Technical Appendix D8

Pathogenic Micro-organism Threats to the Terrestrial Vertebrate Fauna of Barrow Island

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GORGON DEVELOPMENT ON BARROW ISLAND

FINAL REPORT

PATHOGENIC MICRO-ORGANISM THREATS TO THE TERRESTRIAL VERTEBRATE FAUNA OF BARROW ISLAND

TECHNICAL APPENDIX D8

Prepared for:

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August 2004

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Pathogenic Micro-organism Threats to the Terrestrial Vertebrate Fauna of Barrow Island

A Quarantine Assessment Report to the Gorgon Joint Venture

August 2004

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1. Background

1.1 Barrow Island

Barrow Island covers an area of 23,567 hectares and is situated 56 km off the Pilbara coast of Western Australia. It has been isolated from the mainland for approximately 6000 - 8000 years (Buckley, 1983; Sharrad and King, 1981), and as such forms an important sanctuary for its flora and fauna. In recognition of its pristine and unique nature, Barrow Island was declared a permanent reserve Class A for the protection of flora and fauna in 1910 (Cox, 1977), and is internationally recognised as a unique biodiversity repository. Introduced stock or feral animals have not grazed its vegetation and introduced predators have not affected its animal assemblages. Barrow Island Nature Reserve is probably the largest island in Australia, and one of the largest land masses in the world that has no introduced animals, making it one of the oldest and most valuable biodiversity conservation reserves in the world (CCWA, 2003; EPA, 2003).

1.2 Oil production and Barrow Island

In addition to Barrow Island's unique conservation and biodiversity values, it has been an actively producing oilfield since 1964 (Butler, 1970). West Australian Petroleum Pty. Ltd. (WAPET) operated the oilfield until 1999, when it was taken over by ChevronTexaco Australia Pty. Ltd. Since 1964 approximately 1000 wells have been drilled on the island, and these along with their attendant roads, gravel pits, campsites and other ancillary activities have only disturbed approximately 3% of the island's total area (Anon., 2003). With the proposed development of the gas processing facility on Barrow Island, this figure is expected to increase to 5% of the total area (Anon., 2003). Surveys of the vertebrate fauna commenced in 1964 to obtain information regarding the impact, if any, of this industry on the island fauna. Monitoring of the island wildlife has continued to the present, with very little indication of any adverse impact on vertebrate populations (Burbidge *et al.*, 2000a; Burbidge *et al.*, 1998; Burbidge *et al.*, 2000b; Burbidge *et al.*, 2003; Butler, 1970; Butler, 1975; Morris *et al.*, 2001; Morris *et al.*, 2002; Morris *et al.*, 1999; Serventy and Marshall, 1964; Smith, 1976).

The continued integrity of the Barrow Island wildlife can be attributed, at least in part, to the stringent quarantine policies put in place by ChevronTexaco with regard to anything coming onto Barrow Island (Anon., 2002b). These procedures have helped to ensure that introductions of invasive species (both animals and plants) do not occur. However, with the recent proposal to expand operations on Barrow Island, the issue of preventing microbial introductions has been identified as an important issue. Therefore this report is intended to assess the potential risk that introduced micro-organisms may pose to the terrestrial vertebrate fauna of Barrow Island.

1.3 Definitions

The terms micro-organism and parasite are used to describe the range of infectious agents, including viruses, bacteria, fungi, protozoa and helminths in this report. The terms pathogen and pathogenic are used to describe those infectious agents that are capable of causing disease. The term infectious is used to describe the capability of the micro-organisms to be transmitted to or between individual animals but is not in itself an indication of pathogenicity. External parasites (ticks, fleas, lice, flies etc.) may contribute a pathogenic effect to their host species (eg. anaemia), however they are deemed to be outside the scope of this report. Nevertheless, their role as vectors of infectious diseases will be discussed in the appropriate section(s). For the purpose of this report vectors are defined as invertebrate species capable of maintaining and introducing micro-organisms (eg. mosquitoes, ticks, fleas).

2. Importance of Micro-organisms in Wildlife

2.1 Importance of disease-causing micro-organisms

Disease-causing micro-organisms of wildlife occur in many different forms in a wide range of species which, when expressed in free-ranging populations, can have a significant effect on wildlife ecologies (Morner *et al.*, 2002). Whilst some micro-organism infections may occur as symptomless, subclinical disease with no obvious impact and/or consequence, occasionally there are dramatic epizootic outbreaks characterised by high morbidity and mortality (Morner *et al.*, 2002). As such, under certain conditions, micro-organisms can be considered a major evolutionary force and an important threat to biodiversity (Gulland, 1995; May, 1988; Scott, 1988).

The impact of micro-organisms on the survival, reproduction or dispersal of host individuals will depend upon the virulence of the pathogen, the infective dose and the resistance of the host to infection (Anderson and May, 1978; Gulland, 1995). These parameters can be modified by a number of factors such as malnutrition, overcrowding, stress and multiple parasitism that complicate the dynamics of the host-pathogen interaction (Gulland, 1995). Micro-organisms may also indirectly affect the survival of the host by increasing their susceptibility to predation or by reducing their competitive fitness (Berdoy *et al.*, 1995; Scott, 1988; Webster, 2001). Therefore, the consequences of these disease-causing agents may well be as important at the population level as at the immediate level of the individual (Lyles and Dobson, 1993).

2.2 Genetic Fitness and Infectious Diseases

Conservation biologists hypothesize that endangered species are especially vulnerable to infectious disease due to their small population sizes, leading to reduced genetic diversity and a reduced ability of the host to respond to pathogens in an evolutionary sense (Lyles and Dobson, 1993; O'Brien and Evermann, 1988). A lack of genetic variability in a population significantly improves the odds of an infectious disease-causing devastating effects, because when it overcomes one individual defence system it more likely than not will overcome the others in a genetically uniform population (O'Brien and Evermann, 1988; Ralls *et al.*, 1979). The same is true of island populations that have been isolated for long periods of time, such as on Barrow Island. Indeed, the reduced genetic diversity observed in some Barrow Island species (CCWA, 2003; King, 1998), could very well increase the effects of any debilitating disease should one be introduced to the island.

2.3 Population Size and Threshold Density

Host population size has a profound effect on the dynamics of a pathogen as every parasite requires a minimum density of hosts (threshold population) whereby it can maintain itself (Bartlett, 1960; Dobson and May, 1986; Lyles and Dobson, 1993). Ironically, the presence of a threshold for establishment suggests that small populations of species are relatively protected from virulent pathogens as there may be too few individuals present to continuously support an infection (Lyles and Dobson, 1993). However, this perceived level of protection actually increases the susceptibility of these animals to catastrophic disease outbreaks, as small populations of species are at a greater risk from non-host-specific pathogens than host-specific pathogens.

The susceptibility of small populations to pathogens may also be enhanced by the loss of endemic diseases once the population size falls below the critical levels required for the maintenance of such diseases (Cunningham, 1996). These populations risk becoming immunologically naïve, resulting in low levels of acquired immunity (Cunningham, 1996; Viggers *et al.*, 1993). Without this level of exposure, these populations are at an increased risk of being adversely affected by epidemics of what were previously endemic diseases, as well as new and emerging diseases (McCallum and Dobson, 1995).

2.4 Human Involvement in Disease Outbreaks

A common factor driving the emergence of wildlife disease is the anthropogenic movement of pathogens into new geographic locations – a phenomenon termed ‘pathogen pollution’ (Cunningham, 1996; Daszak *et al.*, 2000). Pathogen pollution is rooted in the unprecedented globalisation of agriculture, commerce, human travel and the transport of domestic animals and their products (Daszak *et al.*, 2001). Human landscape changes that remove portions of host populations, alter host migration patterns or increase host density are also likely to increase the risk of pathogen emergence (Dobson and May, 1986). Pathogen introductions have a particularly high impact when naïve host populations are involved and introduced pathogens may contribute to the competitive success of the invading carrier hosts (Hudson and Greenman, 1998).

2.5 Disease and Biodiversity

Wildlife populations have long been considered a link in the chain of pathogen emergence, by forming the reservoirs from which pathogens may emerge (Daszak *et al.*, 2001). However, wildlife populations are seldom the guilty party in the event of a disease outbreak, though more often than not they bear the brunt of its effects. Emerging infectious wildlife diseases have been responsible for mass mortalities as well as local (population) extinctions and global (species) extinctions (Cunningham and Daszak, 1998; Daszak and Cunningham, 1999). This direct loss of biodiversity due to infectious disease may lead to further impacts on ecosystems via 'knock-on' effects. These knock-on effects may lead to the extinction of species further up the food chain that remain uninfected by the pathogen. Hence, apart from the immediate direct and indirect effects on individual animal species, the introduction of disease may also have broad, long-term, and unforeseeable effects on ecosystems (Cunningham, 1996).

3. Vertebrate Species on Barrow Island

3.1 Mammal Species Present on Barrow Island

Barrow Island Nature Reserve is best known for its abundant mammal species. Oil exploration on Barrow Island commenced in 1954 (Cox, 1977), and since then, although a complete census has not been performed, numerous studies of the vertebrate fauna have been undertaken, focussing primarily upon the mammal fauna (Burbidge *et al.*, 2000a; Burbidge *et al.*, 1998; Burbidge *et al.*, 2000b; Burbidge *et al.*, 2003; Butler, 1970; Butler, 1975; Morris *et al.*, 2001; Morris *et al.*, 2002; Morris *et al.*, 1999; Serventy and Marshall, 1964; Smith, 1976). Presently there are 14 resident species and 1 vagrant species of mammal (Table 1) recognised as occurring on Barrow Island (Anon., 2002a).

Despite the relatively low number of mammal species present on Barrow Island, its mammal fauna is highly significant, as six of its species are listed as threatened pursuant to the *Wildlife Conservation Act 1950* (CCWA, 2003; EPA, 2003). Additionally, the Black-flanked Rock-wallaby (*Petrogale lateralis*) has declined across much of its former range due to habitat disturbance and introduced predators (Anon., 2002a; CCWA, 2003), whilst five of the mammal taxa (*Bettongia lesueur*, *Isoodon auratus barrowensis*, *Lagorchestes conspicillatus conspicillatus*, *Macropus robustus isabellinus* and *Pseudomys nanus ferculinus*) are regarded as being endemic subspecies or races (Anon., 2002a; CCWA, 2003; EPA, 2003).

Table 1. Terrestrial mammal species resident on Barrow Island based upon surveys conducted for ChevronTexaco environmental impact assessment and DCLM mammal monitoring reports.

Family	Species	Common Name
Dasyuridae	*Planigale* sp. *Pseudantechinus* sp.	- -
Macropodidae	*Lagorchestes c. conspicillatus* *Macropus robustus isabellinus* *Petrogale lateralis*	Barrow Island Spectacled Hare-wallaby Barrow Island Euro Black-flanked Rock-wallaby
Peramelidae	*Isoodon auratus barrowensis*	Barrow Island Golden Bandicoot
Phalangeridae	*Trichosurus vulpecula arnhemensis*	Northern Brush-tailed Possum
Potoroidae	*Bettongia lesueur*	Barrow Island Boodie
Emballonuridae	*Taphozous gergianus*	Common Sheathtail Bat
Mollosidae	*Tadarida (Nyctinomus) australis*	White-striped Bat
Vespertilionidae	*Vespadelus (Eptesicus) finlaysoni*	Inland Cave Bat
Pteropodidae	*Pteropus alecto*	Black Flying-fox (vagrant)
Muridae	*Hydromys chrysogaster* *Pseudomys nanus ferculinus* *Zyzomys argurus*	Water-rat Barrow Island Chestnut Mouse Common Rock-rat

3.2 Reptile Species Present on Barrow Island

Barrow Island has an abundant terrestrial reptile fauna, comprising 35 species of lizard and 8 species of snake (Table 2). The assemblage of reptile species present on Barrow Island is somewhat more diverse than would typically be expected due

Table 2. Terrestrial reptile species present on Barrow Island based upon surveys conducted for ChevronTexaco environmental impact assessment and DCLM fauna monitoring reports.

