Special challenges of maintaining wild animals in captivity in Australia and New Zealand: prevention of infectious and parasitic diseases

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Summary: The authors review infectious and parasitic diseases of eutherians (excluding marine mammals), marsupials, reptiles and birds in Australia and New Zealand. The diseases discussed are those which are common and/or more likely to affect humans. The emphasis is placed on the type of animal affected, the epidemiology, and hence the control or prevention measures necessary. Clinical signs, pathology and treatment are not considered in any detail.

Other areas covered include legislation affecting wildlife and emu farming.


INTRODUCTION

Maintaining Australian wildlife in captivity represents quite a challenge in itself. Many of the species are nocturnal (e.g. possums, gliders and the bilby [Macrotis lagotis]), or are solitary dwellers and are difficult to maintain in group enclosures (e.g. wombats [Vombatidae]). Australia also possesses an enormous array of small, cryptic animals which are difficult to house adequately while still presenting them for public or private display (e.g. dunnarts [Sminthopsis spp.] and the kowari [Dasyuroides byrnei]).

The platypus (Ornithorhynchus anatinus) may be taken as an example. Between 1934 and 1988, only 22.4% of 228 platypuses held in Australian Zoological Institutions survived for more than one year, and there was no difference in the survival rate between animals which were purposefully caught and animals 'donated' by the public (51). Of ten platypuses held in five Australian Zoological Institutions in 1991, five had survived for more than seven years. Of ten captive platypuses which died over the previous five-year period, six had survived for more than six years (44). This increased survival is due to several factors, but improved knowledge of platypus requirements and better facility design have played a major role. Nevertheless, at

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present, the platypus has only bred once in intensive captive enclosures, indicating that a problem remains in captivity with regard to environment, husbandry and/or diet.

When assessing whether disease and parasite problems affecting the wild population will have a major impact on the same animals in captivity, it has been necessary to extrapolate from knowledge of already captive animals. This is because knowledge concerning the importance of disease in native vertebrates in Australia and New Zealand is very limited. ‘Even in countries where funding for wildlife disease research is more readily available, the role of diseases in regulating wildlife populations often goes uninvestigated’ (52).

The other method for assessing the prevalence and possible significance of infectious and parasitic diseases in free-ranging wildlife is retrospective post-mortem or clinical examination analysis of animals presented to veterinary clinics or laboratories. These studies are necessarily biased, as the animals presented are only those which are affected severely enough to be ‘rescued’ or found dead. They do not represent an accurate picture of the remaining population, for which information is often unavailable.

Extrapolation from captive animals does not invalidate the material presented, as ‘although disease studies on free-living macropods are limited, it appears that, for the most part, the types of disease conditions are similar to those present in captive marsupials but that their prevalence varies’ (8). It is reasonable to assume that captivity magnifies the prevalence of some diseases, as the environmental, nutritional and social situation of an individual has changed greatly. ‘The occurrence of disease is invariably due to the interaction between environmental factors, the host and the disease agent. Infectious agents are often found in the absence of signs of disease in their host. A change in environmental conditions or host immunity can result in an otherwise innocuous parasite becoming a serious pathogen’ (23). In a well-studied population of free-living eastern barred bandicoots (*Perameles gunnii*), it was noted that: ‘The impact of any diseases will probably be magnified in captive colonies of *P. gunnii*, and other infectious or stress-related diseases not currently important in the wild population at Hamilton could also become serious problems under restricted conditions’ (23).

Another factor making the maintenance of Australian wildlife in captivity a challenging and, at times, difficult exercise is the nature of the immunological systems of some of these animals. Generally, immune responses are somewhat slower and less accentuated than in placental (eutherian) mammals (22). In the koala (*Phascolarctos cinereus*), antibody responses to antigen are very slow to develop, and histological studies have shown relatively low densities of lymphocytes in the spleen and very few activated follicles with germinal centres in various lymph nodes (53). This has led to the conclusion that, in vitro at least, the humoral and cellular response to antigens in koalas is both retarded and delayed (R. Wilkinson, personal communication). Bringing animals into captivity from the wild invariably results in stress of one kind or another; this, acting with reduced immunological capacity, may exacerbate the incidence of disease in these animals.

