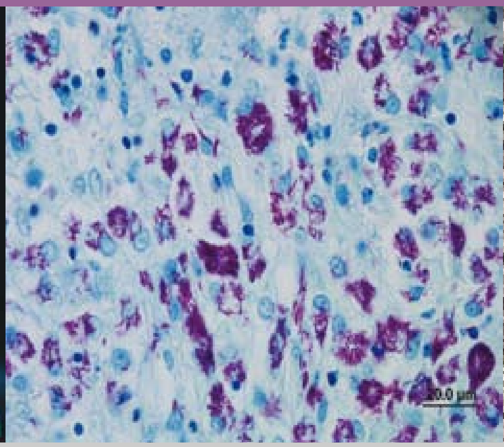
Invasive Animals Cooperative Research Centre



Research on wildlife disease preparedness in Australia

Wendy Henderson

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Wendy R. Henderson (2008)

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Report prepared for Invasive Animals Cooperative Research Centre Project 8.D.2: Review of Wildlife Exotic Disease Preparedness Program (WEDPP).

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Contents

Summary

This report provides an overview of recent research related to wildlife disease management and preparedness in Australia. It includes a summary and brief critique of the projects funded by the Wildlife Exotic Disease Preparedness Program (WEDPP) of the Australian Department of Agriculture, Fisheries and Forestry, from 1999 to 2007. Results from a literature search for Australian journal articles (1999-2007) related to disease preparedness are presented. Current research on wildlife disease by the Invasive Animals Cooperative Research Centre (IA CRC) and the Australian Biosecurity CRC is also outlined. A brief description of the major diseases of concern to Australia, particularly those in which invasive animals are implicated, is also provided.

The aims and outcomes of this project are to:

- summarise WEDPP projects funded between 1999 and 2007
- provide information on other recent research related to diseases of concern in Australian wildlife, including feral animals
- address the IA CRC's milestone of collating and disseminating current information on diseases, particularly with regards to invasive animals.

Overall it is clear that WEDPP has had useful input to a wide range of projects relevant to disease preparedness in Australia. The projects have, however, been relatively small due to constraints put on funding and duration of research. Some final reports are missing, and much of the research has not been formally published or further evaluated. As such, the return on investment is unclear.

WEDPP is well placed to seek research outcomes and implement them into preparedness policy. The contribution made by WEDPP to disease preparedness in Australia could be significantly enhanced by increased funding for larger projects and greater administrative support. It would also benefit from increased evaluation and follow-up of research outcomes and report recommendations to incorporate them into disease preparedness policy, training or further research.

The published research briefly reviewed here covers a variety of areas, but the emphasis of this report is on wildlife diseases in which invasive animals are indicated as carriers or hosts. Disease management implications have not been included in many of the research articles. Disease preparedness could be better served if researchers explained practical and generic implications of their research, and if policy makers were made more aware of the importance of such research.

Abbreviations

AB CRC	Australian Biosecurity Cooperative Research Centre
AI	avian influenza
AIV	avian influenza virus
AUSVETPLAN	Australian Veterinary Emergency Plan
AWHN	Australian Wildlife Health Network
CRC	Cooperative Research Centre
DAFF	Australian Department of Agriculture, Fisheries and Forestry
ELISA	enzyme-linked immunosorbent assay
FMD	foot and mouth disease
GIS	geographic information system
HPAI	highly pathogenic avian influenza
IA CRC	Invasive Animals Cooperative Research Centre
LPAI	low pathogenic avian influenza
NDV	Newcastle disease virus
NSW	New South Wales
OIE	World Organisation for Animal Health
PCR	polymerase chain reaction
RT-PCR	reverse transcriptase PCR
WEDPP	Wildlife Exotic Disease Preparedness Program (DAFF)

1. Introduction

1.1 Scope of this report

There are many significant infectious diseases of potential threat to the Australian environment, economy and/or society. The growing rate of global trade; closer proximity of livestock, people and wildlife; and other human interventions such as animal translocations for conservation or recreation purposes continue to increase the potential for a serious disease outbreak in Australia. Factors outside of human activities, such as climate change or natural disasters present other real disease threats that need to be prepared for.

This report presents a summary of research related to wildlife disease preparedness in Australia. The majority of the research described here is from project reports submitted to the Wildlife Exotic Disease Preparedness Program (WEDPP) between 1999 and 2007. However, Australian research formally published in international journals over the same period is also briefly outlined. The aims of the report are to:

- summarise WEDPP-funded research, training and workshops
- provide information on other recent research related to diseases of concern in Australian wildlife including feral animals
- address the IA CRC's milestone of 'collating and disseminating current information on diseases, particularly with regards to invasive animals'.

Definitions: For the purpose of this report, 'invasive animals' include exotic feral pests and overabundant native species. 'Wildlife' is defined here as any free-living animals, including endemic and exotic species.

1.2 Background on the Wildlife Exotic Disease Preparedness Program (WEDPP)

WEDPP is a joint program between the Australian Government's Department of Agriculture, Fisheries and Forestry (DAFF) and state/territory governments. WEDPP's mission[1] is:

> 'to improve Australia's emergency animal disease preparedness through the development of strategies to monitor, prevent, control or eradicate emergency diseases in wildlife and feral animals that threaten Australia's livestock industries.'

WEDPP was established in 1984, initially to develop survey and control techniques for feral pigs in an exotic animal disease emergency. A large variety of projects on a range of native and exotic animal species has been funded since then, including epidemiological studies, assessments of control techniques, workshops, pest animal surveys, and development of diagnostic tools. Recently, the focus has been on improving wildlife surveillance, particularly of feral pigs and wild birds (the latter mainly for avian influenza).

The specific objectives of WEDPP are to:

- enhance and refine technologies for the surveillance, containment and control of wildlife

1 taken from WEDPP website *http://www.daff.gov.au/animal-plant-health/emergency/wildlife_and_exotic_disease_preparedness_program (*accessed Feb 2008)

- develop a national team of competent personnel to perform control roles in an emergency animal disease event, and promote the integration of personnel with animal health and wildlife expertise
- assist development of Australia's animal disease preparedness, particularly wildlife strategies and Australian Veterinary Emergency Plan (AUSVETPLAN) procedures.

WEDPP is developing a website (see footnote 1, page 5), which to date lists its aims, and projects funded 2003–2006. Only one project report is currently available to download from this site. The remainder are filed as hard copies in the office of the Chief Veterinary Officer in DAFF, Canberra City.

1.3 Diseases of concern to Australia

Many diseases of potential threat to the Australian environment, economy or society could be introduced by invasive animals to wildlife, livestock or humans. Feral pigs are exotic pests of particular concern with regards to spreading disease and as such have been a major focus of disease preparedness research. An example of an overabundant native animal that may present a significant disease risk is the flying fox, which can carry several zoonoses (eg Australian bat lyssavirus and Hendra virus in Australia, and Nipah virus in Malaysia).

A list of diseases of concern to Australia was compiled for this report, primarily from AUSVETPLAN disease strategies, the World Organisation for Animal Health's (OIE) list of notifiable diseases, and Australian Government's threat abatement plans. A table outlining characteristics of these diseases, their hosts, causative agents and occurrence in Australia is given in Appendix 1.

Most of the diseases listed in Appendix 1 affect animals of agricultural importance. Some significant diseases that affect native species, and that invasive animals are implicated in, are also included (eg hydatidosis, toxoplasmosis, air sac mites). It is acknowledged that this is not an exhaustive list, and many more diseases could be included (eg diseases carried by feral birds; see http://globalbirdcontrol.com/bird-diseases.htm). A national list of notifiable animal diseases in Australia is available on the DAFF website (http://www.daff.gov.au/animal-plant-health/pests-diseases-weeds/animal/notifiable). A list of notifiable diseases more specifically relating to wildlife in Australia is currently being developed by the Australian Wildlife Health Network (R. Woods, pers. comm.).

Some examples of significant wildlife diseases with possible feral animal hosts have been recently reviewed. They include:

- neuroangiostrongyliasis — neurological disease affecting marsupials and birds; lungworm carried by rats (Spratt 2005)
- cryptococcosis — systemic fungal disease affecting a large range of native mammals, birds and reptiles; fungus carried by cats, dogs, horses, goats (Krockenberger et al 2005)
- sarcoptic mange — mange affecting wombats; parasitic mite carried by foxes and dogs (Skerratt 2005)
- mucormycosis — fungal disease affecting frogs, platypus; soil fungus but also present in cane toads (Speare et al 1994; Stewart and Munday 2005)
- hydatidosis — parasite affecting a range of Australian wildlife; tapeworm carried by dogs and foxes (Jenkins 2006).

While some diseases can affect or be carried by multiple hosts (eg anthrax, surra, rabies, foot-and-mouth disease), others have a much higher degree of host specificity. The specificity and consequences of infection, the disease agent involved and potential transmission routes influence management strategies for disease preparedness.

2. Summaries of WEDPP project reports 1999 to 2007

Table 1 lists all the reports submitted to WEDPP between 1999 and 2007. Only final reports are summarised in this chapter. Several projects that had submitted progress reports some years ago had no final report available for review (see Table 1).

A shift in emphasis in WEDPP projects has occurred over the past eight years; from more general activities (establishing a wildlife health network and registry, conducting general pest surveys, and reviewing disease preparedness), to researching specific viruses in birds. Of the 38 projects listed, almost half (16) involve birds, particularly avian influenza in wild birds. Three projects involve bats, and five projects involve pigs. The remainder involve the more general activities mentioned above, and also bee mite and mosquito research.

A summary of the aims, methods, results and recommendations of each final report is included in this chapter. Reports are listed under key topic areas: disease preparedness reviews, wildlife health network development, pig projects, bird projects, and 'other' WEDPP-funded projects. Several reports are also included at the end of this section on workshops in which WEDPP representative/s participated.

Table 1 Reports submitted to WEDPP between 1999 and 2007

Year	Title	Author/s	Report type
1999 – 2000	Wildlife and exotic disease preparedness in Australia — Feral herbivores	R. Henzell, P. Caple, G. Wilson	Final
	Wildlife and exotic disease preparedness in Australia — Rabies	G. Saunders	Final
	Development of a Wildlife Health Centre: Proceedings of a workshop 8-9 November 1999	Author not stated	Final
	Surveillance of mega- and microchiroptera in Northern and Western Australia for evidence of infection with Australian bat lyssavirus, Hendra virus, Nipah virus, menangle virus, Japanese encephalitits virus and specified arboviruses	H. Field	Progress (no final report available)
	Aerial baiting of feral pigs (*Sus scrofa*) for the control of exotic disease in the semi-arid rangelands of NSW	P.J.S. Fleming, D. Choquenot, R. J. Mason	Final
	Training in the use of Gen-Wed (generic models for wildlife and exotic disease)	S. McLeod, J.P. Druhan, G. Saunders	Final
	Sentinel cattle, pigs and poultry for monitoring flavivirus activity in the Northern Territory	L. F. Melville, S. J. Walsh, N. T. Hunt, A. K. Broome	Final
	Veterinary conservation biology wildlife health and management in Australasia	Author not stated	Final
2000 – 2001	The development of a Wildlife Health Network for the Wildlife Exotic Disease Preparedness Program	H. Bryant	Final
	Honeybee abatement using Ivermectin	H. Lamb	Progress
	Australian Registry of Wildlife Pathology/Health	K. Rose	Progress
	Valuing Australian wildlife – A basis for improving resource allocation for wildlife management	G. R. Wilson	Proposal
	Exercise 'Wild Thing' – Report and review	Author not stated	Final

Year	Title	Author/s	Report type
2001 – 2002	Honeybee abatement using Ivermectin	H. Lamb	Progress
	Detection of Newcastle disease and other haemagglutinating viruses amongst Victorian wild birds population	I. Peroulis, K. O'Riley	Progress
	Establishment of an Australian Wildlife Health Network	Author not stated	Progress
	Identification of the feeding behaviour of mosquitoes of the Murray Darling Basin	J. Azuolas	Progress (no final report available)
	Surveillance of high-risk (non-bat) animal population for Australian bat lyssavirus (ABL) infection	H. Field	Progress (no final report available)
	Investigation of the dynamics of Hendra virus infection and excretion in flying foxes	H. Field	Progress (no final report available)
	Update key risk areas and examine representative risk areas of feral pig and goat densities in NSW to advance preparedness in an exotic disease outbreak	G. Saunders	Progress
	The Development of an Australian Wildlife Health Network – Part 2	H. Bryant	Final
	Update key risk areas and examine representative risk areas of feral pig and goat densities in NSW to advance preparedness in an exotic disease outbreak PLUS copy of Pest animal survey	G. Saunders, P. West, G. Jones	Final
2002 – 2003	Distribution and abundance of pest animals in the agricultural region of Western Australia	A. Woolnough	Progress
	Risk analysis of feral and wild animals as a component of exotic and emergency disease preparedness planning	S. McLeod, P. West, G. Saunders	Progress (no final report available)
	Enhancing the Australian Registry of Wildlife Pathology	K. Rose	Final
2003 – 2004	A novel molecular-ecology approach to ascertaining emigration/immigration and potential disease spread in feral pigs	S. Lapidge	Progress
	Distribution and abundance of pest animals in the rangelands of Western Australia. Attachment: Pest animal survey	A. Woolnough	Progress
2004 – 2005	Preliminary investigations for measuring animal contact rates	A. Woolnough	Progress (no final report available)
	The feasibility of targeting surveillance for avian influenza in wild birds	J. Tracey, G. Saunders, S. McLeod, B. Lukins	Progress
	Feasibility of delivering oral liquid vaccines or contraceptives to feral pigs	S. Lapidge	Progress
	Development of rapid molecular surveillance tools for the detection of avian influenza virus within Victorian wild bird populations	S. Warner, K. O'Reilly	Progress
	Pathogenicity of H5N1 strain of highly pathogenic avian influenza virus in Australian native ducks	L. Gleeson	Progress (no final report available)
	Development of rapid molecular surveillance tools for the detection of avian influenza virus within Victorian wild bird populations	S. Warner, K. O'Riley	Final
	The feasibility of targeting surveillance for avian influenza in wild birds	J. Tracey	Final
	Distribution and abundance of pest animals in Western Australia	A. Woolnough, G. S. Gray, T. J. Lowe, W. E. Kirkpatrick, K. Rose, G. R. Martin	Final

Year	Title	Author/s	Report type
2005 – 2006	Application of rapid diagnostic tests in the targeted surveillance of avian influenza virus within Victorian wild bird populations	S. Warner	Progress
	Surveillance for avian influenza viruses in Tasmanian wild bird populations	C. Bell	Final
	Avian influenza surveillance in Victorian wild birds and at-risk domestic poultry	S.Warner, C. Ainsworth	Progress (no final report available)
	Avian influenza surveillance in wild waterfowl in SA	C. Dickason	Progress
	Genetic structure of Australo-Indonesian waterbird populations	D. Roshier, J. T. Have, T. Chesser	Final
	Development of cyanide bait for rapid disease sampling and surveillance of wild animals	M. Gentle	Progress
	Surveillance for avian influenza virus at Bolivar Lagoons, SA	C. Dickason	Final
	Application of rapid diagnostic tests in the targeted surveillance of avian influenza virus within Victorian wild bird populations	S. Warner	Progress
	Application of rapid diagnostic tests to detect West Nile antibodies and virus during surveillance of wild birds, mosquito populations and sentinel flocks	S. Warner, J. Azuolas	Final
	A cross-jurisdictional model for targeted surveillance of wild bird species in Queensland	A. Gordon, H. Field	Final
	Detecting avian influenza in wild birds in New South Wales	P. Kirkland, J. Tracey	Final
	Application of rapid diagnostic tests in the targeted surveillance of avian influenza virus within Victorian wild bird populations	S. Warner	Final
	A novel molecular-ecology approach to ascertaining emigration / immigration and potential disease spread in feral pigs	S. Lapidge P. Spencer, J. Hampton, B. Cowled, J. Scanlon	Final
2007	Development of cyanide bait for rapid disease sampling and surveillance of wild animals	M. Gentle	Final
	Feasibility of delivering oral liquid vaccines or contraceptives to feral pigs	S. Lapidge	Final
Not listed by WEDPP but stored with other reports	Workshop: 'Decision support tools and the management of feral pigs in an emergency animal disease event' Nov 2003	P. Black	Workshop summary and cd available Summarised here
	Avian influenza workshop March 2004	C. Bunn, J. Mortier, B. Milne, C. Moore	Summarised here

2.1 Disease preparedness reviews

Wildlife and exotic disease preparedness in Australia — Feral herbivores

Henzell, R., Caple, P. and Wilson, G. (1999).