Family	Species	Common Name
Lizards		
Agamidae	*Ctenophorus caudicintus*	Ring-tailed Dragon
	Gemmatophora longirostris	Long-nosed Water-dragon
	Pogona minor	Bearded Dragon
Gekkonidae	*Diplodactylus jeanae*	
	Diplodactylus stenodactylus	Crowned Gecko
	Gehydra variegata	Tree Dtella
	Gehydra pilbara	Pilbara Dtella
	Heteronotia binoei	Bynoe's Gecko
Pygopodidae	*Delma borea*	
	Delma nasuta	
	Delma tincta	
	Lialis burtonis	Burton's Legless-lizard
	Pygopus nigriceps	Hooded Scalyfoot
Scincidae	*Carlia triacantha*	
	Cryptoblepharus carnabyi	
	Ctenotus duricola	
	Ctenotus grandis	
	Ctenotus hanloni	
	Ctenotus pantherinus acripes	
	Ctenotus saxatilis	
	Ctenotus serventyi	
	Cyclodomorphus melanops	
	Eremiascincus richardsonii	
	Glaphyromorphus isolepis	
	Lerista bipes	
	Lerista elegans	
	Lerista muelleri	
	Menetia greyii	Dwarf Skink
	Morethia lineoocellata	
	Morethia ruficauda	
	Notoscincus ornatus	
	Proablepharus reginae	
Varanidae	*Varanus acanthurus*	Spiny-tailed Goanna
	Varanus brevicauda	Short-tailed Goanna
	Varanus giganteus	Perentie

Snakes Boidae	*Antaresia stimsoni*	Stimson's Python
Elapidae	*Brachyurophis (Vermicella) approximans* *Demansia rufescens* *Furina ornate* *Pseudechis australis* *Suta (Rhinoplocephalus) monachus*	 Rufous Whip-snake Moon Snake Mulga Snake Monk Snake
Typhlopidae	*Ramphotyphlops ammodytes* *Ramphotyphlops longissimus*	

primarily to its geographic location, which encompasses species from both northern and southern regions (Smith, 1976). Whilst the majority of Barrow Island's reptile species are represented on the Australian mainland, the skink *Ctenotus pantherinus acripes* is an endemic subspecies, and the blind snake *Ramphotphlops longissimus* is the only endemic vertebrate species exclusive to Barrow Island (Anon., 2002a).

3.3 Amphibians Present on Barrow Island

The Western Australian Museum database suggests that three species of frog may occur on Barrow Island; *Cyclorana maini*, *C. platycephala* (Water-holding Frog), and *Litoria rubella* (Inland Tree Frog) (Anon., 2002a). However, there are no records of the Water-holding Frog and the Inland Tree Frog is believed to be an introduced specimen from the mainland in 1965 (Anon., 2002a). At present the only frog species recognised as being present on Barrow Island is *Cyclorana maini* (Table 3), which is also widespread throughout the adjacent Pilbara region (Anon., 2002a).

Table 3. Amphibian species present on Barrow Island based upon surveys conducted for ChevronTexaco environmental impact assessment and DCLM fauna monitoring reports.

Family	Species	Common Name
Hylidae	*Cyclorana maini*	-

3.4 Bird Species Present on Barrow

Barrow Island is recognised as providing major and significant habitat for migratory wading birds which are protected by international treaty and by Commonwealth and State law (CCWA, 2003). As such, 110 species of birds have been recorded on Barrow Island, of which only 32 species are known to breed there (CCWA, 2003), making the island a major stopover/feeding ground for both locally and internationally migratory birds. Whilst some bird pathogens may potentially be brought on to Barrow Island via food and/or materials, the greatest potential for micro-organism introductions would be through migratory birds which is thus outside the control of Gorgon. Therefore it has been decided that the inclusion of birds in the present study under the aspect of controlling micro-organism introductions is outside the scope of this report as it would not be feasible to attempt to prevent birds from bringing micro-organisms onto Barrow Island.

3.5 Population Sizes and Dynamics

The mammal fauna on Barrow Island is currently subject to an annual monitoring programme run by the Department of Conservation and Land Management (DCLM) (Burbidge *et al.*, 1998; Burbidge *et al.*, 2000b; Burbidge *et al.*, 2003; Morris *et al.*, 2001; Morris *et al.*, 2002; Morris *et al.*, 1999). Several attempts have been made to obtain estimates of population size for the larger mammal species on Barrow Island prior to the establishment of a mammal monitoring programme by DCLM (Butler, 1970; Short and Turner, 1991; Short and Turner, 1993; Short *et al.*, 1988). However, obtaining accurate population size estimates agreeable to all parties has proven difficult due to the variety of techniques used (eg. spotlight transects, monitoring grids, quadrat surveys, track count surveys) and the sampling errors associated with each technique. Data collected via spotlighting surveys has generally been considered inaccurate due to variation between different operators as well as the visibility of particular mammal species. However, it is still a common and widespread method used to estimate species population size.

The spotlight monitoring transects set up and run by DCLM on Barrow Island since 1998 using the same techniques and transects (detailed in their mammal monitoring reports) have provided data collected by a common means over a number of years, providing an estimation of population size for the larger mammal species (Table 4). However, there is no similar data available for the smaller mammal species present on Barrow Island. Likewise, there is a dearth of information regarding population size and distribution of reptile species on Barrow Island with data on their patterns of distribution limited to reports of them being closely related to the soil type, areas of accumulation of leaf litter and to distinctive vegetation types present across the island (Anon., 2002a).

Table 4. Estimates of minimum total population size of commonly sighted mammals on Barrow Island, sourced from Burbidge *et al.* (2003).

	Barrow Island Euro	Boodie	Brushtail Possum	Golden Bandicoot	Spectacled Hare-wallaby
Butler (1970)	200+	400+	-	1000+	600+/800+*
Short *et al.* (1988)	1500	2500	-	3200	8600
Burbidge *et al.* (1998)	914 (554-1526)	2884 (1883-4589)	1360 (1149-1945)	3679 (2867-4235)	1661 (1389-1988)
Burbidge *et al.* (2000)	761 (462-1268)	564 (444-716)	650 (491-861)	1753 (855-1333)	1016 (749-1067)
Morris *et al.* (2001)	935 (497-1714)	2223 (1583-3125)	1366 (951-1973)	1971 (1515-2597)	888 (720-1098)
Morris *et al.* (2002)	528 (305-924)	1718 (1368-2176)	910 (683-1213)	1679 (1327-2133)	828 (650-1053)
Burbidge *et al.* (2003)	851 (462-1607)	1896 (1454-2472)	1468 (1033-2110)	2528 (2031-3145)	1137 (908-1423)

*600+ estimated in 1966, 800+ estimated in 1969 (Butler, 1970).

4. Micro-organisms Infecting Barrow Island Terrestrial Vertebrates or Related Mainland Species

4.1 Micro-organisms present on Barrow and surrounding islands

Despite the extremely high biodiversity conservation values of Barrow Island, there is relatively little published data on the biology and ecology of its terrestrial vertebrate species and even less is known of its invertebrate fauna. Very little information exists regarding micro-organisms present on Barrow Island. Therefore, in assessing and compiling a list of potential micro-organisms that may pose a risk to the vertebrate fauna on Barrow Island, we have had to extrapolate our results from studies on similar vertebrate species which have been conducted elsewhere in Australia, and in some instances overseas.

The only known research conducted on Barrow Island related to micro-organisms involved the isolation of *Salmonella* species from seagulls in 1986 and several observed cases of "Lumpy Jaw" in euros (presumably *Fusobacterium necrophorum*) (Butler, W. H. pers. comm., 2004). Recent studies carried out by a PhD student on Barrow Island have detected ticks and fleas on mammals however their identification is still ongoing. In addition, analysis of ticks from mammalian hosts has identified two novel *Rickettsia* species within the Spotted Fever Group and these are still being characterised. Spotted Fever Group rickettsiae are zoonotic organisms that are well documented as disease agents in many parts of the world including Australia. The pathogenicity of these rickettsiae for humans and animals on the island is as yet unknown.

4.2 Micro-organisms infecting Barrow Island vertebrates and related species in Australia

Due to the dearth of information regarding micro-organisms present in the terrestrial vertebrate species of Barrow Island it was necessary to refer to the literature detailing the occurrence of micro-organisms in similar and related host species elsewhere in

Australia. However, in comparison to the amount of information available regarding pathogens of humans and domestic livestock, there is still very little information available with regard to disease/infection risks for Australian native mammals, and even less for reptiles.

The typically destructive techniques involved with collecting and identifying internal parasites has lead most investigations to focus on the study of parasites in the more common native species (O'Donoghue and Adlard, 2000; Spratt *et al.*, 1990), however systematic surveys of native species are still rare. As such, comprehensive records of parasitic infections and disease infections are known for very few of our native species. Similarly, the less invasive methods required for surveying gastro-intestinal parasites of wildlife species has resulted in a more thorough understanding of them as opposed to the more cryptic species of pathogen. In addition, much of the available information relates to surveys of fauna for infectious micro-organisms rather than to actual disease occurrence.

Diseases in wild populations should be investigated from the perspective that multiple aetiological agents and predisposing factors are involved (Fowler, 1982), as they are an aspect of wildlife death-rate that must be understood in order to gain an accurate view of population dynamics (Speare *et al.*, 1989). The occurrence and localisation of disease in wildlife is determined by a variety of factors, including those that relate to the host, the causative agent and the environment (Morner *et al.*, 2002). Indeed many parasites have well-established commensal relationships with their host species and outbreaks of disease only occur following a shift in the hosts' ecology caused by environmental or physical stress. The vast majority of parasitic species recorded from host animals have no obvious pathological effects upon their host under normal conditions. Therefore, the presence of a parasitic agent in a host species does not necessarily indicate the occurrence of disease.

For the purpose of this review of the species of micro-organism that may potentially pose a risk to the terrestrial vertebrate species present on Barrow Island, we have grouped the mammalian species into their family assemblages (except for the bats which have been grouped into their order Chiroptera), the reptile species into lizards and snakes, and the single frog species is dealt with as a whole.

Additionally, the micro-organisms known to occur in these vertebrate hosts are presented in three sections. The first list of micro-organisms describes those genera that have been reported as occurring in the above host groups throughout Australia, encompassing both disease-causing as well as commensal micro-organisms. These are presented in Appendices 1-3 for the mammals, reptiles and amphibians respectively. Secondly, an abbreviated list, including only those pathogens reported as causing disease in host species representative of the Barrow Island vertebrate fauna, is presented for the mammals (section 4.2.1; Table 5), reptiles (section 4.2.2; Table 6) and amphibians (section 4.2.3; Table 7). Thirdly, a shortened list is presented concerning only those micro-organisms considered to pose a significant risk to the Barrow Island vertebrate fauna. This list is based on pathogenicity, transmission risk to Barrow Island and occurrence in Western Australia fauna (section 4.2.4).

4.2.1 Mammalian hosts

The abbreviated list of pathogens reported as potentially causing disease in mammalian host species representative of the Barrow Island fauna is presented in Table 5. Below is a brief synopsis of the disease syndromes for each pathogen listed.

4.2.1.1 Viruses

Wart Disease in bandicoots – newly discovered unidentified viral disease-causing debilitating wart-like lesions in Western Barred bandicoots from Bernier Island off Western Australian coast, cross species infectivity unknown (Swan *et al.*, in prep.).

Macropod Herpesvirus – cause of conjunctivitis, muco-cutaneous blisters and ulcerations and may progress to death; reported as a cause of disease in numerous species of captive macropods, clinical disease not reported from free-ranging macropods (Speare *et al.*, 1989).

Macropod Poxvirus – causes two types of lesions including wart-like lesions in several species of wild macropods; its natural history in free-ranging populations is unknown (Speare *et al.*, 1989).