It should be noted that marine mammals, amphibians and fish are also taken from the wild and may suffer from the same or similar conditions, or conditions specific to their taxonomic group, but they have not been included in the interests of brevity. This paper has concentrated on diseases which are either very common or highly pathological, or have serious zoonotic potential. It should be noted that this is in no way an exhaustive list, especially from a parasitological viewpoint.
LEGALISATION

Under the Wildlife Act 1953, the Department of Conservation administers all wildlife in New Zealand. Parks and Wildlife Services (PWS) in each Australian State administer their respective parks and wildlife Acts. These Acts state that all native wildlife is the ‘protected property of the Crown’ and must not be killed, taken, etc. except under permit. Fauna parks and sanctuaries are licensed under these Acts and are monitored by the State PWS. All States and Territories allow the keeping, to a certain extent, of native wildlife under permit. An extensive licensing system allows some control over requirements for facilities and personnel in establishments wishing to keep specialist species.

The majority of injured or diseased wildlife in Australia ends up under the care of one of any number of volunteer rehabilitation/rescue organisations found in each State. Perhaps the best known of these is the Wildlife Information and Rescue Service in New South Wales. These groups are licensed by their respective State PWS and are responsible for training carers, who become licensed. The PWS exerts little control over individual animals and there are no requirements for veterinary checks on entry into the system or before release. Most efforts are directed towards rehabilitation/release, and to this end Taronga Zoo in New South Wales, Healesville Sanctuary in Victoria and Currumbin Sanctuary in Queensland provide guidelines and attempt a scientific approach to rehabilitation and release.

The following are signatories to the recent establishment of the National Wildlife Rehabilitation Trust: the Maritime Safety Authority, the Department of Conservation, the Royal New Zealand Society for the Prevention of Cruelty to Animals, Bird Rescue and Auckland Zoo. The objective of this trust is to coordinate the rehabilitation of wildlife in the Auckland region and wildlife affected by oil spillage throughout New Zealand. The formation of this trust will provide the opportunity to monitor more closely infectious and parasitic diseases found in the wild, which could well become significant if introduced into the captive situation. It is hoped that the trust will undertake research into the causes of disease and the success of rehabilitation.

Unreleasable animals are often euthanised; alternatively, they may find their way into privately-owned fauna parks/sanctuaries or – in South Australia and Tasmania – into private hands under a rescue permit system.

Care of injured or diseased native wildlife is undertaken at the expense of the private individual or group. Corporate sponsorship of some rescue organisations does occur, but no government funding is available. Veterinary practitioners, when called upon, often charge only the cost of any drugs used or request much reduced fees.

Animal welfare legislation

Each State or Territory in Australia and New Zealand has an organisation, known as the Royal Society for the Prevention of Cruelty to Animals, which enforces animal welfare Acts within that State or Territory. These Acts differ slightly in name between States, but are general Acts covering very basic aspects of husbandry (feed, shelter, etc.) for all animals. These organisations are very active nation-wide, responding to complaints by the general public regarding treatment of animals.
Exhibited Animals Protection Act

The Department of Agriculture administers the Exhibited Animals Protection Act, but this legislation applies only in New South Wales. The Act defines minimum standards for the keeping and holding of exotic and native species, and is aimed at fauna parks, sanctuaries and zoological institutions.

EMU FARMING

The emu (Dromaius novaehollandiae) is one of two native Australian ratite species. It is a source of good-quality leather, low cholesterol meat and oil. Emu farming was legalised in Western Australia in 1970. At present, there are fifty-four farms in Western Australia and others in Tasmania and Queensland. All States have now given approval for farming emus. In December 1993, approximately 50,000 birds were being farmed in Western Australia, with the industry estimating that up to 85,000 birds would be available for processing in 1995.

The emu is protected under the Wildlife Conservation Act in Western Australia, but has also been declared a pest as a result of damage to crops, pastures and fences. The taking of emus for initial stocking purposes and periodic replenishment of genetic material has been allowed, but development of a commercial industry based on taking from the wild is not permitted. All birds being farmed must be bred in captivity, and all products exported must have come from captive stock.

