Eastern Barred Bandicoot: Proposed Translocation to French and Phillip Islands

Disease Risk Analysis

DRAWorkshop Participants, 4 August 2016, Melbourne Zoo

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Jakob-Hoff R, Coetsee A, Bodley K, Lynch M (2016) *Disease Risk Analysis for the Proposed Translocation of Eastern Barred Bandicoots to French and Phillip Islands*. IUCN SSC Conservation Breeding Specialist Group: Apple Valley, MN.

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Executive Summary

A recovery program for the eastern barred bandicoot (EBB), *Perameles gunnii*, was initiated in 1989. Intensive management efforts have seen the growth of the population from a founder base of just 19 individuals to around one thousand. The loss of suitable habitat, combined with fox predation, limits the available space to continue to grow the population, the majority of which is managed behind predator-barrier fences at three sites in Victoria. Phillip and French Islands, off the southern coast of Victoria have been identified as areas with suitable habitat but are outside this species' historic range. Both islands are also inhabited by people with their livestock and pets as well as a range of wildlife species, some of which are also endangered (e.g. long-nosed potoroo, *Potorous tridactylus)* while others, such as the little penguin, *Eudyptula minor*, are a major tourist attraction.

As part of its due diligence in assessing the potential for establishing populations on these islands, Zoos Victoria commissioned this comprehensive disease risk analysis (DRA). The Conservation Breeding Specialist Group's (CBSG) regional independent expert in wildlife disease risk analysis was contracted to facilitate the analysis with the combined input and collaboration of community representatives from both islands and a group of experts representing wildlife medical, diagnostic, captive management, wildlife biology and public health disciplines. The process used has been endorsed as best practice by the International Union for the Conservation of Nature's (IUCN) Species Survival Commission and the World Organisation for Animal Health (OIE). It is evidence-based, systematic, robust and transparent.

A review of published literature was combined with unpublished information for further discussion and qualitative analysis by the expert group assembled in Melbourne for a two day workshop on 4-5 August, 2016. Knowledge gaps were identified for future research.

A comprehensive list of disease hazards reported from bandicoots - or for which these animals were considered to be potential carriers - was reviewed against the likelihood of exposure to the islands' resident wildlife, domestic animals and people and the consequences should such an exposure occur. It was agreed that any potential disease risk identified to people and domestic animals must be able to be managed to a negligible level, low to negligible for resident wildlife and low to moderate for the bandicoots themselves.

Three potential non-negligible disease risks were identified: toxoplasmosis (to the bandicoots), enteric pathogens (*Salmonella, Campylobacter, E.coli, Yersinia, Cryptococcus* and *Giardia* – to humans and domestic animals), ectoparasites (fleas, ticks and mites – to resident wildlife). The expert panel considered that the bandicoots were very unlikely to add significantly to the risk posed by Ross River Virus (RRV) to the human population, but agreed that a risk assessment should be conducted on this pathogen given public concern following recent cases of this mosquito-borne disease reported from French Island.

Conclusion
For all potential disease hazards considered in this DRA, risk mitigation strategies, in the form of pre-translocation health assessments combined with preventative treatments are feasible and, when applied, will enable disease risks to be managed to be within the acceptable levels identified above.

Introduction: DRA Methodology

This Disease Risk Analysis (DRA) was developed with tools and processes described in the *Manual of Procedures for Wildlife Disease Risk Analysis* published jointly by the OIE/World Organisation for Animal Health and the IUCN-Species Survival Commission (Jakob-Hoff *et al.* 2014a). It was completed in three stages:

Stage 1: A thorough review of published (and available unpublished) information on EBB biology, captive husbandry and disease susceptibilities. This was compiled into a briefing document circulated to 22 individuals identified as having relevant expertise and/or a significant interest in this project ('stakeholders').

Stage 2: These stakeholders were invited to participate in a two-day workshop from 4-5 August 2016 in Melbourne with independent facilitation provided by Dr. Richard Jakob-Hoff of the IUCN-SSC Conservation Breeding Specialist Group (CBSG Australasia). The workshop was structured to systematically work through the six steps of the DRA process (Figure 1), building on the information gathered in the briefing papers. Participants alternately worked in small topic-focussed groups, reporting back to the whole group to seek further input and to critically review their initial work.

Stage 3: Subsequently the workshop outputs were used to correct, update and refine the briefing papers and assemble a draft report. The draft was then sent for review by workshop participants and their comments taken into consideration in completing this final report.

The detailed tools and processes used in the DRA Workshop are outlined in Appendix 1.

Figure 1: Disease Risk Analysis Process Steps
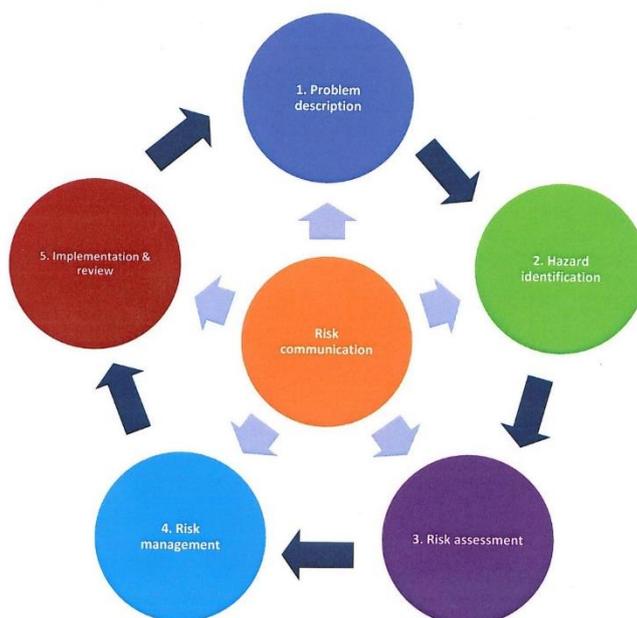
Problem Description

Justification for this DRA

The mainland eastern barred bandicoot (EBB) *Perameles gunnii* (unnamed sub sp.) is extinct in the wild (Advisory List of Threatened Vertebrate Fauna in Victoria 2013) with a current estimated population size of around 1,200. The species has been subject to a recovery effort that commenced in 1989, resulting in nine different release sites. Five of these populations are now extinct. Three of the remaining sites occur within the EBBs historic distribution and are surrounded by predator-barrier fences (Hamilton Community Parklands, Mt Rothwell and Woodlands Historic Park) and the fourth, Churchill Island, is an unfenced island trial site that lies beyond the historic range. Captive breeding has been part of the recovery effort from inception and since captive management was transferred to Zoos Victoria in 1991, a total of 896 EBBs have been produced in captivity and >550 released at one of the nine different release locations.

While disease does not appear to have been a significant factor in the decline of the species, resistance to disease is frequently compromised in populations with reduced genetic diversity. In addition, the translocation of EBBs between captive and wild sites and different wild sites carries the risk of the inadvertent transfer of disease-causing organisms (pathogens) between these sites, thereby potentially exposing EBBs and other vertebrate fauna at the recipient sites to novel organisms to which they have no innate resistance. EBBs that appear healthy may also be carriers of pathogens that, under the stresses of translocations, may manifest and cause overt disease in the carrier animal, although this has not been identified thus far. Currently toxoplasmosis is the only known disease that has compromised an EBB release, but only into an area with presumed high densities of feral cats (i.e. French Island).

In recognition of these risks, all EBBs intended for translocation between wild sites or release from captivity undergo a health examination by a veterinarian prior to transfer. In addition, a regimen of parasite treatments is applied. These treatments are in response to knowledge gaps regarding the presence or absence of parasite types between sites and a recognition of parasite-related mortalities of a few individuals in some populations.

The EBB recovery strategy is now looking towards releasing bandicoots onto large islands, specifically French and Phillip Island that lie beyond the species' historical range (Figure 2). These islands could have been isolated from certain diseases for some time and the vertebrate populations currently residing on them could be at some risk of bandicoots passing a disease onto them or vice versa. For this reason, the decision was taken to conduct this disease risk analysis to focus on identifying key disease risks associated with the proposed translocation of EBBs to French and Phillip Islands and mitigation measures for managing these risks.
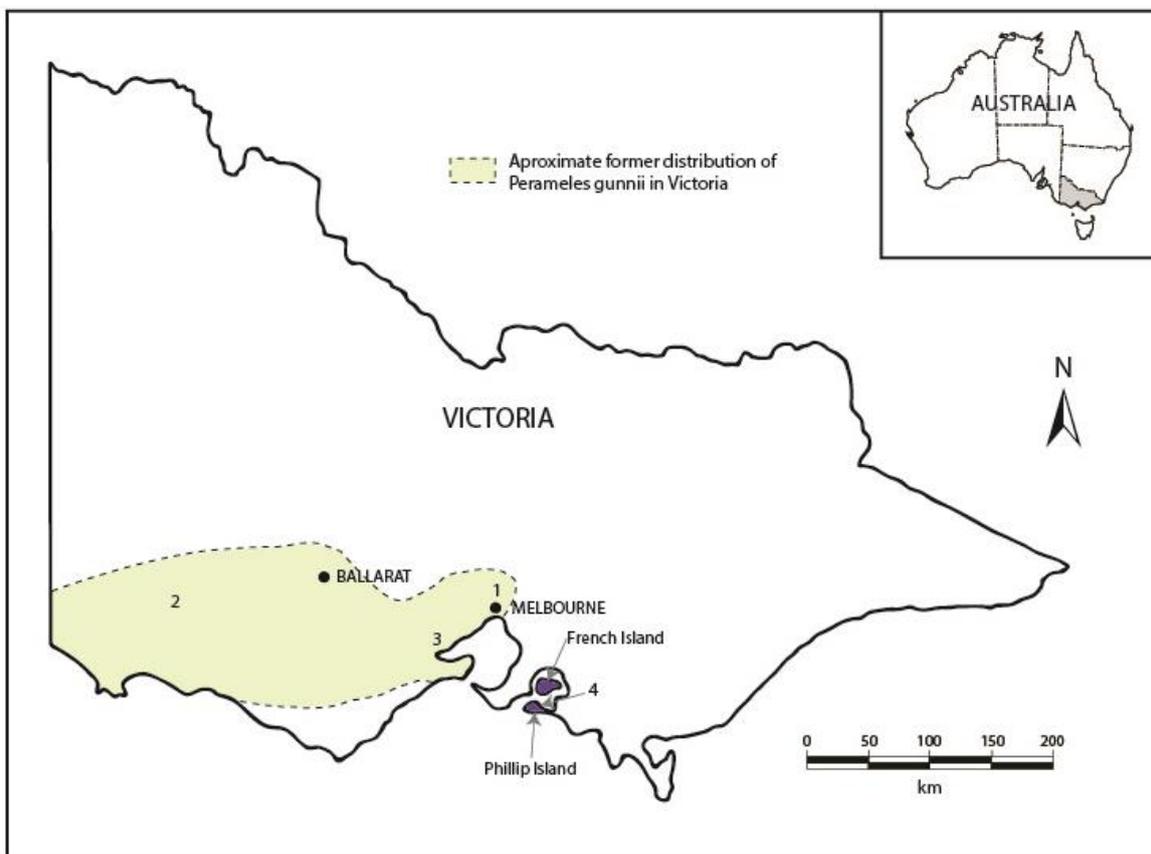
Source sites: 1 = Woodlands Historic Park, 2 = Hamilton Community Parklands, 3 = Mt Rothwell, 4 = Churchill Island. Destination sites: French Island and Phillip Island.

