

# Managing animal disease risk in Australia: the impact of climate change

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## Summary

Climate change is one of a number of factors that are likely to affect the future of Australian agriculture, animal production and animal health, particularly when associated with other factors such as environmental degradation, intensive animal production, an increasing human population, and expanding urbanisation. Notwithstanding the harshness and variability of Australia's climate, significant livestock industries have been developed, with the majority of products from such industries exported throughout the world. A critical factor in achieving market access has been an enviable animal health status, which is underpinned by first class animal health services with a strong legislative basis, well-trained staff, engagement of industry, effective surveillance, good scientific and laboratory support, effective emergency management procedures, a sound quarantine system, and strong political support. However, enhancements still need to be made to Australia's animal health system, for example: re-defining the science-policy interface; refining foresight, risk analysis, surveillance, diagnostics, and emergency management; improving approaches to education, training, technology transfer, communications and awareness; and engaging more with the international community in areas such as capacity building, the development of veterinary services, and disease response systems. A 'one health' approach will be adopted to bring together skills in the fields of animal, public, wildlife and environmental health. These initiatives, if managed correctly, will minimise the risks resulting from global warming and other factors predisposing to disease.

## Keywords

Animal health – Australia – Climate change – Foresight – Policy development.

## Introduction

Climate change is one of a number of factors that are likely to affect the future of Australian agriculture, animal production and animal health. Climate change is likely to increase the vulnerability of the primary industry sector to both biophysical and economic stresses. In particular, it is likely to have a significant effect on the supply of water as a result of the combination of increased temperatures, increased evaporation, and reduced rainfall. Increased climate variability and increased frequency and severity of extreme weather events such as drought are also likely to lead to additional stresses (59).

Although there is quite a substantial scientific literature on the likely effects of climate change on human health,

the literature on its likely effects on animal health and production is sparse (3). There is a rapidly growing literature on the future of animal health, including aquatic animal health and veterinary public health (26, 27, 28, 32, 34, 37, 40, 47, 78). This literature focuses particularly on 'one medicine' and 'ecohealth', but does not often discuss the likely effects of climate change on animal health and production, although this is not always the case (13, 25). More recently, the Food and Agriculture Organization (FAO) of the United Nations has reviewed the effects of global livestock production on the environment, focusing in particular on its effects on land degradation, water, biodiversity and climate (67).

This paper explores a number of case studies that illustrate the likely effects of climate change on animal health and

production in Australia and discusses desirable policy settings and means of adapting to the challenges presented by climate change. It provides an overview of approaches in Australia to managing animal health risks and explores how these systems might be strengthened to provide greater resilience against future risks arising from the effects of climate change. It outlines the organisation of the country's animal health services and describes a range of policies and programmes that are in place or being developed to increase the preparedness for, and resilience to, changes to the risk of animal diseases from climate change and other causes.

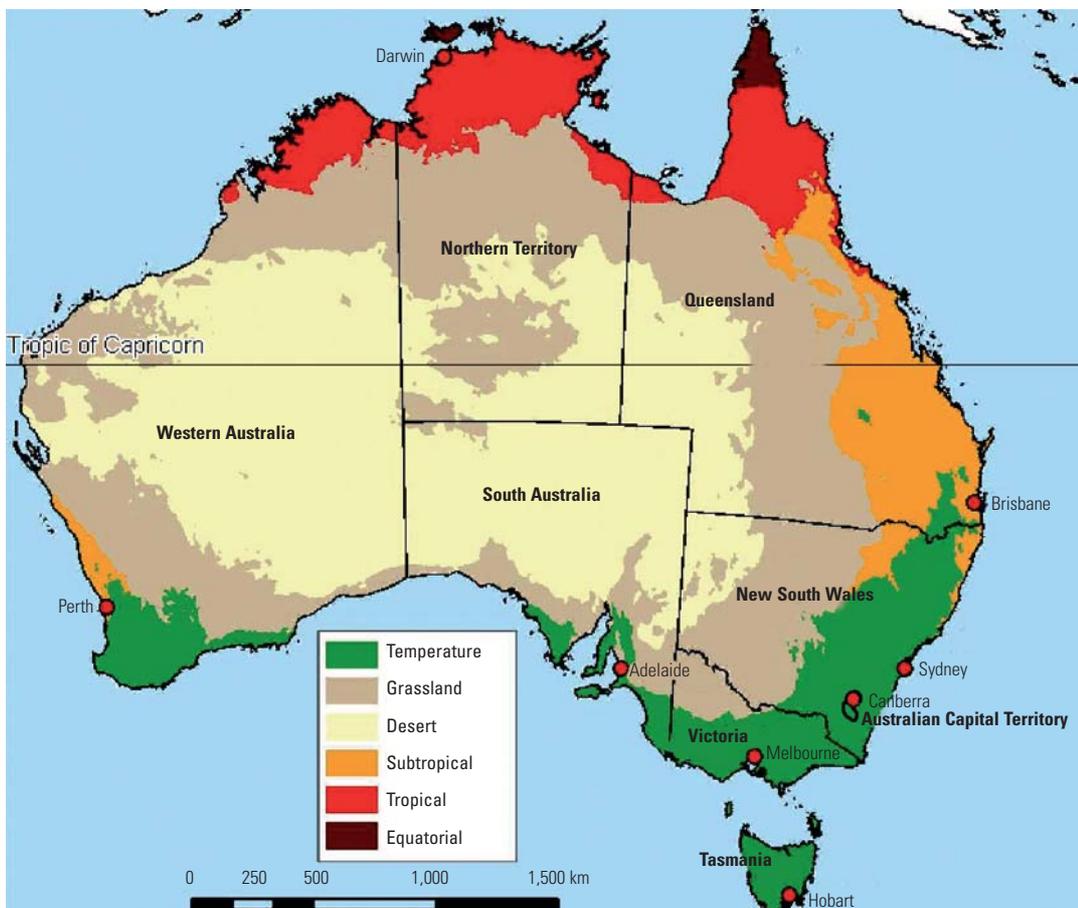
## Geography and climate

Australia is the largest island and the smallest continent in the world and has a population of 21 million people. Australia's climatic zones range from the tropics and subtropics in the north to the Mediterranean and temperate climates of the south, and arid and semi-arid country in the middle of the continent. Climatic features include tropical cyclones in northern Australia, migratory mid-