The husbandry of emus bred in captivity is detailed in the Australian model Code of Practice for the welfare of animals. The average annual output of eggs from a mature hen is twenty-two. A fifty-week old bird with an average live weight of 33 kg will yield on average 0.7 m² of skin for leather, two leg skins, 12.5 kg of meat, 41 of oil and 0.75 kg of feathers (33).

For optimal hatchability, strict attention should be paid to the following:

a) egg collection procedures, e.g. allowing wet and dirty eggs to dry before cleaning with steel wool or abrasive paper, and then decontaminating with a detergent sanitiser at a temperature at least 20°C higher than the temperature of the egg

b) hatching hygiene, e.g. meticulous cleaning of incubators and establishment of separate areas for egg setting and hatching; a hatchability rate of up to 66% has been achieved with artificial incubation (33).

The emu is a seasonal breeder, and this limits the availability of fresh meat to the market place. The chilling of vacuum-packed fresh meat at between −1°C and 0°C extends the life of fresh meat to as long as twelve weeks, and microbial profiles taken during storage have been found to be similar to those of other meats (14).

The emu farming industry still has to refine certain areas of production, processing, marketing and product development. Producing birds seems to be a minimal problem, but should be enhanced with research into nutrition and genetics. At present, processing is very labour-intensive, and the exact needs and methods for efficient slaughtering, transportation, de-feathering and skinning are yet to be worked out.
SELECTED IMPORTANT BACTERIAL INFECTIONS

Salmonella spp.

Reptiles

Species of Salmonella have been isolated from wild chelonians, crocodilians, snakes and lizards in Australia, and wild geckoes and skinks in New Zealand. These Salmonella spp. would appear to be normal commensal organisms in this class of animals, in view of the relative infrequency of overt disease. Environmental stressors (e.g. overcrowding, inappropriate ambient temperature and incompatibility) can be easily overlooked, due to the nature of this class of animal. Knowledge of the biology of each species is important when considering housing. Attention to the following husbandry factors is important:

- provision of visual barriers
- correct environmental temperature
- basking spots
- substrate
- layout (to prevent abrasions)
- ease of cleaning
- water quality
- temperature.

Monitoring the Salmonella status of whole body prey for snakes and crocodiles may prevent introduction of this organism into a ‘clean’ colony.

The presence of Salmonella and Arizona spp. is of major zoonotic importance in young children (24). Carers should adhere to good hygienic practices, e.g. use of gloves, separate faecal collection instruments and regular hand washing.

Monotremes

Salmonellae can be carried as a normal inhabitant in the gut of both the platypus and the echidna (Tachyglossus aculeatus), and contamination therefore readily occurs if insufficient attention is paid to water quality (platypus) or substrate (echidna). Overt infectious disease would appear to be uncommon (51) but septicaemia and death caused by Salmonella has been reported in the echidna (4). In one study, six of eighteen recently-captured or captive echidnas died from salmonellosis, probably as a result of the stress of captivity (26).

Both these species have relatively unusual diets, and feeding in captivity is therefore less simple than for other animals. The platypus is essentially a live food feeder — taking yabbies (crayfish), small fish, mealworms, earthworms and fly pupae — while the echidna readily takes an artificial mix (beef or horse mince, calcium and insectivore meal). Food must be fresh and uncontaminated.

Wombats

Salmonellae have been reported in hairy-nosed wombats (Lasiorhinus latifrons) and common wombats (Vombatus ursinus) (12), with mortalities in both adults and young. Wild animals are commonly subjected to stressors (e.g. drought in hairy-nosed wombats and sarcoptic mange in common wombats), and this may predispose these species to salmonellosis.
Adult animals rescued or taken from the wild do not immediately acclimatise. The following must be provided:

   a) a variety of foodstuffs, paying close attention to what is eaten and when (mostly crepuscular feeding)
   b) a large volume of straw and, possibly, supplementary heat
   c) single accommodation, as individuals of these species are rarely compatible under unfamiliar conditions
   d) correct milk replacer for pouch-bound or very young animals; good milk replacers are available for marsupials (2).

Once acclimatised, these species are hardy.