Background and Context

EBB Recovery Program

Formerly distributed across the basalt grasslands of south west Victoria, the EBB has undergone a catastrophic decline in range since European settlement. The last wild population was found in the city of Hamilton in south west Victoria, but this population was in decline. In response to this continued decline, the EBB Recovery Team was established in 1989. Wild bandicoots were initially taken from Hamilton and placed into large captive breeding pens at Woodlands Historic Park (Winnard & Coulson 2008). This set up was not ideal and hard to manage, so in 1991 captive breeding management was transferred to Zoos Victoria. In 2013 the EBB was classified as extinct in the wild by the Advisory List of Threatened Vertebrate Fauna in Victoria. As noted above, the mainland EBB is now only found in three fenced reserves and on Churchill Island totalling around 860 ha. The total population is currently estimated at around 1,200 EBBs (Eastern Barred Bandicoot Recovery Team 2016, unpubl. data).

Causes of decline

The main causes of decline are introduced predators, particularly the red fox *(Vulpes vulpes)* but also cats *(Felis catus)* and >99% loss of native grasslands and grassy woodland habitat within the EBBs former range (Scarlett *et al.* 1992). Foxes continue to be the primary threat

to bandicoot populations with the main requirement for successful and sustained reintroductions at sites being that they must remain fox-free. To date this has been achieved by building predator-barrier fences. While fenced sites have prevented the extinction of EBBs and are currently the only successful recovery model, it is uncertain whether they can be sustained in the long term, due to financial uncertainty and the cost of maintaining aging fences. Therefore, the EBB Recovery Team is now considering the suitability of fox-free islands for bandicoots. Only two Victorian islands (French and Phillip Island) are fox free and contain enough suitable habitat to establish a large, free-ranging bandicoot population, however, both islands lie beyond the EBBs historic distribution.

Recovery Strategy

To recover this species from near extinction more fox-free habitat is required. EBBs are relatively flexible in their habitat preference (Winnard *et al.* 2013) with their broad habitat requirements being the presence of open areas where bandicoots can forage adjacent to structurally complex areas that provide nesting opportunities.

Overall Recovery Plan Aim

To minimise the probability of extinction of EBBs by establishing self-sustaining reintroduced populations, which total a minimum of 2,500 individuals (Hill *et al.* 2010).

Recovery Objectives

These objectives are taken directly from the 5-year Eastern Barred Bandicoot National Recovery Plan (Hill *et al.* 2010) that has now expired but is still valid.

Objective 1. Minimise the probability of extinction by establishing self-sustaining reintroduced populations that total a minimum of 2,500 individuals.

Objective 2. Manage the sub-species to minimise any further loss of genetic diversity.

Objective 3. Maintain and enhance community and institutional support.

Captive Insurance Program

Husbandry

Each EBB is provided with a unique microchip for identification and its pedigree can be tracked through an in depth studbook and on the international zoo management system, ZIMS. Bandicoots are housed in individual pens unless breeding. Bandicoot enclosures differ slightly from institution to institution but the recommended enclosure size is about 5.0 x 3.5 m (or a longer enclosure of similar floor size). Enclosures must be fully enclosed with sheet metal lining to a minimum height of 1.2 m and 12 x 12 mm vermin proof mesh (EBBs can jump over 1.2 m and climb up mesh). A 10-20 cm substrate of turf, soil, mulch and/or sand is laid with plentiful cover provided in the form of tussocks (*Poa* spp. and *Lomandra* spp.), logs, large eucalypt branches and/or artificial nest boxes. At least one shelter in the form of bedding underneath a slanted wooden board is also provided at the ends of the enclosure to provide a dry area during periods of rain.

Bandicoots are fed a daily diet of 40 g Advance Puppy Plus Chicken Rehydrate Kibble, 35 g diced vegetables (e.g. sweet pot, broccoli, corn, carrot, pumpkin, endive, mushroom) and 10-15 g of mealworms or cockroaches daily. Additional live food such as earthworms,

crickets, moths and fly pupae are given when available. Sprouted seeds can also be offered once or twice a week. Mealworms, earthworms and fly pupae are available from suppliers. Some food is provided in bowls to monitor bandicoot feeding while other items are dispersed over the enclosure floor to promote foraging behaviour. Earthworms and crickets can be bred and maintained onsite, whereas moths and other flying invertebrates can be collected using a light source trap as required. Prior to translocation, the live food component of the diet is greatly increased to promote natural foraging behaviours.

In enclosures with breeding pairs and/or young, more than one food dish is offered to avoid competition at any one food station. Each food station is separated by a visual barrier, for example tussocks or branches. For young at foot, kibble is crushed for two to three weeks or until separated from their mother.

Breeding
EBBs have a gestation of 12.5 days, can breed throughout the year and readily breed in captivity. At captive institutions breeding is usually confined to May - October as breeding success is higher during these months, but they have been previously bred in captivity year-round. When breeding, males and females are housed in the same enclosure or two joined enclosures. Pairs are weighed weekly until pouch young are present. After weighing, each bandicoot is placed in a box in which a meadow hay nest has been made. If pouch young are not produced within 50 days the male is removed and replaced with another genetically suitable male if possible. Females are not introduced to a new male for a minimum of 2 weeks in case they are pregnant when the initial pair is separated. When pouch young are found, the pair will be left for 60 days from estimated date of birth. At 60 days, the young at foot are caught and sexed. Young are vet-checked at 75 days, have a genetic sample taken, are given a microchip and separated from their mother.

Population genetics
The mainland EBB studbook lists 23 founders from Hamilton and Mooramong as producing young in captivity in the early 1990's, however genetic analyses suggest all bandicoots are descendants of 19 individuals (Weeks *et al.* 2013). While there has been a decline in genetic variability (Weeks *et al.* 2013), there has been no decline in breeding output and no reproductive issues or changes have been observed. However, in an attempt to improve breeding output (time to first litter and percentage of pairs producing young), mate choice experiments have been conducted (Hartnett 2015). Preliminary findings show that when a female is allowed to choose her own mate, the number of pregnancies per pairing is significantly higher and the time to pregnancy is significantly shorter than when females are paired based on pedigree recommendations alone.

Acclimatisation
All captive bred bandicoots being translocated to free-ranging sites undergo a 6-week pre-release program that involves a two-week pre-release diet with increased live foods, a four-week program of providing new native nesting material and removing old nests to encourage nest building behaviour (in the wild, bandicoots will build a new nest every 1-2 nights) and a veterinary program involving health checks, two faecal checks and at least two parasite treatments. Bandicoots being translocated from free-ranging sites are vet checked but do not go through any acclimatisation processes and are released within 24 hours of capture.

Release

Based on the recommendations of de Milliano *et al.* 2016, all EBB releases are hard releases, as soft release (i.e. releasing into a 1 ha pen for 1 week with supplementary feeding) was found to not significantly increase survival. Post release monitoring using cage traps in introduced predator free sites has revealed a high survival rate of released bandicoots into empty reserves (72% of EBBs released into Woodlands are known to have survived at least 100 days, sufficient time to raise a litter (A. Coetsee unpubl. data)). At Woodlands, EBBs were still regularly caught 2 years after release (lifespan of EBBs = 2-3 years). Bandicoots released from captivity generally lose weight (<10% body weight) during the first two weeks post release and then regain all lost body weight by four weeks post release. Bandicoots found to have lost >10% body weight should flag concern and if weight loss exceeds 15% then the bandicoot is highly likely to die. Currently, these animals are removed to captivity and reasons for their failure to adapt to the wild environment considered. In contrast, bandicoots translocated to Churchill Island from Mt Rothwell generally did not experience any weight loss (D. Sutherland unpubl. data). However, there has been no difference observed in the survival or breeding success of captive-released or wild-translocated animals (A Coetsee unpubl. data).