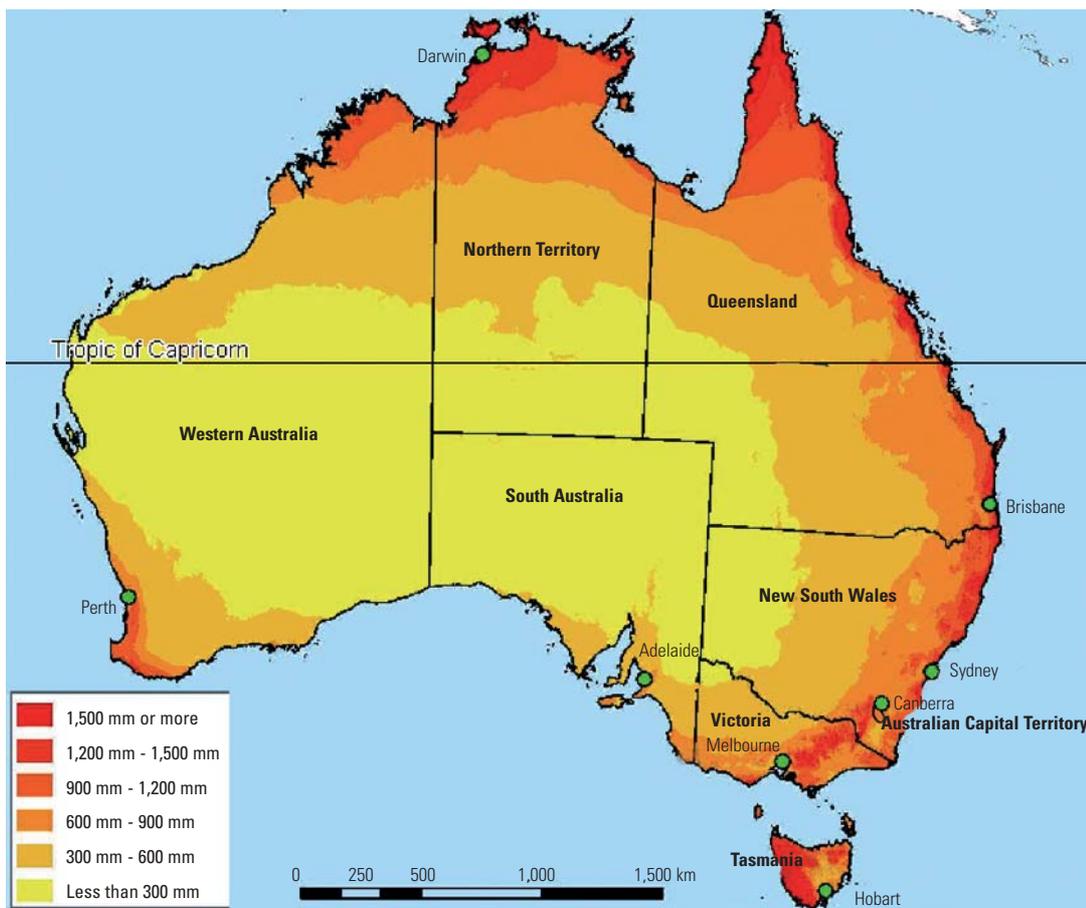
latitude storm systems in the south and the El Niño-Southern Oscillation (ENSO) phenomenon, which causes floods and prolonged droughts, in Eastern Australia (59). Land use is heavily influenced by climatic conditions, particularly as rainfall is unreliable and recurring droughts and floods are a natural feature of the landscape. Irrigation is used extensively in southern parts of Australia, mainly for crops, and great efforts are put into soil management because of problems such as erosion and salinisation.

Australia's landforms, geography and climate divide the continent into six climatic regions (Fig. 1).

With the exception of Antarctica, Australia is the world's driest continent: 80% of the continent receives an annual median rainfall of less than 600 mm and 50% receives less than 300 mm (Fig. 2). Rainfall is strongly seasonal, with a winter regime in the south and a summer regime in the north. Average annual air temperatures range from 28°C along the Kimberley coast in the north of Western Australia to 4°C in the alpine areas of south-eastern Australia to 4°C in the alpine areas of south-eastern



**Fig. 1**  
Australia: climatic regions



**Fig. 2**  
**Australia: average annual rainfall**

Australia. The lowest average temperature in all parts of the continent occurs in July. The highest average temperature occurs in January or February in the south and in November or December in the north. Periods with a number of successive days having temperatures higher than 40°C are common in summer over parts of Australia.

In spite of Australia's harsh environment, agriculture is the dominant land use, and livestock grazing accounts for the largest area of land use in Australian agriculture. This activity has led to the replacement of large areas of native vegetation by introduced pastures, particularly in the higher rainfall and irrigated areas. Key policy issues for governments are biosecurity, water, and natural resource management.

### Climate change and variability

A number of scientific studies have investigated the expected effects of climate change in Australia (27, 57, 76). There is general agreement that the annual average

temperature is likely to increase by between 1°C and 6°C over much of inland Australia by 2070, with the increase less in coastal than in inland areas (58, 59). Expected changes in rainfall are much more variable and complex, both seasonally and regionally. Over most of Australia, rainfall is likely to decrease, especially over the south-west and south-east mainland. However, an increase in heavy rainfall is projected even in regions with small decreases in average rainfall. The increase in temperature will lead to greater potential evaporation and reduce the water balance, even in areas with slightly higher rainfall. These changes will lead to both more drought and to more severe droughts. Tropical cyclones in the northern region are projected to become more frequent and more intense, and it is possible that mid-latitude storms will also increase in intensity. Overall, there is expected to be increased variability (59), with more intense rainfall and consequent flooding in La Niña years (years in which there is abnormal cooling of the central and eastern Pacific) and decreased rainfall and an associated increased frequency of drought in El Niño years (years in which there is abnormal warming of the central and eastern Pacific).

# Animal production and health in Australia

## Animal production

Animal production has contributed significantly to the Australian economy since the late 1800s and led to major cattle and sheep industries by the middle of the 20th Century.

Partly as a result of its small human population, Australia's animal production has been strongly geared towards exports. About two-thirds of the country's agricultural commodities are exported and Australia is one of the world's largest beef exporters. It is the second largest producer of sheep meat, and produces about one-third of the world's raw wool.

In recent years in Australia, aquaculture has expanded significantly, the dairy industry has undergone major structural changes, poultry and pig production and processing have consolidated and intensified, and there has been increased investment in other livestock industries including goat, llama, alpaca, ostrich and emu production.

## Animal health

Animal health is a function of animal production and critical to the economic viability of Australian producers, processors and exporters and the nation as a whole.

Legislative power in Australia is divided between the Commonwealth (also known as the Federal or the Australian Government), the States, and two self-governing Territories. The Australian Government has responsibility for external affairs, quarantine, defence, and taxation, and plays a key role in coordinating the development, implementation and funding of programmes that support national and international objectives. States and Territories have responsibility for the delivery of programmes within their jurisdiction, such as health (including animal health), education, and local government.

