occurred in southern and eastern Australia, as described in Section 4. This section reports that around 30 million hectares of land has been cleared for sown pastures to support beef and sheep production in Australia. For sheep, most of this clearing was in Victoria, NSW and Western Australia. Because the main focus of the sheep industry in Australia has until recently been on wool production, we attribute most of this clearing to managing sheep for wool rather than meat production. This assumes that most farming enterprises that graze meat sheep on sown pastures are using systems that were originally cleared for wool production.

This is not to say that there has been no vegetation cleared specifically for meat sheep, especially in more recent years when this component of the sheep industry has expanded. Quantifying the proportion of native vegetation cleared this purpose however would take a considerable amount of work, assuming that the information is available. Based on this interpretation of vegetation clearance, which a more detailed study would help refine, it is concluded is that the direct pressures of the sheep meat industry on biodiversity through the clearance of native vegetation is limited compared to cattle and sheep managed for wool production.

The lack of tree regeneration in the extensively grazed landscapes of south-eastern Australia represents a less obvious form of clearing, which has been an increasing focus of research over the last decade. The nature and findings of this research is covered in the following section on altered grazing regimes.

Altered grazing and fire regimes

Section 3 describes some of the complexities of grazing regimes and disentangling their impact on biodiversity. It notes, for example, that different types of grazing animals select and eat plant species differently, including some of the different sheep breeds used for wool and meat production (i.e. Dorper sheep). Teasing out the differences that different sheep breeds have on biodiversity has not been undertaken in south-eastern Australia, as far as the authors are aware. In the southern rangelands of Western Australia, a trial was undertaken to compare the impacts of Damara (meat sheep), Merinos and Rangeland goats on rangeland condition. This trial was driven in part by concern from some parties that meat sheep breeds and rangeland goats have a greater capacity to adversely affect rangeland condition. Alchin et al. (2007) reporting on the Damara component of this trial, found that rangeland condition was negatively affected by these sheep, with over-utilisation of favourable perennial grass and shrub species and the breakdown of woody patches. Because of the dry conditions under which the trial was conducted, trial flock numbers were considerably reduced and major destocking was undertaken. The main conclusion drawn from these preliminary results was that regardless of the livestock enterprise, matching stocking rate to carrying capacity is of the first importance (Alchin et al. 2007).

Native and sown pastures are utilized for sheep meat production on better soils in the wheat belt and on drier inland margins, in addition to wetter areas in non-arable country (MLA, personal communication, June 2009). All animals utilise sown pastures at some stage in their production cycle to increase growth rates. In south-west Western Australia sown pastures are used for the entire production cycle, as native pasture grasses largely disappeared with the advent of livestock grazing in that region (Lefroy 1991). Studies that examine the impact of sheep on biodiversity in this region focus on unfenced remnant vegetation which sheep have access to from the sown pastures that surround them. In south-eastern Australia, impacts of sheep grazing on biodiversity have been studied in both woody remnant vegetation and native pastures.

Up until recently, sheep grazing and biodiversity maintenance have been perceived to be mutually exclusive by conservationists and many ecologists. For example, Duncan et al. (2007) state that “Grazing from domestic stock is known to have profound effects on the ecology of native vegetation remnants. Stock pressure comprises grazing and browsing (removal of plant biomass, prevention of formation of reproductive tissue), trampling and compaction (soil desiccation, destruction of seedlings, exposure and desiccation of young root networks, destruction of soil bio-pores, break up and loss of litter layer, degradation of soil invertebrate habitat), and camping (concentrated deposition of urine and faeces and feed provision, intensive physical disturbance, rubbing and ringbarking of mature woody plants)” The context of these comments were small, often degraded remnants in western Victoria that are often used as stock shelter for sheep. The sentiments expressed here that grazing, rather than particular grazing regimes, have profound and negative impacts on native biodiversity are widely held. This sentiment is slowly changing, based on some of the work described below.

The Sustainable Grazing Systems Program (SGS) focused on sheep grazing systems (Lodge et al. 2003). The Biodiversity theme of this program undertook the first comprehensive study across southern Australia of the relationships between plant diversity (both native and exotic) and the productivity and stability of pastures grazed by sheep (Kemp et al. 2003). While the focus of this work was on maximising plant diversity (largely in sown pastures) for sheep production, some of the results are relevant to describing the potential impacts of sheep on pasture systems. For example, although the results of the study were variable across sites, the trends found suggested that maintaining pasture systems with the range of 2-4 t DM/ha would optimise the diversity of species and minimise the risk of species loss. Guidelines such as these can be used to maintain native species in sown pastures where they occur, and assist with maintaining ground cover.

The reviews undertaken by Lunt (2005, 2007) on the impact of grazing on biodiversity in south-eastern Australia largely draws on studies that have examined sheep grazing on native pastures and in remnant vegetation. While these studies don't separate the type or production system being examined (e.g. whether the sheep are being farmed for wool or meat), the findings are relevant to enterprises where sheep meat utilise native pastures or have access to remnant vegetation. As noted in Section 4 of this report, Lunt (2005) identified 3 main ways that grazing can have an impact on biodiversity. One of these was the direct impact of grazing, whereas the other two were indirect impacts on soil characteristics through hoof action and nutrient build-up.

Like the findings of the review of cattle impacts on biodiversity, certain sheep grazing regimes can lead to a degradation of native systems, including negative changes in the composition of species, the introduction of weeds, reduced soil health and altered fire regimes (Lunt 2005, 2007, Prober et al. 2002, Yates et al. 2000; see also other references in Sections 3 and 4). The use of fertilisers, particularly super-phosphate, in native pasture systems grazed by sheep has also been demonstrated to reduce native plant species diversity (Dorrough et al. 2006). Fertiliser use on native pastures needs to be very carefully managed, or the system can quickly change to one dominated by annuals such as clover and introduced grasses, with native species being lost (Mokany et al. 2006).

The lack of regeneration of farm trees (mainly eucalypts) across the extensive grazing landscapes of south-eastern Australia has been of concern for some time. The importance of paddock trees to conservation and production systems, their rate of loss over time through factors such as dieback and clearing, and the implications of their lack of regeneration have been addressed by authors such as Reid and Landsberg (2000), Gibbons and Boak (2002) and Dorrough and Moxham (2005). Fischer et al. (2009) are undertaking research that demonstrates that farm trees can regenerate under certain grazing regimes (by sheep, cattle or both), with fast-rotational grazing producing the greatest benefits. In some ways the research community is catching up with what farmers already know with at least two families near Armidale NSW, used as Land, Water & Wool (LWW) case studies, observing eucalypt regeneration in grazed paddocks. In addition to adopting certain grazing regimes, Fischer et al. (2009) identified a range of options for increasing tree regeneration, including ceasing to use fertilisers on pastures to enhance conditions for natural regeneration.

The Land, Water & Wool Program (Wagg et al. 2007) made a major investment in examining the relationships between sheep and biodiversity on wool production on native pastures, primarily through the Native Vegetation and Biodiversity Sub-program of LWW (Williams and Goodacre 2008). Under certain management conditions, it was found that production and conservation objectives were compatible on sheep properties. For example, sheep grazing was found to be compatible with the conservation of most native plant species in the Midlands region of Tasmania (Kirkpatrick et al. 2005). This was in systems where there are relatively low stocking rates and low fertiliser use. While grazing sensitive plants were more likely to persist if they were protected from sheep, threatened native plant species such as

Leucochrysum albicans (Grassland Paper Daisy) and *Colobanthus curtisiaerelies* (Grassland Cupflower) were commonly found in well–managed sheep grazing habitats. Kirkpatrick et al. (2005) concluded that sheep can graze on native pastures while maintaining a high native plant species diversity on–property, including threatened and declining species – if the properties are well managed. Lunt (2005, 2007) has also identified certain situations where sheep grazing and conservation outcomes are compatible in native systems.

As noted above, the management systems for sheep-meat can differ from sheep raised for wool, with an increased reliance on exotic pastures as the feed-base for sheep-meat. This is where the debate about the value of landscapes that are intensively managed, compared to extensive landscapes, comes into play. Dorrough et al. (2007), based on work undertaken in LWW, addressed the question of whether intensification in one part of a property can save land elsewhere on the property for conservation outcomes. They concluded that at both the paddock and farm scale, increasing productivity via fertiliser application could come at a cost to biodiversity. In contrast, improving grazing management across broad scales was considered likely to result in enhanced profitability and could also benefit native vegetation. The authors concluded that extensive management, rather than more intensification, may be necessary to maintain biodiversity and prevent further long-term degradation of the resource base (Dorrough et al. 2007).

The conclusions about the importance of extensive systems for biodiversity do not discount the contribution that intensive sheep management systems can make. A critical finding from the LWW biodiversity project in northern NSW was that irrespective of choice of production system (e.g. intensive or extensive), any wool property can make a worthwhile contribution to nature conservation (Reid 2006a). To achieve this, the managers need to be informed about the natural values of their property and willing to manage parts of their property for conservation or in a conservation-compatible way. Farms with a higher proportion of pastures compared to grains may have a head-start in managing for biodiversity outcomes. For example, as reported in the section on grains, a comparison of farms with high proportions of pastures compared to a high proportion of grains showed those with more pastures had greater biodiversity in the form of spiders and birds (Bridle et al. 2009). This was associated with the likelihood that the properties with pastures tended to have higher proportions of remnant vegetation that acted as harbours for the spiders and birds.

The role of features such as shelterbelts (e.g. Cleugh 2002) takes on increasing importance on properties that mainly utilise sown pastures. Native shelterbelts can have important benefits for biodiversity. For example, woody vegetation was found to provide important habitat for the mammals, birds and bats in wool growing landscapes in northern NSW. Both native and introduced woody vegetation played a range of roles in providing habitat but were also important for shade and shelter for both sheep and pastures. Bird surveys in on 24 wool properties between Walcha and Glen Innes recorded 109 bird species (Reid 2006b). The number of bird species was lowest in pasture areas with no trees and highest in wooded riparian zones. Areas with scattered trees and windbreaks in pasture fell between these two habitat types. Similar to these findings, work in south-eastern Queensland (Martin and McIntyre 2007) found that if trees are present in cattle grazing properties found that a rich and abundant bird fauna can coexist with moderate levels of grazing.

At the beginning of this section it was noted that sheep were introduced in south eastern Australia over two hundred years ago. Fire regimes have been altered in systems used for sheep grazing since aboriginal tribes stopped or altered their traditional fire management practices following European settlement. In some cases fire has been effectively removed from remnant native vegetation in agricultural landscapes (Gill and Williams 1996), or is used as part of sheep production systems to encourage new growth for grazing (Kirkpatrick and Bridle 2007). As reported for cattle production systems, interactions have been found between fire, grazing and biodiversity in sheep production systems (Kirkpatrick et al. 2005), with plant species showing different responses depending on the combination of fire and grazing involved.

<u>Pollution and Altered hydrology</u>

There appears to be almost no research on the impacts of sheep feedlots on the environment under Australian conditions, apart from work in Western Australia (e.g. Dowling and Crossley 2004, Dowling et al. 2005). These authors report that while sheep feedlots are likely to pose an environmental hazard, their potential for land degradation, pollution and related effects such as erosion, nutrient run off, groundwater contamination, greenhouse emissions, odour, dust, noise and flies at the farm and catchment level have not been quantified. Consequently, any inferences about their impact must come from studies overseas.

Because sheep meat production requires nutritious and vigorous pasture growth to finish off lambs, access to water is an important part of the farming system. Consequently, the hydrology of natural systems can be altered by the use of irrigation and the building of dams. These actions affect the natural flows of river systems through the direct use and interception of rainfall, which has a flow through effect on aquatic biodiversity. Grazing of sheep along river banks can cause major erosion and lead to large amounts of sediment moving downstream. A recent study near Canberra (LWA no date) for example recorded a major slug of sediment after a rainfall event. Losing this amount of soil has effects on both the stream bank and the course of the river. In turn, this has an impact on both terrestrial and aquatic biodiversity.

<u>Other pressures</u>

Killing of dingoes

An indirect impact of the sheep industry, which has only received recent attention, is the exclusion of dingoes from south-eastern Australia by the 5400km long ‘dog-fence’ (Woodford 2003). This begins at the Great Australian Bight just west of Penong in South Australia and ends in Queensland north-west of Brisbane. The fence was designed to keep the dingo out of the southeast corner where the richest grazing and pasture land was found, because it was believed that the dingo caused major losses to domestic stock. Attributing the loss of stock to dingoes is complicated by their hybridisation with wild dogs (Fleming 2001). Because of the challenges of separating the two, the economic costs of wild dogs and dingoes are reported together (Fleming et al. 2001, Rural Management Partners 2004, Fleming et al. 2006). Production losses have been highest for sheep enterprises, with the value of cattle determining how important the losses to wild dogs are to this industry (Fleming et al. 2006). Because of these stock losses, in addition to the building and maintenance of dog fences, techniques such as the use of 1080 poison (usually by aerial baiting) and dog traps have been used to manage wild dog populations (Woodward 2003, Fleming et al. 2006).

The understanding of the role of the dingo in both production and conservation systems is starting to change (Glen et al. 2007, Johnson et al. 2007, Wallach et al. 2009). In the absence of the dingo, introduced pest animals such as the red fox, feral cat and European rabbit can proliferate, with significant, often detrimental, impacts on the ecosystem, such as the loss of the rufous hare-wallaby. As a top predator, the dingo may have become essential to the biodiversity of the Australian landscape, but has been poisoned, trapped and shot in large parts of Australia. Interbreeding with wild dogs has also seen changes to the behaviour of the dingo and its role in Australian ecosystems (Claridge and Hunt 2008). Research is underway and planned to tease out the role of the dingo in biodiversity conservation in the modern context. If it turns out that maintaining populations of dingoes (cf hybrid wild dogs) is important for biodiversity conservation, this will need to be weighed up against the estimated costs to livestock industries. For example, five years ago, the estimated cost of wild dogs (including dingoes) was AU$66.3 million per annum in production losses and control activities, with additional unquantified social and environmental impacts (McLeod 2004).

Responses

As demonstrated in the section on beef cattle, there have been numerous responses of industry and government to address the impact of sheep on the environment. Most of the responses by governments, such as legislation (i.e. to regulate the clearance of native vegetation) and incentive programs addressing biodiversity management, are designed for agricultural landscapes in southern and eastern Australia as a whole, rather than sheep-meat production systems in particular. Examples of incentive programs designed to improve the management of native vegetation in agricultural landscapes in southern and eastern Australia include fencing incentives available through the Bush Care Program (funded through the Natural Heritage Trust) and ‘auction’ style programs such as Bush Tender and Eco Tender in Victoria and the Midlands Biodiversity Hotspots Program in Tasmania. These programs focus on patches of native vegetation in the landscape, whereas pilot projects such as Green Graze in Victoria delivered incentives in the context of the farming system. Because of the broad-scale clearing of agricultural landscapes for sheep grazing and cropping, a major response of governments has also been providing funding for revegetation programs.

Other programs (principally through industry) are designed specifically for sheep that are farmed to produce meat, while some are relevant to both meat and wool sheep, or sometimes primarily to sheep farmed for wool. Selected examples of these responses follow, focusing on projects directly relevant to sheep-meat production, run or funded by MLA.

- The MLA Lamb and Sheepmeat Livestock Production Research & Development Strategic Plan, covering the period 2006-2011, identifies a number of current and new R&D areas under the banner of ‘Increasing the environmental sustainability of the whole farm system’. These include a life cycle analysis of red meat products and their contribution to environmental outcomes/changes and investigating new markets for environmental services. The Strategic Plan also reports that operationally, the Lamb and Sheepmeat and Goat Meat Programs address industry and government issues, collaborate with organisations that share a responsibility for natural resources, and deliver NRM solutions within a production systems context.
- DAFF and MLA are jointly funding a project titled ‘Breeding for low methane sheep’ ($1,045,000 over 2 years), which is being run by the Sheep CRC.
- Sustainable Grazing Systems (SGS) was a 5 year program funded by MLA that focused on sheep production systems. The findings of this program were published in a

special issue of the Australian Journal of Experimental Agriculture in 2003 (Lodge et al. 2003), including a paper on the SGS Biodiversity theme (Kemp et al. 2003) (see section on altered grazing regimes above).

- More recent programs that MLA have been partners in, that examine relationships between sheep and the environment, include Land, Water & Wool (see the section on grazing above), Grain & Graze (Bridle et al. 2009) and Evergraze. Some elements of these programs specifically examine biodiversity in sheep-meat production systems, such as the Sustainable Grazing on Saline Lands (SGSL) component of LWW. Like LWW however, most programs examine sheep-meat production as part of a mixed farming enterprise – consisting of meat sheep and/or both wool sheep and/or cropping systems and/or cattle grazing.
- 'Making More from Sheep' is a best practice package designed by Australian Wool Innovation and Meat & Livestock Australia to assist sheep producers (both wool and meat) increase the productivity and profitability of their enterprises and have the personal satisfaction of operating a successful farming business. The package has modules on protecting the farm's natural assets and managing for healthy soils amongst many others on managing a farm business. The section on growing more pastures has information on the application of fertilisers to native pastures and advises not to add fertilisers to high conservation areas.

Monitoring and effectiveness of responses

A range of production based monitoring programs at the paddock level have been developed for sheep production systems that measure features such as pasture production and ground cover. At a larger scale, the Pastures from Space Program is designed to provide estimates of pasture production during the growing season in southern Australia by means of remote sensing (http://www.pasturesfromspace.csiro.au/). The aim is to improve the utilisation efficiency of pasture use through better management of feed resources. In an attempt to link monitoring for both production and conservation outcomes, Land, Water & Wool developed a monitoring scheme for wool growers so that multiple goals could be measured at the one time. The monitoring program, called 'Quickchecks' (Land & Water Australia 2007), was based on the goals and interests of farm families. Tools were developed to measure pasture health (including ground cover), soils, woody vegetation, farm watercourses, paddock production levels and birds.

As found for other aspects in this section, teasing out the effectiveness of the responses of different players to the impacts on biodiversity of sheep-meat production, compared to the sheep industry as a whole, can be challenging. Wagg et al. (2007), for example, reported that an evaluation of the Native Vegetation and Biodiversity component of LWW showed early adoption of some of the findings. Approaches developed through the Native Vegetation component of LWW were also taken up in other programs such as Green Graze. Evaluations of some of the auction programs outlined above have demonstrated a good return on investment in terms of the native vegetation conserved. One of the important issues to be addressed however is supporting the farmers who are involved in these schemes in the longer term, including the provision of management advice and setting up monitoring programs (Williams and Price 2008). Fischer et al. (2009) notes that changes in policy are urgently needed to address the 'tree regeneration' crisis in the grazed landscapes of southern and eastern Australia.

Perceptions

Recent research from Land, Water & Wool and other projects, as well as case studies from ‘switched-on’ land managers, are starting to change some of the perceptions about sheep and biodiversity, at least for sheep used for wool production. The native vegetation ‘Insights’ publication from LWW, which highlighted a number of wool producers who were managing profitable and sustainable farming systems (LWA 2005), was a highly sought after publication.