This 125-page report covers feral herbivores (donkeys, horses, buffalo, goats, deer, camels and cattle) and the main exotic diseases they can carry or succumb to. The aims of the project were to:

- collate and review results of WEDPP projects and other information on feral herbivores relevant to wildlife and exotic disease preparedness
- review current Australian Veterinary Emergency Plan (AUSVETPLAN) national disease strategies, and the operational procedures manuals on wild animal control
- recommend research and development priorities and other activities to meet deficiencies in wildlife and exotic disease preparedness with regards to feral herbivores.

Diseases covered in the review had National Disease Strategies written at the time, and include foot-and-mouth disease (FMD), bluetongue, rinderpest, screw-worm fly, capripox, lumpy skin disease, African horse sickness, Rift Valley fever, vesicular stomatitis, swine vesicular disease and vesicular exanthema. These diseases and the species of feral herbivore likely to be epidemiologically involved are outlined.

Problems associated with feral herbivores in spreading disease are emphasised, particularly that the animals are difficult to survey and contain, and that they are potentially highly mobile, widespread and long-term hosts of infection. These features make effective control of herbivore diseases extremely difficult. The likelihood of feral herbivores causing or exacerbating a disease outbreak would depend on circumstances: which suite of species are involved, their abundance and distribution (affecting contact rates and transmission), breeding status of the population, domestic species present, where the outbreak occurs, season and weather conditions. Australia has such a diversity, abundance and continuity of herbivores rarely seen overseas, so overseas experience can only be used as guidance.

The report reviews the National Disease Strategies and the Operational Procedures Manuals: Wild Animal Control. While the national strategies deal with diseases and broad principles for their eradication, the control manuals deal with the survey, containment, surveillance and destruction of wildlife species.

The report also gives a brief overview of the 18 WEDPP-funded herbivore projects from 1984–1994. These include projects on: drafting training manuals and contingency plans; survey and control exercises with donkeys (Western Australia), goats (South Australia), pigs, buffalo, horses and cattle (all in Northern Territory); risk management of FMD (Tasmania); and a review of NSW legislation. A significant number of other projects had no final report to review, or their status was unclear.

Gaps in outcomes and information are identified, and a large number of recommendations for WEDPP's future directions are given, summarised in the following list.

1. National Disease Strategies should:
    - inform managers of behaviour of wildlife populations with regard to control and containment difficulties (ie these populations are highly mobile, evasive, unpredictable, and uncontainable, so can transmit or be reservoirs of disease, to allow repeated outbreaks)
    - provide guidance on wildlife control and containment emphasising uncertainties in the epidemiological role of feral herbivores and wildlife
    - pay more attention to the role of scavengers in spreading disease
    - develop strategies to deal with wildlife (eg it may be timely and economical to control or eliminate feral herbivores in high-risk areas rather than trying to do so after a disease outbreak)
    - be cross-referenced to wild animal control manuals.
2. Wild animal control manuals should:
    - include a variety of control and containment techniques and the performance targets achievable with those techniques (performance data should be obtained from new research if not already available)
    - include descriptions of uncommonly used wild animal techniques in more detail
    - include sympatric species operations
    - be restructured to deal with elements common to several species, with separate manuals for species-specific matters.
3. Further research should be done into:
    - distribution and movement of ferals and semi-ferals in high disease risk areas
    - intra- and inter-specific contact between susceptible ferals and how this varies with control operations, population density and breeding and environmental factors
    - improvements to surveillance, containment and control techniques for wildlife, to be effective against low-density populations and to allow dispersing animals to be dealt with
    - computer software for mathematical techniques likely to be used by control centre wildlife biologists, to facilitate surveys of distribution, movement, abundance, etc
    - factors and techniques that cause wild animals to disperse, to allow risk to be more accurately assessed
    - persistence of pathogens in carcasses.
4. A program to pre-emptively eradicate or control ferals and semi-ferals in high disease risk areas should be established with interested parties.
5. Training for exotic disease preparedness should continue, particularly for key roles.
6. Regarding management of WEDPP, written contracts should be drawn up for all funded projects to ensure funds result in useable products.

Wildlife and exotic disease preparedness in Australia — Rabies

Saunders, G. (1999).

This 117-page report provides a review of the wildlife and exotic disease preparedness in Australia with regards to rabies. The aims of the review were to:

- collate and review results of WEDPP projects and other information on rabies relevant to wildlife and exotic disease preparedness
- review and draft amendments for the AUSVETPLAN National Disease Strategy on Rabies, and the emergency operations manuals on wild canids and felids, bats, and marsupials
- report on research and development priorities and other activities to meet deficiencies in wildlife and exotic disease preparedness, particularly with regards to rabies.

This comprehensive review is divided into three main sections: background information on rabies, summary and recommendations for WEDPP research, and a review of AUSVETPLAN manuals.

Rabies background: The review gives a general background on the occurrence and epidemiology of rabies worldwide and available control methods (at the time of the report the now widely-used recombinant vaccine for rabies was still being trialled). Sylvatic and urban cycles of rabies are described, and implications for rabies in Australia are discussed. Australia has widespread populations of known hosts of rabies — mainly foxes, wild dogs (and dingoes), feral cats and bats. The report notes that the role that native Australian mammals (particularly quolls, Tasmanian devils, native bats and possums) might play in a rabies outbreak is undefined.

It was considered that the species of greatest concern to rabies contingency planning in Australia are the red fox and dingo/wild dog. This disease could only be brought into Australia via an infected animal in the incubative stage; most likely from smuggling or illegal landings of an Asian dog. Although the risk of such an entry may be low, the potential for subsequently establishing rabies in Australia would be high. If transmitted to a wild dog population, rabies could then spread widely in Australia before being detected. Thus, strategies should be in place to rapidly eliminate the disease at its point of introduction, most likely using population reduction techniques. Vaccination should be investigated as an option, depending on the circumstances of an outbreak.

Review of WEDPP: WEDPP projects funded in 1985-1992 were reviewed. They include projects on possum baiting (to determine potential for a rabies vaccination program), a simulated sylvatic rabies outbreak exercise, fox control exercises and evaluations (including baiting, shooting, mock vaccinations, surveying, contact rates), a National Wildlife Rabies Workshop and studies on stray dogs and urban foxes in Victoria. The majority of reports were on fox research. A significant number of projects funded by WEDPP had not submitted final reports.

Since the overall risk of rabies being introduced to Australia was considered low, and its impact on agricultural production considered minimal compared with other exotic animal diseases, it was suggested that work related to rabies should receive a comparatively lower priority for WEDPP funds. Any WEDPP-funded rabies projects should place emphasis on species other than foxes (since most of the previous rabies-related projects have involved foxes).

A large number of recommendations were provided for future WEDPP activities, summarised in the list below.

Research and development

1. High priorities for research and development include:
    - research into wildlife control and containment strategies for remote parts of northern Australia (where rabies is most likely to occur), particularly for wild dogs and dingoes
    - further development of innovative, non-invasive disease-sampling procedures
    - assessment of initiating wildlife vaccination campaigns for Australia
    - modification of existing rabies models (developed in Europe and North America for foxes), or development of new models for environmental conditions and species (such as the dingo and feral cat) relevant to Australia
    - documenting existing methodology for relative estimates of wildlife species (particularly the carnivores).
2. The register of wildlife specialists should be updated, and individuals should be trained in specific skills where the need is identified.
3. The potential need for control of native carnivorous marsupials (*Dasyuroidea*) should be reviewed urgently.
4. Field exercises that evaluate wildlife control operations should continue to be encouraged under WEDPP funding arrangements.
5. WEDPP should monitor the progress of research projects on the control of feral cats for possible applications to exotic disease preparedness.
6. Education campaigns should be targeted at the parts of northern Australia at greatest risk of rabies, involving shipping ports, local residents, tourist operators and resorts, hunters, pest control personnel and others.

WEDPP funding and project administration

The report recommends that WEDPP:

- obtain outstanding WEDPP reports, including research failures
- collate and incorporate findings of reports into wildlife operations manuals
- referee project reports more broadly
- consider greater levels of funding, guaranteed for more than one year, for projects aimed at identified knowledge gaps
- encourage applications for postgraduate scholarships to solve specifically identified problems in exotic disease preparedness.

Review of AUSVETPLAN manuals: The highest priority identified was to rewrite the national disease strategies and the wildlife operational manuals. More specific recommendations for improving the AUSVETPLAN manuals are listed below.

1. The Rabies Disease Strategy should clearly explain that endemic rabies is primarily a disease of domestic/stray dogs and wildlife, and should emphasise difficulties associated with controlling rabies in wildlife.

2. Welfare concerns for techniques outlined in wildlife operations manuals, such as the poisoning of protected species, should be clarified in collaboration with relevant agencies.

3. The wildlife operations manuals need to:
   - convey the degree of difficulty associated with wildlife survey and control
   - give more attention to rabies control in urban and suburban wildlife, since feral cats, stray dogs, foxes and possibly possums constitute a risk
   - be cross-referenced, laid out in a consistent format and linked with the relevant disease strategies and register of wildlife specialists
   - be updated with recent research and innovations (particularly global positioning systems, manufactured baits, cyanide baiting techniques and information on urban foxes)
   - provide information on general biology and ecology of risk species
   - contain an appendix with information common to all of the wildlife operations manuals, such as techniques and resources used for a number of species.

4. Both the Rabies Disease Strategy and wildlife operations manuals should:
   - acknowledge the option for using oral vaccines to control wildlife rabies in Australia and provide consistent vaccination advice and methodology
   - incorporate the ability of epidemiological models to predict the behaviour of a disease such as rabies in wildlife populations (and their use should be identified as a matter of training priority).

Note: There was a draft review of Feral Pigs and Exotic Disease Preparedness (Wilson, G. and Choquenot, D. 1995), written at the same time as the above reviews on feral herbivores and rabies. However, this draft was not published as a final WEDPP report and is not summarised here.

2.2 Wildlife Health Network development

Development of a Wildlife Health Centre — Proceedings of a workshop 8-9 November 1999

Author not stated (1999).

This workshop proceedings is the first report in a series of three on the development of a national wildlife health network (see others below). The workshop acknowledged the need for a national, coordinated approach to wildlife health, to better enable identification of and response to emerging diseases, mass mortalities and other wildlife health issues. Over 60 representatives from a wide variety of industries (including conservation and agriculture departments, zoos, hunting industries, universities, pathologists) attended the workshop to discuss recent case studies of significant wildlife disease, and to review existing national and regional wildlife health organisations from other countries. A basic framework for an Australian network was discussed, including aims, funding arrangements and structure. A steering committee was appointed to create a funding proposal for the network, including a business plan.

The development of plans for an Australian Wildlife Health Centre/Network – Part 1

Bryant, H. and Saunders, G. (2001).

This project conducted a feasibility study of establishing a national wildlife health network to coordinate a response to wildlife disease issues. It included the following activities:

- reviewing existing wildlife disease preparedness arrangements in Australia and overseas
- determining the scope of activities required to improve preparedness to deal with wildlife disease in Australia
- examining possible organisational models for an Australian wildlife health network and providing recommendations for the most appropriate structure and functions
- costing each option and investigating possible sources of funding for the various options.

A wide range of stakeholders was consulted from agriculture, health and environment agencies through workshops, a questionnaire and various other meetings. This consultation identified a lack of wildlife disease preparedness, inadequate funding for investigations and diagnosis, inefficient monitoring and surveillance operations, and poor management of diagnostic information. The feasibility study concluded that there was a need to establish a national, coordinated response to wildlife disease issues, through an Australian Wildlife Health Network.

It was recommended that this network coordinate information on disease incidents and investigations, expertise, research, training and education activities (including AUSVETPLAN revisions). It should strengthen existing collaborations. A business plan for a model network was proposed, including the key elements of a host agency, a coordinator, a national database, a website and a listserver.

The study established networks between stakeholders in Australia, including state and Commonwealth agriculture, primary industry and health agencies, veterinarians, universities, CSIRO, Animal Health Australia, museums, zoos, wildlife carer groups and animal welfare associations. Several overseas centres for wildlife health were also included. The project also established an electronic mailing list and a listserver.

Development of an Australian Wildlife Health Network

Bryant, H. (2002).

This project was a follow-on from 'The development of plans for an Australian Wildlife Health Centre/Network – Part 1' project of 2001 (see above). It involved the coordination and actual establishment of the Australian Wildlife Health Network (AWHN), to promote and facilitate collaboration in the investigation and management of wildlife health. Targets completed include:

- securing core funding for the AWHN from the business plan previously drafted
- selecting a host agency for the network (Zoological Parks Board of NSW and NSW Agriculture)
- establishing the structure and appointment of a management committee to govern the network
- developing a strategic plan for the network

- managing the transition of the network to the host agency
- officially launching the network in August 2002.

The report comments that despite several previous reviews of WEDPP, priority issues and activities have not been formally established, which is unusual for a Commonwealth program. It also states that the 50:50 state: Commonwealth funding contributions for WEDPP preclude applications from universities and other institutions. It recommends that future priorities of emerging wildlife disease issues be considered jointly by the Commonwealth and the states through the mechanisms of the Standing Committee on Agriculture and Resource Management (SCARM).

An assessment of WEDPP for 1992–2002 was also conducted, with guidelines developed for future funding proposals. These guidelines did not appear to be filed with the final report.

2.3 Projects on pigs

Aerial baiting of feral pigs (*Sus scrofa*) for the control of exotic disease in the semi-arid rangelands of New South Wales

Fleming, P.J.S, Choquenot, D. and Mason, R.J. (2000).
Wildlife Research 27: 531-537.

Meat baits containing biomarker chemicals were distributed at various densities over three different test sites to determine factors influencing bait uptake by feral pigs. A sample of pigs in each area was shot and analysed for biomarker presence. Main findings of the study were:

- The maximum percentage of sampled pigs that had eaten baits varied from 31% to 72% across the three sites.
- Bait uptake did not appear to be significantly different between pigs of different age or gender.
- Seasonal foraging behaviour may have affected bait uptake.
- A large number of baits were taken by non-targets, particularly birds and foxes, so an alternative toxin to 1080 may be required for aerially baiting pigs in Australia.
- The amount of bait hypothetically needed to eliminate a population of pigs was estimated at 1577 baits per unit of pig density in two of the sites, and 1874 baits per unit for the third site.