Monitoring

Monitoring at Churchill Island, Hamilton Community Parklands and Woodlands Historic Park is conducted a minimum of twice a year (spring and autumn) for 3-4 consecutive nights using wire cage traps baited with peanut butter honey and oats. At Mt Rothwell, cage trapping is unsuccessful due to a high number of other small mammals that saturate the traps.

Sources of Eastern Barred Bandicoots for Translocation

Captivity

In 1991, 23 EBBs were transferred to Healesville Sanctuary (Krake & Halley 1993) to commence a captive breeding program within the zoo system. Since then, nine institutions have successfully bred EBBs for release (in alphabetical order: Dubbo Western Plains Zoo, Healesville Sanctuary, Kyabram Fauna Park, Melbourne Zoo, Monarto Zoo, Serendip Sanctuary, Taronga Zoo, Taronga Western Plains Zoo and Werribee Open Range Zoo). Currently, EBBs are bred at five locations: Healesville Sanctuary, Kyabram Fauna Park, Melbourne Zoo, Serendip Sanctuary and Werribee Open Range Zoo (Table 1). Originally the primary role of the captive breeding program was to breed for release, but now it is to hold an insurance population until the mainland EBB is secure in the wild. Offspring produced are still released as founders into new sites along with free-ranging individuals from other reintroduction sites.

Table 1: Institutions that have held and bred Eastern Barred Bandicoots for release

	Dubbo	*Healesville*	*Kyabram*	*Melbourne*	*Monarto*	*Serendip*	*Taronga*	*Werribee*
Bred	15	248	85	355	120	5	19	45
Breeding start date	1993	1991	1993	1991	1995	2014	1993	1992
End date	2001				2009		1999	

Free Ranging Sites

Churchill Island

In August 2015, 20 EBBs where released onto Churchill Island, a 57-ha island connected to Phillip Island by a 100 m concrete bridge. This release is a trial to determine the suitability of islands for EBBs. There are now at least 58 bandicoots on the island (D. Sutherland 2016 unpubl. data). See 'Species that are present at source sites and may have contact with EBBs' (p. 84) for a list of other wildlife on the island.

Hamilton Community Parklands

Hamilton Community Parklands in south-west Victoria is the smallest reintroduction site at 100 ha. This site was also established in 1989 and is surrounded by a predator-barrier fence. The bandicoot population declined to very low numbers in 2015 due to a fox incursion, so a release of 21 bandicoots occurred in April 2016 to boost numbers and genetic diversity. See 'Species that are present at source sites and may have contact with EBBs' (p. 84) for a list of other wildlife in the reserve.

Mt Rothwell Biodiversity Interpretation Centre

Mount Rothwell, near Little River, is a 470-ha privately owned reserve surrounded by a predator-barrier fence. EBBs were released in 2004 and currently holds around 600 individuals (A. Rypalski 2016 unpubl. data). See 'Species that are present at source sites and may have contact with EBBs' (p. 84) for a list of other wildlife in the reserve.

Woodlands Historic Park

Woodlands Historic Park is situated 20 km north of Melbourne and was the first EBB reintroduction site in 1989. This 235 ha reserve is surrounded by a predator-barrier fence and currently holds around 500 bandicoots (A. Coetsee 2016 unpubl. data). See 'Species that are present at source sites and may have contact with EBBs' (p. 84) for a list of other wildlife in the reserve.

Outbreeding

Gene-mixing trials between Tasmanian and Victorian EBBs are planned to commence in 2017. These trials will take place at Mt Rothwell within captive breeding pens and a secure free-ranging area. The aim of these trials is to boost the genetic variation in the mainland EBB. If successful, hybrids could be translocated to French Island and/or Phillip Island. Results of this trial are expected in late 2018.

Proposed Release Locations

French Island

French Island is an 18,000 ha island in Western Port Bay. Around 9,000 ha is thought to contain suitable habitat for EBBs. A large proportion of this is private farm land. Around 100 people live on the island. See 'Species list of terrestrial mammals present on Phillip Island and French Island' (p. 85) for other vertebrates present on French Island.

Phillip Island

Phillip Island is a 10,000 ha island in Western Port Bay. Approximately 20% of the island is public land of coastal and woodland habitats managed by the Phillip Island Nature Parks, another 20% is urbanised and the remaining 60% agricultural farmland. Around 10,000 permanent residents live on the island, though the population can swell to more than 60,000 at peak times of year. See 'Species list of terrestrial mammals present on Phillip Island and French Island' (p.85) for other vertebrates present on Phillip Island.

DRA Goal

Using the knowledge and specialist expertise of key stakeholders and wildlife disease experts, develop a disease risk management strategy for EBBs being translocated to French and Phillip Islands based on structured, evidence-based analysis of currently available information.

DRA Scope

Conduct a qualitative analysis of relevant published and unpublished information on the susceptibility of EBBs contracting an infectious or non-infectious disease on French or Phillip Island or passing a disease onto existing vertebrate island fauna including seabirds, native mammals (particularly the long-nosed potoroo (*Potorous tridactylus*) that is listed as threatened), livestock, domestic animals and humans.

DRA Focus

The identification, assessment and mitigation of all significant health risks to EBBs and existing vertebrate island fauna, including seabirds, native mammals, livestock, domestic animals and humans associated with the translocation of EBBs to French and Phillip Island.

DRA Questions

1) What is the risk of disease arising in EBBs from identified health hazards associated with their translocation and release on French and Phillip Island, that may constitute a significant threat to the survival of free ranging bandicoots on these islands and how can these disease risks be minimised?

2) What is the risk of EBBs passing a disease onto existing French and Phillip Island wildlife, domestic animals and people, as a consequence of a bandicoot translocation and how can these disease risks be minimised?

Acceptable Risk

A zero risk scenario is not feasible in the real world (Box 1). Consequently, to enable decisions on realistic risk mitigation measures to be made, the level of acceptable risk should be determined for each population of interest.

For example, we would assess a bandicoot found to be shedding coccidian oocysts, but lacking signs of clinical disease, as healthy in regards to release or translocation. This type of judgement call is frequently made in recognition that in all animals, potential pathogens and parasites can be carried as part of that animal's microbiota without clinical consequence. For certain pathogens, such as coccidian parasites in bandicoots, we recognise that exposure is important for young bandicoots to boost their immunity. However, disease from normally benign pathogens may occur if host or environmental factors alter to favour the pathogen's expression. The judgement on risk therefore needs to be made taking into account all known factors that might ultimately result in negative impact on bandicoots and in-contact fauna at destination sites.

"Zero risk is seldom, if ever, attainable and some degree of risk is unavoidable. For this reason, deciding whether or not a particular risk is acceptable is generally a societal or political decision because the benefits of a particular activity for one stakeholder group may have adverse consequences for another." (cited by Travis *et al*. 2014).

Box 1: Acceptable Risk

The following statement on acceptable risk was discussed at length by workshop participants until consensus agreement was reached:

Potential at-risk populations considered in this DRA are 1) the EBBs proposed for translocation and 2) the wildlife, domestic animals and people resident on French and Phillip Island. Potential disease risks to individuals and populations, that could be associated with the introduction of bandicoots, were considered by the expert panel.

It was agreed that the panel would need to identify risk mitigating measures that would reduce any identified disease risks to acceptable levels for these translocations to go ahead. The group defined 'acceptable levels' as:

For people and domestic animals: That the EBB introduction would pose a negligible risk of disease.

For resident wildlife: That the EBB introduction would pose a low risk to individual animal health and negligible population impacts.

For EBBs: That the health impacts to the EBB populations released to French and Phillip Islands are low to moderate.

Assumptions and Limitations

All wildlife DRAs involve a high level of complexity and uncertainty. Given this, an essential part of the DRA process is transparency. By this we mean the context of the DRA is clearly described (as above), the basis of risk assessments are clearly stated and any assumptions and limitations are made explicit. The vast majority of DRAs applied to wildlife are qualitative rather than quantitative because, compared to what we know about diseases of people and domestic animals, the data available on wildlife diseases are very limited.

Consequently, wildlife DRAs take an iterative approach i.e. they should be regularly reviewed to incorporate and consider new information as it becomes available. Documenting significant information gaps during the development of the DRA (Appendix 3) can provide a basis for directing research efforts that will enable a refinement of the analysis over time.

All risk analyses usually begin with a qualitative approach and quantitative techniques are used to develop further insights where needed and where sufficient relevant data is available for a meaningful result. Qualitative approaches can provide meaningful results when the available information – published and unpublished – is considered systematically with input from individuals with relevant expertise.

The assumptions and limitations of this DRA are stated below.

Assumptions
- EBBs are susceptible to the full range of health hazards recorded to date in the Peramelidae.
- EBBs are susceptible to pathogens that have been demonstrated to have a broad host range in mammals.
- The available data combined with the analytical and decision-making processes used by the experts involved in this Disease Risk Analysis will enable reasonable decisions to be made to minimise health risks associated with a translocation to French and Phillip Island.

Limitations
- Compared to disease knowledge available for domestic animals and humans the understanding of the range of potential pathogens of EBBs and the epidemiology of these pathogens is poor.
- There have been very few systematic studies that have proactively screened for potential pathogens and assessed the health of free-ranging EBB populations.
- The pharmacokinetics and pharmacodynamics of drugs that may be used for disease treatment has not been conducted for this species and extrapolation from other species is necessary.