**Macropods**

It has been reported from south-east Queensland that normal, healthy macropods may have a very high (50%) carrier rate of *Salmonella*, and that this state can persist for long periods. Presence of *Salmonella* in the gut, however, cannot necessarily be taken as implicating these animals in disease occurrence, unless all other causes have been eliminated (43). Eighty-five serotypes have been listed (46).

Macropods can breed freely in captivity, as well as in the wild. In captivity, this may lead to overcrowding which may result in incompatibility stress and heavily-contaminated, unhygienic substrate. These factors – together with the presence of young animals – may combine to cause overt salmonellosis. A reduction in the level of nutrition was responsible for an increased shedding rate in quokkas (*Setonix brachyurus*) in Western Australia (19). With the current profusion of free-ranging macropods in wildlife parks, the general public is coming into closer contact with carrier animals and some zoonotic potential therefore exists.

**Birds**

In Australia, twenty-six serotypes of *Salmonella* have been isolated from sixteen bird species in a state-wide survey of Western Australia (25). Salmonellae have also been isolated from emu farms (R. Swan, personal communication) and have been implicated in mortality of blue duck (*Hymenolaimus malacorhynchos*) and black stilts (*H. novaezealandiae*) (34).

The presence of the organism does not always imply clinical disease, but environmental conditions of food/water deprivation, adverse climatic conditions and exposure to a virulent serotype could predispose to *Salmonella* infection. Overseas studies have especially implicated gulls in contaminating water supplies and pastures; the ability of this organism to survive in the environment can lead to heavy contamination where a large number of birds roost at the same site. This is a potential health hazard to humans and other animals (36).

The incidence of mass mortality would appear to be very low under Australian conditions, both in the wild and in captivity. Recently-quarantined birds should be isolated, and their faeces should be tested for the presence of *Salmonella*.
Fusobacterium spp.

Marsupials

*Fusobacterium necrophorum* is the organism most commonly found in cases of 'lumpy jaw' in macropods. The organism has also been found in many other marsupials on an irregular basis. This anaerobe, which creates an unpleasant odour especially apparent on opening the mouth, is probably the most important pathogen of macropods in captivity. In a well-managed establishment, mortality may not be especially high if treatment is administered, but re-occurrences can never be ruled out. Treatment is mostly limited to the endangered species of macropod (and pets), euthanasia being the preferred option for an individual in a herd of the more common species. The disease is not confined to captive animals, but morbidity would appear to be low in the wild except in high-density populations (D. Obendorf, personal communication).

The disease manifests mainly as swelling around the head and jaws, but can also be responsible for abscessation within internal organs and infection of wounds.

The organism is not part of the normal oral flora of macropods (43), and transmission therefore appears to occur via the faecal/oral route. This hypothesis is supported by many authors, who have reported lower disease incidence in an area which is free from faecal contamination. Several theories have been proposed regarding the exact pathogenesis, as follows:

- a) the molar eruptions at the back of the jaw and their subsequent cranial migration create a favourable niche for *F. necrophorum*
- b) the mucosa is penetrated by sharp pieces of vegetation
- c) profuse development of plaque around all teeth leads to an unhealthy tooth/gum margin and subsequently creates a favourable niche for an anaerobe.

The discolouring calculus observed in wild macropods does not appear to result in any gum disease, unlike the case of the captive kangaroo which is fed on a soft diet of pellets, fruit and a few vegetables. This difference in diet probably accounts for the higher incidence of *F. necrophorum* infection in these species in captivity. Correct management thus centres on preventing a high level of faecal contamination, adequate feeding and provision of hiding places to reduce conflict, and the feeding of hay, grains and browse to keep teeth clean.

Mycobacteria

Marsupials

Marsupials (and monotremes) are relatively susceptible to infection with mycobacteria, but epizootics do not appear to occur in the wild in Australia. The brush-tailed possum (*Trichosurus vulpecula*) in New Zealand has become a host to *Mycobacterium bovis* over a wide area, and the suppurating skin lesions continue to pose a threat of reinfection to cattle. This is facilitated by the habit in New Zealand possums of grazing on pasture, whereas in Australia (where the disease has not been reported) the animal may find enough food in trees.
The koala has been reported as being susceptible to *M. ulcerans*, an atypical *Mycobacterium*. In Victoria, this organism was recovered from eleven of 200 individuals in lesions on the flexor aspect of the limbs, face, rump and groin. Cases were consistent with wounds resulting from fighting or social behaviour subsequently becoming infected, the source being the environment (28).