The authors conclude that aerial baiting could be a useful way of reducing or immunising feral pig populations in the event of an outbreak of exotic disease such as FMD. However, different threshold density values in the available predictive models, and a general lack of information on FMD transmission by pigs overseas made it difficult to draw further conclusions.

Sentinel cattle, pigs and poultry for monitoring flavivirus activity in the Northern territory

Melville, L. F., Walsh, S. J., Hunt, N.T. and Broome, A. K. (2000).

Kunjin, Murray Valley encephalitis (MVE) and Japanese encephalitis (JE) viruses are flaviviruses belonging to the JE antigenic complex of the *Flavivirus* genus in the family Flaviviridae. This project describes results from monitoring for flavivirus activity in the Northern Territory using sentinel cattle, pigs and poultry, between 1996 and 2000.

The cattle were located at six sites, and 20 animals were tested monthly for flavivirus activity, as part of a national arbovirus (insect-bourne viruses) monitoring program. Pigs were located at two of these sites; six of these animals were tested monthly for flavivirus activity. Sera from cattle and pigs showing general flavivirus activity were subsequently screened with specific tests for Kunjin, JE and MVE viruses. Sentinel poultry were located at seven sites in the state; about 12 poultry from each site were tested monthly for general flavivirus activity. Sera reacting to a flavivirus group ELISA (enzyme-linked immunosorbent assay) were subsequently tested for MVE and Kunjin virus activity.

Sites tested included some locations near Darwin, some near Katherine (300 km south of Darwin), and one site south of Alice Springs. The results showed that cattle, pigs and poultry are all useful indicators of flavivirus activity, but vary in levels of sensitivity and persistence.

Cattle showed flavivirus seroconversion rates (5–45%) similar to chickens but lower than pigs. Seroconversion in sentinel cattle occurred mainly in the wet season at most sites, except at one site near Darwin with known high arbovirus activity, where seroconversions occurred at low levels over most months. Cattle recorded titres to both MVE and Kunjin virus. These titres tended not to persist in cattle, allowing for the detection of multiple flavivirus infections in a population over time.

Seroconversions with sentinel poultry also occurred predominantly in the wet season, or in years of above average rainfall in the arid zone near Alice Springs. Seroconversion rates varied from 36–78%, dependent on the site studied. The advantage of using sentinel poultry is their ease of handling in urban environments. A disadvantage is their requirement for specialised housing in rural environments to prevent predation.

Pigs are the most sensitive indicators of flavivirus activity, making them the preferred sentinel for monitoring marginal areas. 100% seroconversion was observed in one site and 60% at the other (both near Darwin). Seroconversion occurred rapidly after pigs were introduced to sites, and in most months. Because of this, replacement pigs would need to be introduced on a regular basis to continue monitoring. High titres to MVE and Kunjin were observed, and these persisted for months.

The report contains no recommendations. It does include progress reports for flavivirus sampling from 1996 as part of a larger project in the Northern Territory, in which a variety of animals were tested. Wild birds, marsupials, native rodents, flying foxes, feral and domestic pigs, sentinel cattle, and several other feral species were sampled and tested with the flavivirus ELISA. Positive sera were subsequently tested for JE, MVE and Kunjin virus. Of 2333 samples tested, 691 were flavivirus positive (ELISA). Of these, 279 were positive to Kunjin, 246 to MVE and 6 to JE virus tests. The report concludes flaviviruses infect a wide variety of hosts, and that flavivirus activity has occurred every year in ferals and sentinels in the Northern Territory.

Exercise ‘Wild Thing’- Report and review

Author/s not stated (2002).

The Wild Animal Management Manual (WAMM) of the AUSVETPLAN had never been field-tested until this exercise. Exercise Wild Thing was a major animal disease preparedness exercise run over about 10 days near Musgrave in far north Queensland, in October 2001. The exercise simulated a foot and mouth disease outbreak using a fictitious disease of pigs with similar symptoms, called 'droopy mouth fever'. The aims of the project were to:

- assess feral pig management options
- test and improve the WAMM of AUSVETPLAN
- improve Australia's preparedness to respond to an animal health emergency.

The exercise tested only the wild animal component of a response to an exotic disease: it did not focus on domestic stock issues. The project was overseen by a multi-agency management group. Representatives from the Department of Natural Resources and Mines (Qld), Department of Primary Industries (Qld), Australian Quarantine and Inspection Service, and Cape York Natural Heritage Trust Weeds and Feral Animals Project carried out the planning (including preparation of a risk assessment and management plan, and a communication plan) and implementation. Participants with pest animal management experience from other states were also involved.

A Wild Animal Section Leader was identified and liaised with about 35 staff. A Forward Disease Control Centre (at Musgrave) was established by the leader. A Local Disease Control Centre (at Cairns) was also established to provide advice and support.

Teams were set up for activities in control, surveillance, GIS and mapping, communications, administration, decontamination and roadblocks. Aerial baiting with 1080 poison was chosen as the initial control and containment method. Strategic ground baiting and shooting (aerial and ground based) were also used as follow-up measures. Pig populations were estimated before, during, and after the exercise.

Recommendations made after the exercise include the need to:

- delineate roles of animal health and vertebrate pest control agencies and individuals
- liaise and communicate reliably and consistently across agencies at national, state and local levels
- regularly train staff in areas such as mapping, disease response and media skills
- improve WAMM and other AUSVETPLAN manuals (strategic guidelines and editorial recommendations arre included, as arre changes to operational procedures)
- educate the public about exotic disease outbreaks and preparedness.

Note: Edition 3 of AUSVETPLAN was updated in 2003 as a result of recommendations made from this exercise.

A novel molecular-ecology approach to ascertaining emigration/immigration and potential disease spread in feral pigs

Lapidge, S., Spencer, P., Hampton, J., Cowled, B. and Scanlon, J. (2005).

This project acknowledges the risk posed by feral pigs in the transmission of significant diseases such as FMD in Australia. Information on pig density, behaviour (of populations and individuals), social contacts and seasonal conditions are useful for predicting disease spread. This study aimed to contribute to disease modelling by using a molecular and ecology approach to get information on sexual contact and genetic relatedness in a low-density pig population.

The specific aims of the project were to:

- determine feral pig density using aerial surveys and shooting
- calculate cost effectiveness of aerial shooting for a low density population
- determine immigration and emigration rates using genetic analyses
- obtain data on pig population demographics and geographics
- predict whether disease transmission would occur in a very low density population, and what the minimum controlled area would be in an outbreak.

An area of 4,430 km^2 of semi-arid woodland and grassland near Cunnamulla in southeast Queensland was studied over 2003 and 2004. Aerial surveys were done to estimate pig density, and later corrected on the basis of shooting results (with a correction factor of 4.3). A total of 306 shot pigs were genotyped using 14 microsatellite makers. Location of shot pigs, their body condition, age and reproductive capacity were recorded. Data from shooting and molecular analyses were used to estimate distance between boars, sows and offspring.

The cost of culling feral pigs, counting helicopter, fuel, labour and bullet costs, was estimated at $68–$76 per pig. Genetic analyses showed the 2003 and 2004 pigs were genetically identical and part of a larger population, whose geographical boundaries were outside the area covered in this project. Immigration and emigration rates and sources could not be determined, but recovery of populations after shooting suggested reinvasion from surrounding areas.

Distances moved each day by feral pigs were calculated from location data and assessed in three home range models. The random movement model gave the best correspondence between field data and model output — it was considered surprising there was no home range component in movement of pigs in the area. Conservative estimates of disease transmission coefficients (from sexual contact rates) indicated FMD would not transmit in such a low density population. The study showed feral pigs can move large distances over short periods; for example, boars were found to move about 3 km linear distance per day. Such movements would allow the spread of disease, particularly during incubation periods when symptoms were not severe. The minimum velocity of FMD advancement was estimated to be about 6 km per day.

The report recommends a more in-depth study of relationships between animal abundance/movement and availability of food and shelter. Ideally such a study would include many movement measurements over an extended period and in a variety of environmental conditions.

Development of cyanide bait for rapid disease sampling and surveillance of wild animals

Gentle, M., MacMorran, D., Aylett, P., Saunders, G. and Eason, C. (2007).

This report acknowledges that current surveillance and monitoring techniques, such as shooting, are very intrusive and often disperse animals. The use of fast-acting toxic baits could provide an alternative technique. Currently available poisons are not suitable for disease sampling, primarily because they have slow modes of action (so carcasses would be some distance from bait stations and difficult to find). Cyanide is a toxin that could be useful for feral animal surveillance, both for disease sampling and population estimates. It essentially prevents the body from receiving oxygen and has been reported in previous trials to result in rapid death in pigs.

This project aimed to improve the current methods for delivering cyanide to feral pigs, by changing the formulation and/or delivery of the toxin. Specific aims were to:

- develop an effective formulation/delivery technique for cyanide to be used in current/likely baits
- demonstrate bait efficacy on captive feral pigs
- trial cyanide delivery techniques for foxes.

Connovation Pty Ltd in New Zealand was contracted to develop a suitable cyanide product for delivery to pigs, based on their success with other vertebrate pests (eg possums). Feral pigs were trapped and pre-fed with non-toxic bait packages, which varied in their bait substrate (meat, grain, dog biscuit etc) and toxin delivery product (capsule type, cyanide concentration). When preference for particular substrates was observed, lethal trials were done. Five different pen trials were done.

The project obtained inconsistent results, which warrant further investigations. The authors concluded that either the formulation of cyanide or its delivery in wax capsules was inadequate to produce a rapid pig death. The capsule design was considered acceptable, since pigs readily ate non-toxic capsules. The presence of the cyanide was somehow recognised by the pigs, which rejected or ejected toxic capsules. It was concluded it may be difficult to successfully compromise between encapsulating the cyanide to mask it, while still providing sufficient reactivity to produce a rapid death. The use of ejectors was also trialled and considered to be a possible alternative to capsules. Foxes were not trialled in this project.

The report recommends that:

- Further work should be done on both cyanide formulations and delivery mechanisms — unless significant changes are made to capsules / baits already tested, wax capsules should not continue to be used.
- Paste formulations should be investigated for direct delivery to pigs by placing on foodstuffs. They should also be tested for their suitability for rapid poisoning of foxes.
- To avoid pigs' aversion to cyanide, more work should be done to produce lethal baits packages.
- Cyanide ejectors should be further tested for their potential to deliver cyanide to pigs.
- Overseas trials on new formulations or delivery of cyanide to feral pigs should be watched for applicability to Australia.

Feasibility of delivering oral liquid vaccines or contraceptives to feral pigs

Lapidge, S. (2007).

This report acknowledges that feral pigs are a significant pest species in Australia, the United Kingdom and United States. The threat of pigs introducing a serious disease (such as FMD) to livestock has prompted research into FMD vaccines and contraceptives. This project conducted trials in Australia, as part of a larger international project assessing the feasibility of oral vaccines and contraceptives for feral pigs. The specific aims of the Australian component were to:

- validate the use of iophenoxic acid (IPA) as a biomarker in feral pigs, prior to field trial bait studies — by quantifying the effect of orally delivered IPA on blood iodine levels

- develop an encapsulation method to effectively deliver simulated oral vaccines to feral pigs
- field trial PIGOUT® baits for use in delivering a pharmaceutical to feral pigs.

Captive feral pigs were administered with different doses of IPA (0–40 mg) via a tube direct to the stomach (gavage) or by feeding PIGOUT® baits containing various gelatine capsule formulations. Blood iodine levels were monitored for eight days after administration. Feral pigs in Namadgi and Kosciuszko National Parks were then baited with PIGOUT® baits containing 20 mg of IPA in the best encapsulation method to simulate a vaccination program. Pigs were subsequently trapped and sampled for IPA uptake and associated factors.

Bait-delivered IPA produced variable and inconsistent blood iodine levels, so prevented accurate quantitative assessments. It was, however, sufficient to show bait uptake. Direct gavage of IPA provided quantifiable results. The most effective encapsulation method was found to be the administration of multiple small capsules of IPA.

PIGOUT® baits containing IPA were readily eaten by feral pigs in both national parks tested. Varying ages, sexes and weights of pig were equally likely to consume baits. Increasing bait density resulted in a higher percentage of baits being consumed, with 80% being consumed in densities of 5.5 baits per animal. The Australian trials indicate that PIGOUT® could be a useful delivery vehicle for vaccines or contraceptives to feral pigs.

The report also includes information on the other, international trials on PIGOUT® target specificity (in the United States) and its feasibility to deliver vaccines to badgers or wild boar (in the United Kingdom). Neither trial in the United Kingdom produced encouraging results. Specificity trials in the United States showed a high proportion of PIGOUT® baits were taken by a variety of non-target species, including raccoons, collared peccaries, rabbits, cattle, coyotes, deer, rodents and skunks. Including a repellent ('Get Away') in baits may have deterred uptake by non-target species, and fish-flavoured baits were found to be more attractive to pigs. Clustering the baits increased uptake by feral pigs. Further trials with other hard-cased baits showed that strawberry flavoured baits could be relatively pig specific, attracting pigs and apparently repelling at least some other species. Future experiments will test strawberry flavoured PIGOUT® baits in the United States.

The report concludes that oral delivery of vaccines and contraceptives to feral pigs is feasible in the field. Pig density should be assessed before baiting programs, to ensure efficient bait uptake. IPA can be used as a qualitative biomarker of bait uptake, but is not suitable for quantitative studies. The future use of PIGOUT® baits containing a vaccine for FMD or a contraceptive (for example) could create a buffer zone around disease hot spots, to prevent or diminish disease spread. However, further epidemiological studies would be needed to validate such a disease management strategy.

2.4 Projects on birds

Detection of Newcastle disease and other haemagglutinating viruses amongst Victorian wild birds populations

Peroulis, I. and O'Reily, K. (2002).

This report concentrates on avian paramyxoviruses, which are common in wild birds, particularly waterfowl. These birds can act as reservoirs for poultry diseases, causing virulent outbreaks.

The most recognised paramyxovirus is Newcastle disease virus (NDV). This virus can cause high mortality, and slaughter of large flocks is required for control. Although NDV strains isolated from wild birds are usually avirulent, it is thought that these strains can mutate to highly virulent forms in poultry. This apparently occurred in an outbreak of Newcastle disease in New South Wales in 1998–2000 and again in Victoria in 2002.

This project aimed to detect and characterise NDV in wild birds, to increase understanding of genetic types of the virus circulating in wild populations. Tracheal and cloacal swabs were taken from 605 birds throughout Victoria over 2001–2002, including ducks, quail and pigeons. Kookaburras, magpies, parrots and other bird species were also included in this number.1210 samples were processed, and from these, 25 haemagglutinating viruses were isolated from ducks and quail. Most viruses were avian paramyxovirus Type 6 and influenza virus subtype A; all of which had low virulence. Two NDVs were identified, but neither was a virulent or intermediate (with potential to mutate to virulent) strain.

The report recommends continued sampling of wild birds, to understand virus types present and to detect possible threats to Victoria's poultry industry.