Table 5. List of mammalian groups present on Barrow Island and pathogens reported as causing disease in these species elsewhere in Australia.

Family Group and Common Names	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Dasyuridae	Bacteria	*Chlamydia*	animal	Yes	WA	(Bodetti *et al.*, 2003)
Antechinus sp.		*Leptospira*	soil; water	Yes	E Aust	(Arundel *et al.*, 1977)
Planigale sp.	Protozoa	*Babesia*	vector	Yes?	E Aust	(Arundel *et al.*, 1977)
		Cryptosporidium	faecal; water	Yes	SE Aust	(Barker *et al.*, 1978)
		Giardia	faecal; water	Yes	Tas	(Milstein and Goldsmid, 1997)
		Toxoplasma	food; water	Yes	WA	(Haigh, 1994)
	Helminths	*Angiostrongylus*	vector	Yes	Qld, NSW	(Prociv and Carlisle, 2001)
		Pelecitus	vector	Yes	Aust	(Spratt, 1979)
		Marsupostrongylus	vector	Yes	E Aust	(Spratt, 1979; Spratt, 1984)
		Ophidascaris	faecal	Yes	Aust	(Speare *et al.*, 1984)
		Spirometra	vector	Yes	Aust	(McMillan and Walker, 1969)
Peramelidae	Viruses	Wart disease	animal	Yes	WA	(Swan *et al.*, in prep.)
Barrow Island Golden Bandicoot	Bacteria	*Chlamydia*	animal	Yes	WA	(Warren *et al.*, in prep.)
		Salmonella	faecal; food; water	Yes*	WA	(Swan *et al.*, in prep.)
	Protozoa	*Cryptosporidium*	faecal; water	Yes*	WA	(Adams, 2003)
		Giardia	faecal; water	Yes*	WA	(Adams *et al.*, in press)
		Toxoplasma	food; water	Yes	WA	(Adams, 2003)
		Trypanosoma	exprmtl; vector	Yes	Qld?	(Bettiol *et al.*, 1998)
	Helminths	*Angiostrongylus*	vector	Yes	Qld, NSW	(Prociv and Carlisle, 2001)

Family Group and Common Names	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Phalangeridae	Bacteria	*Bacillus*	faecal	No	Aust	(Speare *et al.*, 1984)
Northern Brushtail Possum		*Chlamydia*	animal	Yes	WA	(Bodetti *et al.*, 2003)
		Leptospira	soil; water	Yes?	SE Aust	(Durfee and Presidente, 1979)
		Mycobacterium	soil	No	SE Aust	(Corner and Presidente, 1980)
		Pseudomonas	animal	Yes	SE Aust	(Speare *et al.*, 1984)
	Protozoa	*Cryptosporidium*	faecal; water	Yes*	SE Aust	(Power *et al.*, 2003)
		Giardia	faecal; water	Yes*	Tas	(Milstein and Goldsmid, 1997)
		Leishmania	exprmtl; (vector)	Yes	Qld?	(Backhouse and Bolliger, 1951)
		Toxoplasma	food; water	Yes	NSW	(Canfield *et al.*, 1990; Cook and Pope, 1959)
		Trypanosoma	exprmtl; (vector)	Yes	Qld?	(Backhouse and Bolliger, 1951)
		Hepatazoon	?	Yes	SE Aust	(Speare *et al.*, 1984)
	Helminths	*Angiostrongylus*	vector	Yes	Qld, NSW	(Prociv and Carlisle, 2001)
		Marsupostrongylus	vector	Yes*	Qld	(Speare *et al.*, 1984)
		Ophidascaris	faecal	Yes	Qld	(Presidente, 1978)
Potoroidae	Bacteria	*Chlamydia*	animal	Yes	WA	(Bodetti *et al.*, 2003)
Barrow Island Boodie		*Salmonella*	faecal; food; water	Yes*	WA	(Swan *et al.*, in prep.)
	Protozoa	*Cryptosporidium*	faecal; water	Yes*	Aust	No record
		Giardia	faecal; water	Yes*	Aust	No record
		Toxoplasma	food; water	Yes	Aust	(Patton *et al.*, 1986)
	Helminths	*Angiostrongylus*	vector	Yes?	Qld, NSW	(Prociv and Carlisle, 2001)

Family Group and Common Names	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Macropodidae	Viruses	Macropod herpesvirus	animal	Yes	WA	(Britt *et al.*, 1994)
Barrow Island Euro		Macropod poxvirus	animal	Yes	WA	(Speare *et al.*, 1989)
Spectacled Hare-wallaby		Wallal & Warrego viruses	vector	Yes	WA	(Hooper *et al.*, 1999)
Black-flanked Rock Wallaby	Bacteria	*Fusobacterium*	soil	Yes	WA	(Speare *et al.*, 1989)
		Leptospira	soil; water	Yes?	SE Aust	(Durfee and Presidente, 1979)
		Salmonella	faecal; food; water	Yes*	WA	(Swan *et al.*, in prep.)
	Protozoa	*Cryptosporidium*	faecal; water	Yes*	NSW	(Power *et al.*, 2004)
		Giardia	faecal; water	Yes*	Tas	(Milstein and Goldsmid, 1997)
		Leishmania	vector	Yes	NT	(Rose *et al.*, 2004)
		Toxoplasma	food; water	Yes	WA	(Jakob-Hoff and Dunsmore, 1983)
		Trypanosoma	exprmtl; vector	Yes	Aust?	(Noyes *et al.*, 1999)
	Fungi	*Microsporum*	soil	Yes	Aust	(McAleer, 1980; Speare *et al.*, 1989)
		Trichophyton	soil	Yes	Aust	(McAleer, 1980; Speare *et al.*, 1989)
	Helminths	*Angiostrongylus*	vector	Yes	Qld, NSW	(McKenzie *et al.*, 1978)
		Filaroids	vector	Yes	Aust	(Speare *et al.*, 1989)
		Pelecitus	vector	Yes*	Aust	(Speare *et al.*, 1989; Spratt, 1972)
		Globocephaloides	soil	Yes*	Aust	(Arundel *et al.*, 1977)
		Hypodontus	soil	Yes*	Aust	(Beveridge, 1979; Speare *et al.*, 1989)
		Marsupostrongylus	vector	Yes	Aust	(Speare *et al.*, 1989)
		Strongyloides	soil	Yes	Aust	(Arundel *et al.*, 1977; Speare *et al.*, 1983)
		Echinococcus	soil	Yes*	WA	(Lymbery *et al.*, 1990)

Family Group and Common Names	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Chiroptera	Viruses	Australian Bat Lyssavirus	animal	Yes	Qld	(Warrilow *et al.*, 2003)
Common Sheathtail Bat	Bacteria	*Leptospira*	soil; water	Yes?	Aust	(McCoy, 1974)
White-striped Bat		*Salmonella*	faecal; food; water	Yes*	Aust	(McCoy, 1974)
Inland Cave Bat		*Mycobacterium*	soil	Yes*	Aust	(McCoy, 1974)
Black Flying-fox (vagrant)	Protozoa	*Toxoplasma*	food; water	Yes	Aust	(Hoar *et al.*, 1998)
		Trypanosoma	exprmtl; vector	Yes	Aust	(Hoar *et al.*, 1998; Molyneux, 1991)
	Fungi	*Histoplasma*	soil	Yes*	Aust	(Hoar *et al.*, 1998)
		Blastomyces	soil	Yes*	Aust	(Hoar *et al.*, 1998)
		Cryptococcus	soil	Yes*	Aust	(Hoar *et al.*, 1998)
	Helminths	*Angiostrongylus*	vector	Yes	NSW, Qld	(Barrett *et al.*, 2002)
Muridae	Viruses	Mossman Virus (MoV)	?	No	Qld	(Miller *et al.*, 2003)
Barrow Island Chestnut Mouse		Murine Cytomegalovirus	animal	Yes	WA	(Moro *et al.*, 1999)
Common Rock-rat		Murine corona virus	animal	Yes	SE Aust	(Smith *et al.*, 1993)
Water-rat		Murine rotavirus	animal	Yes	SE Aust	(Smith *et al.*, 1993)
		Mouse adenovirus	animal	Yes	SE Aust	(Smith *et al.*, 1993)
		Parvovirus	animal	Yes	SE Aust	(Smith *et al.*, 1993)
		Reovirus type 3	animal	Yes	SE Aust	(Smith *et al.*, 1993)
	Bacteria	*Leptospira*	soil; water	No	Qld	(Glazebrook *et al.*, 1978)
		Pseudomonas	soil; water	Yes	Qld	(Glazebrook *et al.*, 1978)
		Salmonella	faecal; food; water	Yes*	Qld	(Glazebrook *et al.*, 1978)
	Protozoa	*Cryptosporidium*	faecal; water	Yes*	WA	(Swan *et al.*, in prep.)
		Toxoplasma	food; water	Yes	WA	(Smales and Obendorf, 1996)
	Helminths	*Angiostrongylus*	vector	No	WA	(Prociv and Carlisle, 2001)

*Indicates those infections that generally only develop clinical signs in host species following exceptionally heavy burdens or illness associated with other stress factors.

Wallal and Warrego virus – orbiviruses responsible for kangaroo blindness throughout Australia; outbreaks have been observed in both kangaroos and euros in Western Australia (Hooper *et al.*, 1999).

Australian Bat Lyssavirus – closely related to rabies; present in numerous species of Australian bat; Black Flying-foxes (*Pteropus alecto*) are known to be infected with Australian Bat Lyssavirus (Warrilow *et al.*, 2003).

Mossman virus – a novel paramyxovirus and respiratory pathogen of both introduced and native rodents in Queensland; disease-causing potential is unclear (Miller *et al.*, 2003).

Murine Cytomegalovirus – has been detected in domestic mice in WA on Thevenard Island; no evidence of transmission to native mice and experimental infections did not produce infections (Moro *et al.*, 1999).

Murine corona virus, Murine rotavirus, Mouse adenovirus, Mouse parvovirus and Mouse reovirus type 3 – these viruses are a widespread cause of disease in domestic mice throughout south-eastern Australia; none of these viruses have been detected in surveys of domestic mice in WA (Moro *et al.*, 1999; Smith *et al.*, 1993).

4.2.1.2 Bacteria

Bacillus – enteric infection often spreading to the liver (Tyzzer's disease), spores shed in faeces are environmentally resistant for at least 12 months (Speare *et al.*, 1984).

Chlamydia – obligate intracellular pathogen causing a wide range of diseases including enteritis, respiratory disease, polyarthritis, conjunctivitis urogenital tract disease and abortion, symptoms range from inapparent through to severe in its many different host species; currently a disease of concern in reintroduced and translocated bandicoots in Western Australia (Bodetti *et al.*, 2003).

Fusobacterium – soil-borne micro-organism; causative agent of "Lumpy Jaw" in macropods, associated with various stress factors, often degenerates to terminal septicaemia in affected animals; widespread occurrence in Australia (Speare *et al.*, 1989).

Leptospira – bacterial pathogen passed in the urine of many rodents; infective to a wide range of hosts; associated with abortion in infected hosts (Speare *et al.*, 1989).

Mycobacterium – causative organism of tuberculosis, infections are generally atypical (Corner and Presidente, 1980).

Pseudomonas – associated with pouch infections leading to death of pouch young due to peritonitis and/or septicaemia (Speare *et al.*, 1984).

Salmonella – can cause gastroenteritis and septicaemia in mammals, infections appear to be related to nutritional and environmental stressors; zoonotic infections reported from marsupials in Western Australia (Iveson and Bradshaw, 1973; Speare *et al.*, 1989).

4.2.1.3 Protozoa

Babesia – blood-borne parasite associated with anaemia and post-mating mortalities in male dasyurids, may potentially facilitate other infections (Arundel *et al.*, 1977).

Cryptosporidium – can cause gastroenteritis in both young and adult animals, environmental and stress factors may influence infections, known to cause deaths in young and juvenile animals, prevalent in water sources throughout Australia (Hallier-Soulier and Guillot, 2000; Power *et al.*, 2004).