Hazard Identification

Potential In-Contact Populations of Interest

One aim of this disease risk analysis is to assess the likelihood of contact between the identified hazards and the species of concern, and the consequences to them if contact occurs. Consideration must be given to the consequences for both translocated EBBs and the consequences for those species that the translocated bandicoots may encounter. Resident terrestrial vertebrate species at source and destination sites can be found in Appendix 2.

For the purposes of this risk analysis the populations of interest were grouped into the following three categories:

- Eastern Barred Bandicoots (EBBs)
- Wildlife resident on French and Phillip Islands
- People and domestic animals (livestock and pets) resident on Phillip and French Islands.

Sources of Information

Published literature and unpublished veterinary records describing diseases affecting bandicoot species (Peramelids) were reviewed and used to create a list of disease hazards that may be significant during translocation of EBBs to Phillip Island and French Island.

Peramelid species referred to in this disease risk analysis comprise:

Eastern barred bandicoot	*Perameles gunnii*
Western barred bandicoot	*Perameles bougainville*
Long-nosed bandicoot	*Perameles nasuta*
Southern brown bandicoot	*Isoodon obesulus*
Northern brown bandicoot	*Isoodon macrourus*
Bilby	*Macrotis lagotis*

A preliminary hazard list provided with workshop briefing notes was reviewed by the workshop participants and additions and corrections made based on their personal knowledge and experience. The final list is presented in Table 2 and Table 3.

Table 2: Potential Disease Hazards to/from EBB to/from species resident on French and Phillip Islands

DISEASE	CAUSATIVE AGENT	RELEVANT FACTORS	REFERENCES
VIRAL			
Herpes disease	Novel herpesvirus	A novel gammaherpesvirus has recently been detected in southern brown bandicoots and EBBs **Risk:** PHV1 transfer from EBBs to other species is unlikely as herpes viruses are usually species or group-specific and there are no other bandicoots on the islands. Risk of this specific virus is low. **Knowledge gap:** we do not know if PHV1 causes disease in EBBs and/or other bandicoot species. We	Stalder *et al*. 2015

		need to establish if source populations are of equal status in relation to PHV1	
Ross River fever	Ross River virus	**Host range**: broad, including people; maintained in the environment within non-human vertebrate reservoir hosts. Seropositive EBBs have been detected in Tasmania. **Risk:** Possible higher incidence of RRV existing on French Island. There is concern that if EBBs are a reservoir host for this virus, then they may increase the risk of human cases. **Knowledge gap:** we don't know if EBBs are a significant reservoir species. Literature and serological investigation on captive EBBs suggest it is unlikely and/or that other species, including potoroos, are more likely reservoirs.	AWHN 2015, Boyd *et al.* 2001, Cutcher *et al.* 2013
EMCV	Encephalomyocarditis virus	If EBBs are exposed the outcome is unknown, however they are unlikely to be exposed. Low probability of EBBs introducing it to Phillip or French Island.	McLelland *et al.* 2005, Reddacliff *et al.* 1997
Papillomatosis virus	*Papilloma viruses*	No risk of EBBs being exposed. Low probability of EBBs introducing it to Phillip or French Island.	Woolford *et al.* 2007, Bennet *et al.* 2008
BACTERIAL			
Coxiella burnetii	*Coxiella burnetii*	**Host range:** broad, including people and Peramelids. **Risk:** Unlikely disease. **Knowledge gap:** Unknown status of EBBs in regards to prevalence of *C. burnetii* infection/reservoir status and if there is a difference in prevalence between captive and wild bandicoots. EBBs will be exposed to livestock on islands, which are more likely reservoirs of *C. burnetii.*	Angelakis & Raoult 2010, Bennett *et al.* 2011, Cooper *et al.* 2013
Bairnsdale ulcer/Buruli ulcer	*Mycobacterium ulcerans*	**Host range**: broad, including marsupials (e.g. koalas, possums, long-footed potoroo), horses, dogs, cats and alpaca. EBBs might become infected.	Fyfe *et al.* 2010, Hufschmid & Holz 2012, Johnson *et al.* 2007, Veitch *et al.* 1997
Enteric bacterial disease	*Salmonella* spp. *Yersinia, E.coli* *Campylobacter* spp.	**Host range:** broad, including people, Peramelids and livestock	Ashbolt & Kirk 2006, Staff *et al.* 2012
Erysipelas	*Erysipelothrix rhusiopathiae*	Disease is widespread. **Host range**: most common in turkeys and pigs; also occurs in birds, sheep, fish and reptiles. Occasionally causes localized infections of fingers or hands in people (erysipeloid). While EBBs could potentially be infected, the likelihood is low. Island environments could increase the likelihood.	Eamens *et al.* 1988, Lynch M 2008, Wang *et al.* 2010
Leptospirosis	*Leptospira interrogans*	**Host range:** broad, including people and Peramelids.	Durfee & Presidente 1979, Roberts *et al.* 2010, Slack *et al.* 2007, Slack *et al.* 2009
Pasteurellosis	*Pasteurella multocida*	**Host range:** broad, including people and Peramelids.	Abrahamian & Goldstein 2011, Holz & Graham 2008, Hufschmid & Holz 2012
Chlamydiosis	Novel chlamydiales *Chlamydia pecorum*	Novel chlamydiales have been isolated from cases of eye disease affecting western barred bandicoots. Further research is needed to determine the host range of this organism.	Legione *et al.* 2015, Warren *et al.* 2005
FUNGAL			

Mycoses	*Dermatophytes* *Cryptococcus*	**Host range:** broad, including people and Peramelids.	Ladds 2009a, Ladds 2012, Lynch 2008
INTERNAL PARASITES			
PROTOZOA			
Cryptosporidiosis	*Cryptosporidium* spp.	**Host range:** broad host range in wildlife including bilbies and bandicoots, cattle and sheep are demonstrated reservoir species.	Dowle *et al.* 2013, Ryan & Power 2012, Shahiduzzaman and Daugschies 2012, Warren *et al.* 2003
Toxoplasmosis	*Toxoplasma gondii*	**Host range:** broad, including feral cats, domestic dogs, marsupials (including. Peramelids), livestock and people.	AWHN 2009, Bettiol *et al.* 2000a, Bettiol *et al.* 2000b, Cornelissen *et al.* 2014, Dubey 2002, Dubey *et al.* 2010, Johnston *et al.* 2011, Lynch *et al.* 1993, Lynch 2012, Obendorf *et al.* 1996, Sibley *et al.* 2009, Centre for Food Security and Public Health 2005
Neosporosis	Neospora	**Host range:** broad, including dingoes and a wide range of mammals and birds.	Almería 2013
Coccidiosis	*Eimeria spp*	**Risk:** Wet environment and high density EBBs.	AWHN 2011, Lynch M 2008, Norman 1991
Kossiellosis	Klossiella	**Host range:** a wide range of marsupials have infections with *Klosiella* spp., but that they are species-specific e.g. *Klosiella quimrensis* is found in bandicoots.	Barker *et al.* 1985, Munday 1988
Giardiasis	*Giardia* spp.	**Host range:** broad, present in livestock, cats and dogs.	Bettiol *et al.* 1997, Tangtrongsup & Scorza 2010
Sarcocystiasis	*Sarcocystis* sp.	**Host range:** broad. Cysts typical for *Sarcocystis* sp. have been reported in the muscle of EBBs.	Ladds 2009b, Ladds 2009c, Munday & Mason 1978
HELMINTHS			
Capillariasis	*Capillaria* spp.	Found in free ranging EBBs from Mt Rothwell and Woodlands Historic Park.	Lenghaus *et al.* 1990, Norman 1991
Sparganosis	*Spirometra erinacei*	Reported in many marsupial species, including northern brown bandicoot. Adult tapeworms are found in carnivores, including dogs, cats and foxes.	Ladds 2009d
BLOOD PARASITES			
Haemoparasitism	*Trypanosomes* *Babesia* *Theileria* *Bartonella* *Hepatozoon*	**Host range:** quite broad.	Bettiol *et al.* 1996, Bettiol *et al.* 1998, McInnes *et al.* 2011
EXTERNAL PARASITES			
Ectoparasitism	Fleas: *Pygiopsylla* sp. *Stephanocircus* sp.	Potential host range may be broad as host-adapted but not host specific, includes EBBs.	Lynch 2008, Lenghaus *et al.* 1990
	Ticks: *Ixodes* spp.	**Host range:** broad, including EBBs.	Doube 1975, Gemmell *et al.* 1991, Jackson *et al.* 2007, Lenghaus *et al.* 1990, Lynch 2008

	Mites: *Sarcoptes* spp., *Demodex* spp., *Haemolaelaps marsupialis,* *Petauralges* sp., *Ornithonyssus bacoti*	**Host range:** broad, including EBBs.	Fraser *et al.* 2016, Lynch 2008, Norman 1991

Table 3: Non-infectious Disease Hazards to EBBs

NON-INFECTIOUS DISEASE HAZARDS*	*COMMENT*
Motor Vehicle Trauma	Motor vehicle traffic is likely to be a significant risk factor on Phillip Island
Predation	Feral cats are present on French Island and Phillip Island. French Island is fox free; Phillip Island is functionally fox free.
Trapping trauma	Minor injuries have occurred in EBBs during live trapping programs.

*Workshop participants decided the consideration of the non-infectious health hazards identified above were outside the scope of this Disease Risk Analysis and should be addressed separately.

Hazard Prioritization

In addressing the goal, scope and focus of this DRA a process (outlined in Appendix 1) was used to select those hazards of highest priority for full risk assessment through elicitation of expert opinion at the DRA workshop. The results are provided in Table 4 to Table 6 and the outcome in Table 7.