Development of rapid molecular surveillance tools for the detection of avian influenza virus within Victorian wild bird populations

Warner, S. and O'Riley, K. (2005).

This report acknowledges that the widespread occurrence of avian influenza (AI) in production birds around the world is emerging as a significant problem. Migratory shorebirds (Charadriiformes) have been identified as the most likely group to introduce AI to Australia from south-east Asia. They have also been implicated as reservoirs for low pathogenic strains of the virus. Many different shorebirds migrate from the north hemisphere annually, congregate in large groups, and often interact with terrestrial bird species. These characteristics, together with their frequent proximity to duck (Anatidae) populations, identified shorebirds and ducks as target birds for AI surveillance. The project involved collaboration with a variety of state and federal government departments and other groups.

The project's main aims were to:

- design and undertake a targeted surveillance program for AI in Victorian water birds
- develop and validate a rapid screening polymerase chain reaction (PCR) for AI virus (AIV) from cloacal samples
- generate a reference genetic database of AIV strains
- further understand the molecular epidemiology of AIV in bird populations, including possible implications to the Victorian poultry industry.

Between February 2004 and April 2005, 1390 cloacal samples were taken over a wide range of locations in Victoria from various types of ducks, migratory and other birds, and some sentinel chickens. Where possible, samples were collected in wetlands where ducks were known to cohabit with wading birds, and with proximity to poultry farms. 170 of the samples were from New South Wales. Samples were tested for AIVs by looking for viral activity in injected embryonated eggs, or for DNA amplification by an optimised PCR reaction (using nested reverse transcriptase PCR; RT-PCR).

Analysis of injected egg samples identified three isolates of AIV, all from ducks. The only AIV subtype was H4, which had low pathogenicity. Several isolates of other avian paramyxoviruses were also detected in several duck and quail samples. The nested RT-PCR test was found to have a high degree of specificity and sensitivity, and could detect AIV directly from cloacal samples. Of the 1390 samples tested, there were 15 PCR positives, which included the same three samples as identified using the injected egg test.

Overall, the results demonstrated a very low prevalence (1.1% from PCR testing) of AIV in wild birds tested, and all of these AIVs were found in ducks. Future studies are recommended to address several factors, including: appropriate species and ages of birds to sample, priority sampling areas, and seasonal fluctuations in virus prevalence. Yearly sampling was considered useful to contribute to a longer-term study.

This project was continued the following year in: 'Application of rapid diagnostic tests in the targeted surveillance of avian influenza virus within Victorian wild bird populations' (see Warner et al 2006, below).

Targeting surveillance for avian influenza in wild birds: a pilot investigation in New South Wales

Tracey, J. (2005).

This report was written for the project 'The feasibility of targeting surveillance for avian influenza in wild birds'. This project acknowledges that broadscale surveillance of wild birds for AIV in Australia would be extremely difficult and expensive due to the low prevalence of the virus. The project was designed to help target more efficient sampling activities by:

- examining the role of wild birds in transmitting AI and identifying species most likely to transmit AI in Australia
- identifying optimal timing for sampling for AIV
- identifying priority areas for AI surveillance
- reviewing protocols for capture, handling, AIV sampling and euthanasia of wild birds.

The report concludes that the probability of detecting AIV in wild birds is likely to be greatest in waterbirds, particularly Anseriformes (including ducks, swans and geese). Maps of commercial poultry operations in New South Wales are provided, along with maps of the occurrence of Anseriformes and important wetlands for Charadriiformes (migratory shorebirds). From these maps, a map was generated showing priority areas for AIV surveillance in the state.

To evaluate the risk of transfer of low pathogenic AIVs to poultry, it is recommended that sampling be prioritised with Anseriformes in several areas of New South Wales, including the central coast and Sydney basin wetlands. Most efficient sampling should be between December and February, based on bird breeding and seasonal fluctuations in virus prevalence.

To evaluate the risk of wild birds introducing foreign AIV subtypes to Australia, it is recommended that sampling be prioritised with Anseriformes in central and south coast regions of New South Wales. Other areas where significant populations of migratory shorebirds cohabit should also be targeted, and sampling should be most effective between August and October.

Protocols for sampling that are reviewed in the report include trapping, targeted shooting (where birds are shot specifically for sampling), and shooting for damage mitigation (where pest birds are shot as a control method).

The report recommends that future research include: targeting surveillance of Anseriformes at priority areas, trialling field sampling techniques, improving predictions of waterbird density and movement, and further investigating virus subtypes in other bird species.

Surveillance for avian influenza viruses in Tasmanian wild bird populations, 2005–2006

Bell, C. (2006).

This project aimed to conduct targeted surveillance of wild birds for the presence of AIV in Tasmania.

Three populations of waterfowl (Anseriformes), silver gulls and shearwaters were selected based on their potential involvement in an AI outbreak: waterfowl are a species likely to act as AIV reservoir, silver gulls are species involved in local virus cycling and migratory short tailed shearwaters are in close contact with humans through harvesting. Waterfowl and silver gulls were sampled from southeast Tasmania, in a region close to commercial poultry operations and wetlands. Shearwaters were sampled on Little Dog Island in Bass Strait.

A total of 442 cloacal samples were collected from 227 waterfowl, 47 silver gulls and 168 shearwaters. Blood samples were collected from 194 of the waterfowl and 24 of the gulls. No birds showed clinical signs of AI. Samples were analysed using RT-PCR and competitive (c)ELISA serology tests.

The author acknowledged some difficulties with the cELISA tests, and also that the sampling was biased due to logistical constraints and so may not be truly representative of wild bird populations. However, AIV was identified by RT-PCR and cELISA testing in a low proportion of duck and gull samples. No evidence for AIV infection was observed in any shearwater samples. Influenza A virus was isolated from three cloacal swabs, and identified as type H3N8 from a mallard duck, H4N6 from a Pacific duck and type H13N6 from a gull. The results present the first report of positive serology and isolation of H13 subtype AIV in the southern hemisphere.

The report concludes that although a very low proportion (1–2%) of waterfowl and silver gulls tested positive for AIV, a higher proportion (20% –29%) showed evidence of previous exposure to AI. It also concludes that the risk of short tailed shearwaters introducing or spreading AIV in Australia is low. The report recommends continued active surveillance in wild birds around Australia to improve current assessments.

Genetic structure of Australo-Indonesian waterbird populations

Roshier, D., Ten Have, J. and Chesser, T. (2006).

This was a very short project to attempt the feasibility of using museum specimens to analyse genetic variation in southeast Asian waterbird populations. The rationale was that variation in mitochondrial (mt)DNA and nuclear DNA can be used as a measure of connectivity between different populations, and could thus provide information on patterns of movement of waterbirds. Currently, little is known about bird movements across the Torres Strait: some populations move regularly with seasonal migrations, other populations or individuals move frequently but irregularly, and others move infrequently in response to environmental pressures and so on (eg drought in Australia). Understanding the movements and connectivity between bird populations will help manage the risks of avian disease outbreaks.

The specific aims of the project were to:

- sequence mtDNA from museum specimens from Indonesia and compare to Australian specimens
- determine microsatellite genotypes (from nuclear DNA) for museum specimens from Indonesia and compare to Australian specimens.

Tissue samples were taken from toe pads of Grey Teal duck specimens collected in Java in the early 1900's. MtDNA and nuclear DNA were extracted, and PCR was used to attempt amplification of specific sequences. The results of this preliminary attempt were not very successful. While some PCR products were obtained with mtDNA samples after optimising reactions, these products were not found to match Indonesian Grey Teal (some degree of similarity was found to mtDNA from other bird species). No PCR products were obtained with nuclear DNA samples from museum tissues.

It was concluded that the DNA extracted from the museum specimens was either contaminated, or possibly degraded. The report did not rule out future analysis of museum samples, but suggested other tissues may yield better DNA, and that extraction and PCR methods may need further optimisation for successful DNA amplification to occur. An alternative approach suggested was to try the existing methods but with newly collected material.

Surveillance for avian influenza viruses at the Bolivar Lagoons, South Australia

Dickason, C. (2006).

This very brief project report describes surveillance for AIV in the wild waterfowl population at the Bolivar sewage plant sedimentation lagoons. The aim of the project was to monitor this South Australian waterfowl population for AIV by PCR testing faecal samples collected from a variety of species.

Waterbird species observed at the lagoons included various ducks, coots, swan, shovelers, plovers, gulls, pelicans and others. 90 fresh faecal samples (30 tubes with three pooled samples each) were collected approximately weekly from lagoon shores, ten times between March and May 2006. Samples were subjected to a PCR test developed by the Australian Biosecurity Cooperative Research Centre for Emerging Infectious Disease. Samples giving a positive or equivocal result in the PCR were cultured for virus isolation to identify H and N types.

Of the 300 pooled samples screened by PCR, two gave positive results for AIV. One pooled sample gave an equivocal result. No virus was isolated from any of these tested samples. The report provides no recommendations.

Application of rapid diagnostic tests to detect exotic West Nile antibodies and virus during surveillance of wild birds, mosquito populations, equines and sentinel flocks

Peroulis, I., Azuolas, J., Warner, S., Brown K., Welch, A. and Heuston, L. (2006).

West Nile Virus (WNV) is a mosquito-borne virus in the family Flaviviridae, genus *Flavivirus*, and is a member of the Japanese encephalitis virus (JEV) serocomplex. Birds appear to be the amplifying hosts for WNV, but incidental hosts are humans, horses and other mammals. In the

United States, WNV has been a serious problem, having severe impacts on horses, humans and many bird species. WNV is a potential threat to Australia, since the mosquito vectors and reservoir host species are present to maintain an epizootic/ enzootic cycle. Accurate diagnosis and effective surveillance systems need to be maintained for biosecurity.

The aim of this project was to survey sentinel chickens, wildlife and horses in eastern Australia for WNV.

Collaborations were established with interstate centres (Westmead Hospital, University of Queensland and Primary Industries Research Victoria) involved in WNV diagnostics and surveillance. Serological (competitive ELISA) and molecular (real-time PCR) methodologies were used during an annual monitoring program of sentinel flocks and mosquito populations within Victoria.

Serological tests were done on: 5200 sentinel chicken blood samples, 60 wild duck blood samples, 2 kangaroo blood samples, 2 raven blood samples and 1500 historical equine samples. No WNV antibodies were detected. 1500 historical and current equine sera were screened for flavivirus antibodies. The samples came from Queensland, New South Wales and Victoria, from 1996–2001 as well as 2005 and 2006. Of these samples, 162 tested positive for flavivirus antibodies (15 for Murray Valley encephalitis, 104 for Kunjin and 56 unknown flavivirus positives).

100,000 mosquitoes were PCR tested for the presence of WNV, but no WNV was detected.

The equine serology data obtained corroborated with previous positive detection of Kunjin in sentinel poultry and with the documented spread of Kunjin and Murray Valley Encephalitis virus in eastern states over the tested years. The report recommends enhancing surveillance for exotic arboviruses by extending current sentinel programs to include equines, as well as wildlife, sentinel poultry and mosquitoes, particularly if drought conditions do not continue.

A cross-jurisdictional model for targeted surveillance of wild bird species

Gordon, A. N. and Field, H. (2006).

Queensland's Parks and Wildlife Service (QPWS) and Department of Primary Industries and Fisheries (DPIF) have recently developed protocols for submitting samples positively biased towards bird species with a high risk of AI, and for morbidity/mortality events more likely associated with infectious disease. The aim of this project was to test the cross-departmental approach to wild bird disease surveillance. A secondary outcome of the project was to provide improved 'cause of morbidity/mortality' data to QPWS and so increase information on disease trends in wild birds.

In this project, high-risk species such as waterfowl and migratory shorebirds were targeted for AIV and Newcastle Disease Virus (NDV) assessment. Bird samples were also tested for the presence of pesticides, heavy metals, botulism and other bacteria or events. Sick and dead birds were submitted from a variety of sources; mostly from the Environment Protection Agency and DPIF, but also from veterinarians, city councils, wildlife agencies and the general public. A total of 47 submissions of wild birds were received and processed between November 2005 and June 2006. Included in these submissions were 103 individual birds from 20 species, and 20 mass-mortality events.

Most birds were tested for AIV using real-time RT-PCR and all of these returned negative results. No AIV was isolated from any cultures. About half the birds were tested for NDV with real-time RT-PCR, but this proved an unreliable method of diagnosis: while no positive PCR results were obtained, a NDV was incidentally isolated from a cloacal swab. Some selected cases were tested for West Nile virus, but results were negative. Causes of mortality were found for some samples, including organophosphorous poisoning, botulism, trauma and parasitism; many samples were still awaiting further diagnosis.

Overall, the report concludes that the cross-jurisdictional model tested was effective at gaining surveillance data on sick and dead birds. The collaborative effort improved over the course of the project, establishing an effective network of submitters. The report recommends future activities clearly define whether sample submissions are for full mortality diagnosis or more simply for excluding the presence of viruses. Where the former is the case, it is recommended that adequate funding is secured, a single pathologist conducts/coordinates the investigations (for consistency), and submission of better quality samples is encouraged (through formal agreement or provision of appropriate kits).

Detecting avian influenza in wild birds in New South Wales

Kirkland, P. D. and Tracey, J. (2006).

This project was a follow-on from the New South Wales pilot project (Tracey 2005, above). The report emphasises that wild birds are known reservoirs for AIVs, but there is uncertainty on their role of introducing foreign subtypes of influenza to Australia. There is also insufficient knowledge on how wild birds may contribute to an outbreak of high pathogenic (HP) AI in poultry, particularly with respect to low pathogenic (LP) AI converting to HPAI. Targeted sampling of bird populations was considered an effective way of improving understanding of these factors and therefore our preparedness for an outbreak of AI.

The aims of this project were to monitor wild bird populations for AIV infection and build capacity to respond to an AIV outbreak. Specific objectives were to:

- identify target populations of wild birds
- field sample these populations and analyse the samples in laboratory tests
- establish collaborations, implement field sampling protocols and building infrastructure to enable rapid detection of AIV
- contribute to a national AIV surveillance program (with the AWHN).

Species of the Anatidae family were targeted for surveillance, from multiple locations across New South Wales. Sites included some with close proximity to commercial poultry operations (Jerilderie), significant wetlands (Narrandera), coastal populated areas, and more isolated inland sites. A total of 1139 birds of various ages were sampled, including: 1071 anatids, 58 eurasian coots and 10 dusky moorhens. Cloacal swabs and blood samples were collected between October 2005 and June 2006, using targeted shooting and live trapping techniques. A number of different laboratory tests were used to screen samples for AIV, including a 'Flu Detect' rapid antigen detection kit, real-time RT-PCR reactions and Influenza A group serology (ELISA assays). Samples that gave positive or equivocal results by PCR were also subjected to virus isolation in embryonated chicken eggs.

Overall results from sample analyses showed a very low prevalence of AIV in New South Wales. The report concludes that the real-time RT-PCR methodology used was an efficient screening procedure, allowing rapid processing of large numbers of samples. However, some (6 out of 1139) PCR reactions gave inconclusive results that would need to be followed up with nucleic acid sequencing. Only one Grey Teal duck sample gave a moderately positive result for the RT-PCR test. No virus was isolated from any of the samples.

The Flu Detect kit was found to be robust and highly specific, and was considered useful for future clinical tests or dead bird surveillance. No AIV was detected in any samples with the kit. The Influenza A group serology test was found less useful, giving a significant number of samples with inconclusive results.