Giardia – disease symptoms range from asymptomatic to severe diarrhoea; responsible for malabsorption; common water source contaminant; human strains shown to be readily infective to bandicoots (Bettiol *et al.*, 1997).

Hepatozoon – blood borne haemogregarine, associated with decreases in body condition and anaemia in animals (Speare *et al.*, 1989).

Leishmania – causative agent of cutaneous inflammation and skin lesions in kangaroos; transmitted between hosts by sandflies, potential zoonotic pathogen (Rose *et al.*, 2004).

Toxoplasma – ubiquitous obligate intracellular parasite infective to virtually all species of warm-blooded animals, common cause of death in captive and wild Australian marsupials (Obendorf and Munday, 1990; Reddacliff *et al.*, 1993).

Trypanosoma – blood-borne parasites causing anaemia, ulcerative gastritis, enteritis and death in its hosts; prevalent throughout southeast Asia; shown to be infective to native marsupials (Bettiol *et al.*, 1998; Reid *et al.*, 2001).

4.2.1.4 Fungi

Blastomyces, ***Cryptococcus*** – fungal genera causing granulomatous disease of mucous membranes; typically acquired from direct contact with soil enriched with bat faeces (Hoar *et al.*, 1998).

Histoplasma – soil saprophyte, thrives in warm, moist environments especially if enriched with organic material; infection occurs predominantly through aerosols and direct contact with contaminated soils (Hoar *et al.*, 1998).

Microsporum, ***Trichophyton*** – soil-borne and animal associated fungi; causative agents of Ringworm; common in captive mammal species throughout Australia, though can cause infections in stressed populations (Speare *et al.*, 1989).

4.2.1.5 Helminths

Angiostrongylus – nematode parasite cycled through slugs/snails with a rodent definitive host; causes neurological disorders and mortalities in non-specific hosts such as macropods and bandicoots (Prociv and Carlisle, 2001).

Echinococcus – cestode parasite cycled between dogs and macropods; intermediate stages form large fluid filled cysts in lungs, liver and other internal organs (Lymbery *et al.*, 1990).

Globocephaloides, ***Hypodontus*** – common nematode parasites of macropods capable of causing anaemia and hypoproteinaemia; known to cause death in wild macropods (Speare *et al.*, 1989).

Marsupostrongylus – mosquito-borne lungworms often associated with a mild to severe interstitial pneumonia; severity usually determined by the number of parasites infecting the lung (Spratt, 1984).

Ophidascaris – nematode found in numerous marsupial species; pythons as definitive host; mortalities have been reported in intermediate hosts such as possums and small dasyurids due to migration of larvae within host (Speare *et al.*, 1984).

Pelecitus – blood-borne nematode; transmitted by biting tabanid flies; infection in macropod hosts ranges from asymptomatic to severe disease (Speare *et al.*, 1989).

Strongyloides – nematode parasite commonly occurring in macropods, may cause focal hyperaemia, responsible for deaths of captive macropods though usually well tolerated by host (Speare *et al.*, 1989).

4.2.2 Reptilian hosts

The abbreviated list of pathogens reported as causing disease in reptilian host species representative of the Barrow Island reptile fauna is presented in Table 6. A brief synopsis of the disease associated with each pathogen is presented below. Diseases occurring in reptile species outside of Australia may have the potential to infect Australian reptiles given their common evolutionary ancestry, however this was deemed to be outside the scope of this report as at this point in time the ports of origin of vessels supplying Barrow Island have not been confirmed. Nevertheless, it must be noted that reptiles can be brought to Barrow Island from outside Australia via equipment and vessels and may therefore act as a source of exotic reptilian disease.

4.2.2.1 Viruses

Ophidian paramyxovirus – recently reported virus affecting numerous snake species; cause of "die-offs" in viperid, elapid, boid and colubrid snakes; produces intranuclear inclusion bodies in lung and brain, respiratory disease associated with wasting and death; reported in snakes from several collections in New South Wales (Ross, 2004).

Inclusion body disease – primarily a boid-specific disease; cause of regurgitation and central nervous system signs; no available treatment and infection is invariably fatal in pythons; present in snakes in Western Australia (Bush, 2000).

Wamena virus – reported to have caused disease in a python in Queensland (Daszak *et al.*, 1999).

4.2.2.2 Bacteria

Chlamydia - obligate intracellular pathogen causing a wide range of diseases in numerous host species; symptoms range from inapparent to severe; present in reptiles in Australia (Bodetti *et al.*, 2002; Jacobson and Telford, 1990).

Dermatophilus – cause of skin disease and debilitation of crocodiles in the Northern Territory (Fenwick, pers. comm., 2004).

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Table 6. List of reptilian groups present on Barrow Island and pathogens reported as causing disease in these species elsewhere in Australia.

Group	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Lizards	Viruses	Ophidian Paramyxovirus	vector?	?	?	No reports
		Inclusion Body Disease	vector?	?	?	No reports
	Bacteria	*Salmonella*	faecal; food; water	Yes*	Aust	(Iveson *et al.*, 1969)
		Leptospira	soil; water	Yes*		No reports
		Rickettsia	vector	Yes*	Aust	(Stenos *et al.*, 2003)
		Dermatophilus	soil; animal	Yes	NT	(Fenwick pers. comm.., 2004)
	Protozoa	*Cryptosporidium*	faecal; water	Yes	Aust	(Oros *et al.*, 1998; Xiao *et al.*, 2004)
	Helminths	*Angiostrongylus*	vector	Yes	Thailand	(Radomyos *et al.*, 1994)
Snakes	Viruses	Ophidian Paramyxovirus	vector(?)	Yes	NSW	(Ross, 2004)
		Inclusion Body Disease	vector	Yes	WA	(Bush, 2000; Carlisle-Nowak *et al.*, 1998)
		Wamena virus	?	?	Qld	(Daszak *et al.*, 1999)
	Protozoa	*Cryptosporidium*	faecal; water	Yes	NSW	(Boylan *et al.*, 1985)
	Fungi	*Chrysosporium*	animal; faecal	Yes*	Qld	(Vissiennon *et al.*, 1999)

*Indicates those infections that generally only develop clinical signs in host species following exceptionally heavy burdens or illness associated with other stress factors.

Salmonella – cause of gastroenteritis; known to occur in reptiles in Western Australia (Iveson *et al.*, 1969).

4.2.2.3 Protozoa

Cryptosporidium – cause of chronic gastro-intestinal disease in snakes with protracted clinical disease eventually resulting in death; generally results in only subclinical infections in lizards; most reports originating from captive reptiles however survey of free-ranging reptiles in South Australia reported infections occurring in snakes (O'Donoghue, 1992; O'Donoghue, 1995).

4.2.2.4 Fungi

Chrysosporium – ubiquitous mould commonly occurring in soil, rarely disease-causing in humans and animals (Vissiennon *et al.*, 1999).

4.2.2.5 Helminths

Angiostrongylus - nematode parasite cycled through slugs/snails with a rodent definitive host, infective stages recently reported in varanid lizards from Thailand (Radomyos *et al.*, 1994).

4.2.3 Amphibian hosts

The abbreviated list of pathogens reported as causing disease in amphibian host species belonging to the family Hylidae is presented in Table 7. A brief synopsis of the disease associated with each pathogen is presented below.

4.2.3.1 Viruses

Bohle virus – highly virulent ranavirus causing systemic infections in frogs from eastern Australia; tadpoles appear to be most susceptible (Daszak *et al.*, 1999).

Table 7. List of pathogens reported as causing disease in amphibian species elsewhere in Australia that may infect *Cyclorana maini*.

Family and Species	Infectious Agent	Genus	Transmission	Disease Association	Location	Reference
Hylidae	Viruses	Bohle virus	?	?	Aust	(Hengstberger *et al.*, 1993)
Cyclorana maini	Bacteria	*Chlamydia*	animal	Yes	Qld	(Berger *et al.*, 1999)
		Leptospira	soil; water	Yes*	Aust	(Charon *et al.*, 1975)
	Fungi	*Batrachochytrium*	animal	Yes	WA	(Berger *et al.*, 2000; Morell, 1999)
		Mucor	animal; faecal	Yes	Aust	(Berger *et al.*, 1997)

*Indicates those infections that generally only develop clinical signs in host species following exceptionally heavy burdens or illness associated with other stress factors.

4.2.3.2 Bacteria

Chlamydia – cause of a wide range of diseases in mammalian hosts; recently reported in amphibians (Berger *et al.*, 1999).

4.2.3.3 Fungi

Batrachochytrium – ubiquitous fungi found in aquatic habitats and moist soil; cause of chytridiomycosis and responsible for mass deaths in amphibans in Australia and worldwide (Daszak *et al.*, 1999).
Mucor – report of disease occurring in frogs belonging to the family Hylidae in Australia (Berger *et al.*, 1997).

4.2.4 Pathogens posing disease risks to Barrow Island fauna

Tables 5-7 are extensive lists of those micro-organisms recognised as infecting native animals but not necessarily causing disease. It is therefore important to look more closely at those that are potentially pathogenic for the vertebrate fauna on Barrow Island. In consideration of this Table 8 lists those micro-organisms that pose the greatest threat to the fauna and their potential routes of transmission. The list has been compiled based on available information from the literature. In all cases these organisms have been associated with disease on more than one occasion and most have been described in Western Australia or are suspected to be present. Details of disease syndromes and related references have already been supplied (section 4.2.1, 4.2.2 and 4.2.3). Although some of these micro-organisms do not cause severe disease the potential effects of debilitation on isolated populations are unclear. However, it must be stressed that without any background information a number of these micro-organisms may already be present on the island. Similarly, micro-organisms not on this list may also be capable of causing disease in the Barrow Island fauna.

Table 8. Pathogenic micro-organisms that pose the highest risk to the Barrow Island terrestrial vertebrate fauna.

Pathogen	Species Affected	Infection Route
Chlamydia	all	animal
Cryptosporidium	all	faecal; water
Toxoplasma	all	food; water
Salmonella	all	faecal; food; water
Wart Disease	bandicoots	animal
Wallal & Warrego virus	macropods	vector
Globocephaloides/Hypodontus	macropods	soil
Australian Bat Lyssavirus	bats	animal
Ophidian Paramyxovirus	reptiles	animal; vector(?)
Inclusion Body Disease	reptiles	animal; vector(?)
Batrachochytrium	frogs	animal
Trichophyton, Microsporum	all	animal; soil

4.2.5 Zoonotic diseases of concern on Barrow Island

Zoonoses are those infections carried by animals capable of causing disease in humans. As stated previously little is currently known of the micro-organisms on Barrow Island or their zoonotic capability (apart from the presence of Spotted Fever Group rickettsiae and *Salmonella* strains), however a number of those that could potentially establish in the wildlife and thus pose a risk are outlined in Table 9.

Previous reports of zoonotic disease on Barrow Island are limited to the possible presence of Q fever (*Coxiella burnetii*), however this caused considerable concern among the workforce in 2002 (Fenwick pers. comm., 2004). With the presence of an expanded workforce on Barrow Island a brief discussion of potential zoonotic diseases, either present or at risk of introduction, was deemed important.

Table 9. Micro-organisms that pose a zoonotic risk to the Barrow Island workforce should they be transmitted to the Barrow Island fauna.

Pathogen	Disease in Animal	Reservoir Host	Infection Route	Reference
Cryptosporidium sp.	Yes	all	faecal; water	(O'Donoghue, 1992)
Salmonella sp.	Yes	all	faecal; water	(Iveson and Bradshaw, 1973)
Coxiella	No	mammals	vector	(Fenwick pers. comm., 2004)
Spotted Group Rickettsiae	No	mammals	vector	(Fenwick pers. comm., 2004)
Ross River virus	No	macropods	vector	(Mackenzie *et al.*, 2001)
Barmah Forest virus	No	marsupials	vector	(Mackenzie *et al.*, 2001)
Murray Valley encephalitis	No	macropods	vector	(Cordova *et al.*, 2000)
Australian Bat Lyssavirus	Yes	bats	animal	(Warrilow *et al.*, 2003)

Cryptosporidium – readily transmissible between host species; highly resistant stages able to persist in environment for long periods of time; commonly found to be contaminating water sources; contact with animals is a known risk factor (Hallier-Soulier and Guillot, 2000; O'Donoghue, 1992).