Despite some of this more recent evidence on the link between sheep and biodiversity maintenance (at least for sheep managed for wool), there is still an ingrained belief that grazing by exotic animals is an anathema to conservation values. It is unlikely that the general public and others who comment on the impact of sheep production separate sheep managed for wool production and sheep managed for meat production, other than when referring to the potential impact of sheep feedlots.

A summary of the pressure – state – responses situation for the sheep-meat industry is provided in Table 10.

Table 10: Pressure – state – response matrix for the sheep-meat industry

Broad pressures on biodiversity	Extent and significance of pressures	State of biodiversity	Root cause	Examples of responses
Vegetation clearance and modification	The widespread clearing for sheep grazing is largely related to wool production. Based on the information available, the extent of land clearing for sheep-meat production is limited. Ongoing 'clearing' through the impact of grazing on tree regeneration, is covered in the next pressure.	Death of animals and plants during clearing; Changed composition and abundance of native plants and animals; Modified vegetation condition; Potential for increased weed invasion in some situations; Reduced quality and quantity of soil organic matter; Changed potential for soil erosion and associated impacts on aquatic biodiversity. Rising watertable (following tree clearing) can lead to soil salinity, waterlogging and/or sodicity and subsequent decreased vegetation condition.	Clearing vegetation to extend the area of exotic pastures (to increase stocking rates) and to provide feed grains. Cost pressures driving the conversion of native pastures to exotic pastures or crops.	Legislation; Setting aside areas for conservation outcomes; Changed management practices to better utilise native systems (and hence not clear them); Revegetation; Incentive schemes.
Altered grazing regimes	Widespread and major significance.	Loss of understorey diversity, changes in abundance and composition of plant and animal species, expansion of grazing tolerant species and woody thickening. Lack of tree regeneration in agricultural landscapes.	Overstocking (by not matching stocking rates to carrying capacity); failure to account for total grazing pressure.	R&D programs e.g. SGS, LWW, Evergraze, Prograze, Monitoring programs e.g. Quickcheck; Changed management practices such as tactical and cell grazing. Fencing incentives, 'auction' programs such as Green Graze (a pilot). Setting aside areas for conservation outcomes.
Trampling and soil compaction	Widespread and significant.	Altered nutrient and hydrological cycles that can lead to altered composition and abundance of native species.	Overstocking (by not matching stocking rates to carrying capacity); failure to account for total grazing pressure.	Reduce stocking rates; keeping stock out of riparian zones at critical periods
Altered fire regimes	Widespread and significant.	Changed composition and abundance of native plants and animals; Modified vegetation condition; Potential for increased weed invasion in some situations; Reduced quality and quantity of soil organic matter; Changed potential for soil erosion and associated impacts on aquatic biodiversity;	Changes to aboriginal fire regimes following European settlement and agricultural expansion; burning pastures to produce 'green pick'; overgrazing by stock (reduced fuel load), cessation of burning in some remnants.	Changes to fire regimes to more closely reflect pre-European patterns.

Broad pressures on biodiversity	Extent and significance of pressures	State of biodiversity	Root cause	Examples of responses
Altered hydrology	Widespread and significant.	Changes in the timing and amount of environmental flows affects aquatic biodiversity and floodplain species; Changes to species composition and abundance at different distances from artificial watering points;	Water extraction for irrigation; building dams.	Increase water use efficiency of pastures and optimise water use from irrigation systems (e.g. 'precision irrigation'). Regulations of farm dams.
Environmental weeds	Localised.	Competition and stress to native vegetation; Changed fauna habitat (food, shelter, access to water, etc); Changed riparian zone affecting buffering capacity and waterway health; Toxic health risk to plants, animals; Altered fire regimes.	Use of species that become environmental weeds; farm machinery dispersing weed propagules.	Contain the spread of species; Codes of practice; weed hygiene practices
Pollution	Minimal for sheep-meat systems, as there are relatively few feedlots. Some pollution of streams through sedimentation from eroded stream banks. High nutrient soil levels in sheep camps.	Death of fish and invertebrates due to reduced dissolved oxygen and toxins released by some algae under bloom conditions; Changed vegetation (aquatic and terrestrial) composition and condition; Increased shellfish contamination; Damage to coral systems;	Potential leakiness (e.g. nutrients, soil) of extensive, intensive and high density enterprises.	Regulations; settling ponds; Changed management practices such as manure spreading. Codes of practice. Changes to stream access.
Climate change	Global impact; contribution of sheep-meat to emissions limited compared to overall livestock by livestock in Australia.	Changes to the composition, abundance and distribution of native plants and animals.	Methane production from ruminants; nitrogen production from feedlots (limited for sheep-meat systems); carbon dioxide emissions from transport and farm machinery.	Responses are covered in the companion MLA report on greenhouse emissions (Weidemann et al. 2009).

5.2 Red meat protein - Emerging industries

The two emerging red meat industries that currently have the largest markets are goats and kangaroos (Foster 2009), with goats being of greater economic value – depending on what statistics you use. While kangaroo is not defined as red meat by Meat & Livestock Australia, this report follows the definition used in NHMRC (2003) which includes kangaroo in its definition.

5.2.1 Goats

Background

The goat meat industry is largely based on wild, rangeland (otherwise known as feral) goats. While a few farmed goats are sold as meat, they are not covered in this report. It is estimated that rangeland goats are found over 2 million square kilometres (TAP 2008), so their impact is widespread. Population density varies depending on a number of factors, with higher densities in wetter areas. Up to a million goats are harvested a year (Forsyth and Parker 2004), so it is a large industry in terms of numbers. Most of the goats that are harvested are exported (Box 7), with a value of $55.1 million dollars for goat meat in 2007-2008.

Box 7: Facts and statistics about the Australian goat-meat industry for the 2007-08 fiscal year

- Australia is the largest goat meat exporter in the world, exporting A$55.1 million of goat meat (ABS). This is up 17% from A$46.9 million in 2002-03.
- The top five markets for Australian goat meat are: the US, Taiwan, the Caribbean, Canada and Japan (DAFF)

Source: MLA

Rangeland goats are listed as a key threatening process in the Environment Protection and Biodiversity Act 1999. As such, a Threat Abatement Plan (TAP) has been written to manage goats, and was most recently updated in 2008 (TAP 2008). Note that the term 'unmanaged goats' is used in the most recent TAP rather than feral goats, which presumably reflects the increasing use of goats as a resource. The background paper for the TAP states that there have been a relatively small number of studies on the direct impacts of goats because it is difficult to separate the impacts of sheep and kangaroos. Even given the limited number of studies, it is reported that unmanaged goats are a threat to 8 bird species, 3 mammals, 1 species of insect and 44 plant species, 2 of these being critically endangered.

<u>Altered grazing regimes</u>

Goats are browsers, but can change to grazing if needed. They are said to have 'catholic' tastes, but do show preferences for different plants, depending on what's on offer. Flexibility in what they'll eat is a key word. They are thought to have a major impact on native vegetation and associated fauna, although it is difficult to tease apart the impacts of the different herbivores (e.g. what contributes what to the total grazing pressure).

The 2004 fact sheet on the feral goat produced by the Australian Government states that "Feral goats have a major effect on native vegetation through soil damage and overgrazing of native herbs, grasses, shrubs and trees, which can cause erosion and prevent regeneration. They foul waterholes, and can introduce weeds through seeds carried in their dung. Particularly during droughts, feral goats can compete with native animals and domestic stock for food, water and shelter. For example, they may threaten some yellow-footed rock wallaby populations by competing for rock shelters and food, leaving the wallabies exposed to a greater risk of predation by foxes and wedge-tailed eagles".

Responses

The two main responses associated with feral goat management are the Threatened Action Plan for unmanaged goats (2008) (and associated activities) and the commercial harvesting of rangeland goats. This activity is promoted as having an impact on the damage caused to native systems by feral goats.

Monitoring

Monitoring techniques have been developed in the context of managing goats as a vertebrate pest (Mitchell and Balogh 2007).

Effectiveness of responses

Forsyth and Parker (2004) state that there are no data available to evaluate whether or not commercial harvesting of feral goats provides any sustainable benefits to the environment or native biodiversity. Harvesting reduces feral goat densities, but it has been insufficient to halt population increases over large areas where feral goat densities had been reduced by control or drought (e.g., the pastoral rangelands of Western Australia).The benefits of harvesting is likely to depend upon the densities to which goats are reduced, the habitat, and the values affected. The benefits are also likely to vary with rainfall and the numbers of other herbivores present (total grazing pressure). Commercial harvesting can also be used as a first step in any pest control strategy, although this can be compromised if the harvest becomes an end in itself.

5.2.2 Kangaroos

Background

In Australia, wild populations of kangaroos and wallabies (the latter only in Tasmania) are commercially harvested for human and pet food. In 2009, six species of kangaroos and wallabies were approved for harvest by the Commonwealth government (DEHWA 2009). There are estimated to be around 25 million kangaroos and wallabies in Australia, which are found in most ecosystems. The combined population size of the six species that are harvested has fluctuated between 15 and 50 million animals over the past 25 years, depending on seasonal conditions (DEHWA 2009). These estimates only include the harvested areas of Australia (which excludes the NT and Victoria (Kelly 2009)) and are considered to be very conservative. Red, eastern grey and western grey kangaroos are the most abundant species and make up approximately 90 per cent of the commercial harvest. They are mostly found in arid and semi-arid Australia, where they cover a considerable area.

Kangaroos are often seen as pests by land managers and as having a major impact on the forage available for sheep and cattle (Griggs 2002, Hacker and McLeod 2003). Olsen and Low (2006) believe that the discontinuation of damage mitigation as grounds for harvesting is in many ways a more honest approach to kangaroo management given that damage is difficult to monitor, predict and even to prove empirically to be an issue. Estimates of the impact of kangaroos have been based in part on calculating the DSE equivalents of kangaroos and multiplying that by population estimates. Recently this calculation has been revised (Olsen and Low 2006), suggesting that previous estimates were as much as three times too high. Confirmation of these figures is critical to understanding kangaroo grazing impacts and interactions.

The state of biodiversity

<u>Altered grazing regimes</u>

An increase in population of kangaroos and wallabies (the latter in Tasmania) to unsustainable levels has occurred in some situations due to changes in the environment caused by clearing of native vegetation and the introduction of sown pastures and crops. In some areas the decreased predation by dingoes and increased access to water has also increased kangaroo numbers (McAlpine et al. 1999). This has put pressure on native systems through over-grazing in certain cases, when kangaroo and wallaby numbers exceed their carrying capacity (Viggers and Hearn 2005, Tony Norton, personal communication).

Because kangaroos cannot be commercially harvested in National Parks their numbers can increase unsustainably in these areas. This impact has been measured in some instances. For example, in biodiversity monitoring conducted following a cull of kangaroos at Hattah-Kulkyne National Park in north-western Victoria, increased abundance of 20 rare or threatened plant species was recorded in culled areas compared with unculled areas (Sluiter et al 1997). Grazing pressure by large numbers of kangaroos suppressed the regeneration of woody species and resulted in reduced abundance of perennial taxa in the shrub and ground layers including the threatened Sand sida, Silky glycine, Upright adder's tongue, Hooked needlewood and the Prickly bottlebrush (DSE, 2003). Where grazing was excluded, native perennial grasses were found to be common and frequently formed a large proportion of the understorey (Sluiter et al., 1997). The remaining proportion of the understorey (up to 10%) is comprised largely of exotic flora.

Additional pressures

Overall, the additional pressures on biodiversity related to protein sources that are covered elsewhere in this review, such as altered fire regimes and pollution, are not relevant to kangaroos. Some concern has been raised about the potential decline of certain kangaroo species from over-harvesting (which falls under the heading ‘other pressures’), however, several publications report that the industry is sustainable based on monitoring data (Olsen and Low 2006, Ampt and Baumber 2006).

Industry and other responses

Under the EPBC Act, the Australian Government approves management plans for the harvest of six kangaroo and wallaby species in five states (Queensland, New South Wales, South Australia, Western Australia and Tasmania). Kangaroos are currently not commercially harvested in the NT because it was felt that the low density of kangaroos could not sustain a viable commercial industry (Neave 2008). The management plans include the requirement for an annual quota. Before approving any management plans that allow for the commercial harvest and export of kangaroo and wallaby products, the Australian Government carefully considers factors such as the biology, population size and trends and conservation status of the species. Management plans must demonstrate that they do not have a detrimental impact either on the harvested species or their ecosystems.

A strategic plan has been developed for the kangaroo industry for the period 2005-2010 (Kelly 2005). Resource sustainability, which focuses on the sustainability of kangaroo populations, is one of the six key issues identified for the industry. The other issues focus on the viability and practices of the kangaroo industry, and the regulatory and marketing environment it operates in. The low recruitment rate of new kangaroo harvesters has been identified as an issue by the industry (Kelly 2005). This has been addressed in a study by Cooney (2009) who has identified both opportunities and barriers for landholders interested in kangaroo harvesting.

The environmental impact of kangaroos is used by at least some meat producers in their marketing. For example, kangaroo meat sold in Safeway supermarkets in Victoria in May 2009 carried the label ‘Good for you, Good for the environment’. There have been ongoing calls for kangaroo meat to replace meat from domestic animals such as cattle and sheep because of the relatively benign impact of kangaroos on the environment (e.g. Grigg 2002, Wilson and Edwards 2008). Research programs such as FATE (Future of Threatened Ecosystems) have been examining ways to create incentives for conservation by mechanisms such as generating commercial returns for landholders through the sustainable harvesting of kangaroos (Ampt and Baumber 2006).

Monitoring

Each state monitors the population numbers of the commercially harvested species and sets sustainable quotas. In the Northern Territory, where commercial harvesting does not occur, monitoring of *Macropus rufus* numbers has been periodically carried out by the PWSNT in response to concerns raised by some pastoralists over perceived high *M. rufus* densities (Neave 2008). M. rufus has also been routinely counted as part of other aerial survey programs such as vertebrate pest animal surveys.

Effectiveness of responses

Olsen and Low (2006) report that the culling of kangaroos is sustainable, based on monitoring information collected over a number of decades. Ampt and Baumber (2006) outline some of the limitations they believe are imposed by State kangaroo management plans on the viability of kangaroo harvesting and the involvement of landholders in conservation related activities.

Perceptions

Hacker and McLeod (2003) listed a number of 'players' associated with kangaroo harvesting and management, who have a range of perceptions of relevance to this report. These are used for a basis for the descriptions presented in Box 8.

An important category not covered in Box 8 is consumers. Ampt and Owen (2008), in a study of consumer perceptions of kangaroo meat, found that there was potential for growth in the market if the industry communicated a consistent message that will satisfy consumers, manufacturers and retailers as to the controls in place to ensure that kangaroos are harvested in a sustainable, humane way under strict quality control. While consumers were largely unaware that kangaroos are wild harvested, knowledge that they are was not found to be a significant barrier to acceptance. They concluded that in terms of its profile, the industry needed to stop justifying the harvest (principally to landholders) on the basis of kangaroos being pests, as culling for this purpose often attracts strong emotional responses from the community. The status of kangaroo as a national icon was found to be no longer a significant barrier to general consumer acceptance of kangaroo meat.

Media perception of kangaroos is also likely to influence consumers. An article May 11th, 2009 issue of Time Magazine in the 'Global Business' section gives some indication of the way kangaroo meat is being reported. The title of the article was "Skippy for Supper", with a by-line that said "Kangaroo meat is jumping off store shelves as Australians go for a greener, cheaper protein source." A comparison of the fat, cholesterol and greenhouse gas emissions of kangaroos compared to beef is provided, and the statement is made that kangaroos do less damage to Australian soil than millions of hard-hoofed cows and sheep. Commentary such as this is likely to have an impact on the choices made by both household consumers and meat wholesalers and manufacturers.

Box 8: Perceptions of kangaroos amongst a range of groups

Pastoralists in the sheep rangelands: Often see kangaroos as competitors with livestock for forage, as an uncontrolled herbivore restricting their capacity to manage land in a sustainable way, or as a cause of physical damage to fences and yards.

Kangaroo harvesters and processors: Kangaroos are seen as a valuable industry with the potential to access increasingly lucrative markets and benefit from the ‘clean and green’ image of products harvested from the wild.

Tourist operators: Can view them as a resource but one whose values lie in non-consumptive uses.

Conservationists: Some (but not all) may see kangaroos as a challenge to achieve ecologically sustainable development and may not encourage eating Australia’s national icon (e.g. groups that rescue native animals).

Animal rights groups and others: Because of their status as wildlife and protected fauna, concern about whether culling practices are humane, and in some cases the absolute rights of animals to exist, these groups can see any form of commercial utilisation of kangaroos as unacceptable.

Ecologists: Many see kangaroos as a viable source of meat that has less environmental impact than beef and cattle (both in relation to direct grazing, trampling impacts and greenhouse gas emissions). They also note that when populations build up to unsustainable levels, kangaroos can cause damage to natural systems.

Source: The first five points are based on Hacker and McLeod (2003), the last point on research undertaken for this review.

5.3 White meat protein

5.3.1 Pork

Background

The Australian pork industry comprises approximately 3,000 pig farms (APL 2003), representing less than one quarter of the farms that existed twenty years earlier. ABARE estimates the number of pig enterprises with an estimated value of production of >$22,500 at about 830 (ABARE 2007). These farms are distributed throughout the grain belt, encompassing all States, positioning them close to feed supplies and major transport infrastructure. Despite the drastic fall in farm numbers, pig numbers have remained at around 2.5 million, while average sow numbers per farm have more than quadrupled (ABARE 2005). This trend is consistent with piggeries around the world (Chynoweth et al. 1998).

In addition to the domesticated pig industry, a small amount of pork is derived (and also exported) from wild (feral) capture. There are approximately 20 million feral pigs in Australia (Foster 2009). Feral pigs create substantial environmental damage and are listed as a key threatening process in the EPBC Act 1999. As the hunting of feral pigs is not a highly structured industry primarily directed towards the production of protein, and because it makes up such a small proportion of pork produced and is likely to have a positive impact on the environment, wild pork is not included in the analyses of this report.

Australian per capita pork consumption in 2006 was 22.2 kilograms, a significant increase over the 1969 level of 6.7 kilograms per capita (DPI 2008). In contrast to the demand for other agricultural products, up to a quarter of pork-based products consumed by Australians is imported (DAFF 2005). This has implications for the biodiversity footprint (Wackernagel 1994) that Australian consumers leave across other parts of the globe.

The state of biodiversity

Very little information exists on the impact of pork production on Australian biodiversity. The paucity of research in this area has been observed elsewhere, including in the United Kingdom (ADAS 2008). As a consequence, the issue is not regarded as significant in Australia and is not reflected explicitly in industry environmental strategies (i.e. Figure 5).

Most Australian pork production involves intensive indoor systems due to Australia’s climatic extremes and variability (Brown and Munckton 2008). In these systems control of environmental impacts through managing point source inputs and outputs can be easier than in outdoor systems (Stevens et al. 2007). However, effluent emissions and disposal and odour impact, both commonly associated with intensive systems, remain major environmental issues for the industry (DAFF 2005). Through their waste, all pigs contribute to the solid and nutrient outputs of piggeries. Table 11 provides estimates for the typical quantities of solids and nutrients in the manure and waste feed of different classes of pig in conventional houses.