Historically, successful efforts have been made to eradicate diseases. Limited incursions of foot and mouth disease (FMD) and scrapie were eradicated in 1872 and 1952, respectively (22). Contagious bovine pleuropneumonia, which was introduced in 1858 and spread throughout much of Australia, was declared eradicated in 1973 after a prolonged national programme (48, 49). Achieving disease-free status for bovine brucellosis and bovine tuberculosis in 1989 and 1997, respectively, reflected the willingness of industry and governments to work together to plan and co-fund an eradication programme costing

some AU\$ 800 million over more than 30 years (33). The eradication of highly pathogenic avian influenza (HPAI) due to subtype H7 viruses on five occasions (between 1976 and 1997), the management and control of virulent Newcastle disease since 2002, and obtaining the 'Negligible Risk' status of the World Organisation for Animal Health (OIE) for bovine spongiform encephalopathy (BSE) (a disease that has never been seen in Australia but has had significant trade impacts) demonstrate the effectiveness of Australia's animal health services.

In recent years, the Australian animal health system has detected and managed a series of disease events. A number of these have been caused by previously unknown aetiological agents that have been found in wildlife and aquatic animals, and some have been zoonotic. Examples include Australian bat lyssavirus, Menangle virus, Hendra virus, Japanese encephalitis, ostrich fading syndrome, porcine myocarditis, *Trichinella pseudospiralis*, pilchard herpesvirus, abalone ganglioneuritis, and Tasmanian devil facial sarcoma.

Similar to recent experience elsewhere with transboundary diseases (e.g. HPAI and FMD) and increases globally in outbreaks due to zoonotic and foodborne pathogens, the Australian experience illustrates the need for animal health services to extend the scope of their activities and influence into areas such as wildlife, feral animals and aquaculture. This recent experience also illustrates the need for animal health services to be more cognisant of social, economic and environmental factors that contribute to the emergence of disease.

## Animal health policies and programmes

During the past 20 years, Australia has been modifying its national approach to animal health in recognition of changing biological risks and their potential effect on human health, animal production and health, and trade.

Central to progress has been political support flowing from recognition that the socioeconomic benefits of effective animal health services are significant. The major elements of Australia's animal health policies are prevention, preparedness, rapid detection, and prompt response through effective management of control or eradication programmes.

With respect to animal health, the Australian Government is responsible for matters relating to quarantine and international animal health, including disease reporting, export certification and trade negotiation. It also advises and coordinates national policy and, in some circumstances, provides financial assistance for national animal disease control programmes. State and Territory governments are responsible for disease control and

eradication within their own boundaries. Consultative committees ensure coordination and work together to serve the overall interests of Australia. Additional links are provided by Animal Health Australia, a not-for-profit public company with membership comprising the Australian Government, State and Territory governments, and the major national livestock industry councils (2). Importantly, governments have the final say on all matters relating to animal health, including legislation, policy, certification and international agreements, and the management of emergency preparedness and response activities.

Some of the essential institutional and governance instruments in Australia include a national legislative basis for action (provided primarily through the *Quarantine Act 1908*) and supporting State and Territory animal health legislation. The Primary Industry Ministerial Council (PIMC) meets formally twice a year to discuss, *inter alia*, animal health matters. A series of Committees (including the Animal Health Committee, which comprises the Commonwealth and State/Territory Chief Veterinary Officers) report to PIMC. Similar arrangements are in place for aquatic animal health (2, 6).

Linkages between PIMC and other Ministerial Councils dealing with the environment and, increasingly, human health are strong. Recent events such as outbreaks of FMD and H5N1 HPAI in other countries and the incursion of equine influenza into Australia have demonstrated to central government agencies, such as the Department of the Prime Minister and Cabinet and the Department of Finance and Deregulation, the importance of animal disease prevention and control in protecting not only the economy but also public health. These agencies are closely involved in and support any major disease emergency managed by animal health services.

### Pre-border, border and post-border activities

Underpinning the overall policy and governance approaches are a number of key strategic priorities and objectives. These include pre-border, border and post-border activities (45).

Australia invests heavily in pre-border activities at the bilateral, regional and multilateral levels. The objectives are to assist in the elaboration of standards and conditions to minimise the spread of disease, assist countries in the management of disease, and gain an improved understanding of the nature of emerging and other diseases in order to support Australia's biosecurity. Australia is a member of, and active participant in, organisations such as the OIE, FAO, the World Health Organization (WHO), the World Trade Organization (WTO), and the Asia-Pacific Economic Cooperation (APEC) forum. Activities in the

region include the AusAID-funded Southeast Asia Foot and Mouth Disease Campaign and the newly established OIE/AusAID Trust Fund to support capacity-building and the establishment of effective veterinary services.

Pre-border activities also include the assessment of risk against Australia's appropriate level of protection for imports entering or likely to enter the country. Import risk analyses are conducted by Biosecurity Australia, which comprises about 100 scientists and operates in a highly consultative manner.

Border quarantine activities take place at sea ports and airports, and at quarantine stations managed by the Australian Quarantine and Inspection Service (AQIS). Border quarantine work involves inspection of passengers and goods to ensure they do not pose a biosecurity risk. It also involves dealing with customs, police and security officers regarding illicit traffic and bioterrorist threats. If deemed necessary, AQIS also undertakes offshore (pre-border) work (e.g. inspecting overseas premises for compliance with Australian quarantine requirements).

The countries to its immediate north are a particular focus of offshore work for Australia. A memorandum of understanding between Australia, Indonesia and Papua New Guinea in 1979 established a tripartite committee on animal health and quarantine that led to regular meetings and joint disease surveys of border areas between the three countries (50); the agreement was subsequently extended to include Timor-Leste. This initiative was followed by the innovative Northern Australia Quarantine Strategy (NAQS [23, 46]), which was introduced in 1989 following a report on aerial littoral surveillance in 1987 (16). NAQS provides a quarantine defence and helps to monitor threats in the vast, sparsely populated areas of northern Australia. It brings together the skills of local people, scientists and communications experts to develop and implement programmes to identify, report and respond rapidly to disease incidents. NAQS also supports cooperative work with animal and plant health authorities in Indonesia, Papua New Guinea, and Timor Leste in the areas of surveillance, laboratory diagnostics, training and emergency management.

Post-border work involves the delivery of effective animal health services by States and Territories, with overall leadership and coordination provided by the Australian Government on major issues, including emergencies that have potential national and international consequences. Considerable effort has been directed toward maintaining a robust emergency management capability. This includes initiatives such as the Australian Veterinary Reserve, which uses trained and accredited practitioners from within Australia and from the International Veterinary Reserve (an agreement between Australia, Canada, Ireland, New Zealand, the United Kingdom, and the United States of

America regarding access to veterinary expertise during an emergency). Formal linkages also exist at the Australian Government level between animal health and human health authorities, including regular meetings between the Chief Veterinary Officer and the Chief Medical Officer (68).