Salmonella – common cause of gastroenteritis in both animals and humans; readily transmitted via food and faecal contamination; contact with marsupials has been reported as causing infection in humans in Western Australia (Iveson and Bradshaw, 1973).

Coxiella – cause of Q fever; maintained in animal and arthropod reservoirs; transmission via aerosols, dust and ticks; cause of concern on Barrow Island however organism has not been isolated; studies are ongoing as to its presence on the island (McDiarmid *et al.*, 2000; Storer *et al.*, 2003).

Spotted Fever Group Rickettsiae – tick-borne organisms causing disease in people in Australia; maintained in animal and arthropod reservoirs; transmission via tick bites; two new species recently isolated from ticks on Barrow Island, significance uncertain, further studies ongoing (Fenwick pers. comm., 2004).

Ross River virus – mosquito-borne virus causing an epidemic polyarthritis, macropods considered to be reservoir hosts, most prevalent in coastal areas and salt marshes; considered to be an emerging disease; increased awareness has lead to improved diagnosis and higher incidence of disease detection (Mackenzie *et al.*, 2001).

Barmah Forest virus – mosquito borne virus causing epidemic polyarthritis-like disease; similar to but distinct from Ross River virus; circulates between mosquitos and terrestrial animals, particularly marsupials; considered an emerging disease; increasing incidence due to greater awareness of symptoms (Mackenzie *et al.*, 2001).

Murray Valley encephalitis – mosquito-borne virus typically more prevalent throughout the Kimberley though reported as far south as the northern Goldfields in Western Australia following excessive rainfall in 2000 (Broom *et al.*, 2002; Cordova *et al.*, 2000).

Australian Bat Lyssavirus – closely related to the rabies virus; cause of illness and neurological disorders in bats; two cases of infection in humans, both resulting in fatal encephalitis; research has shown that two genetically distinguishable strains occur, one in frugivorous bats and the other in insectivorous bats; insectivorous bat colonies are present on Barrow Island and frugivorous bats have also been recorded on the island (Mackenzie, 1999; Mackenzie *et al.*, 2001).

5. Pathogen Pathways

Major transmission pathways for exotic organisms onto Barrow Island have been identified in relation to the movement of building and related materials, personnel and their belongings, and food. These pathways are common for movements between the Australian mainland, other countries and Barrow Island. In addition to higher organisms, these pathways are also potential routes for micro-organism incursions onto the island. For the purpose of this report the high risk pathogens for Barrow Island identified in Table 8 have been used as examples of how transmission onto the island might occur. Table 10 details the micro-organisms associated with each pathway and possible steps to prevent introductions. Many of the major pathways listed below are linked to each other and will be discussed in further detail.

Table 10. Potential pathways for high risk micro-organisms onto Barrow Island and recommended procedures for minimising pathogen entry.

Pathway	Pathogen	Steps to Avoid Introduction
Soil	*Globocephaloides* *Hypodontus*	Sterilisation (eg. steam or chemical) Containment of soil within development site, and isolation from island fauna
Equipment	Wart Disease Wallal & Warrego virus *Globocephaloides* *Hypodontus*	Disinfection (eg. spraying) Cleaning to remove soil Inspection for vector species prior to shipping Futher monitoring on island or at materials off-loading facility
Food	*Cryptosporidium* *Salmonella* *Toxoplasma*	Inspection of fresh produce Appropriate protocols to dispose of food scraps around camp and in the field HACCP plans at food supply areas to include steps to avoid introduction
People	*Cryptosporidium* *Salmonella* Ophidian Paramyxovirus Inclusion Body Disease Wart Disease Ringworm	Reporting of disease symptoms eg. diarrhoea Appropriate protocols for disposal of human waste, both around camp and in the field Education for workforce on risk factors involved with introductions eg. pet ownership
Personal Goods	Ophidian Paramyxovirus Inclusion Body Disease Chytridiomycosis	Disinfection protocols on arrival eg. footbaths, change of clothes Quarantine inspection Education
Transport Vessels	Wallal & Warrego virus Ophidian Paramyxovirus Inclusion Body Disease	Control of onboard vermin eg. baiting, spraying Only essential vessel landings to occur Thorough inspection of all materials carried Regular inspection of transport vessels

5.1 Soil

Soil is primarily involved in the transport of dormant or environmental stages of pathogens (eg. *Globocephaloides* and *Hypodontus* larvae, *Toxoplasma* oocysts). This can occur when soil/aggregate destined for Barrow Island is contaminated prior to its arrival on the island (eg. soil associated organisms, animal faeces). Soil can also transfer pathogens via infected vector species (both vertebrate and invertebrate). For example, the mechanical transmission of *Toxoplasma gondii* has been demonstrated with earthworms and cockroaches (Bettiol *et al.*, 2000; Wallace, 1972).

5.2 Equipment

The movement of equipment onto Barrow Island can facilitate the transport of micro-organisms via soil, animals or insect vectors. Strategies to prevent animal incursions and soil contamination are currently under review. Insect vectors such as mosquitoes can be trapped inside vehicles and their larvae can be present in puddles of water present inside vehicle tyres or other equipment. Additionally, vertebrate animals including mammals and reptiles can also be introduced via equipment, particularly in large prefabricated modules stored for long periods of time prior to shipping to Barrow Island. Invertebrate vectors such as mosquitoes, ticks and fleas can potentially introduce a number of infections identified in the high risk and zoonotic lists (Table 8 and 9).

5.3 Food

Micro-organisms capable of causing disease in wildlife are commonly found in unprocessed foodstuffs such as meat and fresh produce (eg. *Toxoplasma*, *Salmonella*), and this may pose a significant risk to the Barrow Island fauna. While food brought onto the island for the workforce should be strictly controlled, it may still be contaminated with micro-organisms. Therefore, food scraps fed to animals in the camp or transported outside the camp by birds or people may also transmit these micro-organisms to animals. Uncontrolled routes also exist whereby food can be brought onto the island (eg. inadvertent or smuggled introductions by workforce or disposal from nearby vessels), and these may pose an even greater risk to the Barrow Island wildlife. Finally, invertebrate vectors capable of transmitting disease (eg. cockroaches, flies), may be brought onto the island inside shipments of food.

5.4 People and personal goods

People are capable of transmitting micro-organisms either directly (eg. *Salmonella*, *Cryptosporidium*) or indirectly via vectors (eg. ticks fleas) or contaminated clothing and/or personal goods (eg. viruses, ringworm fungi). These introductions would for the most part be inadvertent and can be controlled by appropriate education and inspection protocols. It must be noted that people are also capable of introducing micro-organisms via smuggled goods such as food, soil contaminated personal goods or (rarely) animals, although similar procedures to those mentioned above should prevent this from occurring.

5.5 Transport vessels

As with the previous pathways, transport vessels may introduce micro-organisms via soil contaminated equipment, invertebrate vectors or vertebrate hosts. Appropriate quarantine strategies should significantly reduce the risk, however monitoring procedures as discussed in the recommendations (section 7) should be put in place. Of particular concern is the issue of privately owned watercraft landing on Barrow Island without being subject to any of the above mentioned quarantine procedures or restrictions. The current development of the Montebello and Barrow Islands Marine Conservation Reserves will result in an increased number of privately owned watercraft visiting the region. With this will come a significant increase in the number of watercraft wishing to make landfall on Barrow Island. If these are not subject to the same quarantine restrictions and procedures as the transport barges ferrying goods and equipment to the island, then these watercraft greatly increase the chance of a quarantine breach and foreign organism introduction(s). The potential for these events to occur puts the Barrow Island wildlife at risk.

5.6 Other pathways

Other pathways with the potential to introduce pathogens onto Barrow Island include: strandings of cetaceans (eg. whales, dolphins) and the “hauling out” of pinnipeds (eg. seals, sea-lions) on the beaches; transmission of disease by wild/migratory birds; and the washing ashore of storm debris (either from the mainland or other islands).

Although these are not deemed to pose a major risk for micro-organism introductions to Barrow Island, they still warrant consideration.

6. Conclusions

6.1 Predisposition of Barrow Island vertebrate fauna to disease

Being an island population, the Barrow Island fauna is isolated from other wildlife populations therefore the opportunities for the introduction of infections from outside are severely limited. In some respects this can be seen as beneficial, as island populations generally only have to deal with a subset of the diseases that their mainland counterpart populations have to. However, this reduced level of challenge can often lead to immunologically naïve populations that, when faced with new or even endemic infections, may suffer much higher levels of mortality and morbidity than do their mainland counterparts that are frequently challenged.

6.2 Genetic bottle neck experienced after separation of Barrow Island from Australian mainland has resulted in a genetically depauperate terrestrial vertebrate fauna

Small island populations isolated for long periods of time, such as those on Barrow Island, typically experience a reduction in genetic diversity due to a lack of "fresh" genetic material in the form of individuals moving between populations. This inbreeding can manifest in numerous ways, such as the reported anaemic status of the island's larger mammal species. The probable genetic homogeneity of the Barrow Island fauna means that if a disease has a debilitating effect on one individual, there is a much greater chance that it will have the same effect on the rest of the population. Thus, the risk of a catastrophic depopulation of a species on the island, following the introduction of what may well be deemed a benign disease, is increased.

6.3 Insufficient data available regarding micro-organisms associated with the vertebrate fauna on Barrow Island

Clearly this report is principally literature-based and relies on the supposition that many of the micro-organisms reported from mainland fauna are transmissible to the Barrow Island fauna. However, the almost complete lack of information regarding micro-organisms present in the vertebrate fauna on Barrow Island (coupled with the dearth of information regarding pathogens and native fauna in general) severely limits the effectiveness of any assumptions made in this regard. As a consequence, the limited data available regarding those species of micro-organism already present on Barrow Island means that in the event of a disease outbreak in the vertebrate fauna, Gorgon would have difficulty in determining whether it was due to an introduced or an endemic pathogen.

6.4 Zoonotic diseases and occupational safety

This report has identified a number of zoonotic diseases that are either present in the wildlife or that could potentially be introduced to Barrow Island. Many of these that are currently of little significance may be of greater concern given the much larger workforce that will be required to construct the gas processing facility. Additionally, the potential for people infected with zoonotic infections arriving for work on the island should not be overlooked, as many of these diseases have incubation periods during which infection is not noticeable or detectable. Given the presence of ticks and mosquitos on Barrow Island, there is significant potential for the fauna to act as a reservoir for many of these diseases, some of which may also cause disease in the vertebrate fauna, particularly those populations under stress. As with other micro-organisms, there is little data available on the presence of zoonotic pathogens on the island however studies are underway to investigate the status of tick-borne infections and their potential to cause occupational diseases.

6.5 Risk of introduction of exotic micro-organisms to Barrow Island

While it is impossible to completely exclude the introduction of 'exotic' micro-organisms onto the island, the risks of introducing micro-organisms potentially pathogenic for the terrestrial vertebrate fauna is considered to be low. However, this is reliant upon appropriate quarantine strategies and effective surveillance and monitoring systems being installed. Although a number of pathways by which micro-organisms might gain access to Barrow Island have been identified, the most likely pathways for micro-organism incursions onto the island are considered to be people (including personal goods) and foodstuffs. This view is based on three factors: i) the relative ease with which all other materials can be exposed to high levels of inspection, cleansing and disinfection; ii) the reduced ability of other materials to support viable stages of pathogenic micro-organisms and iii) the documented role of animals and foodstuffs in the frequent transmission of pathogens.