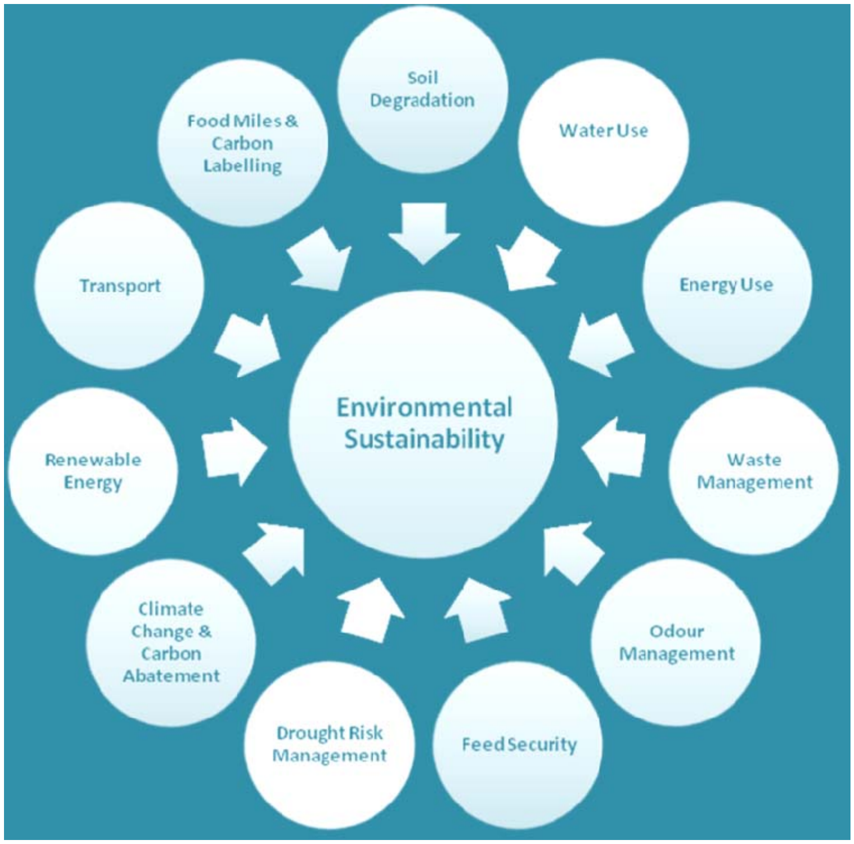

Figure 5: Current and future key environmental sustainability challenges for the Australian pork industry (Source: APL 2008)

Table 11: Predicted solids and nutrient output for each class of pig (Source: APL 2004)

Pig class	Output (kg/yr)					
	Total solids	Volatile solids	Ash	Nitrogen	Phosphorus	Potassium
Gilts	197	162	35	12.0	4.6	4.0
Boars	186	151	35	15.0	5.3	3.8
Gestating sows	186	151	35	13.9	5.2	3.7
Lactating sows	310	215	95	27.1	8.8	9.8
Suckers	11.2	11.0	0.2	2.3	0.4	0.1
Sow and litter	422	325	97	50	13	11
Weaner pigs	54	47	7	3.9	1.1	1.1
Grower pigs	108	90	18	9.2	3.0	2.4
Finisher pigs	181	149	32	15.8	5.1	4.1

Effluent (pig slurry) escaping to waterways or leaching into groundwater can carry with it high available N and P content (ADAS 2008) (Figure 6). Research evidence in the United Kingdom has shown nitrate leaching from pig systems can represent 13% of the total N applied in pig slurry, compared to 15% of broiler litter but only 1% of cattle FYM (with its lower available N content) (ADAS 2004).

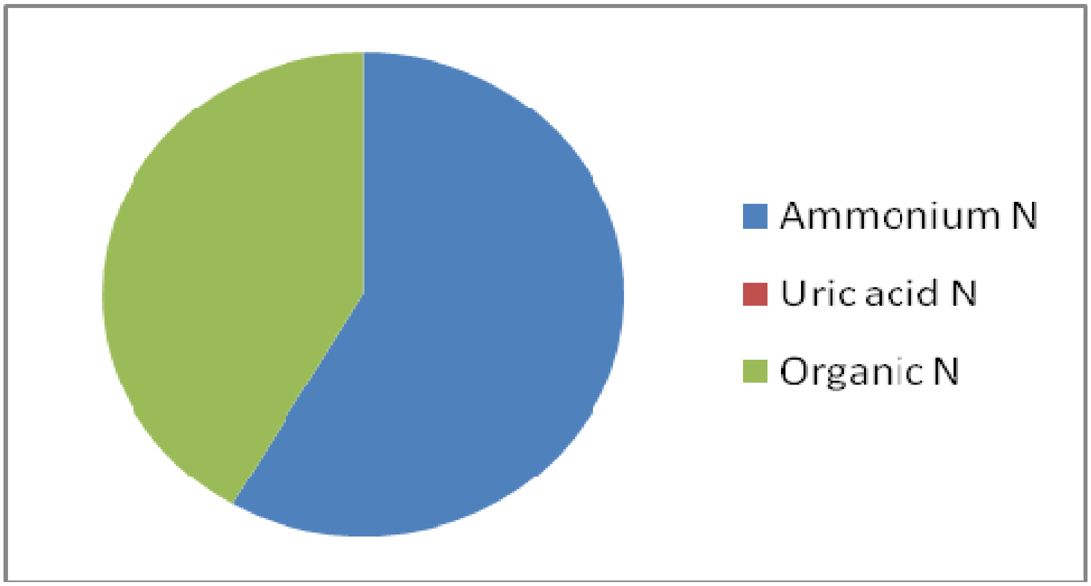

Figure 6: Typical pig slurry content (Source: ADAS 2008)

Heavy metals, including copper and zinc can also be found in effluent, particularly where these are components of feed supplements (Dourmad and Jondreville 2007; ADAS 2002). The impact of Cu and Zn on biodiversity has not been explored in the Australian context, however, in the Netherlands Mulder and Breure (2006) found that these heavy metals affected 5% of the 56 plants species which provide food and habitat to *Microlepidoptera* (leaf-miners and pollinating adult butterflies) in a nature reserve over a period of five years.

Intensive piggeries carry a higher risk of rapid disease spread than outdoor piggeries (FAWC 1996), and so antibiotics play an important role in animal health management (Stevens et al 2008). Pathogens potentially present in piggery effluent include bacteria campylobacter, salmonella, and erysipelothrix (APL, 2004). The movement of antibiotics through the environment has had limited study, particularly in the agricultural context. Boxall et al. (2008) have shown the impact of antibiotics on earthworms and soil microbes, with microbes exhibiting some sensitivity. This work did not suggest what levels of concentration are needed in field conditions to have an impact on biodiversity.

High levels of ammonia can be emitted from piggeries and from piggery waste usage (Misselbrook et al. 2004). If high enough, concentrations of ammonia are known to damage lichens, mosses and heather where these are found close to major piggeries (ADAS 2008). In waterways, degraded conditions associated with high ammonia have caused major kills of fresh fish of all species in the affected areas (Burkeholder et al. 1997). Similar impact assessments have not been undertaken in Australia. Aspects of the environmental fate of ammonia are discussed in Box 9.

Box 9: Environmental fate of ammonia

Ammonia is released to the atmosphere by natural processes such as the decay of organic matter and animal excreta, or by volcanic eruptions. It can also be released to the atmosphere by anthropogenic activities such as fertilizer use; spillage or leakage from storage or production facilities; or loss from waste water effluents. The average global ammonia concentration in the atmosphere ranges from 0.3 to 6 ppb, with concentrations sometimes higher in the vicinity of agricultural or industrial areas. For example, near industrial sources or manure heaps in Germany, ammonia concentrations ranged from 10.3 to 89 ppb. Concentrations may be orders of magnitude higher near some types of livestock areas, such as pigpens, where local atmospheric concentrations have been reported to be as high as 47 ppm.

Elevated concentrations of ammonia in water are usually due to effluent discharges from sewage treatment plants or industrial processes, or runoff from fertilized fields or livestock areas. Ammonia concentrations can therefore vary widely in aquatic environments, with concentrations being lower in bodies of water that are unimpacted by residential, industrial, or farming effluents, compared to those that are impacted (where concentrations can be orders of magnitude higher). In unimpacted waterways, ammonia concentrations have been reported to range from 8.5 to 43 ppb, whereas in impacted waterways, concentrations as high as 16 ppm have been reported.

Because ammonia, as ammonium ion, is the nutrient of choice for many plants (Kramer 2000; Rosswall 1981), uptake of soil ammonia by living plants is an important fate process. The rate of uptake by plants varies with the growing season. At normal environmental concentrations, ammonia does not have a very long residence time in soil. It is either rapidly taken up by plants, bioconverted by the microbial population, or volatilized to the atmosphere. Because of these processes, and because ammonia generally exists in soils as NH_4^+ (which binds to soil particles), ammonia does not leach readily through soil; thus, it is rarely found as a contaminant of groundwater (Barry et al. 1993). In soil, ammonia that results from the application of fertilizers is usually found in the top 10 inches of the soil (Beauchamp et al. 1982).

However, nitrate derived from ammonia may leach to groundwater.

Source: Direct extraction from U.S. Department of Health and Human Services (2004)

U.S. studies (i.e. Burkholder et al. 2007; Webb and Archer 1994) show that animal wastes are extremely rich in organic and biochemical oxygen-demanding materials (BOD) compared to human waste. For example, while treated human sewerage contains 20-60 mg BOD/L and raw sewerage contains around 300-400 BOD/L, swine waste slurry carries up to 20,000-30,000 BOD/L. At these levels, nutrient losses into receiving waters can exceed levels known to support noxious algal blooms (Mallin 2000).

Disposal of piggery effluent into waterways has been implicated as a possible contributing cause of various forms of fish poisoning (Ryan 1998). Dinoflagellates in water can be poisonous to fish and have been correlated with high nutrient levels (Lehane 1999), which have in turn been attributed to sewage and livestock waste inputs (Weaver 1993). In small amounts, ammonia can cause stress and gill damage, and fish exposed to low levels over time are more susceptible to bacterial infections and have poor growth (Francis-Floyd and Watson 1996). In higher concentrations ammonia is fatal to many life forms (ibid).

As with other intensive industries dependent on grain and other feed, the ecological footprint of the pork industry extends to include a proportion of the impacts on biodiversity of the feed producing industries. While most feed used in Australian piggeries is domestically produced, and therefore retaining most of its footprint in Australia, the 25% consumption of imported pork means that some of the footprint extends across the globe, not only to areas where the pork was produced, but also to those areas where the feed was produced. Danish piggeries, for example, which make up 35% of pork imports to Australia (APL 2009), import up to 80% of their feed (Johansson 2005), with more than half of this coming from Brazil and Argentina (Dyball 2007) where the impact of feed grain production on biodiversity is considerable (FAO 2006).

A summary of the potential impacts of the pork industry is provided in Table 12.

Table 12: Pressure – state – response matrix for the pork industry

Broad pressures on biodiversity	Extent and significance of pressures	State of biodiversity	Root cause	Responses
Vegetation clearance and modification	Minor clearing has occurred for placement of intensive piggeries. Free range piggeries tend to have been established on pre-cleared land. The reliance of the industry on grain feed has an indirect relationship to land clearing, although this is equivalent to less than 1% of land cleared for crops.	The pork industry has had negligible direct impact on biodiversity as a result of vegetation clearance. The reliance on feed supply means that it has an indirect impact through cropping practices.	Clearing vegetation to establish intensive piggeries or free range piggeries.	Compliance with State vegetation legislation which limits vegetation clearing.
Altered fire regimes	Not applicable	Not applicable	Not applicable	Not applicable
Altered grazing regimes	Minor impact due to the small number of outdoor piggeries.	Minor loss of understorey diversity, changes in abundance and composition of plant and animal species, expansion of grazing tolerant species and woody thickening.	Potential overstocking (by not matching stocking rates to carrying capacity); failure to account for total grazing pressure.	Outdoor rotational strategies incorporated into the Industry *Environmental Guidelines for Piggeries*.
Altered hydrology	While a significant user of water, piggeries amount to only a minor portion of agricultural water use.	Minor potential for changes in the timing and amount of environmental flows affecting aquatic biodiversity and floodplain species; Rising watertable (following tree clearing) can lead to soil salinity, waterlogging and/or sodicity and subsequent decreased vegetation condition;	Water extraction for feedlots, including water for pig consumption, cooling, cleaning and waste management (effluent shandying) practices.	Implementation of best management practices as coded by the industry; *Environmental Guidelines for Piggeries.*
Trampling and soil compaction	Minor potential for compaction of soils in intensive and extensive outdoor systems.	Minor potential for altered nutrient and hydrological cycles that can lead to altered composition and abundance of native species.	Excessive grazing pressure and lack of adequate paddock rotations in outdoor systems.	Implementation of best management practices as coded by the industry (paddock design; rotations, vegetation monitoring); *Environmental Guidelines for Piggeries.*

Broad pressures on biodiversity	Extent and significance of pressures	State of biodiversity	Root cause	Responses
Environmental weeds	Not applicable	Not applicable	Not applicable	Not applicable
Pollution: aquatic	Potential for nutrient (N and P) and heavy metal (Cu and Zn) leakage into groundwater and runoff into surface waters. This can be exacerbated where Cu and Zn are included as supplements in feed.	Potential for death of fish and invertebrates due to reduced dissolved oxygen and toxins released by some algae under bloom conditions; Changed aquatic vegetation composition and condition; Increased shellfish contamination.	Poor housing condition in intensive piggeries, and overgrazing in extensive operations, combined with a lack of, or poor, outflow monitoring in either system.	Compliance with State environmental regulations. Implementation of best management practices as coded by the industry (including site selection, buffering, waste management); *Environmental Guidelines for Piggeries.*
Pollution: terrestrial	Potential for contamination and acidification of soils close to housing.	Potential for loss of soil biota and invertebrates due to toxicity. Changed vegetation composition and condition.	Excess nutrients and heavy metals in feed supplements; inappropriate waste management practices.	Compliance with State environmental regulations. Implementation of best management practices as coded by the industry (including site selection, buffering, waste management); *Environmental Guidelines for Piggeries.*
Pollution: atmospheric	High emissions of ammonia into the atmosphere.	Direct toxic effect on trees. Changed vegetation composition and condition directly from ammonia emissions and indirectly from longer-term soil acidification.	Ammonia volatilisation from piggery sheds and from waste collection ponds.	Implementation of best management practices as coded by the industry (slurry removal to covered stores, buffering, soil pH maintenance through liming; *Environmental Guidelines for Piggeries.*
Disease and pathogen spread	Risk of pathogen spread through bacteria (possible, including campylobacter, salmonella, erysipelothrix and E. coli) and viruses (minor) from pigs and piggery effluent.	Biosecurity issues, including potential loss of pig herds/breeds; cross species infection.	Poor housing condition and monitoring in intensive piggeries.	Implementation of best management practices as coded by the industry (ventilation, cleaning, effluent disposal); *Environmental Guidelines for Piggeries.*

Broad pressures on biodiversity	Extent and significance of pressures	State of biodiversity	Root cause	Responses
Climate change	Global.	Changes to the composition, abundance and distribution of native plants and animals.	Methane production from pigs; nitrogen production from feedlots; carbon dioxide emissions from transport and feedlot machinery.	R&D investment on methane.
Direct biodiversity loss	Reduction of breeds.	Loss of genetic diversity at critical levels required to maintain species.	Specialisation in fewer, higher yielding breeds	

Industry and other responses

The primary representative body for the pork industry, Australian Pork Limited (APL), has recognised the need to incorporate responses to the range of environmental issues confronted by pig farmers into a single best management practice manual, National Environmental Guidelines for Piggeries (APL 2004). The primary focus of this document is effluent and odour management, through which a broad range of environmental and community amenity outcomes can be achieved. Preparing environmental plans and carrying out environmental risk assessments are key recommendations of the guidelines.

Explicit mention of biodiversity in the 177 page document is made only once, however the authors acknowledge the benefit to biodiversity of a broad range of management practices recommended. For example, the guidelines suggest that the placement of piggeries should avoid the clearing of native vegetation. Pork producers are reminded of their obligations to comply with vegetation management legislation, as well as other legislation covering effluent disposal. Indeed, operators of piggeries must hold a registration certificate under State environmental protection legislation. Recommendations for outdoor piggeries in the guidelines include the need to maintain good levels of vegetation (pasture) cover and minimal compaction levels, both through good farm layout and regular rotations. A minimum of 40% groundcover is recommended in Queensland (QDPI 2005). As with other industries covered in this report, maintenance of groundcover is a key biodiversity management tool (Kirkpatrick et al. 2005; Kemp et al. 2003).

The APL has also commenced the preparation of an environmental strategy, represented in Figure 5. Biodiversity does not receive an explicit mention in the background materials released about the strategy, although as with the Guidelines, components of the strategy would have beneficial biodiversity outcomes, including improved waste management.

Government legislation significantly influences the activities of piggeries. Pig farming, whether indoor or outdoor, is prescribed in State environmental protection legislation as a potentially harmful activity. Each State has its own codes of practice and specific guidelines for the establishment and management of piggeries. Advisory services, including advice on environmental management, are provided in all States, while research is carried out in most. A considerable proportion of industry research is funded through APL. A Pork Cooperative Research Centre acts to facilitate collaborative research, primarily aimed at production and competitiveness (PCRC 2008).

With odour being a significant issue for the industry, the placement of piggeries can often involve extensive odour buffers. This offers the opportunity of piggeries to maintain and enhance surrounding native vegetation (APL 2007). Windbreak buffers upwind of piggeries have been shown to reduce transport of odour constituents (Sauer 2008). The biodiversity benefits of windbreaks have also been demonstrated in Australia (Burke 1998), although not in the context of piggeries.

Monitoring

Following the release of its National Environmental Guidelines, APL established Envirocheck, a voluntary on-farm environmental assessment process available to all pig farm operators (APL 2006). The project was developed using government funds through the Australian Government’s Pathways to EMS program (DAFF 2009a). The audits are carried out by independent environmental expert nominated by APL, with measurements made against criteria set out in the guidelines. No estimates are publicly availability about how many operators have participated in this program.

The national guidelines and State codes of practice all recommend farm operators establish in-situ monitoring systems, particularly in respect to providing early detection of surface runoff and groundwater leaching of effluent. All piggeries are subject to Environmental Protection Authority (EPA) compliance audits.

As previously suggested, all piggeries are subject to State licensing and monitoring. In NSW, a licensing system based on a Load Calculation Protocol was introduced to avoid the potential for piggeries to meet concentration targets by diluting effluent without reducing the overall quantity of pollution (DECC 2008). Fees are calculated by project pollution emissions against a schedule of pollutants. Such schemes make it clear not only about which pollutants to monitor to avoid potential discharge fines, but which to reduce in order to lessen the cost of operation (in this case from reduced licensing fees).