### Key tools and approaches

Some of the key tools and approaches used to ensure consistency of approach and a common understanding of processes and responsibility include:

- high level training in whole-of-government emergency management processes and the use of simulation exercises to prepare government agencies, industry and the community at large to respond to disease events
- pre-agreed formal cost-sharing agreements between governments and industry for emergency diseases to ensure that all parties are aware of their responsibilities and funding commitments in the event of a disease occurrence
- training for producers and private veterinarians on disease identification, reporting obligations and management
- establishment of strategic alliances with a range of institutions (including government agencies, research organisations, human health agencies and wildlife authorities) to improve intelligence-gathering and to harmonise surveillance programmes
- development of laboratory strategies, including standardisation of test methods and the transfer of technology between laboratories
- introduction of effective communication strategies
- introduction of animal identification and traceability systems to support animal health management, trade and consumer confidence
- engaging universities and higher education institutions to increase teaching and research to support animal health in areas such as veterinary epidemiology, veterinary diagnostic pathology, and aquatic animal health
- using cost-benefit analyses to support the case for increased investment in animal health services.

Australia has political support and a strong legislative and governance base for its animal health services, as well as innovative strategies and tools to minimise risk. As a result of its international work, border security activities and integrated approaches, it has in place key elements of a

system to prevent, identify and manage disease. Australia has a proven record in this regard. However, to meet new and emerging threats, a range of institutional activities and scientific approaches will need to be strengthened. The threats and proposed approaches are outlined in the following sections of this paper.

## Emerging and re-emerging threats

### Global risk context

Animal diseases are having an increasing number of adverse socioeconomic effects on human health, animal production, trade and development. These trends are likely to continue unless strong and well-coordinated measures are taken to prevent and manage animal diseases at source.

The recent FAO report entitled 'Livestock's long shadow: environmental issues and options' (67) clearly describes the significant impact that livestock activities have on almost all aspects of the environment – including on land and soil, water and biodiversity, air and climate change. It is important to recognise that as a result of these wide-ranging environmental impacts, a number of critical policy developments will include livestock as an important focus of attention. For example, responses to climate change will include alterations in livestock production systems and some of these will have animal health implications. Climate change thus contributes to changing animal health risks both directly (e.g. via the effects of increasing temperature) and indirectly (e.g. via changes in production systems designed to mitigate or adapt to climate change).

From a global perspective, emerging diseases have often spread between countries, regions and continents. It is estimated that up to 75% of newly recognised infectious diseases of humans are zoonotic – that is, they can be transmitted between domestic animals and wildlife to humans (4, 10, 39, 65, 79, 80, 81, 82). Wildlife diseases can also have significant effects on the wildlife hosts themselves, in some cases threatening biodiversity (15, 70), and the livestock–wildlife interface is a source of introduction of diseases to domestic animals and humans (54). As both livestock producers and wildlife adapt to climate change (e.g. via changes in where livestock are farmed and changes in the distribution of wildlife populations in response to climate-induced changes to water and vegetation), opportunities will undoubtedly arise for further diseases of wildlife to infect domestic animals and humans. If one of the adaptations to climate change is increased intensification of animal production in some areas, there will also be further opportunities for the

emergence of previously unknown diseases and the re-emergence of known diseases (53, 55).

Production-diminishing diseases, such as FMD and classical swine fever, have resulted in severe hardship for many small farmers, inhibited livestock development, and restricted or closed access to markets (69). The highly infectious nature of such diseases has resulted in transboundary spread, particularly from countries that have suboptimal veterinary services and animal health systems, creating risks to countries free of such diseases.

Emerging and re-emerging food safety issues (e.g. microbiological, viral, prion, chemical and toxin contaminants) as well as zoonotic infections, often of uncertain public health significance, have posed problems throughout the world. Episodes of foodborne illness in recent years include BSE, *Escherichia coli* O:157, *Campylobacter jejuni* and salmonellosis, as well as problems associated with antimicrobial resistance and a range of chemical residues and toxins (14, 64).

Factors contributing to the increase of disease include demographic changes, intensive animal production, trade, tourism, urbanisation, mass production and transport of food – as well as climate change and damage to the environment that influence the ecology of microbiological agents (12). Some recent forecasts suggest that the world's population will increase from about six billion people now to some nine billion by 2050, with most of this growth occurring in Africa, Asia, and Central and South America. Some authorities estimate that demand for animals and animal products will increase between 2% and 3% per annum for at least the next 10 years and argue that much of this demand can be met from developing countries if animal diseases can be prevented or properly managed.

The adverse socioeconomic impacts of the occurrence of a range of diseases in Australia would be severe. For example, in 2001 the cost of an outbreak of FMD was estimated to be about AU\$ 13 billion (61), without including social costs (e.g. suicide or long-term health impacts on producers), the negative effect on land values, and the effect on the viability of regional towns and communities. A single case of BSE would also result in lost trade worth several billion dollars. The outbreaks of virulent Newcastle disease in 2001 cost AU\$ 50 million in direct losses such as compensation, but the total costs were far greater. The full economic effects of the incursion of equine influenza in 2007 have not been calculated, but are expected to be substantial.

## Climate change

Australia's climate is diverse, ranging from cool temperate to hot tropical, and quite variable. Inter-annual variability

in rainfall depends on factors such as atmospheric winds, ENSO and sea surface temperatures. Many animal diseases are affected by climate, which can affect the distribution of disease, the time when outbreaks occur, or the severity or intensity of outbreaks (3).

Climate change may affect future patterns of livestock density, distribution, production and trade that could affect the probability of an infected or infested animal contacting a susceptible one and thus affect the risk of disease spread. For example, a recently constituted Australian Government parliamentary committee is now exploring the likelihood of a shift in agriculture, including livestock production, from temperate areas in southern Australia to the northern tropics as a result of the expected effect of climate change on each of these regions. European breeds (e.g. meat sheep for fat lamb production, British breeds of dairy cattle) are likely to be disadvantaged, not only by the more sub-tropical climate of northern Australia, but also by their greater susceptibility, in comparison with more tropical breeds, to a range of vector-borne diseases to which they will be more exposed.

Significant investment has recently been provided to support research into new approaches to modelling climate change and its potential impacts on agriculture and animal production in Australia. To date, there have been few attempts to use such modelling to try to estimate the effects of climate change on animal health in Australia. Compared to, for example, Europe or North America, the continent of Australia has complex and highly variable weather patterns (58), particularly affecting northern Australia (even before any increased variability as a result of climate change). This variability makes climate modelling particularly difficult and the outputs of current models are rather coarse and imprecise. Recent investment should improve both the data going into models and the models themselves, reducing associated uncertainties and increasing the validity of model outputs and of consequent projections and inferences related to animal production and animal health. A recent study of the projected impact of climate change on wheat, beef, sheep meat and wool (29) illustrates the sort of outputs that current modelling provides at the level of quite large areas. This study examined likely impacts of a high-rainfall and a low-rainfall scenario by 2030 on two areas – the Western Australian wheat belt and the central western slopes and plains of New South Wales. Under the low-rainfall scenario, projected productivity would fall by 1.8% to 4.2% in the New South Wales study and by 0% to 7.3% in the Western Australian study area. With the hypothetical adoption of a number of adaptive responses, the projected fall in productivity was approximately halved. This study specifically noted that the projected impacts of climate change remain highly uncertain, reinforcing the need for improved inputs and models to reduce the uncertainties of model outputs and associated inferences.