Hazard Prioritization Criteria
In allocating the disease hazards (to EBBs or other wildlife species) into the risk prioritization matrix the following definitions of High, Medium and Low **consequence** were applied:

High   High risk of local extinction due to significant population decline at unsustainable levels

Medium   Temporary detectable population decline without risk of extinction from this disease

Low   Individual morbidity/mortality but no population consequences

Allocation of **likelihood** related to the likelihood that a translocated EBB could act as a carrier of the disease hazard and assist in its transmission to another animal.

For humans or domestic animals (pets and livestock), any individual morbidity/mortality or more was considered a high consequence.

Table 4: Risk hazard prioritization matrix for EBBs

		Consequence to Population			
		High (3)	Medium (2)	Low (1)	Negligible (0)
Likelihood	High (3)		*Toxoplasma gondii*		Eimeria
	Medium (2)				Ross River Virus
	Low (1)		Enteric Bacteria	Haemoparasites Coxiellosis Ringworm Bairnsdale ulcer *Erysipelothrix* Leptospirosis Ectoparasites *Chlamydia* *Cryptosporidium* Giardia Sarcocystiasis	
	Negligible (0)	Cryptococcus	Papillomatosis EMCV	Herpesvirus	

Rationale for risk estimation

- *Toxoplasma*: EBBs have a high likelihood of exposure to *Toxoplasma,* due to suspected high prevalence of cats on French and Phillip Islands and long survival time of the infective stage (oocyst) in the environment. Cat control programs may increase turnover of the feral cat population resulting in an increase of younger cats. Given that kittens are most likely to be shedding *T. gondii* then this may increase environmental contamination. However, Tasmanian EBB populations coexist with feral cats and some EBBs released onto French Island persisted, so we assume that the population consequence is medium.
- Ross River Virus: Confirmed cases in mammals on French and Phillip Islands. We assume that EBBs are likely to be exposed but clinical disease is likely to be limited to infrequent, sporadic cases, therefore negligible to the EBB population.
- Eimeria: All EBBs are expected to be exposed but clinical disease is rare.
- All other diseases have a low or negligible likelihood of being contracted by EBBs.
- *Cryptococcus*, enteric bacteria, papillomatosis and EMCV could have a high to medium consequence on the EBB population but the likelihood of these diseases.

being contracted on French or Phillip Island is low or negligible and therefore not of concern.

Table 5: Risk hazard prioritization matrix for resident wildlife

		Consequence to Population			
		High (3)	Medium (2)	Low (1)	Negligible (0)
Likelihood	High (3)			Ectoparasites	GI nematodes *Physaloptera*
	Medium (2)			*Salmonella* (new serotype) *Campylobacter* Other enteric bacteria	
	Low (1)		Sarcoptic mites	*Leptospira* Dermatophytes	*Toxoplasma/Neospora /Sarcocystis* *Cryptosporidium* GI protozoa (including *Giardia*)
	Negligible (0)		Herpesvirus	Ross River Virus Coxiellosis Papilloma virus *Mycobacterium ulcerans* *Salmonella* (endemic serotypes) *Chlamydia* *Erysipelothrix*	*Pasteurella* *Cryptoccocus*

Rationale for risk estimation

- Ectoparasites (fleas, ticks and mites): high likelihood of infection as they are difficult to control but of a low consequence. Most ectoparasites don't have population level effects. Sarcoptic mange would be the only real issue with potential moderate consequence, it has been reported in koalas on Phillip Island albeit at low infection rates. The likelihood of EBBs carrying it based on current experience is low.
- Enteric bacteria: (including *Salmonella* and *Campylobacter*): Any animal can carry enteric bacteria. EBBs from Mt Rothwell may have contracted it from other species at the site. An EBB could introduce a new strain into a new environment. A conservative estimate of the likelihood of this is moderate, but the consequence is low, as many species on both islands already have it and EBBs are unlikely to introduce a new type.

- Leptospirosis: some studies have found a high prevalence of *Leptospira* spp in bandicoots, so it is possible that EBBs can carry it, but the impact on other wildlife is likely to be low. Therefore, there is a low likelihood and low consequence of leptospirosis.
- Herpesvirus: usually species-specific, so negligible likelihood, but the consequence could be medium if it crossed species.
- Ross River virus: EBBs could be reservoir, but there are probably lots of other reservoirs on French Island. Native wildlife are not usually affected, therefore likelihood is low and consequence negligible.
- Papillomatosis virus: quite species-specific and may cause tumours in individual animals but has never been reported in EBBs. Likelihood is negligible and consequence low
- *M ulcerans*: probably endemic on French and Phillip Islands. Unlikely that EBBs have it, so negligible likelihood and low consequence as it would probably only impact individual animals.
- *Pasteurella*: common pathogen that is usually opportunistic. EBBs are unlikely to be a source and it will already be present on French and Phillip islands. Likelihood is negligible and consequence is negligible.
- *Chlamydia*: Negligible likelihood that EBBs would introduce it to French or Phillip Island, consequence is low-moderate as it could affect some animals.
- *Erysipelothrix*: ubiquitous but can cause some disease. The likelihood of transmission is negligible and the consequence low.
- *Dermatophytes/Cryptococcus: Cryptococcus* are environmental, so unlikely to be introduced with EBBs. Likelihood is negligible and consequence is low. Dermatophytes have a low likelihood and negligible consequence.
- *Toxoplasma/Neospora/Sarcocystis*: unlikely that EBBs will introduce these parasites to the islands, low likelihood and negligible consequence as there are many other reservoirs already on the islands.
- *Cryptosporidium /Giardia*: it is possible that EBBs carry *Cryptosporidium*, so low likelihood, but negligible consequence as there will be other carriers of *Cryptosporidium* spp on the island, in wildlife and domestic livestock.
- Nematodes: High likelihood that EBBs will have nematodes if released onto the islands, but these are mostly species-specific so consequences are likely to be low as only individual animals may be affected.
- Haemoparasites: Low-moderate likelihood of EBBs introducing haemoparasites but the consequence is low as there are probably other species already on the islands
- Shorebirds and seabirds are most likely to be affected by enteric bacteria introduced by EBBs but negligible/low risk of adding significantly to existing sources.
- Potoroos: habitat segregation from EBBs but there could be some overlap. Enteric bacteria, mange, dermatophytes, internal and external parasites could transfer between species but negligible/low risk from contact with EBBs.
- Snakes: *Salmonella* is likely to be present in snake populations found on both islands. Negligible/low risk of EBBs introducing a new type and passing it onto snakes.
- Frogs: no known diseases that could be passed from EBBs to frogs

Table 6: Risk hazard prioritization matrix for resident people and domestic animals

		Consequence to Individuals			
		High (3)	Medium (2)	Low (1)	Negligible (0)
Likelihood	High (3)				
	Medium (2)				
	Low (1)				
	Negligible (0)	EMCV Coxiellosis	Ross River Virus *Mycobacterium ulcerans* *Cryptosporidium* *Toxoplasma gondii* *Neosporum* *Cryptococcus*	*Salmonella* *Yersinia* *Campylobacter* *Leptospira* *Giardia* Dermatophytes Fleas Mites	Gammaherpesvirus Papillomavirus Erysipelothrix *Pasteurella* *Chlamydia* Ixodes ticks *Eimeria* *Capillaria* *Spirometra* Haemoparasites

Rationale for risk estimation

- Most diseases are host-specific or already present in potential release locations. EBBs are unlikely to introduce or increase the risk to domestic animals or humans.
- There is public interest in Q fever and Ross River Virus so basis for the assessment of risk of these diseases is important to explain in further reports to address public concern.
- Gammaherpesvirus: is marsupial/species specific so the likelihood of EBBs passing it onto people or domestic animals is negligible with a negligible consequence.
- Ross River virus: bandicoots can be serologically positive, but are not necessarily reservoirs. There are likely to be other marsupial reservoirs currently on both islands. It can cause clinical disease in horses and humans.
- EMCV: not currently in Victoria and has not been detected in EBBs.
- Coxiellosis: Bandicoots are not the primary reservoir and ticks are unlikely to aid transmission. There are unknowns regarding current status of domestic animals and EBBs.
- Papillomatosis: Host specific, not currently in Victoria
- Bairnsdale Ulcer: Bandicoots are unlikely reservoirs

- NOTE: Any EBB released onto either island is assumed to be healthy and will be treated for parasites using selemectin, moxidectin and fipronil. An additional assessment of these hazards assuming animals are NOT parasite treated, concluded that there were no significant alterations to risk and no changes to the above table.

Table 7: Hazards selected for detailed risk assessment

HAZARD	RANK
Toxoplasma gondii	1
Ectoparasites (Ticks, mites and fleas)	2
Enteric bacteria (*Salmonella*, *Campylobacter* etc)	3
Ross River Virus	4

Given time constraints and the number of people at the Workshop it was agreed that a small working group with relevant expertise (comprising Michael Lynch, Paul Eden, Jasmine Hufschmid and Simon Firestone in consultation with the Victorian Arboviral Task Force) would complete the risk assessment for Ross River Virus post workshop. Although the likelihood of EBBs contributing significantly to the dissemination of this hazard (already present on French Island) was ranked negligible, community concern regarding its consequences to people, made it worthy of consideration for a detailed risk assessment.

Risk Assessments

Translocation Pathway

The first step in this process is to gain an overview of the entire translocation pathway (Figure 3). Given the focus of this DRA, the translocation pathway considered commenced at the captive or introduced predator-free source sites and culminated at French and Phillip Island (the destination sites).