Effectiveness of responses

In an audit of 27 piggeries in New South Wales in 2005 (DECC 2005), non-compliances were found to exist across all categories assessed: effluent management – waste water collection systems (6 non-compliances); waste water management ponds (6 non-compliances); effluent utilisation area management (12 non-compliances); preventing pollution of waters/groundwater (3 non-compliances); containment of point-source pollutants (7 non-compliances); carcass disposal (4 non-compliances); organic waste from deep litter piggeries (2 non conformances) and from conventional piggeries (3 non-conformances); and odour control (7 non-conformances). With respect to monitoring compliance, 9 were found to be non-conforming for effluent volume and pollutant concentration monitoring, 5 for irrigated soil monitoring, 3 for groundwater quality monitoring, 2 for weather monitoring and 2 for ambient water quality monitoring.

This extensive list of non-conformances from just one audit in one State does not demonstrate an industry in environmental crisis but rather reflects the extensive nature of the checks in the industry that act as the basis for continuous improvement. No significant environmental impacts were noted from the audit. That said, audits such as this relate more to pressures that might influence the status of biodiversity rather than the status itself. The impact of the non-conformances listed above on biodiversity, for example, was certainly not included in the audit methodology.

Public Perceptions

Australian Pork Limited acknowledges that piggeries are often perceived negatively by the community (APL 2004). In a survey of three peri-urban communities in Australia, respondents presented with scenarios for major development on land adjoining their own expressed strongest opposition to an airport, then a quarry, factory and a pig or poultry farm (Kelleher 1998). Negative perceptions of piggeries commonly revolve around odour (Hudson et al. 2007), animal welfare (Barnett et al. 2001) and effluent pollution (Redding 2001). As with the case of intensive poultry, animal welfare aspects of piggeries have long elicited the most emotive response from consumer and social interest groups (Kilgour 1978). This response is often manifested in violent protest (Eastwood 1995). Lassen et al. (2006) note that there is a systematic disagreement between lay and expert views of what good animal life is, while a French study on consumer perceptions of pork (Dransfield 2004) found that while consumers strongly preferred the notion of outdoor organically produced pork, they were only willing to pay between 3 and 10% extra for such a product, well below the additional 30-35% production cost.

A link between animal welfare and biodiversity is the reliance on fewer animal breeds in intensive production systems, which has seen 140 breeds of pig become extinct and a further 133 of the remaining 599 breeds at risk of extinction (FAO 2007). The efficacy of using breed extinctions as a surrogate of biodiversity loss should be balanced with consideration that most breeds appear to originate from 16 sub-species of wild boar during a process of domestication that began 9,000 years ago (Larson et al. 2005).

5.3.2 Chicken meat

Background

The Australian chicken meat industry is dominated by large vertically-integrated companies that own most aspects of the production process from breeding farms and feed mills through to growing farms and processing factories (ACMF 2009a). Three such companies dominate 80% of production, while a further 7 companies account for the remainder. These companies in turn contract 80% of production to 800 chicken meat farmers, while producing 20% on company farms. The vertical integration of the Australian industry is common throughout the developed world (Bell et al. 2002).

As with most meat consumption, Australian per capita chicken meat consumption has risen drastically over the past thirty years, to an average of 38 kg in 2008 (ABARE 2009), making it the most commonly consumed meat in Australia. Consumption of duck and turkey adds an additional 1.9 kg of consumption to the wider poultry category (ACMF 2009a). Production of chicken meat in Australia increased from 91,000 tonnes (75 million birds) in 1968 to a 2008 level of 812,000 tonnes (466 million birds) (ACMF 2009a). Only 3% of Australia's chicken meat is exported, while a small amount of processed chicken meat is imported from USA, Thailand and Denmark. Both live chicken and raw chicken meat is not allowed into Australia, although this policy is under review (DAFF 2009b). To this extent, the ecological footprint of the Australian chicken meat industry is largely confined to home.

The state of biodiversity

As with pork, very little information exists on the impact of poultry production on Australian biodiversity, and again the paucity of research in this area has been observed elsewhere (ADAS 2008). The FAO view the industry in a positive light compared to other protein production competitors:

> *Poultry production has been the system most subject to structural change. In OECD countries, production is almost entirely industrial, while in developing countries it is already predominantly industrial. Although industrial poultry production is entirely based on feed grains and other high value feed material, it is the most efficient form of production of food of animal production (with the exception of some forms of aquaculture), and has the lowest requirements per unit of output. Poultry manure is of high nutrient content, relatively easy to manage and is widely used as a fertilizer and sometimes feed. Other than for feed crop production, the environmental damage, though sometimes locally important, is of a much lower scale than for other species.* (Gerber and Steinfeld 2008)

This finding is consistent with ecological footprint studies undertaken of different food industries. For example, an ecological footprint study undertaken for the city of Canberra (CSIRO 1998) showed poultry products (meat and eggs) to have a lower footprint than dairy products and significantly lower than red meat (see Table 12). More recently, Foran et al. (2005) undertook a triple bottom line of the Australian economy that analysed social, financial and environmental indicators for 135 economic sectors. While the authors used a different reporting approach to Table 13, poultry and eggs still had a much lower impact in terms of land disturbance, greenhouse gas emissions and water use than beef and dairy cattle/milk production.

Table 13: Ecological footprint of certain protein products for Canberra, Australia

Food Type	Ecological footprint Canberra (ha)	Ecological footprint per person (ha)
Meat and Meat Products	228,900	0.7630
Dairy Products	242,280	0.0251
Poultry and Eggs	5,850	0.0195
Source (cf CSIRO 1978)		

Chicken meat in Australia is largely produced in intensive indoor systems with over 95% of chickens raised this way (ACMF 2009a). The remaining production comes from free range chicken farms, half of which are certified organic. Free Range Egg and Poultry Australia Ltd is the organisation responsible for the certification of free range farms. Organic farms must ensure that all feed is predominantly sourced from certified organic ingredients and they must not use routine vaccinations unless specified by law. In many ways the production profile of chicken meat is similar to that for pork, and hence the two industries have common environmental issues to confront (ADAS 2008). The key environmental issues for the Australian chicken meat industry have been identified as effluent disposal and nutrient loss; discharge of pathogens; and odour emissions from chicken factories (RIRDC 2004).

Australian chicken meat sheds use litter to absorb manure and reduce off-site discharges (Qld EPA 2001). Analyses have found this litter to contain traces of nitrogen, phosphorus and potassium (Qld EPA 2001). Similar studies in the UK suggest that litter also includes the heavy metals zinc and copper (Nicholson et al. 2003). No studies have been undertaken to quantify the impact of these or other components of poultry waste on biodiversity. From a biodiversity perspective, the issues of disease and pathogens are likely to be more pertinent.

While the addition of hormones, mainly oestrogen, to poultry feed occurs in some parts of the world, it has been banned in Australia (ACMF 2009b). Endogenous oestrogen has been known to be transported from poultry farms in some parts of the world, and can act as an endocrine disruptor affecting fish reproduction (Shore et al. 1988). This phenomenon has not been observed in Australia.

Avian influenza (HPA1) has recently spurred some studies on the links between this disease and the potential for poultry farms to spread it. Over 250,000,000 birds have been estimated to have been killed or slaughtered as a result of this disease since 2003 (FAO 2007). In the Australian context, East et al. (2007) suggest that HPA1 is most likely to enter the country via migratory shorebirds transferring the disease to native waterfowl in shared ecosystems. Modelling the location of key migratory patterns and the proximity of poultry farms to these ecosystems, the researchers found that all Australian farms have a low risk exposure to HPA1 and are therefore not likely to act as transmittal points.

A summary of the potential impacts of the chicken meat industry is provided in Table 14.

Industry and other responses

Unlike the pork industry, the chicken meat industry does not have a single environmental management manual. Instead, advice to chicken farmers is made available through a wide range of sources, including State research and advisory services, the Poultry Cooperative Research Centre, private advisers and web-based information sources, including the Poultry

Hub (Poultry CRC 2009). All chicken farm operators are also subject to compulsory State codes of practice.

The primary representative body for the chicken meat industry, Australian Chicken Meat Federation (ACMF), includes environmental information on its website (ACMF 2009b); however, much of its content is reliant on overseas studies which suggest the industry's environmental superiority over its competitors (i.e. Williams et al. 2006). An environmental management system was developed for the industry in 2002 (McGahan and Tucker 2003), and updated as part of the Pathways to EMS initiative discussed previously in respect to pork (FSA and ACGC 2007). The pathways report places biodiversity and other catchment based issues in context:

> *While the issue of the potential for chicken farms to impact on the broader catchment has been discussed at the training sessions there is currently no clear strategy to engage other than in South East Queensland where growers have been involved in projects relating to tree plantings for biodiversity (which also contributes to minimising off-site impacts) and water quality programs investigating off-site impacts for agriculture in general.* (FSA and ACGC 2007: 35)

Table 14: Pressure – state – response matrix for the poultry industry (chicken meat and eggs)

Broad pressures on biodiversity	Extent and significance of pressures	State of biodiversity	Root cause	Responses
Vegetation clearance and modification	Minor clearing has occurred for placement of intensive poultry farms. Free range operations tend to have been established on pre-cleared land. The reliance of the industry on grain feed has an indirect relationship to land clearing, although this is equivalent to less than 1% of land cleared for crops.	The poultry industry has had negligible direct impact on biodiversity as a result of vegetation clearance. The reliance on feed supply means that it has an indirect impact through cropping practices.	Clearing vegetation to establish intensive poultry farms or free range farms.	Compliance with State vegetation legislation which limits vegetation clearing.
Altered fire regimes	Not applicable	Not applicable	Not applicable	Not applicable
Altered grazing regimes	Minor impact due to the small number of free range poultry farms.	Minor loss of understorey diversity, changes in abundance and composition of plant and animal species (Faried et al. 1998).	Potential overstocking (by not matching stocking rates to carrying capacity).	Rotations and stocking rate management. Adoption of State extension best practice guidelines.
Altered hydrology	A significant user of water (NSW Agriculture 2004), poultry farms amount to only a minor portion of agricultural water use.	Minor potential for changes in the timing and amount of environmental flows affecting aquatic biodiversity and floodplain species; Rising watertable (following tree clearing) can lead to soil salinity, waterlogging and/or sodicity and subsequent decreased vegetation condition.	Water extraction for poultry farms, including water for animal consumption, cooling, cleaning and waste management (effluent shandying) practices.	Adoption of State extension best practice guidelines. Irrigation scheduling to manage runoff.
Trampling and soil compaction	Minor potential for compaction of soils. Soil erosion and runoff in over-grazed free-range is a more likely issue.	Minor potential for altered nutrient and hydrological cycles that can lead to altered composition and abundance of native species.	Excessive grazing pressure and lack of adequate rotations in free-range systems.	Adoption of State extension best practice guidelines.
Environmental weeds	Not applicable	Not applicable	Not applicable	Not applicable

[illegible]

Broad pressures on biodiversity	Extent and significance of pressures	State of biodiversity	Root cause	Responses
Pollution: aquatic	Potential for nutrient (N and P) and heavy metal (Cu and Zn) leakage into groundwater and runoff into surface waters. This can be exacerbated where Cu and Zn are included as supplements in feed.	Potential for death of fish and invertebrates due to reduced dissolved oxygen and toxins released by some algae under bloom conditions; Changed aquatic vegetation composition and condition; Increased shellfish contamination.	Poor housing condition in intensive poultry farms, and overgrazing in free range operations, combined with a lack of, or poor, outflow monitoring in either system.	Compliance with State environmental regulations. Adoption of State extension best practice guidelines.
Pollution: terrestrial	Potential for contamination and acidification of soils close to housing.	Potential for loss of soil biota and invertebrates due to toxicity. Changed vegetation composition and condition.	Excess nutrients and heavy metals in feed supplements; inappropriate waste management practices.	Compliance with State environmental regulations. Adoption of State extension best practice guidelines.
Pollution: atmospheric	High emissions of ammonia into the atmosphere.	Direct toxic effect on trees. Changed vegetation composition and condition directly from ammonia emissions and indirectly from longer-term soil acidification.	Ammonia volatilisation from poultry farms and from waste collection ponds.	Adoption of State extension best practice guidelines.
Disease and pathogen spread	Risk of pathogen spread through bacteria.	Biosecurity issues, including potential loss of breeds; cross species infection.	Poor housing condition and monitoring in intensive chicken farms.	Many chicken meat companies have their own testing laboratories. Adoption of State extension best practice guidelines.
Climate change	Global.	Changes to the composition, abundance and distribution of native plants and animals.	Methane production from poultry; nitrogen production from feedlots; carbon dioxide emissions from transport and feedlot machinery.	R&D investment on methane.
Direct biodiversity loss	Reduction of breeds.	Loss of genetic diversity at critical levels required to maintain species.	Specialisation in fewer, higher yielding breeds.	

Although this quote suggests little attention is paid to the externalities of industry operations, the reality is that on-site management practices do act to minimise off-site impacts. These practices include the management of shed litter, provision of adequate shed ventilation, controlling shed temperature and humidity, manipulating diet, utilising odour neutralisation agents and exhaust filters, and maintaining windbreaks (Briggs 2004; McGahan et al. 2002). Other studies, such as Formosa and Singh (2002) show that native bushland buffers the effects of ammonia dispersion from chicken farms, while planted buffer strips can act to trap particulate matter, depending on the species planted (Adrizi et al. 2008; Bottcher et al. 2000).

Government legislation is as prominent in the activities of chicken farms as it is piggeries. Prescribed in State environmental protection legislation as a potentially harmful activity, each State has its own codes of practice for the operation of chicken farms. As with pig farming and many other forms of agriculture, a multitude of legislation covers various aspects of chicken farming. In New South Wales, for example, over 20 separate Acts of Parliament pertain to the operations of a chicken farm (NSW Ag 2004) (see Box 10).

Research is supported by both the industry, through levies, and governments and universities. Biodiversity does not feature as a priority in research activities.

Monitoring

The chicken meat industry encourages ongoing monitoring through its EMS training programs, with government and private advisory services alike offering to provide independent environmental audits (i.e. FSA 2009). As previously discussed, the Free Range Egg and Poultry Association (FREPA) provides accreditation to free range chicken farms, which are subsequently audited on a regular basis by independent auditors assigned by FREPA to ensure that its minimum standards are met (FREPA 2009). These standards are publicly available on FREPA's website. Many of the 20 or so pieces of government legislation require that chicken meat operation be available for audit as required under the terms of the legislation. While all states have mandatory licensing arrangements, only Victoria has a mandatory code of practice to which chicken meat farmers must comply (Cowley 2009).

Hormonal growth promotants (stilbenes) are tested for in the Commonwealth Government's National Residue Survey program. No residues had been detected to 2005 (FSANZ 2005).

Effectiveness of responses

Minimal data is publicly available on the environmental achievements of the chicken meat industry.

Public Perceptions

Consumers exposed to mass media coverage of negative fresh food can be greatly influenced in their consumption behaviour (Verbeke 2000). As the most commonly eaten meat now in Australia, the rapid increase in chicken meat consumption suggests that any negative images of the industry do remain short-term. Negative images of chicken meat relate to food health scares (Yeung and Yee 2002), animal welfare - more specifically, perceptions of shedding and caging conditions (Edge, et al. 2008; Verbeke 2000) and slaughtering practices (Boyd 1984) - and influenza outbreaks (i.e. avian flu) (Manning et al. 2007). Many of these images are played upon in the media by interest groups, such as the animal rights movement, specifically to influence public perceptions and change consumption behaviour (Francione 1996).

The doubling of free range chickens for meat consumption in recent years has been attributed to negative public perception of intensive chicken meat production (HSI 2008; Sharman 2007). Choice (http://www.choice.com.au/viewArticle.aspx?id=103508&catId=100501&tid=100008&p=1&title=Consumer+expectations+of+chicken+meat+(archived)) observes that some of the negative perception of chicken meat in Australia is a spill-over from foreign production practices that do not occur locally, such as the addition of hormones to feed.

Box 10: Example of legislation relating to the Chicken Meat operations in New South Wales, Australia

The Environment Planning and Assessment Act 1979

Water Management Act 2000

Rivers and Foreshores Improvement Act 1948

Water Act 1912

Native Vegetation Conservation Act 1997

Protection of the Environment Operations Act 1997

Pesticides Act 1999

National Parks and Wildlife Act 1974

Threatened Species Conservation Act 1995

Road and Rail Transport (Dangerous Goods) Act 1997

Local Government Act 1993

Stock Diseases Act 1923

Exotic Diseases of Animals Act 1991

Poultry Meat Industry Act 1986

Stock Foods Act 1940

Stock Medicines Act 1989

Stock (Chemical Residues) Act 1975

Prevention of Cruelty to Animals Act 1979

Occupational Health and Safety Act 2000

Sydney Water Catchment Management Act 1998

Public Health Act 1991

Other (non legislated)

NSW Industrial Noise Policy

Model Code of Practice for the Welfare of Animals – Domestic Poultry

Source: NSW Agriculture 2004

5.3.3 Fish

Background

The commercial fishing sector is Australia's fifth largest food producing industry. For the purposes of this report, the industry comprises the commercial sector covering the high seas – generally between 3 and 200 nautical miles from the Australian coast – the coastal zone – within 3 nautical miles – and inland fishing and aquaculture. The aquaculture sector is highly intensive and has grown rapidly to the point that it now accounts for one-third of the value of the Australian fishing industry (ABARE 2008).

Australian per capita consumption of fish was around 16kg in 2005 (AFMA 2009), an increase from 14kg in 1968 (FAO 2009). Total production in 2006-07 was 240,000 tonnes (ABARE 2008). Close to a further 200,000 tonnes of seafood is imported each year, while 60,000 tonnes is exported (SIAA 2009). That said, the high-value of exported crustaceans, tuna and farmed salmonoids is greater than that of the imports.

Responsibility for the regulation of the fishing industry is shared between the federal government through the Australian Fisheries Management Authority (AFMA), responsible for the commercial high seas commercial fisheries, and State and Territory governments, responsible for commercial coastal and recreational fishing and aquaculture.

The state of biodiversity

The greater part of commercial fishing industry, the non-aquaculture component, is essentially a harvest of wild species (Freese 1998). Tidwell and Allan (2001) suggest that today, fish is the only important food source that is still primarily gathered from the wild rather than farmed. In one sense, because of this, more is known about the biodiversity impacts of the fishing industry than nearly any other, as measuring the population status of the target species, while not giving a comprehensive picture of the broader condition of marine species and ecosystems, can indicate broader ecological change, particularly if the target species shows serious decline (Beeton et al. 2006). Monitoring of Australian fish stocks (see Table 15) suggests that half of those stocks where a full assessment could be made have been over-exploited (Caton and McGloughlin 2005). The large number of stocks where the assessment is uncertain is of ongoing concern to the Australian government (AFMA 2004).

At the global scale, which is particularly relevant given the level of fish imports consumed in Australia, over half the world stocks have been fully exploited and close to a third have been over exploited (Figure 7).