Some diseases exhibit endemic stability, in which disease is less severe in younger animals and immunity post-infection is long-lasting. Tick-borne diseases such as babesiosis and anaplasmosis show a degree of endemic stability and if changes in climate allow their vectors to expand periodically into new areas, outbreaks of severe disease in susceptible animals of all ages can be expected. Climate change may affect the future density and distribution of susceptible hosts, or the numbers of competitors or pathogens and parasites of disease vectors, and influence patterns of disease that can not be extrapolated by consideration of only the direct effects of climate change.

Higher temperatures can increase the rate of development of certain pathogens or parasites that have one or more stages of their life cycle outside an animal host. This may shorten generation times and lead to increases in the population of some pathogens and parasites. For example, the range of the cattle tick (*Boophilus microplus*) is likely to extend southwards and lead to significant losses (from a decline in total loss of live-weight gain and from tick-borne diseases) that will reduce the productivity of the beef cattle industry (77). Some agents (e.g. endoparasites such as those that cause haemonchosis) may be affected by opposing influences – higher temperatures that increase their numbers, and lower rainfall and increased dryness that decrease their numbers. It is difficult to project with any accuracy the likely changes in the prevalence or distribution of such diseases.

Climate change will not increase the risk from all diseases. Many livestock diseases will be little affected, or even unaffected, by climate change. Such diseases include those that are transmitted primarily by close contact between hosts or that are foodborne (e.g. mastitis, salmonellosis, infectious bronchitis). In some cases, the risk from disease may decline. For example, the snail intermediate hosts of the liver fluke *Fasciola hepatica* depend on moisture to survive and multiply. The decreased rainfall and soil moisture (particularly in summer) that is projected as a result of climate change in areas of south-eastern Australia where fascioliasis is endemic may reduce the current prevalence and distribution of the disease in that region.

### Case study: wool production

Australia's wool industry provides a case study that illustrates some of the likely effects of climate change on animal health and production (24). Australia's sheep production occurs in three distinct zones – the wheat–sheep zone, the high-rainfall zone, and the pastoral zone. Specialist wool-producing farms account for about one-third of Australia's wool output. The wool industry makes up between 7% and 10% of the gross value of Australia's agricultural production and returns between

AU\$ 3 billion and AU\$ 4 billion a year from exports. During the past decade, there has been a decline in global wool consumption and a corresponding fall in wool production and sheep numbers, but wool production remains an important component of Australian agriculture.

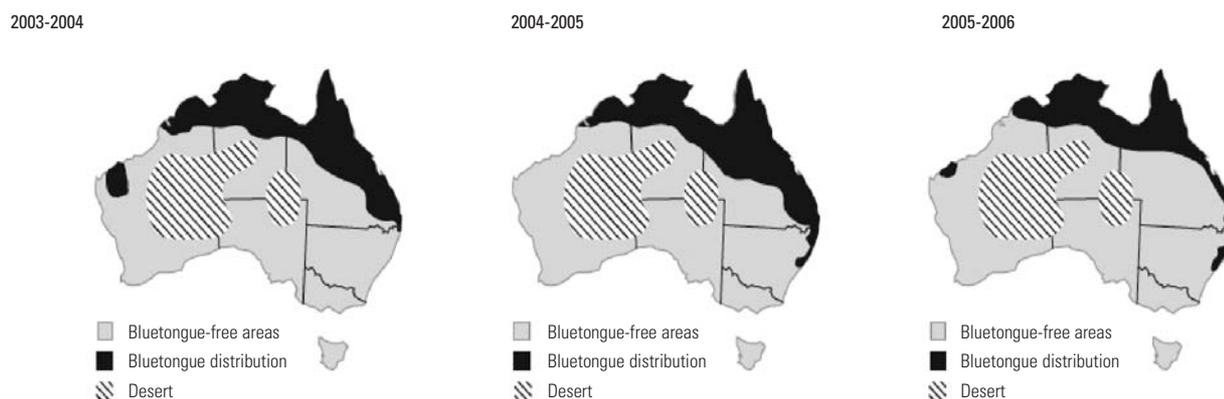
Projections suggest that by 2030 the average annual temperature may increase by 0.4°C to 2°C over most of Australia, with an accompanying increase in the likelihood of extreme hot or cold days. Projected changes in precipitation by 2030 are less certain and range from –20% to +5% in the south-western high-rainfall sheep zone to ±5% in the northern pastoral zone.

Climate models forecast an increased frequency of El Niño events, with more frequent heavy rainfall events and flooding in those areas where average rainfall increases, but with reductions in extreme daily rainfall where average rainfall declines significantly. Evaporation is projected to increase under warmer conditions, which, when combined with potential declines in rainfall, may further decrease available moisture. In each region and each season the ranges of possible change in rainfall include both increases and decreases, with up to a 30% variation (e.g. –15% to +15%) – a challenging variability for industry planning and adaptation.

Climate change is likely to affect a range of factors that have an impact on production, including water availability and demand, and the growth of pasture and fodder crops. Associated thermal effects on reproduction and indirect effects on animal health are also projected to affect wool production.

Many livestock in northern Australia are subjected to periods when there are high levels of heat stress. Climate models forecast increased temperature and humidity that will increase the thermal stress on livestock, particularly in tropical and sub-tropical zones.

Climate change is likely to affect the health of sheep as it affects the distribution and prevalence of a range of pests and diseases, particularly those that are insect-borne. For example, the range of *Culicoides* vectors of bluetongue virus can be expected to expand into areas where climate change is projected to lead to increased summer rainfall, expanding southwards into areas that currently carry large numbers of sheep. The distribution of bluetongue vectors is likely to shift from the current limit of the north coast of New South Wales to extend along all of the New South Wales coast, with periodic excursions further south and west. The distribution of bluetongue viruses in Australia has always been climate-dependent (see Fig. 3). However, with climate change, these periodic expansions and contractions of the bluetongue zone can be expected to be more pronounced.



**Fig. 3**  
Limits of the distribution of bluetongue viruses in Australia

In areas where climate change results in more humid conditions and higher summer rainfall, the prevalence of blowfly strike on sheep can be expected to increase, with consequent higher costs of prevention and treatment as well as reduced wool production and quality. In addition, other insects could become more abundant. Some parasites (e.g. the liver fluke *Fasciola hepatica*) are likely to become less prevalent in areas where conditions become drier and hotter. The abundance of some pests and parasites might also become more variable in response to increased variation between seasons (e.g. they may appear earlier in the season and go through more generations each year). These effects might be exacerbated by the reduced nutrition of sheep resulting from increases in poorer quality forage species and decreases in the nutritional value of existing species as a result of climate change

## Policy direction and emphasis

Modern societies, particularly in developed countries, expect their governments to ensure safety (18, 20) – including the management of risks of disease. Australia's highly urbanised and well-educated society demands high levels of certainty and safety and is uncomfortable with increasing risk from diseases, including those exacerbated by climate change and climate variability.