Both targeted shooting and trapping had advantages as sample collecting methods. While adequate numbers of samples could be obtained over short periods with knowledgeable shooters, site selection was limited by shooter availability and location. Targeted trapping was more labour intensive but enabled more detailed information to be collected.

Improvements to data collection, sampling and laboratory testing are recommended, including: ongoing training of personnel, more intensive focusing of sampling (location and timing) and serum collection for antibody detection. The report also recommends continued efforts to accumulate data in a national database, and to validate/standardise testing protocols between different jurisdictions.

Application of rapid diagnostic tests in the targeted surveillance of avian influenza virus within Victorian wild bird populations

Warner, S., Welch A., Ainsworth, C., Tracey, J., Zikesch, F., Saunders, G. and Lukins, B. (2006).

This project was a continuation of Warner (2005) described above. Its general aim was to undertake a targeted surveillance program for avian influenza in Victoria. Specific objectives and outcomes were:

- development of a geographic information system (GIS) for Victoria for identifying key areas for wild bird surveillance, including maps of poultry farms close to wild birds, and bird abundance maps
- field sampling of targeted species at high-risk locations
- recommendation of a PCR screening test for use in AI surveillance
- adaptation of PCR methodologies for high throughput testing
- incorporation of data within a national surveillance database.

This project involved collaboration between the Victorian and New South Wales Departments of Primary Industries (DPI): NSW DPI did the GIS mapping and risk assessments, and Victorian DPI did the wild bird sampling based on their results. The project was designed to establish the basics for a longer term AI surveillance approach, for Victoria and ultimately for Australia.
GIS was used to identify the high-risk areas for the transmission of AI between wild ducks and domestic poultry in Victoria. A series of maps is provided in the report showing the: location of commercial poultry farms, Anseriformes density, and presence of important wetlands for Charadriiformes. Key areas of AI risk were determined by proximity of poultry operations to major wetlands with high Anseriformes density.

Cloacal samples were collected from 723 anatids and 1500 shorebirds and other waterbirds as part of a national surveillance program for AIV. Samples were collected from high-priority areas and also some non-priority areas. They were processed using AIV Type A PCR (a nested PCR test designed to detect any of the 16 subtypes of Type A AIV), developed in the previous project.

45 samples tested positive by PCR, 40 from anatids (a prevalence of 5.5%) and 5 from shorebirds and other waterbirds (0.33%). High prevalence species included black swan, Australasian Shoveler, Chestnut Teal duck and Grey Teal duck. The majority of positive duck samples came from the Gippsland region, which was not identified as a high-risk area from the GIS mapping and risk assessment.

No live virus could be cultured from any of the PCR-positive samples. The authors conclude that inadequate transport and/or storage conditions, or a very low virus level was responsible, or that the viruses were not alive in the birds at the time of sampling. More extensive PCR tests and sequencing were done to confirm the initial PCR results.

PCR tests used in the project showed different levels of diagnostic sensitivity: the researchers' nested PCR test was several orders of magnitude more sensitive than a real-time PCR test being used by various laboratories in a coordinated PCR testing program at the time. The PCR methodologies described in the first project were adapted for high throughput testing, allowing hundreds of individual samples to be processed in a day.

The results of the survey were incorporated into the eWHIS national AIV surveillance database.

The report recommends that:

- future samples of shorebirds should be pooled to reduce testing costs, given their overall low prevalence of AIV
- future samples from ducks and black swans should be processed individually, due to their apparent higher prevalence
- more work should be done to determine optimal conditions for sample collection, transport and subsequent storage to improve success rate of live virus culture
- future projects should include virus subtyping analysis to provide information on the ecology of endemic AI viruses in Australia, to help inform risk management.

2.5 Other WEDPP projects

Training in the use of Gen-Wed (generic models for wildlife and exotic disease)

McLeod, S., Druhan, J.P. and Saunders, G. (2000).

This report acknowledges there are many wildlife disease models available, but they often require expert knowledge and / or mathematical training to use for disease management. The role of such models in disease contingency planning is essential. This project sought to create a more user-friendly model that could be used by a variety of personnel as a disease management and training tool. The specific aims were to construct mechanistic models that could:

- predict the behaviour and impact of key exotic diseases of carnivores, feral pigs and feral herbivores
- be operationally useful and user friendly
- monitor impacts of population reduction and vaccination on disease spread
- evaluate the necessary extent and usefulness of disease sampling procedures
- predict the effect of natural dispersal mechanisms on the spread of disease.

The 'Gen-WED' package was developed to deliver the above outcomes. An overview of the program is given, and an example of its use as a training tool is demonstrated for FMD. Spatial or non-spatial simulations can be run, and model results can be displayed in a variety of ways, including a time series of the disease dynamics or a table of data.

Workshops were run to train state and federal representatives in the use and interpretation of the Gen-WED program, and feedback allowed further refinement of the model. A cd-ROM of the package was supplied with the report, and the authors were confident it would be a useful training, administrative and predictive management tool for disease preparedness.

Proceedings of the conference 'Veterinary Conservation Biology Wildlife Health and Management in Australasia' July 2001, Sydney

Author not stated (2001).

Various presentations on wildlife health and management are included in the proceedings, including the following topics:

- Conservation — including dingoes, cats, ticks, zoos, indigenous protected areas, and including a model for a national wildlife health network
- Sustainable use of wildlife — including aboriginal use of wildlife in Northern Territory, kangaroo harvesting, coarse fish in Ireland, animals in medical research
- Marine wildlife and birds — including diseases and management in New Zealand, little penguins, kiwis, stitch birds, feral pigeons, lorikeets, seals in United States, and sea lions
- Wildlife translocations and recovery — including kangaroos, wallabies, koalas, whooping crane, tigers, and issues of fertility control, welfare, and disease
- Wildlife health — including bat viruses; avian vacuolar myelinopathy; chytridiomyosis; diseases of platypus, wallabies and wombats; role of nutrition; online diagnosis of diseases in Australia; monitoring diseases in wildlife.

Enhancing the Australian Registry of Wildlife Pathology

Rose, K. (2003).

The aim of this project was 'to enhance the capacity of the registry to integrate and disseminate information and diagnostic materials to agencies involved in wildlife exotic disease preparedness and response'.

The primary outcomes of the project were the:

- determination of the best ways to enhance the capacity of the registry to collect and manage data on wildlife health — data gathering, reporting, entry, analysis, storage and dissemination were addressed, as was storage of materials/samples
- improvement of the registry's computerised archival system, for data analysis and reporting
- development of a registry of expertise and resources
- improvement of storage facilities for the registry's specimens (paraffin blocks)
- production of an informative brochure on the materials, information and services of the registry, for distribution to stakeholders.

NSW pest animal survey and update of key risk areas

Saunders, G., West, P. and Jones, G. (2003).

This report was written for the WEDPP project entitled 'Pest animal survey 2002: an analysis of pest animal distribution and abundance across NSW and the ACT'. The report emphasises that information on the distribution and density of pest and wildlife populations needs to be reliable and readily accessible, especially to enable an efficient response to an emergency disease outbreak. The purpose of this project was to conduct a statewide survey of wildlife species that have the potential to spread or act as reservoirs for exotic animal diseases.

The project aims were to:

- conduct a statewide survey of wildlife pest species
- update and improve accuracy of distribution and abundance maps
- provide baseline information for identifying populations at risk of disease
- establish uniform survey techniques and a database for survey information.

Outcomes of the project included accurate distribution maps and recommendations for ongoing monitoring programs. The 2002 survey results using GIS mapping technology are given. Standardised pest density scaling systems were used in consultation with local information sources (eg National Parks and Wildlife Service, catchment authorities, hunting associations, wildlife harvesters and Aboriginal Lands Councils).

The survey focused on foxes, rabbits, feral pigs, feral cats, wild dogs/dingoes, feral goats, hare, wild deer, wild horses and feral livestock. Diseases that these species are susceptible to or can carry are outlined. The most abundant species reported were foxes, rabbits and feral pigs. Feral cats, wild dogs, feral goats, hare and wild deer were also reported as abundant. Wild horses and feral livestock were reported as scarce. A summary of the findings on each pest species is given below.

Foxes were reported to have increased in distribution (to 98% of NSW and ACT) and abundance over recent years. However, control efforts had also increased, suggesting a lack of effectiveness of the techniques chosen: an over reliance on baiting with 1080 poison was mentioned. Impacts of foxes were cited as predation of livestock and wildlife, and risk of rabies.

Rabbits had increased in distribution across the state (to 69%), but decreased in density. The reduction in numbers was largely attributed to the success of rabbit calicivirus disease (RCD), although a varied effectiveness of the RCD virus was noted. Control efforts varied across the state, with some landholders relying solely on RCD, and others employing a more integrated approach.

Feral pigs had increased in abundance and distribution (to 20% of NSW and ACT) since 1996 when a previous survey had been done. Control efforts had also increased; suggesting a more proactive approach (eg targeting pre-breeding seasons) could be more successful. A wide range of control methods were used, including hunting and commercial harvesting. The highest impacts of feral pigs were considered to be pasture and land degradation, and disease risk.

Feral cats were thought to be widespread in NSW and the ACT, although their elusive nature made estimates difficult. Wildlife predation was cited as their major impact. Control efforts were uncommonly used, but included shooting and trapping.

Wild dogs were thought to be widespread in the tablelands, coastal and far-western regions of the state. They were reported by some respondents to have slightly increased in distribution since 1996, inhabiting 28% of NSW and ACT. In many small areas their density was considered high, but the majority of the state had a low abundance. Livestock predation seemed to be the main impact of wild dogs. Control efforts had increased, with 1080 baiting being the most common method.

Feral goats had slightly decreased in both overall distribution (to 37%) and density since 1996. However, some localised increases in eastern NSW were reported. Mustering and ground shooting were the main control methods used, with commercial harvesting providing an incentive in western NSW.

Wild deer were seen to be an emerging pest increasing in abundance, with six species inhabiting 5% of NSW and ACT (primarily in the Great Dividing Range and coastal regions). The main impacts cited for deer were the risk of exotic disease, spread of livestock disease, and pasture competition. Suitable control methods had not been identified.

Hares had a patchy but widespread distribution across the state, but were not considered a major pest. Wild horses were localised in several small regions of NSW, and were not considered high impact pests. Feral livestock were reported to have a very low abundance and were seen to present a disease risk.

The survey reported that rangers rated exotic disease as a moderately high risk, particularly with feral pigs, feral goats and wild deer. About half the rangers considered themselves adequately prepared for an exotic disease emergency. Their pest management experience was stated as providing an adequate skills base to deal with disease outbreaks in wildlife populations.

The report concludes that the information provided would be useful to assess whether wild animal densities pose a disease transmission risk, and to help plan an appropriate disease response strategy.

Another proposed outcome of the project was a risk analysis for potential wildlife and disease associations, and identification of resource requirements for controlling wildlife populations in key risk areas. However, no final report for this part of the project was available.

Distribution and abundance of pest animals in Western Australia

Woolnough, A., Gray, G. S., Lowe, T. J., Kirkpatrick, W. E., Rose, K. and Martin, G. R. (2005).

This project acknowledges that reliable assessment of pest animal distribution and abundance is essential for effective pest management. Availability of high quality information on pest distribution and abundance allows identification of potential hot spots for disease or for significant impacts on production or biodiversity. It also provides data for triple-bottom-line (economic, environmental and social) assessments. This project consisted of two main parts to capture institutional knowledge of pest animals in Western Australia: (1) a questionnaire about pest animal abundance and impacts, and (2) collection of spatial data on abundance and distribution on a property basis.

For the purposes of the survey, the state was divided arbitrarily into an agricultural and a pastoral region. Pest animals covered in the agricultural region included feral pigs, feral deer, feral goats and wild dogs. In the pastoral region, these animals and feral donkeys, feral camels, feral horses and livestock were surveyed. Overabundant species, such as rabbits, foxes and feral cats were not included in the mapping exercise, but were included in the questionnaire. The same applied to overabundant native animals. Data was collected over 12 months from November 2002.

Staff from the Western Australian Departments of Agriculture, and Conservation and Land Management were interviewed. The main observations are listed below.

- Foxes were rated as having the biggest (triple-bottom-line) impact in the agricultural region. In the pastoral region, wild dogs were rated as the worst pest for economic impacts, but feral cats were ranked highest for impacts on social and biodiversity values.
- Feral pigs, feral cats, foxes, emus and kangaroos were thought to be increasing in abundance in the agricultural region. Wild dogs were considered to be increasing in number in the pastoral region.
- The key impacts of herbivorous pests were considered to be damage to native and agricultural plants, and soil erosion and watercourse damage. The key impacts of carnivorous pests were considered to be predation of native animals and livestock.
- Different pest control methods were being used in different jurisdictions, with different levels of effectiveness. Standardised operating procedures could be useful.

The mapping data was standardised using clear definitions of abundance, and was deconstructed into 10 km grids to avoid privacy issues. This allowed spatial comparability across local, regional and national scales and also allowed hot spots of high disease risk to be identified.

The report recommends that such surveys (with some refinement of the techniques used) be repeated at regular intervals, and on a national scale. It was considered that empirical data on pest animals and disease should be obtained to support the survey results. Staff from both departments could be better trained in exotic disease preparedness, including the role that people could play in an emergency outbreak.

2.6 Other reports included in WEDPP files

These reports are included in this chapter, since a representative/s of WEDPP was a key participant in these workshops.

Feral animal risks and foot-and-mouth disease — An Australian perspective

Black, P. (2002).

This report to Veterinary Committee was from a working group that included a representative of WEDPP (Chris Bunn). The report was the outcome of a Consultative Committee on Exotic Animal Disease meeting in 2001, which nominated a working group to review feral animal risks and FMD. The review:

- summarises the situation of FMD risk to Australia at that time, taking into account feral animal distribution and abundance, relevant legislation, and disease preparedness
- summarises information on FMD in pigs and ruminants, and the AUSVETPLAN
- provides recommendations for future research and policy development.

The report concludes that while much of the necessary work on feral animals and their role in FMD has been done, the results of this work need to be more widely disseminated. Public and agency perceptions about the role of ferals, and disease-response actions need to be addressed. Pest control and disease management agencies need to collaborate and agree on their roles and actions now, before an emergency outbreak occurs.

Recommendations of the review include: developing feral animal and FMD policies as a collaboration between key vertebrate pests/animal health committees and agencies; promoting the AUSVETPLAN Wild Animal Management Manual; prioritising projects addressing feral animal risk analysis, disease surveillance and epidemiology; developing and maintaining a national wildlife health database; conducting large-scale disease simulation exercises; and standardising and maintaining distribution and abundance data between states. The report also recommends consideration of the game harvest industry when developing policies for managing emergency disease outbreaks. A review of the suitability of current legislation with regard to managing an emergency outbreak is also recommended.

Decision support tools and the management of feral pigs in an emergency animal disease event

Black, P. (2003).

This report contains proceedings from a workshop (with the same title) held in Canberra in November 2003. The range of participants included disease modellers, epidemiologists, veterinarians, quarantine officials and wildlife specialists. The workshop aims were to:

- review feral pig ecology and epidemiology of diseases of concern
- increase understanding of, and assess suitability of, current feral pig disease models
- increase familiarity with the Wild Animal Resource Strategy (WARS)
- identify improvements to WARS and other relevant sections of AUSVETPLAN
- define future actions as appropriate.