Table 15: Trends in AFMA managed fish stocks

Stock status	1992	1993	1994	1996	1997	1998	1999	2000-2001	2002-2003	2004
Not overfished	17	29	28	28	20	18	17	19	20	17
Overfished	5	5	3	3	4	6	7	11	16	17
Uncertain	9	9	13	17	31	35	38	34	34	40
Unclassified	43	31	30	26	19	15	12	10	4	0

Source: Caton and McGloughlin (2005)

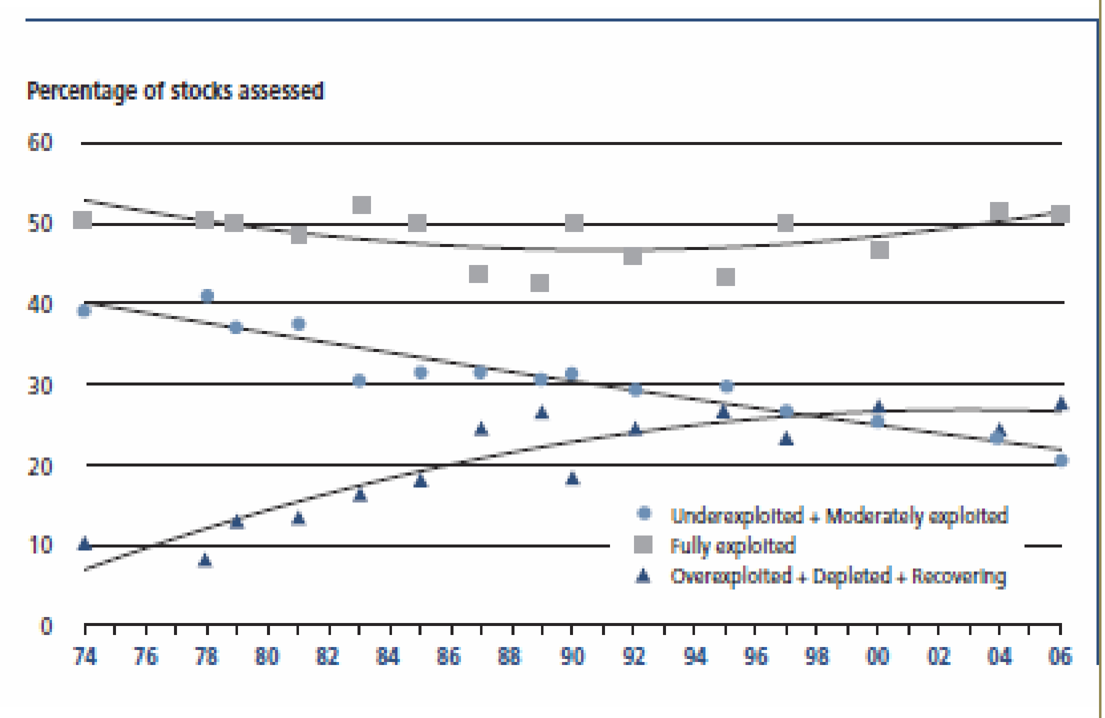

Figure 7: Global trends in the state of world marine stocks (source: FAO 2008)

There are a range of threatening processes on biodiversity levels in fisheries (Beeton et al. 2006), including the direct loss of biodiversity from harvesting process, further loss resulting from unintended by-catch (Tudela et al. 2005), disturbance of the benthic zone (water floor) (Rodrigues et al. 2001), and the breakdown of the food-chain (Polisand and Strong 1996). In a trans-Pacific research collaboration on fish ecology, the researchers concluded: Ecological extinction caused by over-fishing precedes all other pervasive human disturbance to coastal ecosystems, including pollution, degradation of water quality, and anthropogenic climate change.

By-catch is of particular concern to biodiversity. The estimated global average of seafood discarded each year from by-catch is 6.8 million tonnes, of which 27.3% comes from prawn trawling (FAO 2008). Approximately two thirds of all prawn trawl catch is discarded (Kelleher 2005).

In response to depleting fish stocks, and by implicit implication potential losses in biodiversity, aquaculture has rapidly grown to point where nearly half the worlds fish production (FAO 2008), and a third of Australia's (ABARE 2008), comes from this source. Aquaculture, however, is not without its biodiversity concerns, where the impacts of aquaculture on biodiversity are rarely positive, sometimes neutral, but usually negative to some degree (Beveridge et al. 1994). These negative impacts may be through habitat loss to create ponds, pollution of local water by intensive production, affects of antibiotics and other chemicals on local fauna, intensive collection of wild seed, competition with endemic fauna by escaped exotics, introduction of pathogens and parasites, genetic introgression with local fauna (Beardmore et al. 1997). While the emphasis here is on inland aquaculture, similar impacts may occur in sea-cage feedlots (AMCS 2009).

Few Australian studies have been undertaken on the impact of aquaculture on biodiversity. In a study on shrimp ponds adjacent to coastal environments in NE Australia, the researchers found that the impacts are complex and not easily measured by any one parameter, but ultimately concluded that the reduction of nutrient discharges is essential to the future sustainability of the industry (Burford et al. 2003). Australia's inland rivers have been subjected to the introduction of exotic fish species (Arthington 1991), including through escapes from aquaculture (Canonico et al. 2005), and this has been attributed as the cause of the decline of 22 native species now classified as endangered (Wager and Jackson 1993).

A summary of the potential impacts of the fish industry is provided in Table 16.

Industry and other responses

Regulation of fishing activities is the primary means of limiting the impact of fishing on biodiversity in Australia (AFMA 2009a). The Fisheries Management Act 1991, interpreted by AFMA, requires that stocks be maintained at a sustainable level and, where necessary, rebuilt to ensure maximum inter-generational equity. It also requires managing fisheries so as to minimise the impact of fishing on biological diversity and ecosystem habitat. As part of this process, research into environmentally friendly fishing methods and by-catch minimisation is seen as a priority.

Australia has largely adopted a property rights approach to fishing management to meet the obligations of the Fisheries Management Act 1991, although the use of marine protected areas (MPAs) is also employed. These two management approaches are based on distinctly different principles that have given rise to confusion and conflict (Baelde 2005). The 'rights' based system is based on licensing and quotas, with each fishery having its own separate rights based on quota assessments (AFMA 2009a). Fishers have their boats licensed and are allocated a catch quota, and may use their right or sell or lease it to other fishers. The AFMA is responsible for managing this system. MPAs on the other hand, largely exclude fishing from zones designated under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (DEWHA 2009).

The regulatory approach also applies to aquaculture and recreational fishing, where, respectively, licences to operate and catch are required. These systems are managed by State and Territory government agencies.

The issue of by-catch has been confronted by AFMA through the development of by-catch actions plans (BAPs) developed for each specific fishery (AFMA 2009). BAPs are presently evolving into By-catch and Discard Workplans developed by working groups consisting of scientific, industry, government and conservation members.

Voluntary-based environmental management systems (EMS) are used by some parts of the fishing sector, responding to consumer perceptions about the efficacy of the fishing industry (MSC 2009a). The Marine Stewardship Council is the leading international environmental accreditation agency for the industry, and can certify fisheries if they can demonstrate that they are sustainably managed. Of the 47 fisheries with MSC certification, 3 are Australian: the Western Australian rock lobster fishery, Australian mackerel ice-fish fishery and the Lakes and Coorong inland fishery (MSC 2009b).

Table 16: Pressure – state – response matrix for the fish industry

Broad pressures on biodiversity	Extent and significance of pressures	State of biodiversity	Root cause	Responses
Vegetation clearance and modification	Minor clearing for placement of aquaculture production facilities.	Potential coastal erosion and changes in abundance and composition of plant and animal species (Shang and Tisdell 2007)	Conversion of mangroves for fishponds. Conversion of cropland for fishponds.	Compliance with State vegetation legislation which limits vegetation clearing.
Altered fire regimes	Not applicable	Not applicable	Not applicable	Not applicable
Altered grazing regimes	Not applicable	Not applicable	Not applicable	Not applicable
Altered hydrology	Inland aquaculture is a significant user of freshwater (including groundwater), although amounts to only a minor portion of agricultural water use.	Minor potential for changes in the timing and amount of environmental flows affecting aquatic biodiversity and floodplain species; Rising watertable (following tree clearing) can lead to soil salinity, waterlogging and/or sodicity and subsequent decreased vegetation condition; use of saline water resources can ease salinity issues.	Water extraction for aquaculture, including water for breeding, farming and waste management (effluent shandying) practices.	Adoption of State extension best practice guidelines.
Trampling and soil compaction	The oceanic equivalent of trampling is gear (nets, rakes, dredges) dragging on the ocean floor. This is significant across the globe (Auster and Langton 1999).	Loss of ocean floor habitat for bottom dweller species; loss of corals; loss of aquatic plants.	Floor dragging to catch bottom dweller species.	Marine reservations. R&D into improved fishing gear and practices.
Environmental weeds/ferals	Escaped exotic species from aquaculture production facilities dominating local native populations.	Potential to reduce local populations (Canonico 2005) through spread of introduced diseases, predation or 'crowding out'.	Poor farm design and monitoring.	Compliance with environmental management plans.

Broad pressures on biodiversity	Extent and significance of pressures	State of biodiversity	Root cause	Responses
Pollution: aquatic	Pollution of riverine, estuary coastal and deep sea waters through boat pollution (fuel, gas and organic emissions/refuse) and aquaculture effluent.	Potential for death of fish and invertebrates due to toxins; Changed aquatic vegetation composition and condition; Increased shellfish contamination.	Poor boat management; inappropriate waste management and monitoring systems in place.	Compliance with State environmental regulations. Adoption of State extension best practice guidelines.
Disease and pathogen spread	Risk of pathogen spread through bacteria.	Biosecurity issues, including potential loss of breeds; cross species infection.	Poor housing condition and monitoring in intensive chicken farms.	Compliance with State environmental regulations. Adoption of State extension best practice guidelines.
Climate change	Global. Contribution to greenhouse gases.	Changes to the composition, abundance and distribution of native plants and animals.	CO_2 emissions from boats. Minor N volatilisation from aquaculture waste.	
Direct biodiversity loss	Extinction of species over-fished in wild (inland and sea).	Irreversible loss of genetic diversity.	Overfishing, including through by-catch.	Industry regulation, including quotas of catch and species. Marine reserve system. R&D to reduce by-catch. Adoption of best management practices to reduce by-catch.

Consumer and conservation bodies complement the EMS approach by educating consumers about the environmental credentials of different industry sectors, individual fisheries or management practices across the industry. The Australian Marine Conservation Society, for example, provides guidance to consumers wanting to make more informed choices about the seafood they consume (AMCS 2009). This in turn places continuing pressure on the industry to not only comply with regulatory obligations, but also improve practices such as by-catch management.

As previously noted, aquaculture has grown rapidly in Australia in response to pressures on wild stocks as well as strong demand for high-valued fish such as southern blue fin tuna (FAO 2009). Environmental management plans are typical requirements in State and Territory legislation in order to receive a license to operate an aquaculture enterprise.

The fishing industry is well served by a network of research providers supported in federal and State agencies and universities. A Co-operative Research Centre for Aquaculture is based in Tasmania. The industry supports research investment through the Fisheries R&D Corporation (FRDC), funded by industry levies and matching government contributions (FRDC 2009).

Monitoring

Monitoring is an essential component of AFMA’s licensing and quota system (AFMA 2009b). Moreover, the EPBC Act requires regular assessments to be carried out for all Commonwealth managed fisheries. AFMA oversees a range of monitoring initiatives, including its Ecological Risk Management Framework (ERMF), compliance monitoring programs and the Observer Program. The ERMF assesses the impact, direct and indirect, a fishery’s activities may have on the marine ecosystem, identifying the key issues in each fishery that require management attention by industry or government. ERAs assess (AFMA 2009c). Compliance monitoring programs are critical to effectiveness and credibility of the quota system and require fishing vessels and the down-stream supply chain (mainly market authorities) to maintain and provide extensive records of catch, disposals and receivals (AFMAd). The Observer Program places observers on vessels to provide the most reliable data on catch composition, fate of target and non-target species and fishing effort (AFMA 2009e).

State of the Environment assessments include the status of Australian fisheries, providing information such as that in Table 15. Aquaculture operations are subject to State and Territory monitoring, including monitoring of nutrient loading if the site is not connected to reticulated sewerage and waste-waters need to be disposed of off-site to surface waters.

Effectiveness of responses

Table 15 clearly shows the declining stocks of Australian fisheries over recent years, with the number of over-fished fisheries increasing from 5 to 17 between 1992 and 2004 (Caton and McGloughlin 2005).

Public Perceptions

In 2003, a comprehensive survey of community perceptions of the Australian fishing industry was undertaken for the FRDC (Aslin and Byron 2003). Respondents generally viewed recreational and traditional fishing and aquaculture positively, but not commercial wild-catch fishing. Only 25% of respondents suggested that wild catch fishing was sustainable, compared to recreational fishing (56%), traditional fishing (64%) and aquaculture (77%). The respondents indicated that the most important source of information about the fishing industry was the mass media.

Retail and consumption surveys of seafood undertaken by FRDC on an occasional basis suggest that Australians generally see seafood as a dining experience, rather than as a food for sustenance (Ruello & Associates 2006). Consistent with the Aslin and Byron survey findings, this suggests that more seafood is consumed by people with a higher income, which may influence their views (concerns) about sustainability issues and therefore their perceptions of the industry. Ruello & Associates (2006) found that 71% of consumers surveyed in Melbourne agreed they eat seafood because it is better for their health while 92% felt that correct labelling was very important when choosing seafood to prepare at home.

5.4 Other protein

5.4.1 Grains, legumes and pulses

Background

The Australian grain industry produces around 34 million tonnes per year, equivalent to around 3% of global production and comparable to that of France (CSIRO 2005). It uses around 20 million hectares of arable land (see Figure 2).

Cereals, pulses and legumes are an additional source of protein complementing meat consumption, and one of the most important sources for vegetarians (Millward 1999). Most cereals have a protein range between 6.5-14%, while pulses and legumes vary between 17-43% (see Table 17). Soya bean, while high in fat, has the highest level of protein in commonly consumed plant-based foods. In Australia, cereals contribute 25.5% of people's protein needs, second after meat (28%), and ahead of dairy (21%) (Kellett et al. 1998)

Table 17: Nutritional content of select plant-based foods

Source	Protein	Fat	Carbo-hydrate
Cereal			
Wheat – Hard	14.0	2.2	69.1
Wheat – Soft	10.2	2.0	72.1
Oats	14.2	7.4	68.2
Rice (Brown)	7.5	1.9	77.4
Barley (Pearled)	8.2	1.0	78.8
Maize	8.9	3.9	72.2
Rye	12.1	1.7	73.4
Millet	9.9	2.9	72.9
Pulse/Legume			
Chick peas (whole)	17.1	5.3	60.9
Mung beans (whole)	24.0	1.3	56.7
Kidney beans	22.9	1.3	60.6
Peas	19.7	1.1	56.5
Soya	43.2	19.5	20.9

These plant-based forms of protein are also important in the production of meat and fibre (wool) in the form of livestock feed. Approximately 12 million metric tonnes of feed is used by livestock industries per annum (Spragg 2008), of which around 95% is used for the production of food. The feed comprises cereal grains, legume grains, vegetable protein meals, animal protein meals, and cereal milling co-products; with other supplements added according to specific nutritional requirements and orders (SFMCA 2009).

From an ecological footprint perspective of protein production, feed production needs to be included in the consideration of livestock's impact on the environment. Another important consideration is the feed conversion efficiency of different livestock. Poultry meat, for example, has a conversion ratio of 2.1-3.0 kg of feed for every kilogram of meat produced, compared to pork (4.0 – 5.5kg) and beef (10.0kg). Farmed fish are highly efficient converters and can reach as high as 1:1, although 2-3:1 is more commonly achieved (Tacon 2005).

As a major grain producer, most plant-based protein for human and stock consumption is domestically sourced, although some feed is imported particularly during times of drought. All imports are strictly monitored by Australia's Quarantine Inspection Service (AQIS), and where these include genetically modified components, the Office of the Gene Technology Regulator (OGTR) is required to consider an application for import license (OTGR 2009).

The state of biodiversity

The impact of grain production on biodiversity is widely acknowledged but its quantification has been highly problematic (Narayanaswamy et al. 2003). Like extensive cattle production, the major impact has come from extensive land clearing. Approximately 20 million hectares of land has been cleared for crop in Australia (BRS 2002), and CSIRO (2005) estimate that the land disturbance factor of the industry is approximately 8 times greater than that of all Australian sectors (including non-agricultural industries). Biodiversity impact comes through the direct depletion of plants from clearance and the subsequent impacts of ecosystem alteration from salinity and other forms of land degradation (McFarlane et al. 1993), vegetation fragmentation (Hobbs 1993), sediment and nutrient loadings to waterways (Barson and Leslie 2004; Finlayson and Silburn 1996) and contribution to global warming (Garnaut 2008).

Other biodiversity impacts come from the management regimes used in crop production. The transport of herbicides and pesticides from fields to adjoining areas through drift (air) and runoff (water) can be significant (Wolf and Cessna 2004). Studies in north America have shown that deposition of herbicides from cropland onto adjoining aquatic (including riparian and wetland) and terrestrial areas damages sensitive plants (Boutin et al. 2000; Nystrom et al. 1999; Faber et al. 1998), while runoff of insecticides from arable land to a stream resulted in the disappearance of eight of the eleven abundant macro-invertebrates (Liess and Schulz 1999). Carr et al. (1997) found that the presence of carbamates and organophosphates from contaminated runoff from treated cropping sites had lead to reductions in cholinesterase activity in fish.

Butterfly and other invertebrate mortality due to the application of insecticides near field margins has been observed, including by Davis et al. (1991) who found that Pieris spp. mortality (24 - 73%) occurred due to direct exposure to diflubenzuron drift as well as contact with Alliaria petiolata plants (10 - 90%) exposed to drift. Johnson (2000) observes that in Europe, there is overwhelming evidence demonstrating that the use of more effective pesticides (including herbicides) over the past 20 years has been a major factor causing serious declines in farmland birds, arable wild plants, and insects.

A study of biodiversity in mixed farming systems in Australia (Bridle et al. 2009) showed that properties with high grain production had less biodiversity in the form of spiders and birds than properties with a high proportion of pastures. This was associated with the likelihood that the latter properties tended to have higher proportions of remnant vegetation that acted as harbours for the spiders and birds (Bridle et al. 2009). Waters and Hacker (2008) suggest that the impact on biodiversity of cropping is related proportionally to the intensity of the cropping management system, with intensive chemical use, more frequent heavy vehicle passes and burning practices having a greater impact than minimal disturbance systems.