The nature and extent of such risks cannot always be clearly defined but they are real, and mean that animal health services need to be strengthened. They also mean that animal health authorities need to build and maintain strong relationships with other professionals, livestock producers and processors, and consumers to develop a 'prepared community' that understands threats and is ready to report disease events and assist in preventing and responding to them. However, the context within which

future animal health policy will be developed is rapidly evolving and a number of new approaches will need to be developed and embraced.

## The science–policy interface

Science is a broad discipline that provides a framework for analysis and synthesis that leads to outputs that can readily be provided as input to policy. However, science is still largely based on classical, reductionist approaches. Some commentators (19) argue that the quality of scientific input to the policy process is known to be 'problematic', as no-one can claim 'truth' nor remove all uncertainty. They argue that when there is high uncertainty and the stakes (or consequences) of a decision are high, the appropriate strategy to adopt is what they term 'issues-based post-normal science'. This strategy requires the engagement of an 'extended peer community' including all stakeholders in the dialogue, to evaluate the quality of scientific information for the policy process. Proponents of 'trans-science' (e.g. Weinberg [75]) distinguish between 'science' (or 'research science') and 'trans-science' (or 'policy science') and recognise a 'grey zone' between science and policy, noting that there are some questions that can be asked of science but can not be answered by science. This approach argues that increased complexity and uncertainty of questions should result in an increase in the democratisation of how to 'do' science when scientific ways of knowing break down, especially if there is a high 'dread' factor (e.g. environmental risks), and that this compels scientists to look beyond the (known) facts to make judgments or determinations. Others (e.g. Carolan [11]) argue that increased complexity and uncertainty require a focus on 'expertise' rather than science, and recognise public expertise that allows the explicit incorporation of values and changes the focus from questions of 'what is' to questions of 'what should be done'.

## Risk analysis

The use of formal risk analysis frameworks will become more important in identifying, characterising, assessing and managing risks, both real and perceived. Risk analysis is a demanding, complex and resource-intensive process. In the natural resource area generally (including quarantine and biosecurity), it involves consideration of scientific and economic factors, often requiring the use of multidisciplinary teams. In complex analyses of animal diseases, risk assessment teams may need to include specialists with skills in disciplines such as communications, mathematics, statistics, computer simulation and disease modelling, ecology and environmental science in addition to those in risk analysis, animal or plant health, and economics (51, 52). Sound risk management approaches will need to be applied at all levels of the supply chain. Given that problems will occur in even the best-managed systems, more effective and more refined approaches to contingency planning will be necessary to protect animal production and health, safeguard human health, and support consumer confidence.

Perceptions of risk by stakeholders or the general public often align poorly with those of 'experts', and a rapidly growing body of work on risk perception and communication has defined a number of key factors that determine individual and group perceptions of risk. For example, factor analysis has shown that hazards that are perceived as unfamiliar or provoke dread are assigned a higher risk than can be demonstrated statistically (66). Unfamiliar or unknown hazards, even with a low probability, that are regarded as having potentially catastrophic effects are perceived as high risk and provoke strong public demands for government to regulate and protect against them (e.g. hazards such as the introduction of an unfamiliar disease that might be a zoonosis, or the introduction of a known disease that might decimate one or more native species). Risk analysts need to be mindful of such reactions to risk and take account of them in their communication with stakeholders (60). Similarly, they should also appreciate the effects of trust, fear and outrage on how stakeholders feel and behave. Improved approaches to risk communication will be necessary to enhance the sharing of information between governments, industry and the public – both nationally and internationally.

## A 'one health' approach

There is now a clear need for veterinarians, medical specialists, and wildlife and environmental experts to improve their interaction by adopting an interdisciplinary 'one health' approach to identifying and minimising risk. The need arises from a clear realisation that infective agents circulate between wildlife, domestic animals and humans.

This approach is progressively being adopted in Australia (e.g. as illustrated below in the case study on the Australian Biosecurity Cooperative Research Centre) and similar approaches should be encouraged in all countries.

Society needs people who can address a wide range of interrelated health problems in many parts of the globe. This task requires exceptional skills in both analysis and synthesis. Most veterinary epidemiologists have had excellent training in the analysis portion of this equation through formal postgraduate studies in this discipline. However, few have had the opportunity to develop skills in the synthesis and integration needed to address the complex, real world problems that challenge both animal and human health. Some postgraduate training courses in Australia (e.g. the Australian National University's Master of Applied Epidemiology programme and the University of Sydney's Master of Veterinary Public Health Management programme) specifically aim to help develop such skills.

Increasingly, animal health issues will need to be addressed within the interdisciplinary and transdisciplinary framework of ecosystems health or 'ecohealth' (35, 36, 56, 74, 78). Embracing this approach will be a challenge for a number of countries, but it is clear that to address threats to animal health – such as climate change – will require a fundamental shift in thinking. It is recognised that there are a range of potential benefits and also inherent difficulties in addressing and understanding the social and ecological contexts in which diseases – including those affected by climate change – emerge.

A critical success factor will be the ability of animal health services to keep pace with and use new scientific developments and technologies. Four such areas are surveillance and diagnostics, emergency management, international cooperation, and foresight.

## Surveillance and diagnostics

The need for enhanced surveillance systems has been recognised as a key component of any strategy to deal with emerging diseases (5), including those associated with climate change. Local and global surveillance systems can be improved in a number of ways. However, new approaches that aim to improve the sensitivity of systems without markedly increasing their cost provide attractive options. Examples include approaches that combine data from a range of different sources and scales, including sourcing data on some of the drivers for emergence that may alert the system before a disease emerges. Climate change data will form part of such improved surveillance in the future. In addition to surveillance, the rapid development of new technologies for disease diagnostics will also influence disease detection and control. One critical focus will be the use of point-of-care (e.g. pen-side)

diagnostic tests, with the capacity to identify a wide range of diseases in the field. Surveillance networks will change in combination with these developments in diagnostic capacity and with changes in other technologies such as vaccines (9, 38). However, new technologies will achieve little unless accompanied by a well-trained and well-prepared workforce.

## Emergency management

A sound system for emergency management – covering prevention, preparedness, response and recovery – is and will remain an essential component of a first class animal health system (30). Approaches to emergency management must be multidisciplinary in nature and involve those parties (e.g. industry) that may be affected by disease outbreaks (1, 43, 44). It is important that conditions for managing emergencies be pre-agreed by all parties, with financial arrangements such as compensation in place to provide incentives to report disease promptly. It is also vital that emergency plans be documented and contingency training and exercises be conducted. Governance arrangements must be clear, particularly in areas in which governments and regulatory agencies have decision-making and leadership roles. Australia will refine its planning and governance approaches in the light of experience, and continue to train veterinarians and others in emergency management, both in classroom settings and via contingency planning exercises. As a direct result of the current H5N1 HPAI situation, improved communications and coordination networks will be developed in the south-east Asia region in conjunction with human health and emergency management organisations, and emergency management training will be a key component of the OIE/AusAID capacity-building project.