Two numbats (*Myrmecobius fasciatus*) in a captive-breeding colony at the Western Australian Wildlife Research Centre were reported to have atypical mycobacterial infections; these were observed on the feet of one animal and on the ventral thorax and abdomen of the other (17). The organisms isolated — *M. intracellulare* and *M. chelonae abscessus* — were different from those isolated from the soil. The soil is a potential source of mycobacterial infection (by contaminating wounds), however, and the management practice of putting some soil in food for these animals (to mimic natural foraging) creates a potential for haematogenous spread.

**Seals**

An organism similar to *M. bovis* has been found in wild Australian fur seals. The source of the infection is unknown but it has been transmitted to humans.

Any animals being brought into captivity should be tuberculin tested, and handlers should take preventive steps against tuberculosis. The Tasmanian Parks and Wildlife Service has instituted a campaign to promote awareness among field workers with regard to mycobacteriosis in seals (D. Obendorf, personal communication).

**Birds**

*M. avium* has been diagnosed in the little penguin (*Eudyptula minor*), black duck (*Anas superciliosa*), cassowary (*Casuarius casuarius*) and little eagle (*Hieraaetus morphnoides*) (41), with most birds being susceptible. There are no reports of epornithics in Australian wild birds; most cases are solitary and occur in captive birds.

**Reptiles**

Atypical mycobacteria occur quite commonly in all reptile groups (24), causing multifocal granulomas.

**Control/prevention**

Prevention is rather difficult when the offending organisms can be present in the substrate. In establishments where the problem has been experienced, extra vigilance is necessary in detecting skin wounds, especially on feet, and in ensuring that these have healed successfully.

Accurate diagnosis is the first prerequisite but this is difficult clinically for the generalised case. Most diagnoses are made on post-mortem examination. Any local granulomatous, suppurative lesion or swelling on the limbs (42) can be caused by acid-fast organisms. This should be borne in mind when sampling, as most of these organisms are transmissible to man.

*M. bovis* has effectively been eradicated from Australia and only occurs in humans, and perhaps in an isolated feral bovid in the far north of the country. In New Zealand, bovine tuberculosis has not been eradicated, due to the significant wildlife reservoir
of infection which includes feral deer, pigs, goats, cats, cattle and ferrets (*Mustela putorius furo*) (11). Atypical mycobacteria have the ability to withstand environmental conditions, and therefore burrowing animals and those ingesting soil with food are particularly at risk. Wild birds may shed this organism and thus contaminate the captive environment. Control of the feral population may reduce the risk.

**Chlamydia spp.**

*Birds*

*Chlamydia psittaci* is responsible for mortalities in wild avians, especially parrots. Parrots legally brought into captivity – for research, translocation or impoundment following illegal capture – must be housed at a density of only a few to each aviary, as the majority of parrots are incompatible. Housing should be isolated, and should be constructed to enable routine husbandry to be performed without undue disturbance of the birds.

In one study, *Chlamydia* was not found in native New Zealand psittacines, namely keas (*Nestor notabilis*) and kakas (*N. meridionalis*) (29).

Impounded birds are often required to stay in captivity for prolonged periods, due to the laws of legal evidence. Initial screening using serological tests may give an idea of the flock status, prompting prophylactic doxycycline therapy. There is a strong zoonotic potential, aided by a high carrier rate, and therefore use of masks, etc. is warranted when working around these birds.

*Marsupials*

Strains of *C. psittaci* are responsible for several syndromes in koalas in eastern and south-eastern Australia, namely rhinitis/pneumonia, a kerato-conjunctival syndrome and a urogenital form. The presence of *C. psittaci* antibody can be tested using an enzyme-linked immunosorbent assay (49). The prevalence of this infection in populations varies from 0% to almost 100%. Together with habitat depletion, *C. psittaci* infection – which results in infertility – may be having an effect on koala population dynamics (6), at least in Queensland.