Biotechnology and the genetic modification (GM) of crop plants to reduce their resistance to herbicides targeted towards weeds as well as to reduce resistance to disease is an emerging issue for biodiversity (Braun and Ammann 2002). Gene transfer is almost inevitable from crops that have interfertile relatives in adjacent natural ecosystems (Johnson 2000). In many parts of the world, genes inserted into GM crops are often derived from other phyla, providing traits not previously existing in wild plant populations. If such genes are introduced accidentally, they may change the fitness and population dynamics of hybrids between native plants and crops, possibly resulting in establishment in native species. Further impacts on biodiversity remain largely unexplored, however:

> *. . .the transfer of certain genes, such as resistance to insects, fungi and viruses could increase fitness (ability to reproduce) of any resulting hybrids, possibly forming aggressive weeds or plants that swamp wild populations. Weeds having tolerance to a range of herbicides could also emerge; these would be difficult to control in agriculture, or in natural ecosystems like grasslands. Farmers may eventually need mixtures of herbicides to control them, causing yet more damage to biodiversity.* (Johnson 2000)

Land cleared for cropping has essentially stabilised in Australia, although some land previously used for grazing has recently been converted to cropping, including in the higher rainfall zones where raised-bed systems are being introduced (Peries et al. 2004). Some elements of the Australian grain industry, and the feed-dependent red-meat industry, are tarnished by significant land clearing taking place elsewhere across the world, most notably in Brazil and Argentina for soya production (World Bank 2008; Steinfeld et al 2006). In Brazil, soya planting between 2000 and 2005 doubled in three states by an area larger than Costa Rica (~50,000km2), while deforestation in the Amazon rose by 18% during this period (World Bank 2008). Much of the soya production is not intended as protein, but rather a biofuel.

A summary of the potential impacts of the cropping industry is provided in Table 18.

Industry and other responses

The grains industry has invested heavily for many years in improved cultivation practices that would minimise soil disturbance and maximise retention of water and make best use of this when needed (Beeston et al. 2005). The primary purpose of this effort has not been for biodiversity outcomes, but rather to reduce soil erosion and help manage Australia's fragile soils in an environment of high climatic variability (Llewellyn 2009). This effort has been rewarded with high adoption of minimal tillage practices. In an ABARE survey of farmer's adoption practices (Oliver et al. 2009), it was found the most common cultivation practice is now reduced tillage (reported by 63% of farms), with a further 20% of farms using no tillage systems. Similar findings appear in other surveys (i.e. Llewellyn et al. 2009). The ABARE survey also found that slightly more than 60% of grain farms reported they had set-aside areas for conservation purposes.

Land clearing for cropping has essentially ceased in Australia, and the total land used for cropping has remained constant for the past twenty years (BRS 2002).

The use of buffer and vegetative zones for spray drift (Ucar and Hall 2001) and the incorporation of woody plants in alleys to manage deep drainage and provide bird and other invertebrate shelter (Coles et al. 2004; Harper et al. 2000) have been advocated across cropping regions of Australia. More recently the grains industry has begun to explore the potential of integrated pest management (Horne and Page 2008), long popular in the cotton industry (Fitt 2000) and to some extent among the horticultural industries (McDougall et al. 1999) as a means of reducing reliance on chemicals.

Monitoring

The grains industry encourages its farmers to monitor for a range of factors, including soil monitoring. This monitoring is largely undertaken for productive purposes. Efforts to establish environmental management systems that include ongoing monitoring and continuous improvement have been explored in Australia (Ridley 2001), but adoption has been highly problematic because of perceptions by farmers about the time and effort required (for all levels of systems) and the transaction costs associated with auditing and compliance (for higher level systems) (Seymour et al. 2009). Biodiversity monitoring does not play a strong part in grain farms (Carruthers and Tinning 2003).

Effectiveness of responses

61% of grain farmers have conservation set-aside areas (Oliver et al. 2009). Of these, 45% suggested that they would increase the size of their set-aside areas in future, while only 1% suggested they would decrease this. The adoption of minimum and zero tillage practices has been discussed above, and this should assist in the maintenance of soil biodiversity in particular (Waters and Hacker 2008).

Public Perceptions

Public perception studies of cropping are dominated by a focus around attitudes towards genetically modified (GM) crops. While many of these relate to perceptions about food safety and health (Weaver and Morris 2004), some describe public concern about the potential dominance of GM crops as landscape monocultures and the subsequent impact on genetic diversity (Grunert et al. 2001).

Table 18: Pressure – state – response matrix for grain and related industries

Broad pressures on biodiversity	Extent and significance of pressures	State of biodiversity	Root cause	Responses
Vegetation clearance and modification	Widespread extent (up to 20 million ha), with considerable impact with changes from natural to significantly modified systems.	Death of animals and plants during clearing; Changed composition and abundance of native plants and animals; Modified vegetation condition; Potential for increased weed invasion in some situations; Changed potential for soil erosion and associated impacts on aquatic biodiversity. Rising watertable (following tree clearing) can lead to soil salinity, waterlogging and/or sodicity and subsequent decreased vegetation condition.	Clearing vegetation to extend the area of exotic pastures (to increase stocking rates) and to provide feed grains. Cost pressures driving the conversion of native pastures to exotic pastures or crops.	Legislation (e.g. Queensland Veg Management act); Setting aside areas for conservation outcomes; Changed management practices to better utilise native systems (and hence not clear them); Revegetation; Incentive schemes.
Altered fire regimes	Extensive. Stubble burning has been significant in the past, although less so more recently (although stubble burning does not imitate original fire regimes.	Changed composition and abundance of native plants and animals; Modified vegetation condition; Potential for increased weed invasion in some situations; Changed quality and quantity of soil organic matter; Changed potential for soil erosion and impacts on aquatic biodiversity.	Burning off to kill potential disease source.	Stubble burning practices have altered (reduced) over time, although this is not in response to imitating original fire regimes.
Altered grazing regimes	Moderate. Some crops are directly grazed.	The impact of biodiversity by grazing crops has not been studied, although anecdotal evidence suggests that it can help reduce overall total grazing pressure, and may therefore have some beneficial effect.	Diversification of enterprises by multi-use of land resources.	Adoption of guidelines on grazing cereals (Grain & Graze 2008).

Broad pressures on biodiversity	Extent and significance of pressures	State of biodiversity	Root cause	Responses
Altered hydrology	Widespread (potentially up to 20 million ha).	Changes in the timing and amount of environmental flows affects aquatic biodiversity and floodplain species; Changes to species composition and abundance at different distances from artificial watering points. Contribution to rising watertables and salinity.	Change from natural perennial systems which have evolved to balance water use where it falls to annual systems which can leak water.	Incorporation of perennial pastures in phase cropping systems; strategic woody perennial and tree planting; farm engineering, including contour banks and drains; introduction of more salt-tolerant species.
Trampling and soil compaction	Widespread (potentially up to 20 million ha).	Reduced biological activity, particularly under wheel tracks (Chan et al 2007).	Use of heavy machinery for planting, chemical application and harvesting.	Adoption of zero and minimum till systems; controlled traffic systems; crop pasture rotations.
Weeds and feral animals	Widespread (potentially up to 20 million ha).	Spread of exotic plants into natural, adjoining vegetation; changed fauna habitat; changed riparian habitat; toxic health risk from pesticides and herbicides (see pollution below).	Farm machinery dispersing weed propagules.	Exotic weed regulations. Refinement of pesticide regimes.
Pollution	Extent not known but potentially extensive.	Toxic risk to adjoining vegetation and aquatic fauna/flora from pesticide and herbicide transport. Runoff of nutrients to surface water bodies. Leakage of nutrients into groundwater.	Excessive or poor chemical application practices. Altered hydrology allowing water to carry nutrients into watertables or runoff into surface water bodies.	Use of buffer strips; alley farming and other systems that maintain groundcover and use water where it falls. Use of chemical application decision support systems.
Disease and pathogen spread	Some potential for crossover spread from crops to other flora. Pressure is for use of a limited number plant species that may be disease resistant.	Gene transfer from GM to related species can occur (Chevre et al. 1997). Mitigation strategies such as pesticide use can have downstream impacts (see 'Pollution' above). Reduction of crop species diversity through plant breeding and genome modification.	Increase plant productivity through reduced plant competition and potentially disease resistance.	Herbicide and other chemical applications. Genetic modification and other plant breeding technologies.

Broad pressures on biodiversity	Extent and significance of pressures	State of biodiversity	Root cause	Responses
Climate change	Limited (2.5% of agricultural emissions of GHGs).	Changes to the composition, abundance and distribution of native plants and animals.	Emissions GHGs from farm machinery. Change in carbon sequestration regimes.	Zero tillage and other minimum disturbance techniques, retaining residue, extending fallows, row spacing, planting density, staggering planting times, controlled traffic, erosion control infrastructure (Stokes and Howden 2008).
Direct biodiversity loss	Significant.	Extinction of crop species diversity.	Reduction of plant species cropped to enhance productivity and efficiency.	R&D into the potential protection and use of wild species.

5.4.2 Dairy

Background

Figures for 2007-2008 indicate that there are 1.7 million dairy cattle in Australia (Source: Dairy Australia). The number of dairy farms has more than halved over the past 25 years, from 22,000 in 1980 to 7,950 in 2008. The estimated area they cover is 3.2 million hectares (Table 1).

While the bulk of milk production occurs in the south-east corner of the country (80% in the three states of Victoria, South Australia and Tasmania in 2007/08), all states have dairy industries that supply fresh drinking milk to nearby cities and towns. Most dairy production regions are located in coastal areas, where pasture growth generally depends on natural rainfall. In northern Victoria and southern NSW irrigated dairy farms account for around a quarter of national milk production. Based on a farm-gate value of production of $4.6 billion in 2007/08, the dairy industry ranks third behind the beef and wheat industries (Source: Dairy Australia). Dairy products produced by sheep and goats are currently an emerging industry (Foster 2009) and only make a small contribution to the market and the economy.

The Australian dairy industry remains predominantly pasture-based, with supplementation with home-grown fodder and crops. Supplementary feeding with grains is becoming increasingly common, with over 25% of milk solids produced by Australian dairy cows now derived from feed grains and concentrates. Full feedlot dairies are also found in Australia but are the exception. The dairy industry uses irrigation water for their pastures in some regions (particularly inland Victoria), as well as using high levels of fertilisers to increase pasture production.

The direct impacts of dairy farming include clearing of native vegetation for pasture establishment and grazing of the remaining vegetation which is often along riparian zones. Indirect impacts include weeds, fertiliser run-off; soil run-off; effluent seepage into waterways, water use and greenhouse gas emissions.

The state of biodiversity

Pollution

A study by Fyfe (2004) of two dairy waste management systems in the highlands of NSW found major shortcomings in nutrient containment and recommended significant modifications in order to meet regulatory requirements.

Coad and Burkitt (2006), in a study on dairy farms in the Montagu catchment in north-western Tasmania, found that the majority of farms had P concentrations in their soils generally well above those required for maximum pasture production. This sort of information, which produced nutrients maps for selected farms, can be used to undertake risk assessments of nutrient loss in the catchment.

Industry and other responses

Dairy Australia has several environmental programs which cover R&D, education, farmer forums etc. Dairying for Tomorrow is the main environmental program of the dairy industry (Dairy Australia no date). It is national in scope and focuses on natural resource management (NRM), with a goal to bring together industry and community partners to develop and implement sound environmental management practices. Some of the environmental measures dairy farmers are putting in place as part of this program are reducing fertiliser loss, changing effluent systems, retaining native bush and fencing off waterways. The program also aims to develop a sustainability scorecard. Responding to the direct and indirect impacts of climate change, and the interactions these have with dairy enterprises, is also a key issue identified by the dairy industry. For example, the industry is examining ways to reduce greenhouse gases from its operations.

Dairy Australia has funded a number of R&D projects on nutrient and water management on dairy farms including a major project on best practice dairy effluent management in Tasmania. Dairy Australia also publishes material related to biodiversity management, including information about native shelterbelts and their benefits and ways to improve riparian management (e.g. Stock and Waterways).

At the state level, groups such as the NSW Dairy Farmers have initiated awards for environmental performance and the Victorian government has supported programs such as 'Productive grazing, healthy rivers'. Like the other intensive industries covered in this review, the dairy industry is subject to an array of regulations, particularly in relation to nutrient management. Examples of the release of effluents into waterways are still reported, such as in north-western Tasmania, with the dairy industry working on ways to minimise these.

Monitoring

In recent years, Dairy Australia has worked closely with both dairy farmers and other agricultural sectors to look at how the dairy industry can improve its environmental performance. An important initiative in this area has been the Dairy Self Assessment Tool (DairySAT) which was set up as part of the Dairying for Tomorrow program. DairySAT is an environmental self-assessment tool for farm businesses. It contains modules on effluent management, irrigation, nutrients, soils, chemicals, farm waste, pests and weeds, biodiversity, energy and greenhouse gas emissions. It was designed and developed for dairy farmers by dairy farmers.

Effectiveness of responses

Dairy Australia states that since DairySAT's inception, over 1500 Australian dairy farmers have used the tool to assess the environmental sustainability of their business. They claim that over 84% of participating farmers have subsequently made changes to their farm management practices to improve environmental performance. The source of this information is still to be checked.

The program 'Productive grazing, healthy Rivers' in eastern Victoria found that the condition of riparian vegetation on most dairy farms was poor.

Perceptions

While this is currently a hypothesis, it is possible that the perception of the impact of dairy farms on biodiversity is less to the general public because the farms are found in high rainfall areas or are irrigated. The presence of lush green pastures and grazing dairy cows is likely to be quite a pleasing image for most of the general public, particularly given the English heritage of many, so the impacts of this on biodiversity may not be as evident or at the top of people's minds. The way people perceive different protein based industries and their impact on biodiversity could be an interesting area for research, based on some of the techniques used in social research.

5.4.3 Eggs

Background

Australian commercial egg production is around 220 million dozen (~144kt) per year with a backyard production of about 26 million dozen (ABARE 2007; CSIRO 2005). Per capita consumption is about 150 per year, representing a significant fall from around 250 per capita in the late 1940s. Around 400 enterprises are engaged in egg production (ABARE 2007), comprising about 14 million laying hens. These hens have a productive laying life of 12 to 15 months, during which they consume 25 to 30 kg of ration yearly (CSIRO 2005).

While a part of the wider ‘poultry’ industry, the egg industry has its own institutional arrangements, including separate industry organisations and R&D levy arrangements. The Australian Egg Corporation (AECL) is the producer owned company which integrates marketing, research and development and policy services for the benefit of egg producers (AECL 2009). It is mainly funded through statutory levies collected under the Egg Industry Service Provision Act 2002 and Australian government funds for the purposes of research and development.

The state of biodiversity

The egg industry shares many of the same attributes as its chicken meat relation, including production systems based on intensive indoor feedlots and intensive outdoor (free-range) systems. While the breeds of chicken used are very different between layer hens (for egg production) and broilers (for meat production), the impacts of both on biodiversity are similar, and hence the reader is asked to refer to the corresponding sections and pressure-state-response table (Table13)

That said, it should be noted that 1,000 layer hens in belt-cleaned cages produce around 21 tonnes of manure annually, while 1,000 free range layers produce around 10 tonnes of manure annually (WABGA et al. 2004). This compares to 0.75 tonnes per 1,000 broilers in about 7 weeks (equivalent of 5.5 tonnes annually).

6 Discussion: Comparative analysis

6.1 Relative contributions to biodiversity pressures

For many industries, drawing a direct link between production systems and actual loss of biodiversity is challenging, if not impossible. Industries rarely interact with landscapes and ecosystems in isolation to other anthropocentric activity. It is far easier to measure the contribution to a pressure than it is to accurately apportion responsibility to the outcomes of that pressure. In one sense it is only in the wild catch industries that we can be more certain about direct cause and effect relationships, although even here the pressures on fish populations come only partly, albeit significantly, from fishing. That said, industries cannot abrogate responsibility for ensuring they minimise or eliminate altogether their contribution to pressures on biodiversity, particularly where we know that those pressures, regardless of the collective contributions to them, adversely affect biodiversity.

Table 19, from a pivotal industry study by CSIRO (Foran et al. 2005), provides one example comparing agricultural industries' performance against a range of criteria, including land disturbance, green house gas emissions and water use. Of these the first criteria is most relevant to biodiversity, although water use and greenhouse gases have also been shown to have an impact.

Table 19: Environmental performance across a range of protein production industries

Economic Sector	Land disturbance (kha)		GHG (kt $CO_{2\text{-}e}$)		Water use (ML)	
	In supplying industry	*% national total*	*In supplying industry*	*% national total*	*In supplying industry*	*% national total*
Beef	89,070	55.12	122,527	23.63	3,229,335	15.41
Sheep & shorn wool	57,392	35.52	23,899	4.61	773,641	3.69
Dairy cattle & milk	1837	1.14	8,801	1.7	3,542,391	16.91
Pigs	49	0.03	1,302	0.25	559	0.00
Poultry & eggs	0	0.00	579	0.11	191	0.00
Commercial fishing	1	0.00	680	0.13	16,487	0.08
Wheat & other grain	7,358	4.55	2,088	0.4	504,984	2.41

Source: Foran et al. 2005

Table 20 attempts to capture the potential relative contribution of ten different protein sources to various pressures on biodiversity outlined in this report. Relative here refers to potential contribution relative to the other industries studies, and so, for example, a 'high relative contribution' should not be taken to mean 'high impact'. While the Table can be used to make comparisons between industries, the authors urge caution against this as it can have the perverse outcome of giving some industries an unwarranted sense of assent that they may divert their attention away from the collective responsibility for protecting biodiversity and ecosystems. Comparisons may also lead to the impression that those industries with a higher impact are not sustainable or are inadequately responding. The practices of the red-meat industry now are not the practices that lead to the high impact that industry has had in the past. We should also acknowledge that land clearing, which has now markedly declined in Australia, was once in response to public policy that reflected the values of the time. Moreover, the investment by the red-meat industry into biodiversity is significant, although will need to continue to be so.

Other challenges associated with comparisons include comparing apples and pears, or invertebrates, lichens and bats. How does one compare the loss of native fish species, resulting from escaped exotic species from aquaculture farms, with the loss of particular chicken breeds, resulting from breeding for specialisation in chicken meat and egg laying? Which industries are better and which are worse?

Readers should note that Table 20 results from the authors' interpretations of the limited studies available. These studies are limited not in number, but rather in scope. Reflecting the challenges previously discussed, most of the literature deals with pressures rather than with actual direct impacts and attribution to these.

Overall, these results show that the cattle and beef industries have the largest impact on terrestrial biodiversity in Australia by both the area covered and the nature of the impacts. This includes the area of native vegetation cleared for grazing, the amount of grain used in high density feedlots, the amount of greenhouse gases emitted. While much of the damage in the rangelands and southern Australia is the legacy of past management actions, it has left a lasting impression about the impacts of the cattle and sheep industries on biodiversity. Feral goats, which are the main source of meat for the commercial market, have been listed as a key threatening process to biodiversity by the Commonwealth Government due to the threats they pose to a number of species and ecosystems.

One of the issues to consider when comparing different protein sources is the interplay between the intensity of the production, for example extensive grazing compared to feedlots, and the area affected. Dorrough et al. (2007) addressed this question by comparing the impacts of low input native pastures (extensive systems) to introduced pastures where fertilisers are used (intensive systems). The question being addressed was whether intensification in one part of a property can save land elsewhere on the property for conservation outcomes. The authors concluded that at both the paddock and farm scale, increasing productivity via fertiliser application could come at a cost to biodiversity. In contrast, improving grazing management across broad scales was considered likely to result in enhanced profitability and could also benefit native vegetation. The authors concluded that extensive management, rather than more intensification, may be necessary to maintain biodiversity and prevent further long-term degradation of the resource base (Dorrough et al. 2007). This conclusion was drawn, in part, because extensive systems still have a major native pasture component. Even the value of these systems for biodiversity can be diminished through factors such as overstocking and weed invasion, which are related to poor management practices.