Figure 3: EBB Translocation Pathway
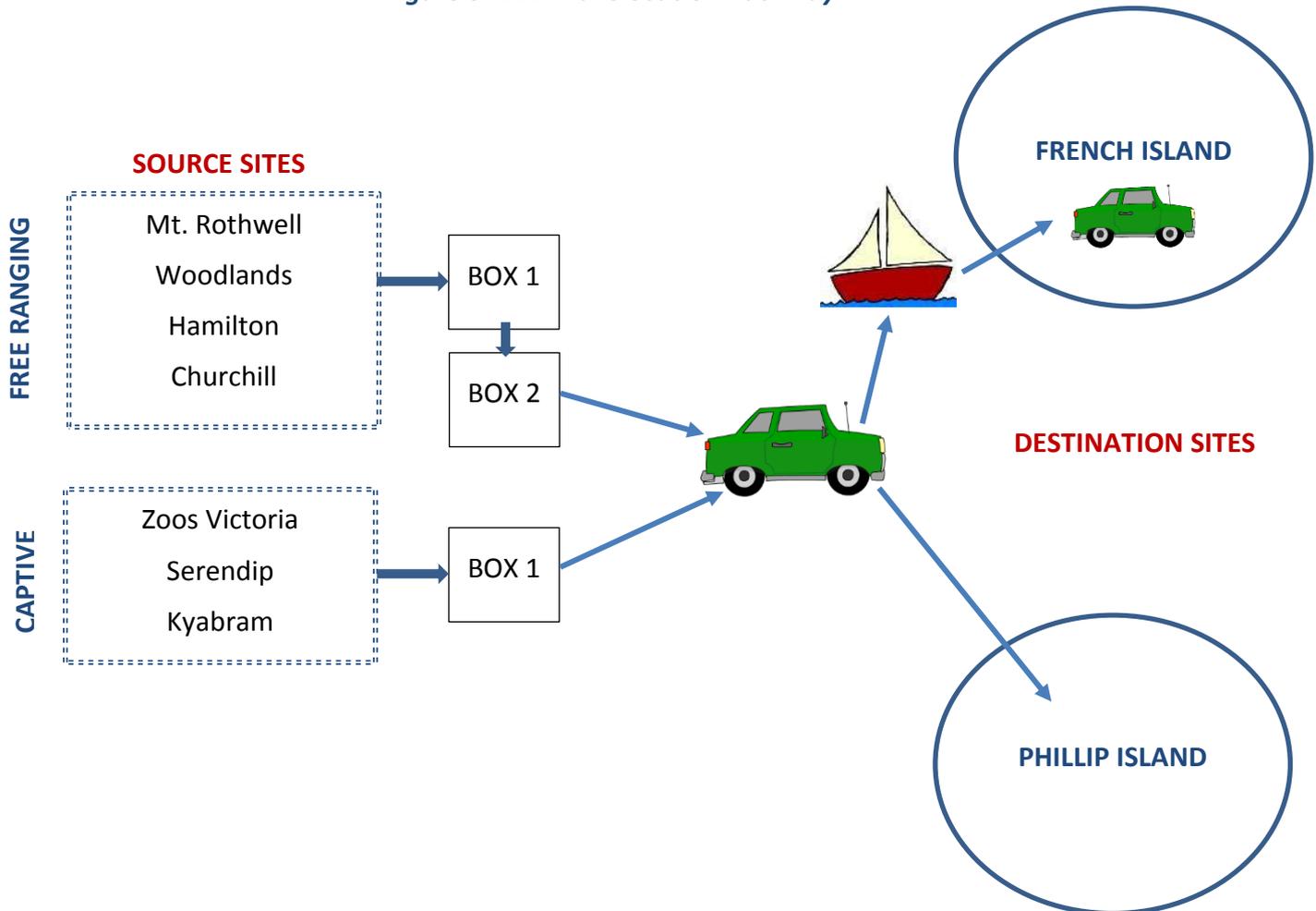
EBBs trapped at free ranging source sites are transferred from their trap into a transport box (Box 1 above), taken to the onsite vet for a health assessment and parasite treatment then placed into a new transport box (Box 2 above) and transported by road vehicle, directly to Phillip Island (accessed via a causeway) or transferred to the French Island car barge and driven to the release site (see also Figure 2).

Hazard Transmission Pathways

A hazard transmission pathway for each priority hazard was captured in a graphical model developed collaboratively by workshop participants for each population of interest (Figure 4Figure 7). These models provided a reference point during the risk assessment and risk

management steps and enabled identification of Critical Control Points (CCPs) at which risk mitigation actions could be applied (see Box 2).

Box 2: Critical Control Points (CCPs)

"Critical Control Points (CCPs) are identified as points in a hazard's biological pathway at which practical risk reduction or prevention strategies could be implemented. This graphical analysis can assist managers to make decisions on where to focus interventions and consider which risk management options are feasible at these points in the pathway." (Jakob-Hoff *et al.* 2014b)

Risk Assessment for *Toxoplasma gondii*

Workshop Group Participants: Amy Coetsee, Paul Eden, Mark Hawes, Michael Lynch, Rebecca Traub

Justification for hazard status:

- Domestic and wild felids are the only definitive hosts of *T. gondii* in which sexual multiplication of the parasite within the gastrointestinal endothelium results in the formation of oocysts that are passed in faeces and sporulate in the environment where they become infective for susceptible hosts, such as marsupials (AWHN 2009).
- Feral cats are present on both French Island and Phillip Island. Feral cats established within the French Island National Park from strayed domestic animals and following historical deliberate releases (Johnston *et al.* 2011).
- Two EBBs released onto French Island during a 2012 trial (Groenewegen 2014), were found dead with evidence of toxoplasmosis (Lynch 2012). One of these animals (MZ B20406) had disseminated toxoplasmosis, the other (MZ B20405) had a necrotic focus in the pancreas associated with protozoa, presumed to be *T. gondii.* Another animal (MZ B10444) died from unrelated causes, but had serologic evidence of exposure to *T. gondii*.
- Following oral inoculation with oocysts, EBBs showed few specific clinical signs prior to death; however, diseased animals are reported to be more likely outside their nest boxes during daylight hours, and to increase their water intake (Bettiol *et al.* 2000a).
- Notable necropsy findings in EBBs were congestion, oedema and patchy consolidation of the lungs, excess and slightly blood-tinged abdominal fluid, petechial haemorrhages to gastric and small intestinal serosa, oedematous mesentery and enlargement of the mesenteric lymph nodes. Animals may have distinctly enlarged spleen and liver, the latter with a distinct lobular pattern to the parenchyma.
- Acute inflammation with detection of numerous tachyzoites and tissue cysts may be found in association with lesions in the lung and heart. Multifocal areas of tissue necrosis, associated with the presence of crescentic tachyzoites, may be seen in various organs, including liver, spleen and skeletal muscle (Bettiol *et al.* 2000a).

Release Assessment:

As cats and *T. gondii* are both known to be present on both proposed destination islands, the release assessment for this hazard is **high**.

- Cats become infected with *T. gondii* primarily by ingestion of either bradyzoite cysts in the tissues of infected intermediate hosts, such as rodents and birds, or sporulated oocysts from other cats. Most cats infected by ingestion of tissue cysts shed oocysts in their faeces within 3–10 days and may continue to shed for up to 20 days (Robert-Gangneux & Darde 2012).
- Any non-felid warm- blooded vertebrate can be an intermediate host, where *T. gondii* tachyzoites can cause acute toxoplasmosis. Thereafter *T. gondii* persists as bradyzoites in tissue cysts. Hosts can be infected prenatally by tachyzoite transfer, or postnatally by bradyzoite or oocyst ingestion. (Figure 4).

Figure 4: Life cycle of Toxoplasma gondii (Sibley et al. 2009)
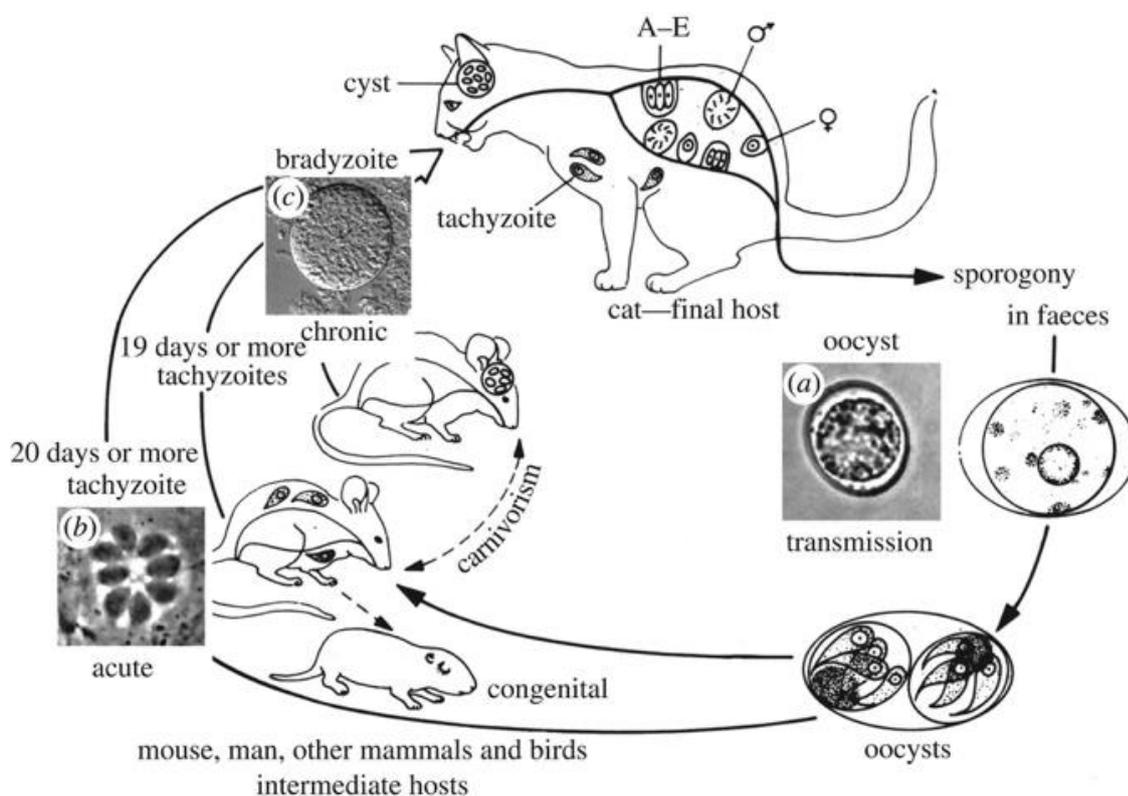
- Invertebrates can carry *T. gondii* oocysts within their gut as a result of coprophagia, or ingestion of soil or plant material contaminated with cat faeces. The route of infection in insectivorous marsupials such as bandicoots is most likely by consumption of paratenic hosts, including soil-associated arthropods, insects or annelids such as earthworms (Bettiol *et al.* 2000b) (Figure 4).
- There is a risk of transmission to direct hosts (canid/felid) following predation of infected EBBs*.*
- As feral cats and *T. gondii* are known to be present on both islands, the risk of EBB exposure to this disease hazard is assessed as **high**.