Koalas are brought into captivity as a result of accident (e.g. attacked by dogs, struck by cars), as part of translocation projects or for research purposes. Animals should be kept isolated, and those showing evidence of chlamydial infection should be treated. The zoonotic potential of such infections is unknown, but is not suspected.

Other bacterial agents which cause disease in both domestic and wild animals in Australia include *Erysipelothrix rhusiopathiae*, *Leptospira* spp., *Clostridium tetani*, *C. perfringens*, *C. botulinum*, *Pasteurella* spp., *Pseudomonas* spp., *Streptococcus* spp. and *Staphylococcus* spp.

**Fungal Infections**

Fungal infectious agents are similar to those causing infections in other countries, and include *Trichophyton* spp., *Microsporum* spp., *Candida albicans*, *Mucor* spp., *Cryptococcus neoformans* and *Aspergillus* spp.
Mucor amphibiorum

*Mucor amphibiorum* was first isolated from a green tree frog and is a pathogen in cane toads (*Bufo marinus*) in Australia (47). This agent therefore constitutes a risk for frogs in captivity.

Monotremes

*M. amphibiorum* infection of the skin of platypuses is a disease of some concern in wild platypus populations, especially in the South Esk River system in Tasmania (D. Obendorf, personal communication). Deaths in platypuses due to *Mucor* infection are the first to have been reported in mammals (32). Susceptibility to infection of both monotremes and amphibians may relate to the low body temperature (32°C in platypuses) of the host and also poor water quality, e.g. during drought conditions (50).

Control/prevention

Managing waterways to give a steady flow rate may help to prevent excess contamination and provide an unpolluted source.

Fighting among male platypuses may lead to spur injuries which allow infection to develop. Adequate habitat provision to reduce fighting is therefore another important factor in preventing the disease (D. Obendorf, personal communication). Other causes of skin damage may be important (e.g. bites from water rats [*Hydromys chrysogaster*] and ectoparasites) (9).

SELECTED VIRAL INFECTIONS

Herpesviruses

*Marsupials/monotremes*

Herpesvirus infections in marsupials can cause conjunctivitis, mucocutaneous blister and ulcers, as well as neurological and hepatic symptoms, and are potentially fatal (46, 30). Nine macropod herpesvirus strains have been isolated, and a wide range of animals have been affected (30, 31, 46). Echidnas (4) and platypuses (50) are also reported as suffering from herpesvirus infections.

Although this is the most pathogenic virus of macropodids, little is known about the epidemiology of the virus (46). Serological evidence suggests a wide distribution of herpesvirus infection in macropods, including in species not reported as being clinically affected (46).

Psittacine circovirus

*Birds*

Psittacine beak and feather disease, a circovirus infection (48), is a common condition of many free-living and captive psittacine birds (35), including feral psittacines in New Zealand. The prevalence of this disease, based on haemagglutination inhibition assay, ranged from 41% to 94% in one survey of wild
psittacines in New South Wales (38). Clinical cases have been reported from all Australian States. The virus was originally thought to affect psittacines only, but a recent report suggests that the virus may now also be affecting a non-psittacine species (*Streptopelia senegalensis*) (35). Cockatoos suffering from the disease inevitably die, and it is therefore a highly significant disease in this family of birds, especially in view of the (still common) practice of legally or illegally removing birds from the wild for the bird trade. The captive-breeding programme to save the orange-bellied parrot (*Neophema chrysogaster*) began with ten wild-caught birds. This population transpired to have an incidence of 50%, which has now been reduced to 13%. Psittacine beak and feather disease accounted for more than 50% of the deaths in captivity over the first five years of the project (27). This experience emphasises the enormous impact which this disease can have on a population. By contrast, members of the lorikeet family have a much higher survival rate if the young flightless cases find their way into protective custody.

**Control/prevention**

Definitive diagnosis of this disease can be difficult, and has generally been based on dystrophy or absence of feathers, and/or beak dystrophy. Haemagglutination and haemagglutination inhibition assays on blood, faeces and cloacal contents have been used to determine the circovirus status of a number of birds (37, 38, 45). Once this test is commercially available, routine testing of aviary birds will be possible. Pre-sale testing of wild-caught birds will also become practicable, and this should help to reduce the number of affected birds being brought into trade and breeding programmes. Unfortunately, many people release affected cockatoos once it is obvious that the birds have a problem, which leads to greater environmental contamination. Work being conducted at present shows promise that this disease may soon be controllable in Australia via vaccination (39), although this is unlikely to be practicable for wild populations where the disease appears to be endemic.