Table 20: Potential contribution of different protein sources to the pressures on biodiversity

Protein source	Potential contribution to pressure on biodiversity																						Response	
	Vegetation clearance		Altered fire regime		Altered grazing regime		Altered hydrology		Trampling & compaction		Invasive species		Pollution (air, water, land)		Disease & pathogens		Climate change		Direct loss of biota		Presence of intervention	
	Pressure	Relative pressure	Pressure	Relative pressure	Pressure	Relative pressure	Pressure	Relative pressure	Pressure	Relative pressure	Pressure	Relative pressure	Pressure	Relative pressure	Pressure	Relative pressure	Pressure	Relative pressure	Pressure	Relative pressure	Pressure	Relative pressure	Regu-lation	BMP
Beef (ext)	H	H	H	H	H	H	H	H	H	H	H	H	M	M	M	L	H	H	L	L	M	M
Beef (feedlot)	M[a]	M	L	L	M[b]	M	M	M	M[b]	L	L	L	H	M	M	M	M	M	L	L	H	H
Lamb (ext)[c]	H	M	M	M	H	M	M	L	H	M	M	M	L	L	L	L	M	L	L	L	M	M
Lamb (feedlot)	L[a]	L	L	L	L[b]	L	L	L	L[b]	L	L	L	L	L	M	L	L	L	L	L	H	M
Goat	L	L	L	L	M	M	M	L	H	L	M	L	L	L	L	L	L	L	L	L	M	L
Kangaroo	L	L	L	L	M	M	L	L	L	L	L	L	L	L	L	L	L	L	L	L	M	L
Pork (indoor)	L[a]	L	L	L	L	L	M	L	M	L	L	L	H	M	M	M	M	L	L	L	H	M
Pork (outdoor)	L	L	L	L	L	L	L	L	L	L	L	L	M	L	M	L	L	L	L	L	H	M
Chicken (indoor)	L[a]	L	L	L	L	L	M	L	M	L	L	L	H	M	M	M	M	L	L	L	H	M
Chicken (outdoor)	L	L	L	L	L	L	L	L	L	L	L	L	M	L	M	L	L	L	L	L	H	M
Fish (wild catch)	L	L	L	L	L	L	M	L	H[O]	H[O]	L	L	L	L	L	L	L	L	H[w]	H[w]	H	M
Fish (aquaculture)	L	L	L	L	L	L	H	M	L	L	M	M	H	M	M	M	L	L	L	L	H	M
Plant-based	H	M	M	M	M	L	H	H	H	M	H	M	M	M	L	L	M	L	L	L	M	M
Dairy	M	M	M	M	M	M	H	M	H	M	M	M	M	M	L	L	H	M	L	L	H	H
Eggs (indoor)	M[a]	L	L	L	L	L	M	L	L	L	L	L	H	M	M	M	M	L	L	L	H	M
Eggs (outdoor)	L[a]	L	L	L	L	L	L	L	L	L	L	L	M	L	M	L	L	L	L	L	H	M

Relative pressure = Contribution relative to other protein sources
H = high; M = medium; L = low
* Extent of contribution
[a] Largely due to clearing associated with feed
[b] Recognises that feedlot animals spend part of their lives extensively grazing
[C] Recognises that the lamb industry is a small, but growing, part of the sheep industry. If wool sheep were included, the results would shift significantly
[O] Ocean floor dragging
[W] Wild catch/harvest
BMP = Industry driven Best Management Practice

H	H	Most significant issues of concern where the potential contribution to biodiversity pressure is high and the relative contribution is high

In terms of aquatic biodiversity, fisheries (wild and farmed) have the main impact. The decline in wild fisheries around the world and the subsequent impacts on biodiversity has led to an increasing focus on aquaculture, with Australia producing increasing amounts of salmon and other sought after products. Aquaculture has a wide range of potential impacts on biodiversity. This includes the impact on wild fish populations which are harvested to provide fish pellets, as well as the impacts of additives to aquaculture pens, the waste they produce and the fish that can escape.

The contribution of each protein source industry to the different pressures on biodiversity has been outlined in Section 4 and 5, and in particular summarised in the industry tables in Section 5. The following provides brief comparative commentary on each of these pressures.

6.1.1 Vegetation clearance

Clearance of vegetation for production purposes in Australia has obviously been most commonly associated with the extensive industries. In this respect the red-meat industry, most notably beef, has been the biggest contributor, although as previously noted, this was sometimes done at the behest of public policy. Comments made to the authors in respect to lamb production reflected a misperception that the lamb and sheep sectors are one and the same. In the past, the lamb sector has been considerably smaller than the wool sector, and much of the land clearance associated with sheep has been for wool. Hence in the authors' assessment in Table 20, the relative contribution to land clearing for lamb is considerate moderate, rather than high as would have been the case for the total sheep industry.

Land clearing for grains has also been significant, both for protein production as well as for feed associated with intensive red and white-meat production. Here, and again, land clearing has been the result of past action (and policy), and the total land dedicated to cropping has long reached a plateau.

6.1.2 Altered fire regimes

The main contributor to altered fire regimes, and the consequences of this for the composition, abundance and distribution of species across huge tracks of Australian land, has been the extensive red-meat industry. It has also been an area of significant R&D investment in northern Australia, including through investment by MLA.

Burning also takes place in some grain production areas, although this has significantly declined in recent years. The presence of the industry across 20 million ha would have had some impact on changed fire regimes, but the nature of this impact remains an area for further research.

6.1.3 Altered grazing regimes

The impact of grazing regimes on biodiversity is covered extensively in Section 4. Red-meat production makes the most significant contribution to this pressure in Australia, as it does across the globe, due to the extensive production nature of much of the industry. Even cattle in feedlots graze extensively at some point in their life cycle. Conversely, it should be recognised that feedlots allow the extensive industry to reduce grazing pressure during periods of drought.

Grazing management is an area where the red meat industry can, and has, improved production practices. Changing grazing management regimes can vary the efficiency in which meat is produced. While the conversion process of feed into protein can be more easily manipulated in intensive production systems, this is less likely to have a beneficial biodiversity impact than manipulation of the feed conversion rate in extensive systems, but only where the process of improving grazing management systems is led by the dual goal of conversion efficiency and biodiversity conservation. The issue of feed conversion and efficiency is discussed in Box 11.

Box 11: Feed use and conversion by different protein sources

The main animal-based protein sources in Australian diets (beef, lamb, chicken, pork and fish) utilise a variety of feed sources to produce meat or fish. Beef, sheep and dairy cattle mostly utilise introduced pastures, although grain is being consumed in increasing amounts. Around 30% of beef production, for example, is finished in high density feedlots, while for sheep-meat this is only around 3%. The chicken and pork industries mostly use high density facilities, so are highly reliant on grain for their meat production. Currently farmed fish, which are carnivorous, are fed fish pellets to produce flesh. This mostly comes from wild population sources.

The amount of grain used by different livestock industries as a feed source in 2007 is shown in Figure 8. Beef feedlots used the highest amount of grain, closely followed by the dairy industry, with chicken not too far behind. The efficiency of converting these feed sources to kilograms of meat is a subject of interest to both the producers of meat and its consumers. For example, the less grain that is used per kg, the lower the costs of production and potential environmental impact. Table 21 shows the feed conversion of poultry, pork, beef and farmed fish from kilo of feed to kilo of edible product. Beef has the least efficient conversion rate, and farmed fish the highest.

Figure 8: Feed use by Australian livestock industries in tonnes for the year 2007 (Source: Spragg 2008). Units are million metric tonnes

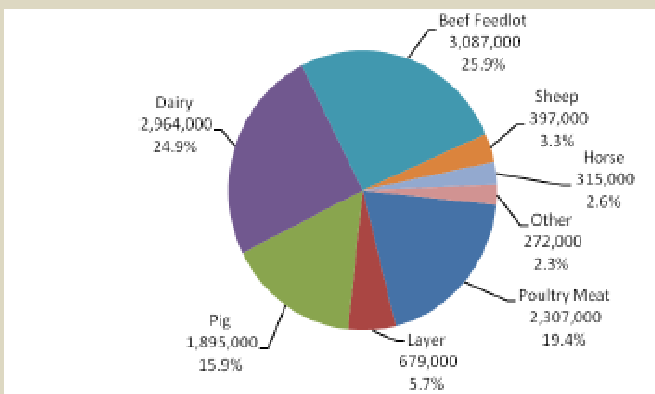

Table 21: Kilo feed per kilo edible product

Poultry[a]	2.1-3.0kg
Pork[a]	4.0-5.5kg
Beef[a]	10kg
Farmed fish[b]	1.0-3kg

Source: [a]CAST 1999; [b]Aquamedia 2009

6.1.4 Altered hydrology

All agricultural production impacts upon hydrology in one way or another, and the impact of extensive industries can be different to the intensive industries. The use of the 'virtual water' concept to assess water use by different food production systems, and its value as a comparative tool, is covered in Weidemann et al. (2009). Associated with the high level of vegetation clearance by the industries (red meat, grain and dairy in particular) is a high level of hydrological intervention, from natural systems to modified ones. The consequences of this, such as salinity and reduced environmental water flows, are discussed in Section 4. This is an example where the impact on biodiversity is one step removed from the immediate environmental impact yet can be considerable.

The intensive industries are also shown to have some impact on hydrology, particularly through their high water extraction, however, as a proportion of total water use in agriculture, remains relatively small.

6.1.5 Trampling and compaction

Most industries in Table 1 contribute to this, however, as to be expected, the extensive hoofed animal industries (cattle and lambs) and heavy machinery industries (grains) feature prominently. Of note, however, is our inclusion of the fishing industry, which has created enormous damage to ocean floor habitats through 'trampling-like' activities such as dragging nets, dredges and rakes along the sea bed.

6.1.6 Invasive species

The extensive grazing industries have been among the major contributors to this pressure on biodiversity. Strong correlations can be made with the land-clearing discussion above, and again it should be noted that the lamb industry should not be confused with the wider sheep industry which has had a major impact in the spread of environmental weeds.

Early attempts at aquaculture have contributed to invasive species of exotic fish in streams and have been blamed for the loss of some species of native inland river fish in Australia.

6.1.7 Pollution

With methane dealt with under the 'climate change' pressure, the contribution of intensive feedlot production systems (beef, pork, poultry, dairy and aquaculture) are shown in Table 20 to have the highest concern for pollution. This is reflected in the regulatory responses of governments. Extensive industries have forms of pollution too, including nutrient transport through erosion and other hydrological processes.

The impact on biodiversity from pollution can be both aquatic, through direct toxicity of pollution releases into water ways or indirect effects on oxygen levels resulting from algal blooms, and terrestrial through toxic exposure to farm chemical and waste.

Box 12: Organic waste from high density feedlots and the nutrient concentration of by-products for a range of protein sources

The leakage of effluents produced by high density feedlots into waterways and groundwater is one of the major potential environmental impacts of this industry. Tables 22 and 23 provide data on the amount of waste per annum for feedlots in Queensland, where many of the operations are concentrated. In this context, cattle feedlots produce the greatest amount of waste. The nutrient content of the waste is another measure of the potential impact of feedlots on the environment. Cattle and poultry systems have similar % contents of solids and total N in their by-products, with poultry having higher levels of P and cattle higher levels of K. In comparison, piggeries have a very low percentage of solids in their by-products, but the highest content of total nitrogen. These figures illustrate the different challenges faced by high density feedlots with different animals to manage and the potential impact if effluent escapes into the environment.

It should be noted that intensive industries are heavily regulated to the point that the potential impacts are unlikely to be realised. In response to regulations, industry quality assurance and compliance initiatives, such as the National Feedlot Accreditation Scheme in the case of beef, ensure that best management practice are in place across the majority of the feedlot industries.

Table 22: Tonnes/annum waste from high density feedlots production (Queensland)

Cattle	395,000
Pig	19,000
Poultry	202,000
Dairy	5,300
Mushroom	11,000

Source: Qld EPA 2007

Table 23: Percentage content of nutrient concentrations in by-products

Content (%)	Cattle	Piggery	Poultry	Mushroom
Solids	73	2	70	50
Total N	2.2	3.4	2.7	1.8
P	0.8	4.7	2.5	0.8
K	2.3	0.8	1.4	1.6

Source: Qld EPA 2007

6.1.8 Disease and pathogens

From a biodiversity aspect this area is under-explored and the results in Table 20 may reflect lack of data about the relationship between disease and pathogens and biodiversity. Intensive systems have been attributed a higher level of contribution to risk due to the capacity for disease to move more quickly between animals.

6.1.9 Climate change

The beef cattle and sheep industries contribute 70.1% of the greenhouse gas emissions from agriculture, followed by the dairy industry at 11.6% (Figure 9). These numbers are high because most of the agricultural emissions come from enteric fermentation. Pigs and poultry, which have different digestive systems, contribute 2.8% of emissions in Australia. Land clearing for pasture establishment is excluded from the calculations – if included, the emissions for cattle and sheep would increase. This comparison is relevant to this report because of the link between greenhouse gas emissions and human-induced climate change. The threats posed to biodiversity by climate change were introduced in the section on trends in biodiversity at the start of this report.

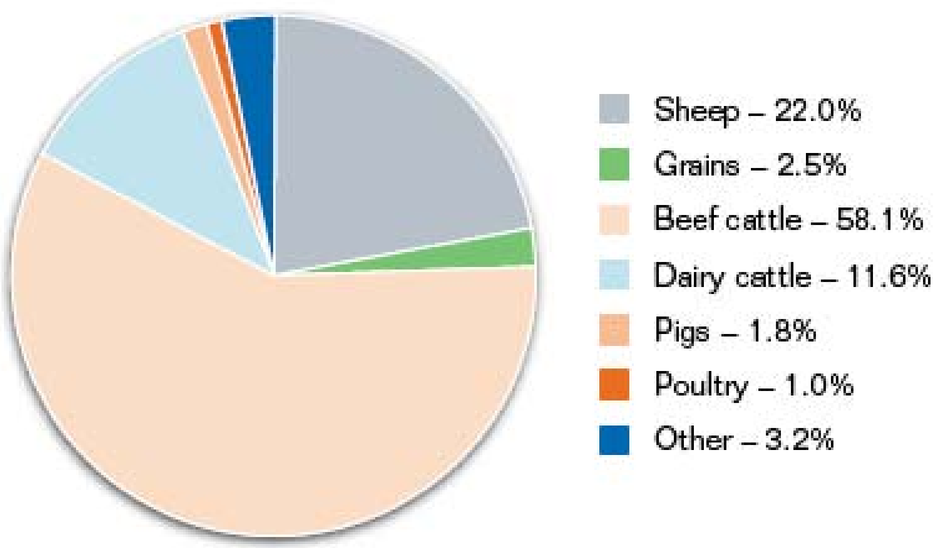

Figure 9: Contribution of rural sub-sectors to Australia's agricultural emissions. Excludes emissions from land clearing (Source: Garnaut 2008)

6.1.10 Direct loss of biota

Two industries explored in this report deal with the direct harvest of wild biota (kangaroos and fish). Of the two fishing remains the major concern, with evidence of over-fishing in both Australian waters and elsewhere across the globe. Although consumer and interest groups hold strong and diverse views about kangaroo culling for meat or for reducing total grazing pressure, concerns about less common species being impacted have been allayed by the scientific community (see Section 4).

7 Conclusions and Recommendations

7.1 Narrative summary

The beef and sheep industries in Australia have been critical in the development and shaping of Australia, from the time of the First Fleet. They have played a significant role in the economic fortunes of the nation in the past and continue to make a major contribution, particularly in the export market. They have also played an important role in the psyche of Australia and in defining the character of the Australian ‘outback’ culture, as well as helping shape the typical Australian diet. National dietary guidelines indicate that 3-4 serves of lean red meat a week can provide easily digestible and high quality protein, as well as a range of important and accessible nutrients such as iron, zinc and Vitamin B12. As such, it can make an important contribution to a diet that includes a wide variety of fresh, unprocessed foods and a lifestyle incorporating exercise.

While wool was, and still is, the major product of the sheep industry since the arrival of a few animals in Botany Bay, the production of lamb has always been an important part of the industry and is becoming increasingly so. Cattle moved from the shores of southern and eastern Australia to the inland and the north in the mid 1800s in the great cattle drives. Since then, cattle have come to occupy a large area of the Australian semi-arid and savanna landscapes in central and northern Australia. This operates along-side more intensive production in southern and eastern Australia on exotic pastures, as well as a burgeoning feedlot industry that has developed in the last few decades.

In addition to being an important economic and cultural force, the beef and sheep industries have left a lasting impact on the biodiversity of Australia. This ranges from the direct impacts of land clearing for conversion to exotic pastures, overgrazing (particularly in drought conditions) and trampling to indirect impacts such as the introduction of environmental weeds, changes to fire regimes, altered hydrological flows and major impacts on soil (e.g. loss of soil and biological crusts, erosion, compaction). Increasingly, the impact of the sheep industry on dingo populations has also been shown to have a potentially major indirect effect on biodiversity in situations where feral predators such as foxes and cats are not effectively controlled. Because the grazing industry covers such a large area of Australia, these impacts are widespread and obvious, especially during drought, compared to protein sources that utilise high-density systems. Added to this is the contribution of the beef and sheep industries to greenhouse gas emissions through land clearing and methane production. These contribute to anthropogenic climate change, which has uncertain but likely major impacts on biodiversity.

While the direct impact of building feedlots is relatively small, potential environmental impacts include pollution of water sources and the impact of grain and water use by these industries. Methane production in areas where cattle and sheep are concentrated can also have an indirect effect on biodiversity through its contribution to climate change. Some research on the environmental impacts of feedlots was undertaken in Australia in the 1990s in support of National Guidelines and Code of Practice documents and the regulatory requirements in each state. In turn, these are reference documents for the National Feedlot Accreditation Scheme (Ausmeat 2009).

In response to the documented and potential impacts on biodiversity, the beef and sheep meat industries have implemented a broad range of responses including research into sustainable land management practices and how the industry can minimise the impacts on biodiversity. It has instigated a number of training and education initiatives, developed codes of practice, monitoring systems management guidelines which increasingly include environmental considerations, and seen changes to land and water management practices. In parallel with these initiatives, governments have introduced a range of legislation and regulations, supported research and training programs, as well as provided a number of incentives for improved management and restoration of landscapes.

In the case of beef and sheep feedlots, potential exists to use these to reduce grazing pressure and cattle numbers or set aside areas for biodiversity maintenance while still achieving the same product output. Such strategies are certainly applied during times of drought.