The participants concluded that pig ecology and diseases were addressed, although the focus had been almost entirely on FMD. They recognised that a number of disease models need to be published in more detail than currently available, to enable reconstruction if necessary. More data for parameterising single or multiple host models is also needed; and information on contact rates and disease transmission is lacking, particularly for emerging diseases.

The most appropriate use of models was considered to be during ‘peacetime’, to enable retrospective analyses and to better understand epidemic behaviour. Use of models during an actual outbreak is most useful for monitoring, and fine tuning management approaches.

The workshop identified several areas for improvement of WARS and other sections of AUSVETPLAN, and provides recommendations, particularly for mentioning surveillance issues.

Future actions identified by the participants include: following up on research into disease transmission from pig carcasses, keeping stakeholders informed of compartmentalisation issues, incorporating improvements into WARS and AUSVETPLAN, publishing a FMD model, and keeping colleagues informed of workshop outcomes (including a journal publication reviewing potential application of disease models as decision support tools).

Avian influenza workshop report

Bunn, C., Mortier, J., Milne, B. and Moore, C. (2004).

Highly pathogenic avian influenza (HPAI) is considered to be a major exotic disease of concern to Australia. Five outbreaks have occurred in Australia since1976; all associated with AI-infected wild birds contaminating the environment close to commercial operations (such as poultry farms). It is recognised that more knowledge concerning the presence and ecology of AI viruses in Australian wild birds is needed.

This report summarises the conclusions and recommendations of an avian influenza workshop held in Melbourne, 4–5 March 2004. The workshop brought together about 30 participants from a diverse range of organisations. It was sponsored by WEDPP, DAFF and the Victorian Department of Primary Industries Research.

The main conclusions of the workshop were:

1. For domestic flocks to become infected with AI, the HPAI virus must pass through a multi-step pathway from migratory waterfowl to commercial operations and then between establishments. There is no evidence that wild bird surveillance will provide an early warning system for HPAI in domestic flocks.

2. The risks for birds (and humans) to become infected at each of the wildlife, free range and commercial stages are different and should be treated separately, particularly with regards to surveillance strategies.

3. The possibility that low pathogenicity (LP) AI subtype viruses (H5 and H7) mutate to virulent forms needs to be further investigated, and incorporated into AI contingency plans (see below).

4. Australian response measures for AI will need to be periodically reviewed to keep in line with changing international standards and information.

5. Government departments of health, agriculture and conservation should maintain a close collaboration on AI issues.

Specific recommendations were put forward by the workshop for the Animal Health Committee and other stakeholders to consider. These include recommendations for surveillance activities, outbreak preparedness and communication strategies:

1. Australia should develop an integrated AI strategy that incorporates surveillance, research, quarantine and vaccination operations, and AUSVETPLAN policies. Response to finding an AI virus should depend on what type of virus is found. World Organisation for Animal Health (OIE) standards and guidelines should be followed. The pig industry should also be considered for inclusion in an AI strategy. Regarding LPAI policy:

   - H5 and H7 subtypes should be included in an Emergency Animal Disease Response Agreement as a cost-sharing disease
   - eradication (if possible) or containment of H5 and H7 subtypes should be a priority (including vaccination).

2. Surveillance objectives and response policies should be established before surveillance is undertaken. Surveillance for AI viruses should be increased and should focus on:

   - assessing free-range industries, to identify high-risk areas

- increasing sample submissions to laboratories, to allow for AI exclusion in suspicious disease occurrences
- a long-term approach to gather spatial, temporal and ecological information.

3. Development, evaluation and training in the use of diagnostic tests are needed. Occupational health and safety protocols should also be developed, resources should be identified and stockpiled and personnel should be trained to use protective equipment.

4. Vaccination options should be considered now, regarding efficacy testing, permits for import and so on.

5. A multi-agency approach should develop compliance mechanisms for industry operators.

6. A communication/education strategy should be developed that targets industry and raises awareness of the potential for LPAI viruses to cause HPAI. Communications should also include information on steps leading to an outbreak and identify potential points of control. The public should also be targeted to boost consumer confidence in the event of an outbreak.

Note: Since this workshop, The Primary Industries Ministerial Council has finalised the policy for 'Response to detection in wild birds' and the AUSVETPLAN has been revised to reflect responses to detection of LPAI and HPAI in wild and zoo birds.

2.7 Concluding comments on WEDPP research

Overall it is clear that WEDPP has had useful input to a wide range of projects relevant to disease preparedness in Australia. These projects have often been collaborations between state agriculture department/s and research institution/s such as Cooperative Research Centres, universities and CSIRO. Private companies have also been involved. Projects funded have included field research, desktop studies, workshops and at least one training exercise.

The projects have, on the whole, been relatively small (due to constraints put on funding and duration of research). Many of the reports describe preliminary work only, or are inconclusive. While in some cases funding has continued over successive projects to progress an issue or research (eg developing the AWHN, and some AI research), most funding appears to be for one-off projects.

Failures to achieve research outcomes have been reported, which is appropriate, and can be useful for determining future research. However, some reports are missing from the office files or have not been submitted at the completion of a project — possibly reflecting limitations in the program's administration.

The variation in quality and comprehensiveness of reports possibly reflects a lack of adequate peer review. Much of the research has not been formally published elsewhere and has apparently not been further evaluated or incorporated into preparedness strategies: there is no supporting documentation stored with the WEDPP files to show whether recommendations have been followed up in further research or policy development. As such, the return on investment is unclear.

A number of reviews of the WEDPP program itself have been done over the years, although the outcomes of these reviews have not always been readily available. Such reviews are essential to ensure research priorities and infrastructure arrangements are regularly reassessed to maximise return on investments.

In conclusion, the contribution made by WEDPP to disease preparedness in Australia could be significantly enhanced by:

- increased funding for longer-term or larger-scale projects
- greater administrative and peer support to ensure high quality project reports are submitted
- increased evaluation and follow-up of research outcomes and report recommendations to incorporate them into disease preparedness policy, training or further research
- supporting documentation to demonstrate when and where such evaluation and follow-up has occurred.

3. Published Australian research related to disease management and preparedness (1999–2007)

3.1 Search methodology

Peer-reviewed scientific literature was searched for Australian research published in 1999–2007, on issues related to disease preparedness and management. Wildlife & Ecology Studies Worldwide (Biblioline version, see http://www.nisc.com/factsheets/qww_.asp), PubMed and Google Scholar databases were searched using key words: feral, wildlife, disease preparedness, invasive animal, Australia. Articles on population-level research of diseases, in which invasive animals are involved as hosts or reservoirs, were particularly sought.

Research articles on individual diseases were not specifically searched. The following exclusions were also made to limit the search:

- technical research on disease agents (molecular biology of viruses, etc)
- descriptions of occurrence and pathology of diseases in wildlife (unless disease management or contingency plans were mentioned)
- research on aquatic animals
- articles on rabbit haemorrhagic disease and its management
- government documents and other 'grey literature'.

The results of the literature search are provided in the list of references in Section 3.3. The list includes applied research into areas considered related to disease management, such as population genetics, modelling and bait uptake, particularly where invasive animals are involved. It is acknowledged the distinction of 'pure' versus 'applied' research with regards to disease preparedness implications was subjective. The reference list shows search results primarily for Australian research, although several key international reviews are included at the end. The list is aimed to provide a starting point for discussion of the recent history and future directions of wildlife disease research and preparedness strategies.

3.2 Research summary

Based on the literature search, recent research related to disease preparedness can be broadly categorised into research on feral pests, diseases in native animals, and more general reviews. Some examples are provided below; the full reference list is provided in Section 3.3.

Feral animals:

- management of feral pigs — models and simulated spatial dynamics of foot and mouth disease (Dexter 2003, Doran and Laffan 2005, Garner and Beckett 2005), incidence of *Brucella suis* (Mason and Fleming 1999), socio/genetic structure of populations (Hampton et al 2004ab, 2005; Spencer et al 2005; Spencer and Hampton 2005; Cowled et al 2007), hunters and disease surveillance (Mason and Fleming 1999), and population control (Saunders and McLeod 1999, Fleming et al 2000, Hone 2002, Heise-Pavlov and Heise-Pavlov 2003, Twigg et al 2005, 2006; Cowled et al 2006ab).

- the potential role of urban foxes in transmitting rabies (Marks and Bloomfield 1999ab)
- contact rates and disease transmission in feral sheep and goats — temporal and spatial models of foot and mouth disease (Fleming et al 2000, 2005)
- simulating/modelling pathogen transmission (McCallum et al 2001, Beckett and Garner 2007)
- hydatidosis and other zoonoses in wild dogs and foxes (Brown and Copeman 2003; Jenkins 2005, 2006; Allen 2006).

Native wildlife:

Surveys or descriptions of diseases in native wildlife with implications for management and preparedness:

- zoonoses in flying foxes (Roetgers 2002, Mackenzie et al 2003, Breed et al 2006, Fields et al 2007)
- sarcoptic mange in wombats (Skerratt 2005)
- zoonoses in white ibis (Epstein et al 2006, McKee et al 2007)
- devil facial tumour disease (Jones et al 2007)
- avian influenza in wild birds (Tracey et al 2004, 2006; Bunn et al 2007)
- hydatidosis in a range of native animals (Jenkins 2006).

The wildlife disease articles mentioned in Section 1.3 of this report are also included in the reference list in Section 3.3.

Other articles:

- cross-cultural management issues (Thompson 2001, Robinson and Whitehead 2003)
- general biosecurity issues/reviews (Daszak et al 2000; Denney 2001, 2007ab; Thompson et al 2003, Thornley 2003)
- networks for disease management (Bunn and Woods 2005, Woods and Bunn 2005, Woolnough et al 2004, Smith et al 2006, Kasbarian et al 2007, McKee et al 2007).

3.3 Reference list from literature search

Australian articles:

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Allen, B. (2006). Urban dingoes (*Canis lupus dingo* and hybrids) and human hydatid disease (*Echinococcus granulosus*) in Queensland, Australia, Proceedings of the 22nd Vertebrate Pest Conference, Berkeley, California March 6-9 2006, pp. 334-338.

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Beckett, S. and Garner, M. G. (2007). Simulating disease spread within a geographic information system environment. *Veterinaria Italiana* 43(3): 595-604.

Breed, A. C., Field, H. E., Epstein, J. H. and Daszak, P. (2006). Emerging henipaviruses and flying foxes — Conservation and management perspectives. *Biological Conservation* 131(2):211-220.

Brown, B. and Copeman, D. B. (2003). Zoonotic importance of parasites in wild dogs caught in the vicinity of Townsville. *Australian Veterinary Journal* 81(11):700-702.

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Daszak, P., Cunningham, A. A. and Hyatt, A. D. (2000). Emerging Infectious Diseases of Wildlife — Threats to Biodiversity and Human Health. *Science* 287(5452):443-449.

Denny, I. (2007a). Biosecurity, livestock health and the livestock producer. *Australian Veterinary Journal* 85(11):N4. (no abstract available)

Denny, I. (2007b). Australia's emergency animal disease preparedness plan. *Australian Veterinary Journal* 85(3):N4. (no abstract available)

Denny, I. (2001). Urgent need for disease awareness. *Australian Veterinary Journal* 79(4):234. (no abstract available)

Dexter, N. (2003). Stochastic models of foot and mouth disease in feral pigs in the Australian semi-arid rangelands. *Journal of Applied Ecology* 40(2):293-306.

Doran, R. J. and Laffan, S. W. (2005). Simulating the spatial dynamics of foot and mouth disease outbreaks in feral pigs and livestock in Queensland, Australia, using a susceptible-infected-recovered cellular automata model. *Preventive Veterinary Medicine* 70:133-152.

Epstein, J. H., McKee, J., Shaw, P., Hicks, V., Micalizzi, G., Daszak, P., Kilpatrick, A. M. and Kaufman, G. (2006). The Australian White Ibis (*Threskiornis molucca*) as a reservoir of zoonotic and livestock pathogens. *EcoHealth* [Published online: http://www.conservationmedicine.org/papers/Epstein_etal_2006_Ecohealth.pdf]

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4. Research by Cooperative Research Centres (CRCs)

The Invasive Animals (IA) CRC and the Australian Biosecurity (AB) CRC are engaged in researching animal diseases of concern and implications for pest and wildlife management.

The AB CRC's focus is on emerging infectious diseases of humans and animals native to the Australia/Asia region. The goals of the AB CRC relevant to this report are to:

- develop tools for disease detection and surveillance, and to expand knowledge of the potential for emerging infectious disease threats to establish and spread within Australia
- equip people within Australia and the Asia-Pacific region with knowledge and skills for responding to emerging infectious disease threats.

The AB CRC has a variety of research on diagnostics, surveillance and disease ecology. Wildlife diseases/agents being studied include: Australian bat lyssavirus, Nipah virus, Hendra virus (hosted by bats); foot and mouth disease, porcine circovirus (pigs); avian influenza (birds); West Nile virus, Japanese encephalitis, surra, leptospira, bluetongue disease (many hosts). Current AB CRC's research projects related to disease preparedness are listed in Appendix 2.

The IA CRC has a less direct focus on disease research *per se*: its research is primarily aimed at understanding the behaviour of invasive animals within Australian ecosystems and producing innovative products (eg baits, toxins, maps) to help manage or control them (and consequently any diseases they may carry).

One of the goals of the IA CRC is to reduce risk of disease transfer from invasive animals to livestock and humans. This goal should be achieved by providing management recommendations, and tools for disease surveillance and containment. Specific aims related to wildlife disease include:

- collating and disseminating current information on invasive animal diseases
- developing tools for disease surveillance and containment
- ecological and epidemiological studies to improve the management of invasive species
- developing remote vaccine delivery systems
- risk analysis and modelling to increase knowledge of disease/vector behaviour and to quantitatively define the risks posed by invasive animal populations.

Current and planned activities of the IA CRC include: national surveys of invasive animal populations to identify hot spots for disease risks, training programs for operational staff in regional areas to enhance preparedness for wildlife disease issues, and decision support systems for invasive animals in disease emergencies. Current IA CRC projects related to disease preparedness are listed in Appendix 3.

5. Conclusions

The research outlined in this report has given an indication of the breadth of the topics that could fall under 'disease preparedness'. Although a variety of research has been described, the emphasis of this report was on wildlife diseases in which feral animals are indicated as carriers or hosts. While basic research into areas such as seroprevalence, pathogen characteristics and population genetics may not directly relate to disease preparedness, most of this research will have some application to management in the event of an outbreak.

Many scientific publications on wildlife disease have not been aimed at providing management recommendations. But evidence-based policy requires researchers to provide answers to questions that are of interest to policy makers. Disease preparedness could be better served if researchers explained practical and generic implications of their research, and if policy makers were made more aware of the importance of such research, as stated by Gortázar et al (2007):

> '… limiting the research effort to the mere reporting of wildlife disease outbreaks is of limited value if management recommendations are not given at the same time. Thus, more experimental approaches are needed to produce substantial knowledge that enables authorities to make targeted management recommendations. This requires policy makers to be more aware of the value of science and to provide extra funding for the establishment of multidisciplinary scientific teams.'