Consequence Assessment:
- As noted above, EBBs are known to be susceptible to this disease and there is previous experience of EBB mortality due to *T. gondii* on French Island.
- If cat density is low enough then environmental contamination with *T. gondii* is likely to be patchy, reducing exposure likelihood and reducing infectious dose (Afonso *et al.* 2008).
- On this basis, although the consequences to individual EBBs can be high, the consequence to the population is assessed as **moderate** (but see level of uncertainty in Table 8).

Risk Estimation:

As EBBs are only capable of transmitting this parasite by being eaten, the risk to humans and non-carnivorous animals is negligible and, given that bandicoots are likely to comprise an extremely small part of carnivore diets, the risk to them is low. The overall risk of this hazard <u>to the EBB population</u> on French and Phillip Islands is assessed as **MODERATE**.

Table 8: Knowledge gaps and measures to reduce uncertainty in this risk assessment

KNOWLEDGE GAPS	MEASURES NEEDED TO REDUCE UNCERTAINTY
Cat density	Cat density estimates
Degree of environmental contamination as influenced by soil moisture, direct sunlight, temperature and prevalence of mechanical hosts	Estimation of environmental contamination by survey of cats, indicator species and soil
Uncertain of EBB susceptibility with regards to % animals that develop clinical disease after infection	Knowledge of serological status prior to release. Longitudinal surveillance of EBBs after release to contaminated environments
Uncertain of whether the immune response is protective	Longitudinal study of survival of seropositive animals

Risk Management

Background

Diagnosis
- Diagnosis may be based on detection of inflammation with tachyzoites/tissue cysts, from collected tissue at necropsy.
- Serologic testing for antibodies to *T. gondii*, using the modified agglutination test (MAT – technique as described by Obendorf *et al.* 1996) is available.

- Ground-feeding birds are considered important in the epidemiology of *T. gondii* and can serve as indicators of soil contamination by oocysts while birds of prey are indicators of *T. gondii* prevalence in rodents and other small mammals (Dubey *et al.* 2010).

Treatment
- Treatment is usually unsuccessful but can be attempted using atovaquone, clindamycin or trimethoprim-sulphonamide (AWHN 2009).

Control
- Oocysts are highly resistant and can survive up to 18 months in the environment. They are resistant to most disinfectants but can be inactivated by iodine, formalin and ammonia. They can also be destroyed within 10 mins by temperatures greater than 66°C and with boiling water.
- *T. gondii* tachyzoites and tissue cysts are killed by contact with soap and water (Centre for Food Security and Public Health 2005, AWHN 2009).

Prevention
- Limit exposure to oocysts:
  - Reduce cat densities. Para- aminopropiophenone (PAPP) formulations are being developed as new tools for the management of feral cat populations. PAPP baits were trialled on French Island during 2008 but not currently available for use in Victoria (Johnston *et al.* 2011).
  - Environmental contamination might be reduced by oral vaccination of the definitive host (cats).
- Assessment of contamination at release site:
  - Local risk of soil contamination by oocysts depends on the initial concentration of infected cat faeces and the survival and diffusion of oocysts in the soil (Afonso *et al.* 2008).
- Increase immunity:
  - Further investigation is required into EBB vaccination. A commercial *T. gondii* vaccine, developed for use in sheep, caused fatal toxoplasmosis when administered to tammar wallabies (*Macropus eugenii*). An oral vaccine consisting of *Hammondia hammondi*, a related protozoal organism, provided partial protection in tammar wallabies (Lynch *et al*. 1993). Neither vaccines have been trialled on EBBs.
- Minimize exposure of individuals to environmental stressors:
  - Management considerations prior to release including parasite management, and pre-release husbandry.
  - Choice of habitat at release site:
    - Vegetation for shelter/nest-building (type and quality)
    - Food supply (soil moisture, invertebrate density)
  - Season of release
    - Food supply (soil moisture, invertebrate density)
    - Temperature/rainfall and its impact on EBBs

Environmental, Agent and Host Factors

Environmental, agent and host factors that may predispose EBBs to toxoplasmosis were reviewed (Table 9) as a basis for developing the hazard transmission pathway diagram (Figure 5) and identifying critical control points (CCPs).

Environmental sources: oocysts in soil, water, paratenic (tissue cysts) and mechanical (oocysts) hosts.

Potential transmission pathways: via direct consumption of contaminated soil, consumption of mechanical hosts, carrion feeding and vertical transmission (see Figure 5).

Table 9: Predisposing factors for Toxoplasma infection

ENVIRONMENT FACTORS INFLUENCING TRANSMISSION	AGENT FACTORS INFLUENCING NEGATIVE CONSEQUENCES TO HOST	HOST FACTORS INFLUENCING SUSCEPTIBILITY TO DISEASE
Soil Moisture	Potential variation in virulence of *T. gondii* types	Immune status of individuals (e.g. age, stress, concurrent disease)
Mechanical host prevalence	Infectious dose	Overall species susceptibility
UV exposure of soil		Carrion eating behaviour
Cat density		
Prevalence of infection in cats		
Cat population demographics		
Cat movement across habitat		
Ambient temperatures		

Figure 5: Transmission pathways for Toxoplasma gondii to EBBs

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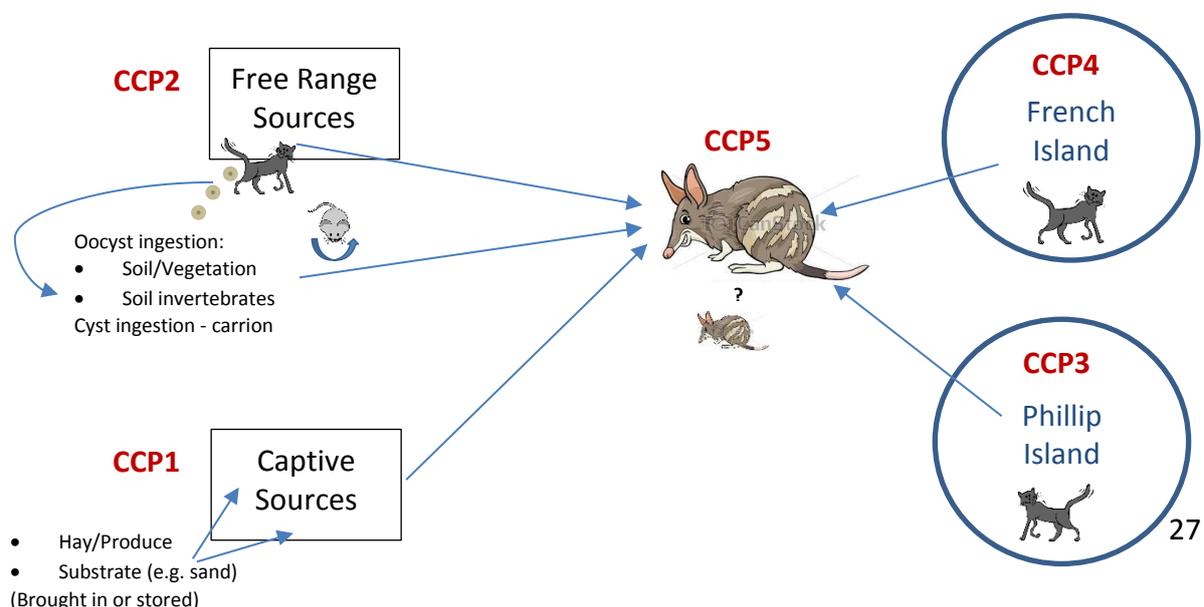
Figure 5 depicts the various transmission routes through which EBBs could become infected with *Toxoplasma gondii*. CCP refers to Critical Control Points (Box 2) at which the risk mitigation actions listed in Table 10 could be applied to minimise risk of exposure.

Risk mitigation options were qualitatively assessed by workshop participants according to their likely feasibility and effectiveness (Table 10; see Appendix 1 for details of the process)

An action plan for recommendations arising from this evaluation was developed and is presented in Table 11.