## International cooperation

International organisations play an important role in building the capacity of animal health services in developing countries (42, 62, 71, 72) and the value of this role should not be understated. Nevertheless, this should be seen as an interim support role until countries themselves take responsibility for providing sustainable long-term investment in animal health and veterinary public health to reduce the risk of animal diseases and zoonoses (37). However, it must be recognised that it will take years for many countries to develop effective animal health services.

Although frequently achieving success, investment in emergency management of disease often provides only a short-term solution. The real need is for the long-term and sustainable prevention and management of animal diseases through investment in Veterinary Services, particularly in developing countries. Australia thus endorses the OIE's

scheme for evaluating Veterinary Services using the 'OIE PVS Tool for the Evaluation of Performance of Veterinary Services' (71), which seeks to evaluate the quality and effectiveness of countries' Veterinary Services and to identify weaknesses that funding bodies can help correct through the provision of additional resources. Australia is providing significant funding support to the OIE/AusAID Trust Fund to help finance PVS evaluations and training in self-evaluations in the Asia-Pacific region. It is also supporting capacity-building projects in the areas of emergency management, governance, legislation, and communications (41).

Efforts to improve animal health services in developing countries should, in the first instance, focus on areas of greatest risk. In doing so, they should consider successful approaches used in other countries, but adapt them to suit their particular circumstances. Key examples include emergency management, governance, legislation and communications systems. Australian animal health authorities will work with authorities in other countries on these activities to help identify and manage emerging disease threats. Such collaboration will help to increase knowledge of emerging disease threats and increase the preparedness of Australia's own animal health service and systems. Sharing of knowledge and the provision of assistance to improve animal health services will provide a 'win-win' situation for participating countries.

## Foresight

Working in the areas of epidemiology, disease surveillance and control, and risk analysis, veterinarians in the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) have been undertaking informal foresight work for some time (albeit without using that term or consciously using a formal foresight or 'futures studies' framework). Early in 2003, the authors initiated a more formal process to help improve strategic planning and build capacity in DAFF through a 'pilot' foresight programme in animal health – in its broadest sense, including aquatic animals, animal welfare, and veterinary public health (zoonoses, residues and contaminants, food safety, etc.).

The pilot project commenced with a series of workshops that exposed participants to a range of tools, including the futures triangle, backcasting, environmental scanning, and causal layered analysis. These workshops drew on foresight and futures thinking (21, 31, 63, 73) to explore ways of improving strategic planning or anticipatory policy planning. The approach focused on assessing the implications of present actions and decisions (consequence assessment), identifying and avoiding problems before they occur (early warning and guidance), and considering the present implications of possible future events (proactive strategy formulation).

The initiative was based on the need to increase capacity to undertake more robust, broad-ranging analysis. Most strategic planning tends to project the past into the future, and this often means it does not capture the breadth or depth of enquiry necessary to ensure high quality responses that take longer timeframes into account. The aim was to help to lift planning horizons from the three-month 'reactive' response and 12-month 'tactical' focus (that tend to dominate departmental planning and operations) to a focus on what might be coming in the next ten years to help determine what should be done now to be best prepared to meet these challenges (i.e. designing coping strategies that increase resilience). Examples of such approaches to increasing Australia's sustainability in a range of areas outside animal health have been explored elsewhere (17).

Policies dealing with the effects of climate change on animal health are an example of an area that requires long-term strategic thinking. The strategies that were developed as a result of the pilot programme in 2003 and the associated timeframes are listed in Table I.

**Table I**  
**Suggested strategies and timeframes**  
**to address emerging diseases**

Strategy	Timeframe
Surveillance – improved networks, increased quantity (global and domestic)	S, M, L
Risk analysis	S, M, L
Response planning	S
Foresight	L
Pre-emptive research	M to L
Enhancing current global early warning systems	S to M
Research and development	
Basic	L
Applied	S to M
Preparedness – epidemiological skills, public awareness, laboratory skills and capacity, standards and networks	M to L
Investment in new technologies	S, M, L

S: short  
M: medium  
L: long

Environmental scanning and backscanning identified several general themes that participants agreed should be included in ongoing foresight work on animal health, including emerging diseases, sustainability and biodiversity, product integrity and food safety, globalisation, new technologies, science and society, and the foresight process itself. Since 2003, 'environmental scanning' of news and scientific articles on these themes

has continued, and outputs are periodically assessed and fed into formal planning cycles. Links have also been made with other groups working in related areas of foresight (in Australia and elsewhere) to share, consolidate and expand on this work (7, 8).

### **Case study: the Australian Biosecurity Cooperative Research Centre**

The Australian Cooperative Research Centre (CRC) for Emerging Infectious Diseases (known as the Australian Biosecurity CRC or AB CRC) is one of a series of CRCs established by the Australian Government. The CRC initiative aims to encourage world-class research and ensure the transfer of research outcomes. It requires agreed programmes and effective collaboration between participating research, government and industry organisations. Support by these organisations, whether cash or in-kind (e.g. inputs of scientists' time to project work) are matched by the Australian Government. Each CRC is supported for a period of seven years, after which it must submit a compelling case for its continuation for another seven years.

The AB CRC deals with animal and public health and its activities are due to finish in 2010. Re-bid proposals are currently being developed to support the AB CRC's continued work from 2010 to 2017. These proposals have in large part been informed by the animal health services in Australia and an International Advisory Steering Committee with representatives from four continents. Most of the elements of the proposals reflect veterinary thinking as to ways to strengthen already good animal health services, and the AB CRC serves as a good case study to demonstrate some key policy and strategic approaches.

The case for continuing to support the AB CRC is premised on the fact that outbreaks and risks of emerging infectious disease (EID) have been increasing, both nationally and globally. The need is seen to bring together expertise from the agricultural, public health and environmental sectors in multidisciplinary teams to address the risks and consequences of EIDs. In short, the approach reflects the 'one health' concept aimed at improving the health and well-being of all species through partnership approaches across scientific disciplines, industry and government sectors – and across national boundaries.

The arguments supporting the case have been dealt with in this paper, but in summary, they include:

- the fact that 75% of emerging diseases identified during the past 25 years have been zoonotic

- the World Economic Forum ranked pandemic risk higher than, for example, tropical storms, earthquakes and fiscal crises, and within the top four for costs
- transboundary diseases of animals cause significant social and economic damage both in countries and in regions
- many diseases of importance reside in wildlife hosts
- climate change has emerged as one of the defining challenges of the 21st Century and its impact on disease emergence has yet to be fully determined.

The key outcomes from continuing to support the AB CRC would be:

- identification and analysis of EID risk
- gap analyses, including analyses of deficiencies in knowledge and capacity
- development of cost-effective tools for managing risk, including the use of new technologies
- improved intelligence networks for EIDs
- improved knowledge and skills base in Australia
- enhanced capability to respond to EID threats in Australia and in the region.