WEDPP is well placed to seek research outcomes and implement them into preparedness policy. It is important the research conducted is relevant, peer reviewed and competently reported. It is essential to ensure that research investments are not lost through a lack of follow-up evaluation and integration into management strategies.

The IA CRC held a WEDPP-funded workshop in April 2008 to address some of these issues. Experts from around Australia, including government representatives from agriculture and environment departments, wildlife veterinarians and university researchers participated. This report was provided as background information. The summary of the workshop itself, 'Workshop Proceedings: Review of wildlife exotic disease preparedness in Australia' [2], recommends future directions for disease preparedness research and infrastructure.

2 See http://www.invasiveanimals.com/research/detection_and_prevention/index2345678910.html (accessed June 2008)

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Appendix 1: Diseases of concern to Australia involving invasive animals

Disease	Characteristics of disease agent	Animals involved	Disease symptoms	Transmission route
African horse sickness [1,2]	African horse sickness virus, a reovirus of genus *Orbivirus*. Can persist in the environment in the absence of horses. Not found in Australia.	Mainly affects equids, although dogs and goats are also susceptible.	Highly infectious viral disease Often fatal in horses. Characterised by fever and then acute respiratory symptoms and/or swellings around the head and heart failure.	Insects.
African swine fever[2]	African swine fever virus, recently classified as only virus in Asfarviridae family. Can persist in environment and in recovered pigs. Not found in Australia.	Pigs	Highly contagious disease that may cause high mortality rates, fever, hyperaemia of the skin and a variety of clinical signs including incoordination, diarrhoea and pneumonia. Clinically indistinguishable from classical swine fever.	Body fluids, direct contact with infected animals, aerosols, contaminated pigmeat and fomites, ticks.
Air sac mite	Parasitic mite, *Sternostoma tracheacolum.* Found in Australia.	Carried by feral pigeons and sparrows, aviary birds. Affects native finches (eg zebra finch and endangered Gouldian finch), manikins and budgerigars.	Mite colonises bird's air sacs. Can cause death through respiratory distress.	Direct contact via the oral route: eg feeding regurgitated food to young; drinking contaminated water.
Anthrax [2]	Bacterium *Bacillus anthracis*. Vegetative form cannot persist in environment, but if sporulation occurs, spores can persist in soil. Uncommon in Australia but has occurred sporadically.	Affects humans and many wild and domestic animals, including cattle, sheep and goats, pigs, dogs, cats and horses.	Toxin production in bloodstream leads to death.	Contact with infected carcasses or products (wool, hides, fertilisers etc), spores in soil, infected blood, meat products. Possibly flies.
Aujeszky's disease or pseudorabies [2]	Pseudorabies virus, a herpesvirus in genus *Varicellovirus*. Can persist in environment at low temperatures. Not found in Australia.	Mainly affects pigs, though sporadic occurrence in cattle, sheep, goats, dogs, cats, foxes, deer, rabbits, mice and rats.	Can cause abortion, high mortality in piglets, and coughing, sneezing, fever, constipation, depression, seizures, ataxia, circling, and excess salivation in piglets and mature pigs. In other animals, causes itching and death.	Body fluids, aerosol, contaminated fomites.

Disease	Characteristics of disease agent	Animals involved	Disease symptoms	Transmission route
Australian bat lyssavirus disease[1]	Australian bat lyssavirus, a zoonotic rhabdovirus of *Lyssavirus* genus. Closely related to rabies virus. Unlikely to persist in environment. Has been found in several species of flying foxes and insectivorous bats in Australia.	Bats, humans.	Can cause human fatality via viral encephalitis- a notifiable disease in Australia.	Direct contact of wound with infected saliva, possibly aerosols.
Avian influenza [1, 2]	Avian influenza virus, a zoonotic orthomyxovirus in *Influenza A* genus. Believed that avirulent strains from wild birds can mutate to virulent forms in poultry. Can persist at low temperatures in environment. Avirulent strains identified to date in Australia.	Wild birds, poultry. Strain H5N1 virus threat to humans.	Strain specific- can cause mild symptoms or severe respiratory, digestion and nervous system symptoms; can cause clumping /agglutination of blood cells; high mortality rates.	Direct contact with infected animals, contaminated materials.
Avian malaria	*Plasmodium relictum*, a protist. Carried by mosquitoes. Not found in Australia, but vector mosquito species are present.	Birds.	Causes anaemia, weakness and death.	Mosquitoes.
Beak and feather disease [2, 3] (Psittacine circoviral disease)	Beak and feather disease virus, a strain of Circoviridae. Appears to have originated in Australia, is widespread in Australian parrots.	Psittacine species — cockatoos and lorikeets.	Effects can range from inconsequential to fatal. Causes progressive symmetrical feather deformity and loss, beak deformities, immunosuppression and eventual death. Can cause very high death rates in nestlings.	Ingestion or inhalation of virus, contact with infected faeces or feather dust. Transmission from parent to offspring prior to birth also possible.
Bluetongue [1, 2]	Bluetongue virus, a reorvirius of *Orbivirus* genus. Not stable in environment. Present in cattle in north Australia.	Affects ruminants — sheep are the most severely affected.	In sheep and goats: abortion, death or loss of production. Cattle infections usually minor. Characterised by high fever, excessive salivation, swelling of the face and tongue and cyanosis of the tongue.	Insects, particularly midges (cattle can act as reservoirs of the disease).
Bovine spongiform encephalopathy (BSE) [2]	Prion considered most likely agent, although possibly a virus or virion. Can persist in environment. Not found in Australia.	Cattle, cats; linked to similar disease (variant Creutzfeldt-Jakob disease) in humans.	Causes progressive neurodegeneration and death.	Ingestion of contaminated meat products. Possible transmission also by sporadic, inherited or transmissible forms of the agent.

Disease	Characteristics of disease agent	Animals involved	Disease symptoms	Transmission route
Bovine tuberculosis [2]	Bacterium *Mycobacterium bovis*. Can persist in the environment. Last reported case in Australia 2002.	Cattle and buffaloes are the principal hosts; can also cause disease in deer, pigs and humans and, occasionally, in horses, dogs, cats and sheep. Australian brushtail possum is major reservoir in New Zealand.	Contagious chronic disease, causing progressive emaciation and tubercle (abscess) formation in respiratory system and other organs, death.	Inhalation of bacteria, ingestion of contaminated materials, handling infected meat.
Brucellosis[2]	Bacterium species *Brucella abortus, B.suis* and *B.melitensis*. Can persist in organic materials such as faeces, abortion fluids and milk, and in environment at low temperatures. *B.abortus* eradicated from Australia in 1989.	Cattle (*B.abortus*), pigs (*B.suis*) and goats (*B.melitensis*), can also infect humans.	Causes abortions, birth of weak or dead offspring, infertility and reduced milk production in animals. Causes fever in humans. Infected animals can excrete brucella for several weeks.	Ingestion of contaminated feed or water, infected placenta, calf or foetus, genitalia, body fluids, contaminated fomites.
Canine distemper (and related diseases) [2]	Canine distemper virus, a paramyxovirus of genus *Morbillivirus*. Unlikely to persist in environment (except in near freezing temperatures). Found in Australia.	Dogs and foxes.	Can cause immunosuppression, pneumonia, encephalitis with demyelination.	Inhalation of virus particles.
Caprine arthritis/ encephalitis [2]	Caprine encephalitis virus, a retrovirus of genus *Lentivirus*. Unlikely to persist in environment. Found in Australia.	Goats	Can cause chronic disease of the joints and, rarely, encephalitis in goat kids.	Ingestion of colostrum, inhalation of virus particles.
Capripox [1, 2] (sheep and goat pox)	Capripox virus, a poxvirus of genus *Capripoxvirus*. Shows strain-host specificity, although some strains infect both sheep and goats. Can persist in the environment. Not found in Australia.	Sheep and goats.	Highly contagious viral skin disease, can lead to serious loss in production or death. Characterised by lumps in the hide, and death can eventually occur from internal swellings.	Aerosols, contaminated materials and insects.
Chytridiomycosis [3]	Fungus *Batrachochytrium dendrobatidis*, known as amphibian chytrid fungus. Can persist in environment. Found in Australia.	Amphibians.	Can cause sporadic deaths in some amphibian populations and 100% mortality in others. Fungus invades the surface layers of the frog's skin, causing skin cast-off, but cause of host death is not yet known.	Direct contact with fungus, or contaminated water.

Disease	Characteristics of disease agent	Animals involved	Disease symptoms	Transmission route
Classical swine fever [2]	Classical swine fever virus, a flavivirus of genus *Pestivrius*. Unlikely to persist in environment, but can persist in meat products. Not found in Australia since 1961.	Pigs.	Causes fever, skin lesions, convulsions and usually (particularly in young animals) death.	Direct contact with infected animals, contaminated meat products, fomites.
Contagious equine metritis [2]	Bacterium *Taylorella equigenitalis.* Unlikely to persist in environment, but can persist in semen. Not found in Australia since 1980.	Horses, donkeys.	Causes inflammation of uterus, temporary infertility and (rarely) spontaneous abortion.	Sexually transmitted. Direct contact with infected animals, aborted foetuses, and contaminated fomites. Carrier horses.
Equine influenza [2]	Equine influenza virus, an orthomyxovirus of Influenza Type A. Can persist in environment for days. Outbreak occurred in Australia August 2007.	Horses, donkeys.	Causes fever, lethargy, flu-like symptoms. Loss of revenue from breeding and racing restrictions. Low mortality, usually in young animals.	Direct contact with infected animals, aerosols, contaminated fomites.
Feline enteritis or panleukopenia [2]	Feline panleukopenia virus, a parvovirus of the *Parvovirus* genus. Can persist in the environment. Found in Australia.	Cats.	Causes decrease in circulating white blood cells (ie a panleukopenia), and intestinal inflammation, leading to profuse diarrhoea. Can cause death.	Contact with infected bodily fluids, faeces, fleas or fomites.
Feline immunodeficiency syndrome (feline AIDS) [2]	Feline immunodeficiency virus, a retrovirus of genus *Lentivirus*. Found in Australia.	Cats and some large cat species.	Affects the immune system, causing death by chronic infections.	Deep bite wounds, contact with mucosa membranes.
Feline leukaemia [2]	Feline leukemia virus, a retrovirus of genus *Gammaretrovirus*. Does not persist in environment. Found in Australia.	Cats, also large cat species.	Effects can range from the host showing no symptoms and extinguishing the infection, host becoming a carrier, or virus causing immunosuppression and death from leukaemia, lymphoma, and anaemia.	Contaminated water and fomites, biting or other contact through mucosa membranes. In utero transmission to offspring.
Foot and mouth disease [1, 2]	Foot and mouth disease virus, a picornavirus of the genus *Aphthovirus*. Can persist in the environment for considerable time. Not found in Australia.	Mainly affects cloven-hoofed animals, but also rodents and some other animals.	Highly contagious and sometimes fatal - has potentially the largest economic ramifications for Australia. Mortality may be high in young animals; causes loss of production in others. Characterised by high fever and blisters in mouth and on feet.	Transmitted by aerosols, and contaminated food and water. Recovered animals may continue to carry the virus.

Disease	Characteristics of disease agent	Animals involved	Disease symptoms	Transmission route
Hendra virus disease (equine morbillivirus)	Hendra virus, a zoonotic paramyxovirus in *Henipavirus* genus. Found in fruit bats (flying foxes). Cannot persist in environment. Found in Australia.	Horses, bats, cats, humans.	Causes illness and death in domestic animals.	Body fluids, contact with contaminated materials.
Hydatidosis[2] (also Echinococcosis)	Parasitic tapeworm larvae of genus *Echinococcus.* Eggs can persist in the environment. *E. granulosus* is found in Australia.	Definitive hosts are primarily dogs and foxes. Disease affects intermediate hosts: wallabies, kangaroos, wombats, livestock animals, humans.	Causes formation of hydatid cysts in the internal organs of intermediate hosts. Can cause death.	Ingestion of eggs/larvae in raw meat products, faeces.
Japanese encephalitis [1, 2]	Japanese encephalitis virus, a zoonotic flavivirus, of *Flavivirus* genus. Cannot persist in environment outside host. Occurred in Torres Strait Islands, and far northern Australia 1998.	Domestic pigs and water birds are main reservoirs of the virus. Horses and humans most affected. Unapparent infections occur in cattle, sheep, goats, dogs, cats, rodents, snakes and frogs.	Causes abortions, stillbirths, weak young in pigs. Can cause severe or fatal encephalitis in humans and horses.	Mosquitoes.
Johne's disease	Bacterium *Mycobacterium paratuberculosis.* Resides mainly in animal intestines but can persist (but not multiply) in outside environment for several months. Occurs in Australia. Bovine and ovine strains.	Bovine Johne's disease (BJD) mainly affecting cattle, goats, camelids and deer. Ovine strain (OJD) mainly affects sheep.	Causes chronic wasting from intestinal damage, often after years of infection.	Ingestion of faeces, or contaminated feed, water, milk.
Leptospirosis [2]	Zoonotic spirochete bacterium of genus *Leptospira*, endemic in ferals. Can persist in environment. Found in Australia.	Affects wide range of mammals (including humans), birds, reptiles and amphibians. Pigs, rats, mice are important primary hosts, but also dogs, deer, rabbits, cows, sheep, possums, and even certain marine mammals.	Causes liver/kidney failure, can cause meningitis. Abortions and stillbirths in animals, loss of milk production.	Body fluids, materials contaminated with urine.
Lumpy skin disease [1, 2]	Lumpy skin disease virus, a poxvirus of genus *Capripoxvirus*. Can persist in the environment. Not found in Australia.	Cattle and possibly buffalo.	Highly contagious viral skin disease of cattle. Can cause serious production losses from debility, or death of calves. Characterised by skin nodules, oedema of the limbs and swelling of lymph nodes.	Insects, contaminated materials.

Disease	Characteristics of disease agent	Animals involved	Disease symptoms	Transmission route
Lyme disease	Zoonotic spirochete bacteria of genus *Borrelia*. Some controversy, but does not seem to occur in Australia.	Carried primarily by deer, cattle, dogs, and sheep. Disease affects humans.	Can cause skin lesions, and later stages involve cardiac, arthritic, or neurological symptoms. Rare cases of fatality.	By tick bite.
Menangle virus disease [2]	Menangle virus, a zoonotic paramyxovirus in *Rubulavirus* genus. Found in fruit bats (flying foxes). Cannot persist in environment. Found in Australia.	Pigs, bats and humans.	Causes flu-like symptoms in humans; still born births and deformities in pigs; bats appear to be an asymptomatic host.	Body fluids.
Newcastle disease [1, 2]	Newcastle disease virus, a zoonotic paramyxovirus in *Rubulavirus* genus. Unstable in environment. Found in Australia.	Wild birds, poultry. Mildly affects humans.	Strain specific — can cause mild symptoms or severe respiratory, digestion and nervous system symptoms; can cause clumping /agglutination of blood cells; high mortality rates.	Direct contact with infected animals, aerosols, contaminated materials.
Nipah virus disease[2]	Nipah virus, a zoonotic paramyxovirus in *Henipavirus* genus. Found in fruit bats (flying foxes). Cannot persist in environment. Not found in Australia.	Pigs, bats, humans.	Causes acute respiratory distress, and neurological symptoms, low mortality in animals. In humans, influenza symptoms or can progress to encephalitis and death.	Body fluids.
Peste des petits ruminants (also goat plague) [2]	Peste des petits ruminants virus, a paramyxovirus of genus *Morbillivirus*. Cannot persist in environment, but can persist in meat at low temperature. Not found in Australia.	Goats, sheep. Possibly cattle, pigs and deer.	Causes fever, necrotic mouth lesions, severe diarrhoea or dysentery, and death. Also causes abortions. Affects goats more severely than sheep.	Direct contact with infected animals, aerosols, body fluids.
Porcine reproductive and respiratory syndrome [2]	Porcine reproductive and respiratory syndrome virus (or blue-ear virus), an arterivirus in genus *Arterivirus*. May persist in moist environment. Not found in Australia.	Pigs. Ducks can also become infected.	Can cause abortions, stillborn and weak pigs, lowered birthing rates, severe respiratory disease and high death rates (especially in young pigs).	Direct contact with infected animals, aerosols, body fluids, in utero transmission, meat products. Possibly ducks.
Q fever [2]	Zoonotic bacterium *Coxiella burnetii.* Most infectious disease in the world (can become infected with single cell). Can persist in the environment. Found in Australia.	Cattle, sheep, goats, cats, dogs and humans.	Most commonly causes flu-like symptoms. Can cause gastrointestinal problems, respiratory problems (eg pneumonia), hepatitis, and death.	Inhalation of bacteria, contact with infected body fluids, wool, meat. Also spread by ticks.