7. Recommendations

The importance of disease in wildlife populations, particularly in pristine environments such as Barrow Island, is of growing concern and must be approached in a methodical and thorough manner. Two examples are the recent reports on the risk assessments for introducing non-indigenous species to Heard and McDonald Islands (Chown, 2003) and diseases of Antarctic wildlife (Australia, 2001). The recommendations arising from the current report deal primarily with the biosecurity of Barrow Island, the health of the native terrestrial fauna and the health and safety of the future Gorgon workforce.

7.1 Biosecurity

7.1.1 Background information on the terrestrial fauna and their endemic micro-organisms

At present there is practically no information available regarding micro-organisms present in the vertebrate fauna or the environment on Barrow Island. As such, a disease outbreak would have to be considered to be associated with an introduced infection. To combat this, it is vital that baseline data is acquired on potentially pathogenic micro-organisms already present in the wildlife. In addition, as a complete census of the Barrow Island fauna has not been performed, it would be advisable to discuss ways of getting accurate population figures in order to monitor the ongoing status of the endemic populations. Such information would be extremely valuable in the unlikely event of a disease occurrence on the island and would help to provide the company with information to refute claims of negligence.

7.1.2 Monitoring of mainland quarantine sites for infections in potential vector species

Whilst a baseline survey of micro-organisms in the Barrow Island vertebrate fauna is considered important for the management of biosecurity on the island, this only addresses post-border quarantine issues. To properly manage the quarantine and biosecurity of Barrow Island an understanding of the micro-organisms occurring in potential vector species present at pre-border quarantine sites is also of high importance. Knowledge of the presence/absence of micro-organisms in potential vector species (rats, mice, mosquitoes, tabanid flies etc) at and around pre-border quarantine sites (i.e. Welshpool, Onslow, Dampier) allows risk assessments to be made regarding current practices, and supports the implementation of pro-active quarantine control measures. Whilst it is recognised that the level of quarantine management is such that the possibility of invasive species landing on Barrow Island is extremely low, the risk of micro-organisms being transported to Barrow Island in goods containing vector species still exists. Therefore, an assessment and ongoing monitoring of the micro-organisms present at these quarantine sites should be an important part of the biosecurity programme.

7.1.3 Disease surveillance system

It is well recognised that countries which conduct disease surveillance of their wild animal populations are more likely to detect the presence of infectious and zoonotic diseases and to swiftly adopt counter measures (Morner *et al.*, 2002). However, it is intrinsically more difficult to monitor diseases in wildlife than in domestic animals, as sampling opportunities may only occur at selected times or locations. In addition, the occurrence of disease in wildlife populations is not static, and the Barrow Island fauna experiences a seasonal exposure to biting arthropods as well as nutritional and environmental stresses. Thus, the development of surveillance and monitoring programmes is a vital first step towards providing an appropriate level of understanding of the health status of wildlife populations. Aspects of a surveillance system for disease on Barrow Island would include the collection and analysis of opportunistic wildlife samples from road kill and other animal mortalities, which, provided relevant information relating to the findings is collected and stored for future reference, will help to create a comprehensive database over time. Additionally, regular health monitoring, as outlined below, should also be established for the terrestrial vertebrate fauna on Barrow Island. The development of both passive and active surveillance systems for disease on the island will assist in the long term protection of the Barrow Island fauna.

7.1.4 Health monitoring of Barrow Island vertebrate fauna

Monitoring of the vertebrate fauna for a range of micro-organisms should be performed twice a year if possible (during spring and autumn to compensate for any seasonal fluctuations in pathogen prevalence). This would entail trapping and the collection of faecal, blood and ectoparasite (ticks and fleas) samples from the vertebrate fauna to allow the detection of micro-organisms of potential concern. As regular population monitoring is performed by DCLM, health monitoring should be integrated with this and other animal-associated activities as far as possible to reduce the stresses on the animals. Analysis of information gained through monitoring would assist in the anticipation of mortality events or adverse health problems.

7.1.5 Laboratory development

While the analysis of samples from the monitoring would usually be performed in mainland laboratories, improvements to the laboratory facility present at the current camp on Barrow Island is highly recommended. This facility could become a designated area on the island for disease/quarantine matters to be investigated, and would include offices for quarantine staff, repositories for storage of opportunistic samples (e.g. roadkills, suspicious deaths) and laboratory space for visiting researchers and monitoring personnel.

7.1.6 Contingency plans in the event of a suspected wildlife mortality event

In a setting such as Barrow Island it is highly likely that non-specialist personnel will discover an unusual morbidity, mortality or disease event in the wildlife. In such an event it is necessary to be able to contact and relay information and instructions to specialists with regard to the correct sampling and storage of specimens (Morner *et al.*, 2002). The drafting of policies and regulations to be followed in the event of an incident or disease epidemic occurring on the island (e.g. contacts of relevant scientists/institutes, types of samples and information to be collected, informing and liaising with island personnel, overseeing occupational safety issues etc.) will improve the capability of researchers to respond to such incidents. Therefore, it is recommended that dedicated quarantine officers should be employed and be present on the island at all times. These employees will undergo training in the correct procedures to follow should an incident occur (eg. potential vector species brought onto island, unexplained mortalities observed), will have the ability to liaise with visiting scientists in regard to quarantine and disease issues on the island and will ensure that as much relevant data relating to the incident is collected as possible including GIS data. The quarantine officers will liaise with the medical staff on the island to ensure that potential infections in the workforce related to animal contact are also investigated and prevented and will be involved in the ongoing education of the workforce on biosecurity issues.

7.1.7 Education of the workforce

Increasing the understanding of the workforce as to the importance of Barrow Island biosecurity with regard to micro-organisms in addition to the plant and vertebrate pest species is vital, as they are potentially the "eyes and ears" of the quarantine management strategies. Information regarding not only the key species of concern and the company's quarantine strategies, but also the correct procedure(s) to follow in the event of an incident or observation should be an integral component of the induction process. Examples of this would be the discussion of contact details for quarantine officer(s) and the procedures for dealing with road-kill incidents and observed mortality events. As discussed later, health protection strategies for those in contact with animals should also be stressed.

Regular on-site meetings or seminars to discuss wildlife and quarantine issues would be important to get the support of the workforce. For example, these could identify risk factors for bringing disease onto the island or the possibility of diseases associated with handling animals, both on and off the island. Such information sessions could be used to alert workers who have visited Queensland within the last two weeks to the potential for presenting with symptoms of tick typhus or Q fever, those from the southwest of Western Australia to the possible exposure to Ross River virus, and even workers from Southeast Asia to the potential risk of tropical zoonoses. Other information could include the risks associated with handling pets at home and the potential for bringing disease or disease vectors (reptile viruses, cat fleas) onto the island on themselves or on personal equipment. This type of education should not be alarmist but should help the workforce to be aware of disease issues and of their role in keeping the island's biosecurity intact.

7.1.8 Footbaths at airport

Use of disinfectant footbaths at the airport would play an important part in decreasing the risk of soil-borne pathogens coming onto Barrow Island, and would serve as a physical reminder to the workforce of the importance Gorgon places on quarantine.

This would supplement the use of educational media (posters, leaflets etc.) on the island highlighting the importance of quarantine and informing the workforce of the correct steps to take in the event of a perceived quarantine breach.

7.1.9 Foodstuffs

Alcohol is not permitted to be brought onto Barrow Island and the same should apply to food regardless of whether it was sourced from the local shop in Perth or the back yard garden. Food (fresh or packaged) can act as an ideal transport medium for agents potentially infectious for both wildlife and people, and all food brought onto the island should be subject to the same quarantine procedures. Bringing home grown foodstuffs onto Barrow Island circumvents existing quarantine procedures and would greatly increase the risk of micro-organisms coming onto the island. Therefore, food should only be brought onto Barrow Island via supplies for the mess, with any alternate or unusual food wanted on the island by the workforce to be requested via the kitchen staff.

One area of concern is the removal of food from the mess and its discard in areas where it might be scavenged by wildlife. This includes both the camp area and the field. While it is not intended to prevent food removal from the mess for future consumption, education of the workforce as to the consequences of discarded food scraps should be a priority. Specialised containers for disposal of such scraps could also be included around the camp and in vehicles.

Provisions for the disposal of kitchen scraps are already in place on the island, with incineration being the method of choice, however, with the expanded workforce consideration should be given to the significant increase in waste that will occur.

7.1.10 Reducing contact between wildlife and the workforce

Isolation of the work camp from the Barrow Island environment and fauna will reduce the potential for pathogens being transmitted to the wildlife and will create a designated border/post-border quarantine area. Vermin-proof fencing around the processing, equipment and camp areas, coupled with electrified pads at entry points, would provide a physical barrier that would prevent the escape of any potential vertebrate vectors onto the island and aid in keeping the workforce and native fauna separated. While it is pleasant for the workforce to be surrounded by animals such as bandicoots in the camp area, their presence and their scavenging habits could compromise the quarantine strategies being developed. As foodstuffs are considered to be one of the most important pathways for potential pathogens onto the island, stores should be vermin and wildlife-proof.

7.1.11 Sewage disposal

In addition to physical separation of people and animals, consideration must also be given to the separation of human waste from the environment. Current procedures incorporate a closed effluent disposal and treatment system however, as discussed previously the expansion of the workforce necessitates careful planning to ensure that biosecurity is not compromised. Regular monitoring of the effluent for potential pathogens (e.g. *Salmonella*, *Cryptosporidium*) following treatment should be included in the island's disease surveillance strategy.

7.1.12 Provision for other potential breaches of biosecurity

A number of potential pathways for micro-organisms to enter the island exist that are difficult to control. These include migratory birds, bats and aquatic mammals. In addition, unlawful landing of tourist boats onto the island could compromise the island's biosecurity. Provision should be made for the monitoring of migratory bird and bat populations for micro-organisms if possible, and stranded aquatic mammals should be removed immediately, or if dead, be subject to inspection and sampling by the quarantine officer. To prevent unlawful landings, material could be developed for dispersal via tour operators, local marinas and the media.

7.2 Health and Safety

7.2.1 Health monitoring of Barrow Island workforce

Workers on Barrow Island suffering diarrhoeal illness should be encouraged to report this to the medical personnel on site and to have samples taken for analysis if possible. This would assist in the monitoring for infectious organisms such as *Salmonella* and *Cryptosporidium* on the island, and is a standard practice within the meat and food industries.

7.2.2 Potential zoonotic infections in the Barrow Island workforce

Potential zoonotic infections have been listed in Table 9. While these are not likely to be a major cause for concern, education programs regarding their presence, methods of transmission and control would be useful. Additionally, in the light of previous concerns over Q fever in the workforce on Barrow Island and the presence of Spotted Fever Group rickettsiae in ticks it would be useful for all new long term or high risk workers (those working in tick infested areas) to undergo pre-employment blood tests with serum stored for future reference. Whether this was made a mandatory requirement is up to the company to decide.

Due to the morbidity currently associated with tick bites in employees on the island it is considered important to investigate the ecology of ticks and the incidence of tick bites, particularly if infections are likely to be present in these ticks. Some data has been gathered on tick bites in conjunction with the company medical staff however more comprehensive studies are required. This can be done in association with the current study of ticks on the mammalian fauna.

7.2.3 Portable toilets for "off-site" work groups

Faecal contamination of the environment has been identified as an important pathway of infection for the vertebrate fauna of Barrow Island. Pathogens such as *Cryptosporidium* and *Salmonella* species are capable of being transmitted directly from the workforce to the fauna should employees openly defecate in the environment. With the current workforce on Barrow Island of approximately 100 employees, this is not a common occurrence. However, with an increase to potentially 3000 employees on the island and "off-site" work groups (i.e. construction crews building the overland pipeline), this becomes a potentially significant pathway for micro-organisms to be transmitted to the native fauna. Portable chemical toilets should accompany groups of workers who will be working away from toilet facilities.