**Newcastle disease**

Newcastle disease (ND) is caused by a paramyxovirus capable of infecting a wide array of avian species. At present, pathogenic strains are absent from Australia (10), New Zealand and Papua New Guinea (18). However, two different lentogenic strains appear to be circulating in Australian avifauna (25, 1). The route of introduction for the more pathogenic strains of ND virus is probably via smuggled birds or free-flying, migratory wild birds (25, 7, 13, 16).

**Control/prevention**

Previous outbreaks of virulent ND in Australia – in 1930, 1931 and 1932 – were eradicated by a slaughter policy (18). Transmission occurs through faecal/oral contamination, aerosols and dust, and wind-borne spread has also been implicated (25); ND is therefore difficult to control once it has become established. Pre-importation testing is essential, and vaccination of birds for importation may be of benefit. As the virus survives for long periods under favourable conditions, strict hygiene is essential (21). Sampling of migratory birds can be performed easily along migration pathways or on breeding islands, and this would constitute an early warning mechanism. Stringent quarantine of new avian species is necessary, together with
improved detection of illegally smuggled birds. Planning is currently under way for a national registration and identification system, with possible DNA profiling of exotic parrots to help combat the large numbers of these birds which are illegally imported into Australia.

**Arboviruses**

**Marsupials**

Serological evidence of arbovirus infection has been found in many marsupials (31), but there has been no reported association with disease. The significance of these viruses and their appearance in macropodids is that this group of animals are probably the primary host for Ross River virus (46), which is a significant virus causing chronic debilitation in humans. Grey kangaroos (*Macropus giganteus*) are also considered effective amplifiers of Australian arboencephalitis (Murray Valley encephalitis) (46).

**Birds**

Several bird species are also considered important hosts for Australian arboencephalitis, namely rufous night heron (*Nycticorax caledonicus*), Australian white ibis (*Threskiornis molucca*), darters (*Anhinga melanogaster*) and three cormorant species (*Phalacrocorax carbo*, *P. sulisirostris* and *P. melanoleucos*) (15). The insect vectors of these arbovirus infections are *Culex annulirostris*, *Aedes vigilax* and *Aedes camptorhynchus* (15).

**Public health implications**

These viral infections are significant zoonoses and are capable of causing dramatic illness. Mortality due to Australian arboencephalitis is high, and survivors may suffer serious permanent sequelae. In the case of Ross River virus, there may be partial or complete incapacity for a month or more, with full recovery taking much longer (15).

**Control/prevention**

Invertebrate vectors should be controlled where possible; this may involve mass fumigation of lowland and residential areas, as occurs in the Northern Territory of Australia. Serological screening of wild animals is not practical on a large scale, but may be conducted to detect changes in host prevalence during outbreaks.

**Chorioretinitis viral complex**

**Marsupials**

Chorioretinitis syndrome primarily affects western grey kangaroos (*Macropus fuliginosus*) but also occurs in red kangaroos (*M. rufus*) and euros (*M. robustus*) (I.J. Hough, unpublished findings; G.L. Reddacliff, personal communication). Two orbiviruses have been isolated from affected western grey kangaroos, namely Warrego virus and Wallal virus (40). Seroconversion to Warrego virus appears to be widespread, while little evidence exists for seroconversion to Wallal virus outside affected areas (40).
Viral ribonucleic acid has been identified at the Australian Animal Health Laboratories, using polymerase chain reaction technology, in two species of midges (Culicoides dicyei and Austral pulparlis) collected from areas where disease has occurred (40).

This disease causes mononuclear cell infiltration of the choroid (which may be moderate to severe, and recent to long-standing) with sloughing of the retina and degeneration of the optic nerve. Some animals develop a mild to moderate encephalitis (20).

It seems that symptoms of disease may not appear immediately after initial infection, and that processes other than direct viral infection are involved in the production of clinical signs (40).