Disease	Characteristics of disease agent	Animals involved	Disease symptoms	Transmission route
Rabies [2]	Rabies virus, a rhabdovirus in *Lyssavirus* genus. Unique variants are specific to a single reservoir host, but still capable of infecting total range of hosts. Cannot persist in environment outside host. Not found in Australia.	All warm-blooded animals, including humans, but different species have different susceptibility. Dogs, bats and foxes are good carriers.	Causes encephalitis (leading to paralysis and coma) and high mortality. Can exhibit furious or quiet, depressed activity before death.	Contact of fresh wound with infected saliva (as occurs with bites).
Rift Valley fever[1, 2]	Rift Valley fever, a zoonotic bunyavirus of *Phlebovirus* genus. Able to persist in mosquitoes. Not found in Australia.	Mainly affecting ruminants and humans.	Characterised in ruminants by near 100% abortion, and death of young infected animals. In humans, the disease is characterised by fever and dizziness, with very low (1%) rates of mortality.	Mosquitoes
Rinderpest [1, 2]	Rinderpest virus, a paramyxovirus of genus *Morbillivirus*. Does not persist in environment, or in the absence of cattle. Persists in meat at low temperature. Not found in Australia.	Cloven-hoofed animals, mainly cattle.	Highly contagious, characterised by fever, oral erosions, diarrhoea, lymphoid necrosis, and high mortality.	Inhalation of virus, close contact with infected animals and eating infected carcasses.
Scrapie [2]	Prion (altered host protein), similar mode of action as BSE. Can persist for long periods in environment, carcasses etc. Not found in Australia (since 1952).	Sheep and goats.	Causes progressive neurodegeneration and death.	Primarily transmitted from mother to offspring, also from products of central nervous system or placenta, possibly contaminated fomites.
Screw worm fly [1,2]	Larvae of screw worm fly (*Chrysomya bezziana*) are obligate parasites burrowing into flesh of open wounds. Not found in Australia.	All warm-blooded animals.	Untreated wounds lead to loss of production and sometimes death.	Screw worm flies, direct contact with affected animals. Transmission can be rapid in moist tropical conditions.
Surra [2]	Parasite *Trypanosoma evansi.* Cannot persist in environment. Not found in Australia.	Wide range of hosts affected. Most severe in horses, donkeys, camels, dogs and cats.	Causes fever, weight loss, anaemia and other symptoms, leading to death.	Flies (especially Tabanids), vampire bats, contaminated blood.
Swine vesicular disease [1, 2]	Swine vesicular disease virus, a picornavirus in *Enterovirus* genus. Highly persistent in environment or contaminated meat. Not found in Australia.	Mainly affecting pigs, but also sheep and cattle in contact.	Highly contagious, characterised by fever and blisters in the mouth and on the snout, feet, and teats: clinically indistinguishable from foot-and-mouth disease. Causes loss in production.	Ingestion of infected food, and direct contact with infected animals and contaminated material.

Disease	Characteristics of disease agent	Animals involved	Disease symptoms	Transmission route
Toxoplasmosis	Parasitic protozoan *Toxoplasma gondii*. Cysts can persist in environment. Found in Australia.	Cats are primary reservoir. Disease affects many animals including livestock, native mammals and humans.	Can cause encephalitis, neurologic diseases; disorders in the heart, liver, and eyes; abortion; stillbirths. Can be fatal in immunocompromised adults. Common cause of death in Australian marsupials.	Ingestion of raw meat products, cat faeces, contaminated water, gestational transmission to offspring.
Transmissible gastroenteritis [2]	Transmissible gastroenteritis virus, a coronavirus in *Coronavirus* genus. Can persist in environment, especially at low temperatures, and in carcasses. Not found in Australia.	Pigs.	Causes profuse diarrhoea and vomiting, death.	Ingestion/inhalation of contaminated faeces, nasal mucous, milk. Mechanical transmission by house flies. Dogs, cats, foxes, starlings passively carrying the virus may also spread the disease.
Vesicular exanthema [1]	Vesicular exanthema virus, a calicivirus in *Calicivirus* genus. Natural hosts believed to be shellfish or fish. Not found in Australia.	Mainly affecting pigs and marine mammals, but has been found in buffalo and donkeys.	Highly infectious, characterised by fever and painful blisters on feet and snout: indistinguishable from foot-and-mouth disease. Causes loss in production due to abortion, death of piglets and cessation of lactation.	Ingestion of contaminated food, direct contact with infected animals and possibly lice.
Vesicular stomatitis [1,2]	Vesicular stomatitis virus, a zoonotic rhabdovirus in *Vesiculovirus* genus. Cannot persist in environment, but may be maintained in insects. Not found in Australia.	Cattle, horses, pigs, humans, other wildlife species, and possibly sheep and goats.	Causes significant production losses and low mortality. Characterised by fever and blister-like lesions in and around the mouth, nostrils, hooves, and teats.	Direct contact with saliva or lesions, by insects and contaminated materials.
West Nile disease[2]	West Nile virus, a zoonotic flavivirus, of *Flavivirus* genus, part of the Japanese encephalitis (JE) antigenic complex. Found in both tropical and temperate regions. Not found in Australia.	Primarily infects birds, but is known to infect humans, horses, dogs, cats, bats and rabbits.	Can cause a neuroinvasive disease termed West Nile meningitis or encephalitis.	Mosquitoes.

1. An AUSVETPLAN Disease Strategy has been written for this disease.

2. This disease is notifiable to the World Health Organisation (OIE-listed disease).

3. A Threat Abatement Plan has been written for this disease.

Appendix 2: Australian Biosecurity CRC projects

Accessed from the AB CRC website (see http://www1.abcrc.org.au/uploads/15387f71-b114-48ea-bbb3-ae9085c7e93e/docs/ResearchPortfolio311007.pdf).

Technologies to enhance detection

To develop new and improved detection methods for significant emerging infectious disease threats through:

- novel diagnostic techniques
- rapid multiplex detection and characterisation systems.

1. Development of diagnostic capabilities for influenza H5N1 isolates
2. Molecular detection systems for emergency diseases
3. Development of a serological test to detect SARS coronavirus antibody in different animal species
4. Enhanced methods of virus detection using biosensors and signal amplification and control via supramolecular chemistry
5. Application of new platform technologies for the development of protein based rapid multi-analyte detection tests
6. Evaluation of rapid molecular detection and characterisation systems for surveillance of arboviruses circulating in northern Australia
7. Development of tools to improve surveillance for surra
8. Selection and validation of diagnostic assays for the detection of Henipaviruses
9. Rapid characterisation of unknown viruses using microarray hybridisation and PCR-Select Subtraction
10. Advanced detection platforms: Use of real-time immuno-PCR and conjugated peptide nucleic acid
11. Evaluation of rapid molecular detection and characterisation systems for risk evaluation of unknown viruses isolated in Australia
12. Multiplex macro-array based identification of flaviviruses
13. Immunological methods to detect exotic virulent strains of West Nile virus
14. Antigenicity studies and development of multiplex tools for foot-and-mouth disease virus
15. Development and production of immunological reagents and tests for emerging infectious diseases using recombinant antibody technology
16. An evaluation of the efficacy of rabies vaccines to protect against Australian bat lyssavirus

17. Porcine circovirus Type 2 and post-weaning multisystemic wasting syndrome in Australian pigs

18. Developing diagnostic tools for pteropid bat serology

19. Development of a multiplexed, Luminex-based approach to diagnosis and serological identification of acute human zoonotic and arboviral infections of public health importance to Australia

20. Rapid diagnosis of known and emerging avian influenzas with human health implications.

Ecology of emerging infectious diseases

To elaborate the disease ecology of prioritised emerging infectious disease threats through the study of:

- host range and interactions
- modes of transmission, maintenance and dispersal.

1. Assessment of the risk of introduction of Nipah virus to Australia via flying foxes

2. West Nile virus susceptibility and transmission studies in Australian avifauna

3. Investigations of SARS-like coronaviruses in bats

4. Investigation of the ecology of bat variant SARS coronavirus (bSCV) in nature and in live animal markets

5. Studies of the potential colonisation and establishment of *Aedes albopictus* (Asian tiger mosquito) as an arbovirus vector in Australia

6. Patterns of emergence of infectious diseases in the Australian region

7. Australian Leishmania [a trypanosome that causes leishmaniasis] lifecycle investigation

8. Transmission dynamics of emerging pathogenic Leptospira [causing the zoonotic disease Leptospirosis] species in an ecological community reservoir

Advanced surveillance systems

To develop new disease surveillance support tools and systems to provide an improved scientific basis for decision making by disease control authorities through:

- efficient data collection
- improved data management
- better decision-making tools.

1. Estimation of prevalence from pooled samples

2. ASEAN: Emerging & resurging infections: Surveillance and Response Program

3. Using algorithms based on routine surveillance and GIS to identify and monitor outbreaks of human disease

4. Quantification of confidence in disease freedom

5. Mosquito-based surveillance systems for Japanese encephalitis and West Nile virus, with a risk assessment for West Nile virus in eastern Australia
6. Advanced surveillance systems – Electronic data collection and decision support
7. Peri-urban regional surveillance for biosecurity for the pig industry in eastern Australia
8. Improving bluetongue virus surveillance in remote areas
9. Adding value to livestock movement data
10. Enhancement of remote area surveillance systems throughout Australia
11. MLA: Annual seroprevalence survey for bluetongue antibodies in the surveillance zone of the Northern Territory and Queensland
12. Spatio-temporal assessment of bluetongue virus and Murray Valley encephalitis host and vector dynamics – Proposal development
13. MLA: Evaluation of Australia's ability to rapidly implement surveillance requiring post mortem sampling under a range of conditions, using transmissible spongiform encephalopathies (TSEs) as an example
14. ACIAR: The development of sustainable surveillance systems for endemic and exotic diseases in Indonesia
15. ACIAR: The epidemiology, pathogenesis and control of highly pathogenic avian influenza in ducks in Indonesia and Vietnam
16. Producer perspectives on reporting diseases in Western Australia
17. Producer perspectives on the management of cattle health and disease
18. Epidemiology of avian influenza in aquatic birds in northern Queensland
19. A risk assessment for West Nile virus in eastern Australia
20. Development of a syndromic surveillance system for remote area cattle production systems in Australia
21. Embedded platform for the Bovine Syndromic Surveillance System
22. Peri-urban and remote regional surveillance for biosecurity within the pig industry in eastern Australia
23. The utilisation of remote sensing and spatial modelling for predicting Murray Valley encephalitis activity in Western Australia
24. Using hospital data for syndromic surveillance
25. Epidemiological studies to support the establishment of a free zone for foot-and mouth disease and classical swine fever in the lower Mekong region of Cambodia and Vietnam
26. Epidemiological studies to support the establishment of a progressive foot-and mouth disease zoning approach in Myanmar

27. The development and evaluation of a risk-based strategy for surveillance and rapid response to foot-and-mouth disease in Indonesia

28. Development of a model for the utilisation of commercial and recreational hunting for surveillance of feral and wildlife species

29. Building capacity to model emerging disease threats in the intensive livestock industries

30. Cultural and social factors affecting the management of sheep health and disease

31. Animal health communication in the control and eradication of epizootic and zoonotic diseases

32. *Trypanosoma evansi* in agile wallabies (*Macropus agillis*)

33. Minimum requirements for an early warning system for epidemic-prone diseases in resource poor countries

34. Risk assessment of transmission of H5N1avian influenza by wild birds to domestic animals in Thailand

35. The role of ducks and waterfowl in the epidemiology and ecology of H5N1

36. Studies on the epidemiology, pathogenesis and control of highly pathogenic avian influenza (H5N1) in ducks in Vietnam

Appendix 3: Invasive Animals CRC projects

Current IA CRC projects aim to:

- improve national information systems and information dissemination (see 1,2 in list below)
- conduct ecological and epidemiological studies (3–9)
- quantify and prioritise disease risks using ecological and disease modelling (10–13)
- develop strategies for detecting and mitigating the risk of disease spreading from invasive species (14–20).

More information on these projects is available on the IA CRC website (http://www.invasiveanimals.com).

National information systems and information dissemination

1. National mapping of invasive animal distribution and abundance
2. Review of the Wildlife Exotic Disease Preparedness Program 1999–2007

Ecological and epidemiological studies

3. Improving our understanding of the role of wild birds in the epidemiology of avian diseases
4. Detecting avian influenza in wild birds in New South Wales
5. Feral pig population structuring in the rangelands of eastern Australia: applications for designing adaptive management units for the control of foot-and-mouth disease
6. Surveillance for exotic diseases and baiting/control of feral pigs
7. Understanding and mitigating domestic pig and wildlife interactions
8. Genetic structure of Australo-Indonesian waterbird populations
9. The spatial ecology and zoonoses of urban dingoes

Quantifying and prioritising disease risks using ecological and disease modelling and existing risk assessment frameworks

10. Validating and refining risk assessment models — aims to test and improve current risk assessment models for a large range of (potentially and actual) imported invasive animals
11. Risk based surveillance for avian influenza in wild birds
12. Movements of anatids and relevance for avian diseases in Australasia
13. Investigating the prevalence, life cycle and risk to cattle and wildlife of *Neospora caninum*

Strategies for detecting and mitigating the risk of disease spreading from invasive species

14. Demonstrating use of avicide for starling management in piggeries — aims include to reduce disease threat from starlings

15. Feasibility of delivering oral liquid vaccines or contraceptives to feral pigs.

16. Minimising the impacts (including disease transmission) of feral pigs using PIGOUT®

17. Delivery of BCG vaccines to badgers for the control of bovine tuberculosis

18. National genotyping facility — DNA methods to detect presence of invasive animals from trace samples

19. A novel molecular-ecology approach to ascertaining emigration/immigration and potential disease spread in feral pigs

20. Control of rodent infestations in intensive crops, industrial and island situations — reducing risks of rodent diseases in domestic storage and intensive livestock facilities.

www.invasiveanimals.com