7.2.4 Contact between workforce and wildlife

Preventing the potential transmission of micro-organisms or vectors from the workforce to the Barrow Island wildlife requires limiting the interface between the two. This would mean that situations such as the presence of golden bandicoots in the wet mess area and around the entrance to the mess/kitchen need to be controlled. Although the close proximity and interaction of this novel and enjoyable experience does much to foster an appreciation for the wildlife amongst the workforce, it is also potentially an avenue for the transmission of disease from people to the wildlife and vice versa.

Personal clothing brought onto the island has the potential to transmit micro-organisms, particularly where it belongs to workers who have pets or regular contact with animals at home. If possible casual clothing should be either freshly laundered or left off the island and be provided by the company.

8. Contacts and Acknowledgements

The following institutions and organizations were contacted over the course of this review for the purpose of obtaining information over the course of this report. These institutions are not listed in any particular order.

Australian Wildlife Health Network
Department of Conservation and Land Management
Agricultural Department of Western Australia
Perth Zoo
Taronga Park Zoo
Armadale Reptile and Wildlife Centre
ChevronTexaco Australia Pty. Ltd.

The following people need to be acknowledged for their assistance in providing information pertaining to this report. These people are acknowledged in no particular order.

Dr Harry Butler
Dr Andrew Breed
Dr Simone Vitali
Professor Ralph Swan
Dr Kristin Warren
Professor Mal Nairn
Dr Rupert Woods
Ms Jenny Mills
Ms Joanne Smith
Mr Russell Hobbs
Ms Felicity Donaldson
Dr David Obendorf

9. Feedback

Over the course of this report we have received feedback and comment from numerous people with various backgrounds. Of particular note was an email received, following a request for information on the Australian Wildlife Health Network, from Dr David Obendorf who has been involved in wildlife disease research in Australia since the early 1970's and has published numerous papers in this field. In his email, Dr David Obendorf made some valuable suggestions and raised several important issues, and as such we feel that the inclusion of his email in this report is both pertinent and warranted.

Date: Thu, 1 Jul 2004 23:13:39 + 1000
From: David Obendorf <davidobendorf@tassie.net.au>
To: padams@central.murdoch.edu.au
Cc: rwoods@zoo.nsw.gov.au
Subject: Response to the posting with AWHN

Dear Peter,

I was interested to read your request for assistance in relation to monitoring of wildlife diseases and pathogens on Barrow Island WA.

I congratulate you on contemplating doing such a study!

I'm guessing that this might be a baseline study for any pre-existing disease-causing agents and pathogens of native fauna – focussing on the significant ones.

I have had a long-standing interest in wildlife disease monitoring, and I sense that islands with unique ecologies and high biodiversities are really great places to strategically test biosecurity theory about quarantine and containment capabilities.

One of the potential difficulties in any such study aiming to assess the microbiological biodiversity of a diverse population of terrestrial vertebrates (mammals, reptiles, amphibians and ?birds) is the need for a range of specialist diagnostic capabilities you might use to test.

In a remote area you almost need a mini-diagnostic lab or the ability to get samples to existing labs.

Yes, you might focus on significant pathogens already identified and/or isolated from related species or in animals interacting with human & synanthropic hosts (like introduced rodents, feral cats, dogs and livestock species).

I would commend you to a paper I co-authored a few years ago for the OIE. ['Surveillance & monitoring of wildlife disease' 2002 by Torsen Morner, David Obendorf, Marc Artios and Michael Woodford, Rev. Sci. Tech. Off. Int. Epiz. **21(1)**]. In it we try to explain the need to take advantage of opportunistic mortality & morbidity events involving wildlife – either in multiple-animal events or from a series of point incidents over time. We also highlight the value of retrospective databases and historical searches for case pathologies or investigations which assist with the direction of prospective research studies.

Cutting to the chase, you might need to initially focus [on] one or two indicator host species as *case species studies*. They could be chosen on the basis of population size, sheer biomass impact on the island ecology, possible interface potential between the humans & their synanthropes (if there are any) or maybe just because they are a threatened species.

As we explain in our paper overt disease expression causing morbidity or mortality is usually the first indication that a new pathogen might have arrived <u>or</u> that epizootiological factors in the population are favouring the expression of a pre-existing endemic pathogen.

It is always easier to work from a clinical malady involving wildlife to defining the pathological diagnosis, then the aetiological diagnosis (i.e. possible exogenous pathogen) and finally the pathogenesis of infection and epidemiology. You need to be also lucky to have access to good samples and that isn't that easy with wildlife investigation in hot climates!

Just screening for a range of microbes can be done but it takes up lots of resources and usually can only focus on the easily recoverable (parasites), culturable (fungi & clinical bacteria and possibly some viruses).

Your access to animals for bleeding, necropsy examination or parasite sampling will be critical to how much you can realistically achieve in any short-term study.

Maybe serum & tissue can [be] collected and banked for retrospective screening when you do have a mass mortality or morbidity event.

You can almost guarantee that the microbial biodiversity of Barrow Island vertebrates will be quite large indeed.

Microbes that might be useful to assess include *Salmonella* (by faecal culture)…I understand that Quokkas on Rottnest Island have a high prevalence of this gut bug. But this type of survey might only be an incidental finding. It would need to be linked to something epidemiological.

The questions I would first ask is:

1. Are there any known disease-causing pathogens associated with mortality or morbidity in any Barrow Island animals?

2. On mainland WA are there any disease-associated *threatening processes* that have caused the decline of similar species that also exist on Barrow Island? If so, do these organisms *per se*, or their vectors, pose a biosecurity entry/establishment & spread risk to the island?

By adopting this approach you might focus on highly significant pathogens in any initial screening efforts. It is likely to appeal to WA Conservation Authorities as well!

Or you might decide to look for a novel (& high profile) virus such as Bat Lyssavirus, or arboviruses by serology through collaboration with a reference laboratory.

Any pathogen screening of a wide range of terrestrial fauna, in my opinion, needs to be strategic and focussed on potential biodiversity risks of pathogen introductions with new animals, insect vectors or breakdowns in island quarantine protocols.

Keep me posted on your work.

Best of luck with your studies,

Regards

David Obendorf

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Appendix 1

Extended list of micro-organism genera reported as occurring in those mammalian hosts belonging to the taxonomic groups outlined below in Australia.

	Mammals		
	Dasyuridae (Dasyurids)		
Viruses	No Records		
Bacteria	*Chlamydia*	*Leptospira*	*Salmonella*
Protozoa	*Babesia*	*Hepatozoon*	*Toxoplasma*
	Cryptosporidium	*Klossiella*	
	Giardia	*Sarcocystis*	
Fungi	No Records		
Helminths	*Abbreviata (N)*	*Fibricola (T)*	*Pelecitus (N)*
	Anatrichosoma (N)	*Filaria (N)*	*Peramelistrongylus (N)*
	Angiostrongylus (N)	*Filaroides (N)*	*Pharyngostomoides (T)*
	Anoplotaenia (C)	*Gigantorhynchus (A)*	*Physaloptera (N)*
	Antechiniella (N)	*Gnathostoma (N)*	*Plagiorchis (T)*
	Antechinostrongylus (N)	*Gongylonema (N)*	*Pseudoleucochloridium (T)*
	Australiformis (A)	*Hymenolepis (C)*	*Pseudorictularia (N)*
	Baylisascaris (N)	*Inglechina (N)*	*Psilorchis (T)*
	Brachylaima (T)	*Linstowia (C)*	*Seurechina (N)*
	Brachylecithum (T)	*Mackerrastrongylus (N)*	*Spirometra (C)*
	Breinlia (N)	*Maritrema (T)*	*Spirura (N)*
	Capillaria (N)	*Marsupostrongylus (N)*	*Sprattellus (N)*
	Cercopithifilaria (N)	*Mehlisia (T)*	*Sprattia (N)*
	Choanotaenia (C)	Metacestode (C)	*Strongyloides (N)*
	Coelomotrema (T)	*Metaplagiorchis (T)*	*Synhimantus (N)*
	Copemania (N)	*Metathelazia (N)*	*Taenia (C)*
	Cyathospirura (N)	*Mirandula (C)*	*Tetrabothriostrongylus (N)*
	Cylicospirura (N)	*Nasistrongylus (N)*	*Trichinella (N)*
	Dasyurotaenia (C)	*Neodiplostomum (T)*	*Trichuris (N)*
	Denticulospirura (N)	*Oochoristica (C)*	*Woolleya (N)*
	Dessetostrongylus (N)	*Ophidascaris (N)*	*Zonorchis (T)*
	Dipetalonema (N)	*Parastrongyloides (N)*	
	Echinonema (N)	*Patricialina (N)*	
	Peramelidae (Bandicoots)		
Viruses	Arbovirus (Ross River virus)	Wart disease - Papilloma-like virus	
Bacteria	*Chlamydia*	*Salmonella*	*Serpulina*
Protozoa	*Babesia*	*Entamoeba*	*Theileria*
	Cryptosporidium	*Hepatozoon*	*Toxoplasma*
	Giardia	*Klossiella*	*Trypanosoma*
	Eimeria	*Sarcocystis*	

Fungi	No Records		
Helminths	*Abbreviata (N)*	*Fibricola (T)*	*Ophidascaris (N)*
	Angiostrongylus (N)	*Filostrongylus (N)*	*Parastrongyloides (N)*
	Asymmetracantha (N)	*Heterakis (N)*	*Peramelistrongylus (N)*
	Australiformis (A)	*Hymenolepis (C)*	*Physaloptera (N)*
	Bashkirovitrema (T)	*Labiobulura (N)*	*Plagiorhynchus (A)*
	Beveridgiella (N)	*Linstowia (C)*	*Platynosomum (T)*
	Brachylaima (T)	*Mackerrastrongylus (N)*	*Spirometra (C)*
	Breinlia (N)	*Marsupostrongylus (N)*	*Sprattia (N)*
	Capillaria (N)	*Mehlisia (T)*	*Strongyloides (N)*
	Cercopithifilaria (N)	*Metathelazia (N)*	*Tetrabothriostrongylus (N)*
	Cylicospirura (N)	*Mirandula (C)*	*Trichuris (N)*
	Dipetalonema (N)	*Nicollina (N)*	*Woolleya (N)*
	Echinonema (N)	*Oochoristica (C)*	
	Phalangeridae (Possums)		
Viruses	No Records		
Bacteria	*Bacillus*	*Leptospira*	*Pseudomonas*
	Chlamydia	*Mycobacterium*	
Protozoa	*Cryptosporidium*	*Hepatozoon*	*Toxoplasma*
	Eimeria	*Leshmania*	*Trypanosoma*
	Giardia	*Sarcocystis*	
Fungi	No Records		
Helminths	*Adelonema (N)*	*Echinococcus (C)*	*Parastrongyloides (N)*
	Amplicaecum (N)	*Fasciola (T)*	*Paraustrostrongylus (N)*
	Angiostrongylus (N)	*Filarinema (N)*	*Patricialina (C)*
	Anoplotaenia (C)	*Filostrongylus (N)*	*Profilarinema (N)*
	Bertiella (C)	*Gongylonema (N)*	*Protospirura (N)*
	Breinlia (N)	*Marsupostrongylus (N)*	*Sprattia (N)*
	Capillaria (N)	*Nematodirus (N)*	*Strongyloides (N)*
	Cooperia (N)	*Odilia (N)*	*Toxocara (N)*
	Dipetalonema (N)	*Ophidascaris (N)*	*Trichostrongylus (N)*
	Potoroidae (Bettongs)		
Viruses	No Records		
Bacteria	*Chlamydia*	*Salmonella*	
Protozoa	*Cryptosporidium*	*Klossiella*	*Toxoplasma*
	Eimeria	*Sarcocystis*	
	Giardia	*Theileria*	
Fungi	No Records		