Additional viral agents causing diseases include poxviruses, adenoviruses, papovavirus-like virus, retrovirus and influenzavirus.

PARASITIC DISEASES

It is not possible to cover all aspects of parasitic diseases of Australian animals in a short chapter. Readers requiring detailed information should consult the references (4, 30, 31, 46, 50: see also ‘Suggested further reading for parasitic diseases’ below). Most orders of parasites are found in one or more species of Australian animals kept in captivity. Whether or not overt disease is caused depends on the environment and stress load. Captive collection managers should monitor parasite burdens and take appropriate remedial action (environmental control or therapy). Australia has strict import regulations which should prevent the introduction of exotic parasite species.

Protozoans

Important protozoan parasites include Coccidia, Cryptosporidia, Toxoplasma, Trichomonas and Tritrichomonas.

Nematodes

Marsupials may harbour unique nematode species (Globocephaloides spp.) or ubiquitous species (e.g. Strongyloides spp., Capillaria spp., Contracaecum spp.).

Cestodes

Echinococcosis, caused by Echinococcus granulosus, is a disease problem in Australia. This does not pose a major threat to captive animals, however, as they are not involved in the sylvatic cycle (dingo/wallaby). If dingoes are brought in from the wild without proper quarantine and appropriate therapy, there could be a potential for zoonotic disease transmission to keepers.

Ectoparasites

External parasites are similar to those occurring in other countries, and include Sarcoptes scabei (causing mange), ticks (various species), tracheal mites (Sternostoma tracheacolum) and various other mites and fleas.
Sarcoptes scabei (mange mites)

Marsupials

Sarcoptic mange is probably the most significant infectious disease in wombats (4). Both common and hairy-nosed wombats are affected, but the disease is most often reported in common wombats. Both free-ranging and captive koalas have been affected by sarcoptic mange (3), with death occurring through inanition in some cases (5). Brush-tailed possums have also been affected by S. scabei (31).

Public health implications

Handling of affected animals places humans at risk and should therefore be avoided. Suitable hygiene procedures should be followed in situations where handling cannot be avoided.

Control/prevention

The use of ivermectin is particularly effective in the treatment of this disease. The possible contributory role of environmental factors (e.g. overcrowding, habitat degradation, and population density of foxes and feral dogs), together with evaluation of Sarcoptes strains, needs further investigation before the epidemiology of this disease is fully understood.

Blood parasites

Haemoparasites include haemogregarines, Theileria spp., Haemoproteus spp., Atoxoplasma spp., Leucocytozoan spp. and Plasmodium spp.

Zoonotic parasites

Zoonotic parasites include Cryptosporidium spp., Toxoplasma gondii (toxoplasmosis), Echinococcus granulosus (hydatid disease), Sarcoptes scabei (mange) and Ixodes holocyclus (tick paralysis).

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Résumé : Les auteurs passent en revue les maladies infectieuses et parasitaires des euthériens (à l’exception des mammifères marins), des marsupiaux, des reptiles et des oiseaux en Australie et en Nouvelle-Zélande. Ils discutent des
maladies qui sont les plus fréquentes et/ou qui peuvent affecter l’homme. Ils mettent l’accent sur les types d’animaux touchés et sur l’épidémiologie, puis sur les mesures nécessaires de prévention ou de contrôle ; ils évoquent enfin les signes cliniques, la pathologie et le traitement.

Les autres sujets abordés concernent l’impact de la réglementation sur la faune sauvage, ainsi que l’élevage des kangourous et des émeus.


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Resumen: Los autores pasan revista a las enfermedades infecciosas y parasitarias que afectan a los euterios (excluidos los mamíferos marinos), marsupiales, reptiles y aves en Australia y Nueva Zelanda. Circunscriben a las enfermedades frecuentes y/o más susceptibles de afectar a los humanos, haciendo énfasis en el tipo de animal afectado y en la epidemiología de la enfermedad, y por lo tanto en las medidas de control o prevención necesarias. No se consideran en detalle los síntomas clínicos, la patología ni los tratamientos.

Entre el resto de cuestiones tratadas se encuentran la legislación relativa a la fauna salvaje, la captura de canguros y la cría de émeus.


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REFERENCES


*Suggested further reading on parasitic diseases*