A number of cross-sectoral research and capacity-building programmes would contribute to successful outcomes. These would include projects on disease intelligence scanning, threat analyses, and priority-setting. A key component of this work would be to explore critical factors predisposing to disease, in particular the effects of climate change on disease emergence. Other work would involve the development of improved risk management tools, skills, networks and frameworks to ensure the extension and adoption of research outputs.

This case study demonstrates the importance Australia places on climate change and variability as a component of risk, and the need to examine and prepare for the effects of such changes – as well as the clear need to implement a ‘one health’ approach.

## Conclusion

This paper has outlined the nature of the Australian continent’s geography and climate, its dependence on livestock production, and the nature of its animal health services. It has argued that climate change and variability, often in association with a range of other factors, will have major impacts on the future nature of disease and

host–pathogen relationships. The paper has also sought to describe institutional approaches and tools needed to prepare for and combat the associated changes in the risk of disease.

Australia has a strong legislative and governance basis for its animal health services, and uses a range of innovative strategic approaches to identify and minimise risk. As a result of pre-border work, border security activities, and integrated approaches to managing animal health within the country, Australia has in place the key elements of a system to identify, prevent, and manage disease risks. Although sound policies and systems are in place, a number of enhancements will help to address these risks and respond to changing circumstances. From a policy perspective, there is a need for:

- strong political support and funding for animal health services
- effective legislative and governance frameworks
- productive engagement of industry and consumers
- improved public communication systems leading to a community familiar with risk and actions that may need to be taken
- adoption and implementation of ‘one health’ and interdisciplinary approaches
- international collaboration of a practical and applied nature, including research and development
- ongoing training of staff
- the provision of ongoing support and guidance from international organisations such as the OIE, FAO and WHO
- scientific underpinning of the system with veterinary leadership in technical animal matters in areas such as epidemiology, surveillance, diagnostics, pathology, technology transfer, risk analysis, and foresight
- changes in the education and training of producers to promote better stewardship of the land they manage and to encourage them to apply adaptive strategies to minimise the negative impacts of climate change on the environment, agricultural production and animal production and health.

Climate change and associated increased climate variability will affect the natural environment and animal production and health in Australia, and will exacerbate the risk of a range of animal and zoonotic diseases. To meet these and other new and emerging threats, a range of institutional activities and scientific approaches will need to be strengthened.

This paper has described a number of new strategies and highlighted the need to develop and implement better policies to deal with changing disease risks, including those that arise from climate change. However, no country can do this effectively in isolation and there is a need for the community of nations to recognise the importance of

supporting effective animal health services in all countries – and to develop innovative ways of providing such support.



## La gestion des risques zoonitaires en Australie et l'incidence du changement climatique

P.F. Black, J.G. Murray & M.J. Nunn

### Résumé

Le changement climatique est l'un des nombreux facteurs susceptibles d'influencer l'évolution future de l'agriculture et de la production et la santé animales en Australie, surtout lorsque ce changement interagit avec d'autres facteurs tels que la dégradation de l'environnement, les systèmes de production animale intensifs, l'expansion de la démographie humaine et l'urbanisation à outrance. Malgré le climat rigoureux et variable en Australie, l'élevage et la production animale ont pu s'y développer avec succès et conquérir des marchés d'exportation un peu partout dans le monde. L'excellent statut sanitaire des animaux d'élevage en Australie a été un facteur déterminant pour accéder à ces marchés, grâce à des services vétérinaires de tout premier ordre bénéficiant d'une assise juridique forte, de personnels compétents et du soutien des éleveurs eux-mêmes, auxquels s'ajoutent l'efficacité de la surveillance exercée, la qualité de l'expertise scientifique et des laboratoires, l'efficacité des procédures de gestion des catastrophes et du système de quarantaine ainsi que le soutien politique dans ce domaine. Quelques améliorations doivent néanmoins être apportées au système de santé animale australien : par exemple, redéfinir l'interface entre l'expertise scientifique et la prise de décision, perfectionner la prospective, l'analyse des risques, la surveillance, le diagnostic et la gestion des urgences, améliorer les initiatives d'éducation et de formation, de transfert technologique, de communication et de sensibilisation, et collaborer davantage avec la communauté internationale dans les domaines du renforcement des capacités, du développement des Services vétérinaires et des systèmes de réaction en cas de foyers de maladie. L'adoption d'une démarche de type « une seule santé » (*one health*) permettra de réunir les compétences en matière de santé animale, de santé publique, de santé des animaux sauvages et de santé environnementale. À condition d'être correctement gérées, ces initiatives devraient minimiser les risques liés au réchauffement planétaire et à d'autres facteurs prédisposant aux maladies.

### Mots-clés

Australie – Changement climatique – Climat – Élaboration des politiques à mener – Prospective – Santé animale.



## Influencia del cambio climático en la gestión del riesgo zoonosario en Australia

P.F. Black, J.G. Murray & M.J. Nunn

### Resumen

El cambio climático es uno de los numerosos factores que probablemente influirán en el futuro de la agricultura y la producción y sanidad animales en Australia, sobre todo si viene asociado con otros factores como la degradación del medio ambiente, la producción pecuaria intensiva, una demografía humana galopante y una creciente urbanización. Pese a lo riguroso y variable del clima australiano, el país ha alumbrado una pujante industria ganadera, que exporta por todo el mundo la mayoría de sus productos. Un factor básico para acceder a los mercados ha sido la envidiable situación zoonosaria del país, que para ello ha podido contar con servicios de sanidad animal de primera calidad, una sólida base legislativa, personal bien formado, la participación de la industria, una vigilancia eficaz, un firme apoyo científico y de los laboratorios, procedimientos eficaces de gestión de emergencias, un buen sistema de cuarentena y una decidida voluntad política. No obstante, el sistema australiano de sanidad animal aún necesita ciertas mejoras, por ejemplo: redefinir la interfaz ciencia-aparato normativo; perfeccionar los pronósticos y diagnósticos, el análisis de riesgos, la vigilancia y la gestión de emergencias; mejorar los planteamientos utilizados en materia de enseñanza, formación, transferencia de tecnología, comunicación y sensibilización; y lograr una mayor participación de la comunidad internacional en ámbitos como la mejora de la capacidad, de los servicios veterinarios y de los sistemas de respuesta a enfermedades. Se abordará la sanidad desde un planteamiento "unificado" (*one health*) con el fin de aunar el saber-hacer de los profesionales de la salud pública y animal y de la protección de la fauna salvaje y el medio ambiente. Si se llevan adelante correctamente, estas iniciativas servirán para reducir al mínimo los riesgos derivados del calentamiento planetario y otros factores favorables a las enfermedades.

### Palabras clave

Australia – Cambio climático – Clima – Elaboración de políticas – Pronóstico – Sanidad animal.



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