Helminths	*Anoplotaenia (C)*	*Dasyurotaenia (C)*	*Paraustrostrongylus (N)*
	Angiostrongylus (N)	*Filarinema (N)*	*Peramelistrongylus (N)*
	Australiformis (A)	*Globocephaloides (N)*	*Potorostrongylus (N)*
	Breinlia (N)	*Gongylonema (N)*	*Potoxyuris (N)*
	Calostaurus (C)	*Hymenolepis (C)*	*Progamotaenia (C)*
	Capillaria (N)	*Labiostrongylus (N)*	*Raillietina (C)*
	Cloacina (N)	*Mastophorous (N)*	*Strongyloides (N)*
	Corollostrongylus (N)	*Ophidascaris (N)*	*Trichuris (N)*
	Macropodidae (Macropods)		
Viruses	Ross River virus	Foot and Mouth Disease	Mucosal Disease Virus
	Macropod Herpesvirus	Murray Valley encephalitis	Encephalomyocarditis virus (EMCV)
	Macropod Pox Virus	Wallal and Warrego virus	
Bacteria	*Chlamydiales*	*Leptospira*	*Salmonellae*
	Coxiella	*Mycobacteria*	*Tetanus*
	Fusobacterium	*Rickettsia*	
Protozoa	*Acanthamoeba*	*Globidium*	*Monocercomonas*
	Babesia	*Hammondia*	*Pfeifferinella*
	Cryptosporidium	*Heterotricha*	*Pneumocystis*
	Cycloposthium	*Ileocystis*	*Retortomonas*
	Dasytricha	*Isotricha*	*Sarcocystis*
	Eimeria	*Klossiella*	*Toxoplasma*
	Entamoeba	*Leishmania*	*Trichomonas*
	Entodinium	*Lymphocystis*	*Trypanosoma*
	Giardia	*Macropodinium*	
Fungi	*Microsporum*	*Trichophyton*	

Helminths	*Alocostoma (N)*	*Fasciola (T)*	*Pelecitus (N)*
	Amphicephaloides (N)	*Filarinema (N)*	*Pharyngostrongylus (N)*
	Angiostrongylus (N)	*Filaroides (N)*	*Physaloptera (N)*
	Anoplotaenia (C)	*Foliostoma (N)*	*Physocephalus (N)*
	Antechinostrongylus (N)	*Gemellicotyle (T)*	*Polydelphis (N)*
	Arundelia (N)	*Globocephaloides (N)*	*Popovastrongylus (N)*
	Austrostrongylus (N)	*Gongylonema (N)*	*Progamotaenia (C)*
	Bancroftiella (C)	*Hypodontus (N)*	*Rugopharynx (N)*
	Baylisascaris (N)	*Labiostrongylus (N)*	*Rugostrongylus (N)*
	Beveridgea (N)	*Macropicola (N)*	*Spirostrongylus (N)*
	Breinlia (N)	*Macroponema (N)*	*Strongyloides (N)*
	Calostaurus (C)	*Macropostrongyloides (N)*	*Sutarostrongylus (N)*
	Capillaria (N)	*Macropostrongylus (N)*	*Taenia (C)*
	Cassunema (N)	*Macropotrema (T)*	*Tethystrongylus (N)*
	Cloacina (N)	*Macropoxyuris (N)*	*Thallostonema (N)*
	Coronostrongylus (N)	*Maplestonema (N)*	*Thylonema (N)*
	Cosmostrongylus (N)	*Marsupostrongylus (N)*	*Thylostrongylus (N)*
	Cyclostrongylus (N)	*Monilonema (N)*	*Thysanotaenia (C)*
	Cylicospirura (N)	*Ophidascaris (N)*	*Trigonostonema (N)*
	Dasyurotaenia (C)	*Papillostrongylus (N)*	*Triplotaenia (C)*
	Dipetalonema (N)	*Paralabiostrongylus (N)*	*Wallabinema (N)*
	Dorcopsinema (N)	*Paramacropostrongylus (N)*	*Woodwardostrongylus (N)*
	Dorcopsistrongylus (N)	*Parapharyngostrongylus (N)*	*Zoniolaimus (N)*
	Durikainema (N)	*Pararugopharynx (N)*	
	Echinococcus (C)	*Parazoniolaimus (N)*	
	Chiroptera (Bats)		
Viruses	Australian Bat Lyssavirus	Hendra virus	
	Menangle virus	Nipah virus	
Bacteria	*Borrelia*	*Leptospira*	*Shigella*
	Coxiella	*Mycobacterium*	
	Escherichia	*Salmonella*	
Protozoa	*Eimeria*	*Polychromophilus*	*Trypanosoma*
	Haemosporidia	*Toxoplasma*	
Fungi	*Blastomyces*	*Cryptococcus*	*Scopulariopsis*
	Candida	*Histoplasma*	*Sporotrichum*
Helminths	*Angiostrongylus*		

	Muridae (Rodents)		
Viruses	Minute virus of mice (MVM)	Mouse hepatitis virus (MHV)	Murine reovirus (reo3)
	Mouse adenovirus (MAdV)	Murine cytomegalovirus (MCMV)	Murine rotavirus
Bacteria	*Leptospira*	*Pseudomonas*	*Salmonella*
Protozoa	*Acanthamoeba*	*Eperythrozoon*	*Plasmodium*
	Babesia	*Giardia*	*Sarcocystis*
	Bartonella	*Hammondia*	*Spironucleus*
	Besnoitia	*Hepatozoon*	*Toxoplasma*
	Cryptosporidium	*Hexamita*	*Trichomonas*
	Eimeria	*Klossiella*	*Trypanosoma*
	Entamoeba	*Naegleria*	
Fungi	No Records		
Helminths	*Abbreviata (N)*	*Hepatojarakus (N)*	*Pseudoporrorchis (A)*
	Amplicaecum (N)	*Hymenolepis (C)*	*Raillietina (C)*
	Angiostrongylus (N)	*Mastophorus (N)*	*Rictularia (N)*
	Ascaris (N)	*Microphallus (T)*	*Spirometra (C)*
	Ascarops (N)	*Moniliformis (A)*	*Spirura (N)*
	Aspiculuris (N)	*Monopylidium (C)*	*Strongyloides (N)*
	Capillaria (N)	*Neoascaris (N)*	*Syphacia (N)*
	Choanotaenia (C)	*Neodiplostomum (T)*	*Taenia (C)*
	Cosmocephalus (N)	*Nippostrongylus (N)*	*Toxocara (N)*
	Echinococcus (C)	*Odilia (N)*	*Trichostrongylidae (N)*
	Eucoleus (N)	*Oligorchis (C)*	*Trichosomoides (N)*
	Fibricola (T)	*Physaloptera (N)*	*Trichuris (N)*
	Ganguleterakis (N)	*Plagiorchis (T)*	
	Gongylonema (N)	*Protospirura (N)*	

Letters in parentheses indicate major taxonomic groups for helminth parasites.

A = Acanthacephala

C = Cestoda

N = Nematoda

T = Trematoda

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Appendix 2

Extended list of micro-organism genera reported as occurring in both lizards and snakes in Australia.

	Reptiles		
	Lizards		
Viruses	Adenoviridae	Iridoviridae	Polyomaviridae
	Herpesviridae	Ophidian Paramyxovirus	Poxviridae
	Inclusion Body Disease	Parvoviridae	
Bacteria	*Dermatophilus*	*Rickettsia*	
	Leptospira	*Salmonella*	
Protozoa	*Babesia*	*Globidia*	*Pirhemocyton*
	Billbraya	*Haemocystidium*	*Plasmodium*
	Bodo	*Haemogregarina*	*Sarcocystis*
	Copromonas	*Haemoproteus*	*Schellackia*
	Cryptosporidium	*Hemolivia*	*Trichomonas*
	Eimeria	*Hepatozoon*	*Trypanosoma*
	Endamoeba	*Isospora*	
	Fallisia	*Nyctotherus*	
Fungi	No Records		
Helminths	*Abbreviata (N)*	*Mesocoelium (T)*	*Pneumonema (N)*
	Acanthocephala (A)	microfilaria (N)	*Porrorchis (A)*
	Acanthotaenia (C)	*Microphallus (T)*	*Pseudorictularia (N)*
	Angiostrongylus (N)	*Moaciria (N)*	*Pseudothamugadia (N)*
	Ascaridoidea (N)	*Oochoristica (C)*	*Raillietascaris (N)*
	Ascaris (N)	*Ophidascaris (N)*	*Skrjabinelazia (N)*
	Bothridium (C)	*Ophiotaenia (C)*	*Skrjabinodon (N)*
	Brachylecithum (T)	*Oswaldofilaria (N)*	*Skrjabinoptera (N)*
	Cardianema (N)	Oxyuridae (N)	*Sphaerechinorhynchus (A)*
	Cylindrotaenia (C)	*Oxyuris (N)*	*Spinicauda (N)*
	Dioctowittus (N)	*Paradistomum (T)*	*Spirometra* (C)
	Filarioidea (N)	*Parapharyngodon (N)*	*Strongyluris (N)*
	Hastospiculum (N)	*Pharyngodon (N)*	*Tanqua (N)*
	Hedruris (N)	Pharyngodonidae (N)	*Terranova (N)*
	Herpetostrongylus (N)	*Physaloptera (N)*	*Tetracotyle (T)*
	Johnpearsonia (N)	*Physaloptera (N)*	*Thelandros (N)*
	Kapsulotaenia (C)	Physalopteridae (N)	Trichostrongyloidea (N)
	Kreisiella (N)	*Physalopteroides (N)*	*Veversia (N)*
	Maxvachonia (N)	*Piestocystis (C)*	*Wanaristrongylus (N)*
	Mermithidae (N)	*Piratuboides (N)*	

	Snakes		
Viruses	Adenoviridae Herpesviridae Inclusion Body Disease	Iridoviridae Ophidian paramyxovirus Parvoviridae	Wamena virus
Bacteria	No Records		
Protozoa	*Babesia* *Caryospora* *Cryptosporidium* *Eimeria*	*Entamoeba* *Haemogregarina* *Pirhemocyton* *Sarcocystis*	*Schellackia* *Trichomonas* *Trypanosoma*
Fungi	*Chrysosporium*		
Helminths	*Abbreviata (N)* *Acanthotaenia (C)* Ascarididae (N) *Ascaris (N)* *Atrophecaecum (T)* *Bothridium (C)* *Capillaria (N)* *Dioctowittus (N)* *Dolichopera (T)* *Goezia (N)* *Harmotrema (T)*	*Hastospiculum (N)* *Herpetostrongylus (N)* *Hydrophitrema (T)* *Kalicephalus (N)* *Maxvachonia (N)* *Moaciria (N)* *Ophidascaris (N)* *Ophiotaenia (C)* *Paraheterotyphlum (N)* *Physaloptera (N)* Physalopteridae (N)	*Piestocystis (C)* *Polydelphis (N)* *Proteocephalus (C)* *Simhatrema (T)* *Sphaerechinorhynchus (A)* *Spinicauda (N)* *Spirometra (C)* Spiruroidea (N) *Sterrhurus (T)*

Letters in parentheses indicate major taxonomic groups for helminth parasites.

A = Acanthacephala

C = Cestoda

N = Nematoda

T = Trematoda

Appendix 3

Extended list of micro-organism genera reported as occurring in amphibians in Australia.

Amphibians			
	Frogs		
Viruses	Adenoviridae	Herpesviridae	Polyomaviridae
	Bohle virus	Iridoviridae	Poxviridae
Bacteria	*Chlamydia*	*Leptospira*	
Protozoa	*Amoeba*	*Karotomorpha*	*Retortamonas*
	Balantidium	*Monocercomonas*	*Spironucleus*
	Chilomastix	*Myxidium*	*Trichomastix*
	Copromonas	*Myxobolus*	*Trichomitus*
	Entamoeba	*Myxosporidium*	*Trichomonas*
	Giardia	*Nyctotherus*	*Trypanosoma*
	Haemogregarina	*Opalina*	*Zelleriella*
	Hoarella	*Protoopalina*	
Fungi	*Batrachochytrium*	*Mucor*	
Helminths	No Records		