Even if current management practices incorporate biodiversity conservation into their objectives, the legacy of past land use practices casts a long shadow over the beef and sheep industries in Australia. This has led to widespread and ingrained perceptions that these industries have had a major and negative impact on the nation’s biodiversity, with ongoing calls to reduce the number of stock and replace them with an industry based on kangaroos. On a global scale, the impact of meat production on natural systems through clearing (for both pastures and grain to feed cattle in feedlots) and greenhouse gas emissions has seen similar calls to reduce consumption and hence the number of stock. The major protein alternatives to beef and sheep meat are chicken, pork, eggs, dairy products and fish. Emerging industries include goats (mainly exports) and kangaroos, which currently contribute a small proportion to the economy. Chicken production in Australia is concentrated on the coast in a number of large farms, where animals are kept at high densities. Pork production is also an increasingly intensive industry. There has been minimal research in Australia on the impacts of these production systems on biodiversity, with the focus being on animal welfare and human amenity. Dairy production systems are very intensive with high use of fertilisers and water to maintain the exotic pasture base required by dairy cattle. While dairy farms can have a major impact on biodiversity, both directly and indirectly at the farm level, they occupy a relatively small area of land compared to beef and sheep meat industries.

The decline in wild fisheries around the world and the subsequent impacts on biodiversity has led to an increasing focus on aquaculture, with Australia producing increasing amounts of salmon and other sought after products. Aquaculture has a wide range of potential impacts on biodiversity. This includes the impact on wild fish populations which are harvested to provide fish pellets, as well as the impacts of additives to aquaculture pens, the waste they produce and the fish that can escape.

The goat industry in Australia is largely based on wild, rangeland goats, which have been identified as a key threatening process to biodiversity in Commonwealth legislation. While the commercial harvest of goats has been developed partially in response to the need to reduce their impact, there has been minimal research on the impact of this practice on biodiversity. The commercial harvest of kangaroos and wallabies is also based on wild populations of six common species. While these species are native to Australia, changes to the environment due to agriculture have seen their numbers increase to unsustainable levels in some regions. This has led to subsequent impacts on systems managed for both production and conservation.

The national dietary guidelines indicate that a well-planned plant-based diet can provide most, but not all, the protein and nutrients humans require. The key nutrients supplied by meat, fish and poultry that aren’t naturally provided by plants are Vitamin B12 and long-chain Omega-3 fatty acids. Supplementation or the use of fortified foods can provide these in a diet that doesn’t include animal products. Genetically engineered plants are being developed that produce long-chain Omega-3 fatty acids, which will provide an alternative to fish which is currently the main source of this nutrient. Soybeans are an important source of protein in a non-meat diet, with Australia currently being a net importer of this product.

Crop production, however, also has its impacts on biodiversity, including altering the natural hydrological regimes of landscapes and contributing to the externalities of nutrient run-off and pesticide transport. The benefits of genetically modified plants can be countered by their potential to reduce agricultural plant diversity and escape and affect the genes of related species.

Many industry initiatives of the beef and sheep industries have the potential to improve the management of biodiversity, but as always the crunch comes in terms of their implementation. In order to minimise the impact of beef and sheep meat systems on biodiversity, the conservation of natural resources has to become a core and integral part of production systems rather than perceived as an optional extra if times are good. The growing number of innovative land managers implementing sustainable land and water management can be used as examples to others and their practices applied more widely. Managing for biodiversity outcomes needs to be rewarded in the market and through government programs, compared to some of the perverse policies in the past. The concept of stewardship payments for the ecosystem services (such as carbon, water and biodiversity) provided by the farming community to the wider society warrants further consideration (e.g. Comerford et al. 2006).

Some of the on-ground practices that can be broadly applied are matching grazing systems to carrying capacity at a number of scales and taking total grazing pressure into consideration when calculating sustainable stocking rates, both in exotic and native pasture systems. Elevating the concept of total grazing pressure and grazing regimes into the language of grazing should help bring a better understanding of impacts of biodiversity. Setting aside some areas from grazing by stock and feral animals will help protect and maintain species that are sensitive to grazing. Temporary destocking is also a critical management activity, especially before the major impacts of drought – which is best done in a risk management framework. Taking into account the variability in impacts and responses, both in space and time, is important when trying to understand and describe the impact of grazing systems. A diversity of management practices and vegetation types is the key to maintaining biodiversity, from the local to the landscape scale. Importantly, robust and long-term monitoring systems are required to measure the impact of these changes to biodiversity and production systems.

Methods to reduce methane production from cattle and sheep are under investigation, although significant challenges remain. Challenges are also found in the calculation of the environmental costs and use of water in livestock production. Only by clearly demonstrating the impact of the beef and sheep industries on the environment generally, and biodiversity in particular – and showing that it is being minimised and where possible reversed – will the overall negative perceptions of these industries begin to change. Developing and building on partnerships with groups such as Bush Heritage Australia should lead to positive outcomes for both ‘industries’.

7.2 Recommendations for the red meat industry

7.2.1 Industry level recommendations

Improve conversion efficiency

The red-meat industry has invested heavily in improving the grazing management practices of graziers across the different ecological zones of Australia. Improving pasture utilisation efficiency has been one such area of investment, however, the ethic behind 'More Beef from Pastures' needs to be extended to cover the conversion efficiency across a range of inputs, including water, and with a view to maintaining and enhancing biodiversity. Improving conversion efficiency may not necessarily provide a benefit to biodiversity, and indeed may lead to more intensive systems with adverse biodiversity consequences.

By supporting this study, the red-meat industry has shown its willingness to benchmark its performance, for better or worse in the short-term, against its protein-based competitors. This benchmarking process should be extended to instil a culture of conversion competitiveness within the industry and not just across industries.

Reduce the hoof-print

The intensification of red-meat production through feedlots changes the nature of the 'hoof-print' and requires the concept of conversion efficiency to include both the inputs (i.e. feed) and outputs (i.e. waste). Many feedlots are located on the basis of efficient access to market and are predominantly located in areas where there is grain grown, providing inputs and also outlet for manure as fertilizer. Such synergies need to be encouraged.

Match land use to land capability

The notion of matching land-use to land capability is not new, and though it has been adopted in a coarse sense among the different livestock industries, there is considerable room for improvement at finer scales, including paddock and sub-paddock scales. Knowing where livestock should be grazed is only a part of successfully matching land use and capability. Day-to-day management of livestock within a complex ecosystem is the challenge – from genetic selection to pasture management, stock movement, pasture and groundcover management, water distribution and nutrient application. The grazing industry should follow the grain industry's lead in investing in precision agriculture innovations which improve resource-use efficiency and resource protection.

Embed a biodiversity culture into grazing (demythologise biodiversity)

Research into grazing and mixed farming systems is demonstrating that biodiversity can contribute to profitable and sustainable farms. Indeed, biodiversity can be made an integral part of a profitable grazing system and can even help reduce input costs, such as where native vegetation is managed to harbour predators of agricultural pests. Moreover, good management of livestock has been shown to contribute beneficially to the environment – the caveat here being good management, as not all graziers are yet good managers. From a grazier's perspective, industry led biodiversity programs are likely to have a level of credibility difficult for others to attain, particularly as non-industry parties may be seen to hold interests and agendas contrary to graziers' values and aspirations. There is a need, therefore, for industry to increase its investment in exploring and demonstrating how the management of native vegetation, and biodiversity more generally, can be incorporated into and even form the basis of profitable operations. Graziers sharing their experiences with other graziers can have an enormous impact in demonstrating this.

Breakdown institutional silos

The legacy of the commodity-by-commodity approach to servicing agriculture that started in the mid nineteenth century hinders environmental management today. Scientific reward systems tend to be disciplinary rather than inter-disciplinary based, and production and natural resource management programs are all too frequently budgeted, managed and implemented in institutional silos (often in separate buildings, towns or even States depending on the organisation). Graziers like most people tend to align themselves to people and institutions they are comfortable with, and unless these people and institutions are fully cognizant of system complexities, then only narrow messages that reinforce the comfort zone will be heard, discussed and carried forward into action. Many industry bodies reinforce a narrow view that industry investments should focus on production and profit while government investment should focus on environment and industry welfare. This is contrary to the often unstated inclinations of industry members, whose sense of place demands a different approach. The red-meat industry has gone some way towards embracing a biodiversity ethic, however it can help instil this ethic into other agencies through the way it forms partnerships, makes its expectations known and directs investment.

Acknowledge and reward good management

Everyone likes to be acknowledged for generating something of value to others. Red-meat producers, in this sense, are like everybody else and also do not like to see poor performance rewarded. Farmer support schemes need to be transformed into reward payments for specified actions and outcomes that result in positive and lasting change, including the provision of environmental services such as enhanced biodiversity. Already there is a growing movement towards paying graziers/private landholders for the services they provide to society, particularly biodiversity conservation, which are above and beyond their duty of care. Further growth of such approaches needs to be stimulated through government and catchment management programs.

Collaborate

As laudable as the initiation of this project was, there is benefit in building on it in cooperation with other protein industries and with the value chains of these industries. Moreover, while Australia competes with other countries for red-meat trade, our reputation can be tarnished by the generalised view often formed by observing less environmentally sustainable competitors. There is a delicate balance to be considered in working with competitors to improve their performance for the good of the overall industry and taking advantage of competitive advantage based on sustainable production. Industry discussion on biodiversity at the international level needs to take place in parallel with, and possibly in response to, the many government discussions that take place in this topic.

Monitoring

Meat & Livestock Australia has supported a range of vegetation monitoring efforts, including AussieGrass under the auspices of the Managing Climate Variability program. Maintaining support for remote sensing of pasture condition provides data not only to underpin important risk management tools to support grazier decisions, but can help provide broad assessments of biodiversity condition. On-the-ground, many graziers participate in biodiversity related networks such as Birds Australia. The feasibility of using these networks to periodically aggregate specific data on grazing lands should be explored. Such endeavours would send a message to biodiversity-minded graziers that their industry values their contribution and can add value to their voluntary data collection efforts.

7.2.2 Enterprise level recommendations

The following enterprise level recommendations are relevant to protein producers that incorporate livestock into their enterprise, including feedlots that finish animals in their businesses. For farming enterprises that grow grain for protein production, either for human or animal production, management approaches that maintain soil health and retain a percentage of the property for biodiversity conservation are important. The planning recommendations apply to all properties.

There is a large variety of producers that incorporate protein into their production systems, from small enterprises who specialise in rare breeds of animal, to the large pastoral stations of thousands of square kilometres in size. Some properties specialise in cattle (particularly in the northern rangelands) or sheep, whereas many more are mixed enterprises. In some cases native pasture forms the basis of the production enterprise, especially in the rangelands and in some regions which produce fine wool. Most protein production properties however utilise some form of introduced or exotic pastures. The ownership of properties also varies, from large corporations who may own several properties, to small family owned farms.

Despite this variation, there are a number of fundamental principles that apply to managing a property to make biodiversity management part of the core business and maintain the sustainability of the enterprise. These are based on decades of experience and research and have been reproduced in many forms over the years. Some of the percentage figures in the recommendations will need to be adjusted for local environmental and climate conditions. However, there is unanimous agreement about the need for effective planning, soil, ground cover and pasture management, the importance of setting aside areas for biodiversity conservation and using strategic grazing to match carrying capacity to land capability.

Planning

- ➢ Develop a vision and set clear goals (personal and financial) for the property
- ➢ Develop, implement and update a property management plan that incorporates biodiversity conservation as a core component
- ➢ Develop a risk management plan, particularly for use in drought and economic down-times
- ➢ Be aware of and adhere to the relevant regulations for your property

On-ground management

- ➢ Match stocking rate to carrying capacity
- ➢ Keep Total Grazing Pressure within the sustainable capacity of the property
- ➢ Manage both the animal and pasture component of the enterprise
- ➢ Use a strategic approach to grazing management, including the use of spelling
- ➢ Utilise perennial pastures

- Maintain diversity in management practices and vegetation type and structure, including pastures
- Take into account the variability in impacts and responses, both in space and time
- Keep soils healthy and in good condition
- Maintain ground cover above 60% - 70%
- Set aside at least 10-15% of the property as core areas for biodiversity conservation
- Maintain or restore a minimum of 30% woodland or forest cover on properties
- Keep weeds and feral animals in check

Monitoring

- Monitor the impacts of management on production and biodiversity goals and incorporate results into new practices

Specific enterprise recommendations, based on ecological principles, have been developed in some regions. For example, McIntyre et al. (2002) developed a number of principles for the grassy woodlands in eastern and southern Australia. This study developed six over-arching principles for management at the property scale, which have a number of detailed recommendations sitting below them. The ones that identify specific numeric targets are included in italics below. While the broad principles are relevant to all farming enterprises, some of the specific targets may require refining depending on the context in which they are applied.

Principle 1: Property planning and management should include a long-term vision which considers the whole of the property and its place in the catchment

Principle 2: Manage soils to prevent erosion and to maintain productive capacity and water quality

Keep the amount of bare ground exposed to no more than 30-40% of the ground surface in pastures

Principle 3: Manage pastures for production and to maintain the variety of plants and animals

Graze conservatively to maintain dominance of large and medium tussock grasses over 60-70% of the native pastures

Limit the extent of intensive land use (grain and forage cropping, sown pastures) to a maximum of 30% of the property area

Principle 4: Maintain local native trees for the long-term ecological health of the property and catchment

There should be a minimum of 30% woodland or forest cover on properties

To be viable in the long-term, woodland patches should be a minimum of 5-10 ha

Principle 5: All properties require core conservation areas for species that are sensitive to agricultural land uses

Manage at least 10% of the property as core conservation areas

Principle 6: Watercourses and riparian areas are particularly important to the ecosystem and grazing enterprises, and require special management

8 Research gaps and future priorities

The paucity of data, both Australian and international, on the impact of specific industries on biodiversity reflects the dearth of research that has been undertaken, for many industries at least. The red meat, cotton and fisheries industries are notable exceptions, and each should be acknowledged for improving their environmental stewardship in recent years.

The role of this project has not been to identify research priorities for industries other than the red meat industry, although other protein-based industries could do well to replicate some of the red meat industry's environmental research specifically relating to biodiversity.

As noted in Section 4, identifying the nature of the grazing regime being studied and the total grazing pressure on a site (including the stock breed and condition), are important aspects of teasing apart the impacts of grazing on biodiversity. Describing the type and condition of vegetation being grazed, as well as the management history where possible, is also an essential element. As this information is often missing, or buried in research and other publications, the authors recommend MLA immediately invest in pulling together as much of this information as could be found for the livestock grazing industry. This is beyond the scope of this review, but would help better understand the interactions between domestic stock grazing and biodiversity in Australia.

Other potential areas for research identified during the course of this review follow. In particular, they draw on recommendations made by various authors associated with the recent publication, Ten Commitments: Reshaping the Lucky Country's Environment (Lindenmayer et al. 2008):

- Describing the benefits of land management versus 'locking land away' for biodiversity outcomes;
- Find out what the different monitoring programs across protein production landscapes (both for production and biodiversity outcomes) tell us about management systems (needs rewording).
- Developing an understanding of the way people perceive different protein based industries and their impact on biodiversity (for example, dairy farms in high rainfall zones compared to grazing in the arid zone), based on some of the techniques used in social research;
- Developing a better understanding of the interactions between grazing and other potential threats to biodiversity such as altered fire regimes and weeds;
- Describing the variation in space and time of the impacts of grazing regimes on biodiversity and the responses to them;
- Describing how to restore functioning ecological communities instead of simply fencing stagnating remnants or planting lines of trees;
- Identifying how best to enhance the adoption of perennial production systems as rapidly as possible, including through policy initiatives that can be conveyed with credibility by industry, and ensuring graziers have the skills to manage these systems;
- Finding better ways of dealing with the pervasive threat of feral predators;
- Initiating or reinstating fire regimes that encourage woodland regeneration in grazing landscapes;

- Adapting comprehensive and robust biodiversity monitoring programs, linked to measurement of the efficacy of management;
- Developing new ways to improve integration of farm forestry with grazing management and on-farm biodiversity conservation;
- Exploring equitable ways for society to pay for ecosystem services specific to red-meat production;
- Facilitating the transformation of grazing activity to ensure land use matches land capability;
- Improving seasonal climate forecasts to help deal with the variability of Australia’s climate, and translating these into appropriate grazing management responses;
- Integrating a biodiversity conservation ethic into livestock grazing systems in both extensively and intensively managed landscapes through systems-oriented extension;
- Invest in labour-saving innovations that enable graziers to focus on the social and environmental elements of the triple bottom line;
- Intensifying research effort to improve our knowledge about the biodiversity-ecosystem functioning-ecosystem services relationship.

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10 Appendices

10.1 Appendix 1 Terms of Reference

Purpose and description

Loss of biodiversity is a serious environmental issue in Australia and all forms of food production contribute to this loss in varying degrees. Severe losses have occurred in some agricultural land, particularly regions subjected to continuous cultivation, but are also significant in some pastoral regions. State and Federal governments have developed biodiversity strategies to provide policy direction for achieving biodiversity conservation through reserves and national parks. There is increasing recognition – in industry, government and amongst environmental non-government organisations – that livestock production systems can play a powerful role in reversing the decline of Australian ecosystems.

The red meat industry recognises its responsibility in biodiversity conservation and management, and the value to production systems provided by sustainable management of natural resources. However, incorporation of biodiversity conservation objectives into livestock production systems requires an understanding of the impact of past and present management practices on biodiversity, and a capacity to document and monitor performance.

In view of the increasing concern to ensure ethical and responsible choices in food consumption, it is critical for MLA and for the wider Australian meat and livestock industries to analyse and monitor the impact of production on key environmental values, and to contribute to consideration of, and improvement in, management of native biodiversity in agricultural systems. In addition to being responsive to community concerns and to the challenges of maintaining environmental best practice, MLA also has a responsibility to ensure, as far as possible, that reporting of the environmental impacts of production systems is fair and comprehensive.

MLA seeks, therefore, to gather the most accurate, scientifically robust information to establish the evidence base for industry performance, to inform better land management, to inform public debate and help shape conservation programs.

Objectives

The objectives of the review project are to:

- Review the literature to establish the impacts – positive and negative, historical and current, direct and indirect – of the beef and sheep meat industries on Australia's biodiversity (aquatic and terrestrial).

- Identify any significant gaps in the literature as areas for further research.

- As far as possible, compare the biodiversity impact of red meat production systems with other major alternative dietary protein production systems in Australia, and, in particular, industry approaches to conservation.

- Provide recommendations for:

1. Practical industry-wide and enterprise-level monitoring of biodiversity values and conservation management in livestock production systems.

2. Industry and enterprise-level policies, strategies and practices that advance biodiversity conservation while maintaining or enhancing productivity and profitability in red meat production systems.

3. Approaches to improve producers' capacity to contribute to production and conservation goals.

4. Processes to improve the capacity of the red meat industry to contribute to conservation science and public policy for biodiversity outcomes.

- Based on the literature review and analysis, prepare a report for inclusion on the MLA R&D database, a 2-4 page fact sheet in the MLA style for hard copy and online publishing, and submit a journal paper for peer review in the third quarter of 2009.

The review and systems analysis should consider:

- Published scientific papers and reports
- State and Commonwealth government and industry project reports where available
- Practical improvements to sustainable management for biodiversity outcomes, i.e. combining native biodiversity conservation and production in grazing systems.
- Options for providing reliable and comprehensive information on biodiversity impacts and related environmental issues to internal and external stakeholders.
- Documented changes in industry attitudes and practices over time, and how these may translate into environmental change.