Table 10: Risk management option evaluation for *Toxoplasma gondii* to EBB

CCP#	MITIGATION OPTIONS	EFFECTIVENESS*	FEASIBILITY*	EXPLANATION	RECOMMENDATION
1	A. Reduce the likelihood of substrate contamination in captive animals through cleaning or disinfecting substrate before use, and protected storage.	H	M	Maintaining disease free source animals. Cover substrate when in storage onsite, cannot control well off site. No effective disinfectant against oocysts that wouldn't damage the substrate.	Y
1	B. Reduce the likelihood of food contamination in captive animals through sourcing and washing food items prior to use.	H	H	Maintaining disease free source animals. Wash vegetables.	Y
1	C. Reduce the likelihood of bedding contamination in captive animals through protected storage and sourcing.	H	H	Maintaining disease free source animals. Protect from cats when in storage onsite, cannot control well off site. Anecdotal reports suggest that round hay bales have much lower risk of contamination.	Y
2/3/4	A. Release EBBs into cat free enclosures.	H	L	Eliminate risk of exposure to infective oocysts. Predator-barrier fencing is costly and may not be 100% effective against cats.	N

CCP#	MITIGATION OPTIONS	EFFECTIVENESS*	FEASIBILITY*	EXPLANATION	RECOMMENDATION
				Fencing restricts range of bandicoot distribution.	
2/3/4	B. Eradication of feral cats from both islands through culling.	H	L	Eliminate risk of exposure to infective oocysts. Elimination of cats from islands likely to be difficult and resource intensive.	Y. but dependent on funding/resourcing
2/3/4	C. Reduce cat density through culling to reduce environmental contamination.	M	M	Reduce risk of exposure to infective oocysts. A cat cull may increase numbers of young cats that are more likely to shed infective oocysts.	Y.
2/3/4	D. Reduce shedding in cats through vaccination.	L	L	Reduce risk of exposure to infective oocysts. No vaccine is currently available so would require research and clinical trials. Timing of vaccination prior to exposure of cat to Toxoplasma would be critical for this to be effective.	N.
2/3/4	E. Reduce numbers of young cats through sterilisation or contraception.	M	L	Reduce risk of exposure to infective oocysts.	N.

CCP#	MITIGATION OPTIONS	EFFECTIVENESS*	FEASIBILITY*	EXPLANATION	RECOMMENDATION
				No immunocontraceptive vaccine currently available. Requires surgical or pharmaceutical sterilisation, which is resource intensive. Need to sterilise a significant proportion of the population for this to be effective.	
3/4	F. 24 hour cat curfew for domestic cats on both islands	L	M	Not a major source of infective oocysts, may be some challenges in community buy-in.	Y. in conjunction with other measures for cat control
5	A. Increase immunity of EBBs through vaccination	M	L	Increase likelihood of survival from infection/disease. No currently identified vaccine for marsupials, previous trials of commercial vaccine in other marsupials resulted in mortalities. Timing of vaccine is critical to effectiveness. Challenges in maintaining vaccination of wild population.	N.

Implementation and Review

Table 11: Risk management action plan for mitigation of Toxoplasma infections

MANAGEMENT TARGET	GOALS	ACTIONS	FREQUENCY	RESPONSIBILITY	SUCCESS MEASURE(S)	DATA REQUIRED
No infection from consumed food	No oocysts on produce	Ensure consistent produce washing practices	Prior to feeding	Precinct Manager	Washing standard met	Regular (monthly) check of practices
					Nil exposure	No seropositive animals detected
No infection from bedding material	No oocysts on hay	Protect hay from cats onsite	Always	Food store manager	Confirmed correct storage	Daily check of storage conditions
		Awareness of hay storage methods offsite. Only purchase from suppliers with suitable storage	Always	Food store manager	Confirmed compliance	Annual check of offsite storage
					Nil exposure	No seropositive animals detected

Management Target	Goals	Actions	Frequency	Responsibility	Success measure(s)	Data required
Unlikely infection from substrate	Reduced risk of contamination of substrate with oocysts	Source substrate from suppliers where contamination with cat faeces is unlikely	Always	Horticulture manager	Confirmed compliance	Annual check of offsite storage
		Store onsite protected from cats	Always	Horticulture manager	Confirmed correct storage	Daily check of storage conditions
					Nil exposure	No seropositive animals detected
Eradication of feral cats on French Island	Reduced environmental contamination with oocysts	Enact legislative change	Single	DELWP	Legislation passed	Documentation
		Integrated cat eradication program	Ongoing until target met	Parks Victoria/DELWP	Declaration of freedom from feral cats	Program monitoring data
Reduction in cat density on Phillip Island and French Island	Reduced environmental contamination with oocysts	Integrated cat eradication program informed by target density that will achieve goal	Ongoing	Parks Victoria/Phillip Island Nature	Target density met and maintained	Program monitoring data

Management Target	Goals	Actions	Frequency	Responsibility	Success measure(s)	Data required
				Parks/French Island Landcare		
Institution of 24 hr cat curfew on Phillip Island	Reduced environmental contamination with oocysts	Approach local council to enact legislation	Ongoing until achieved	Phillip Island Nature Parks	Legislation passed	Documentation
		Implementation of Cat Curfew on Phillip Island	Ongoing	Bass Coast Shire Council	No free-ranging domestic cats	Council records
		Public education around curfew	Ongoing	Phillip Island Nature Parks/Local Council	No free-ranging domestic cats	Council records

Risk Assessment for Enteric Pathogens

Workshop Group Participants: Simon Firestone, Jenny Hibble, Marissa Parrott, Natalie Rourke, Duncan Sutherland

The enteric bacteria considered in this risk assessment were possible new strains/serovars of *Salmonella*, *Campylobacter*, *Yersinia*, *E.coli*, *Giardia* and *Cryptosporidium.*

Justification for Hazard Status

On the basis that these pathogens are widespread, known and very likely to be present on French and Phillip Islands, this group of organisms were assessed by the expert workshop panel as comprising a **moderate likelihood and low impact** hazard to wildlife on the proposed destination islands. Also noted was that many pathogen strains are species-specific and therefore unlikely to cause any issues for domestic animals or humans. It is possible that EBBs could spread bacteria via faeces or by being hunted or scavenged by resident wildlife, dogs or cats. The likelihood that EBBs might introduce anything new or increase the risk of exposure or disease in these animals is, however, unknown and consequently a detailed assessment of potential risks to resident wildlife on the islands was justified.

E.coli

- *E. coli* is naturally present in the intestinal tracts of warm-blooded animals. As *E. coli* is released into the environment through contamination with faecal material, this bacterium is widely used as an indicator of faecal contamination of waterways (Ishii & Sadowsky 2008).
- Given the appropriate host setting (e.g. chronic stress and immunosuppression, underlying disease process), infection with these environmental organisms may result in disease.
- Within managed animal populations, stress may occur when there is overstocking of enclosures (e.g. due to high intraspecific and interspecific competition for nesting sites and food). Examples of stressors in zoos include forced proximity with humans and exposure to uncomfortable temperatures or substrates (Hing *et al.* 2016).
- Two septicaemias, one caused by *E. coli* and the other by a *Proteus* spp. infection, were attributed to complications from traumatic toe injuries in two EBBs (Melbourne Zoo 2006, unpubl. data).
- In terms of infectious disease, costs of stress can include increased infection susceptibility, shedding of infectious agents, and severity of clinical signs.

Yersinia spp.

- Yersiniosis may be caused by *Yersinia pseudotuberculosis* or *Y. enterocolitica.* It may be found in a wide range of animals, and is a zoonosis. Disease is primarily gastrointestinal. Transmission is via faecal-contaminated water or food sources. Outbreaks may be precipitated by environmental stressors (Gasper & Watson 2008).

Salmonella

- The disease salmonellosis has been recognized in all parts of the world but is most prevalent in regions with intensive animal husbandry. *Salmonella* is commonly found in an environment subject to faecal contamination. Faeces of infected animals can contaminate water and pasture.

- *Salmonella* infection usually presents as acute gastroenteritis, with sudden onset of headache, abdominal pain, diarrhoea, nausea and sometimes vomiting.
- In rare cases, *Salmonella* spp. can cause septicaemia, or focal infections such as abscesses or arthritis.
- In 2007, there was a localized NSW outbreak of salmonellosis among humans that was associated with indirect contact (via playground sand) with long-nosed bandicoots (Staff *et al.* 2012).
- In Tasmania, native wildlife are the likely reservoir for *S. Mississippi*, and can contaminate untreated drinking water (Ashbolt & Kirk 2006).
- Rodents and wild birds are also sources of infection for domestic animals.

Campylobacter
- *Campylobacter* species often inhabit the intestinal tract of sheep, cattle and poultry.
- The evidence that wildlife is an important reservoir for human *Campylobacter* infections is equivocal (Altekruse & Tollefson 2003). To be a substantial source of human infections, faeces from wildlife would need to enter the human food or water supply. However, several studies have demonstrated the importance of wild birds as (generally asymptomatic) carriers of *Campylobacter* spp. infection.
- Although *Campylobacter jejuni* and *C. coli* can exist as commensal organisms of domestic poultry and livestock, they are considered human pathogens. In humans, the clinical spectrum of *Campylobacter* enteritis ranges from loose faeces to dysentery. Self-limiting acute enteritis is the most common syndrome (Acheson & Allos 2001).

Cryptosporidium spp.
- This protozoan parasite causes self-limiting diarrhoea in immune-competent patients, but may be chronic and life-threatening in those that are immune-compromised (Shahiduzzaman & Daugschies 2012).
- Faeco-oral transmission via contaminated drinking/recreational water (Figure 6).
- *Cryptosporidium* spp. have been identified from a range of marsupial hosts in Australia but there is a low disease incidence in these hosts. In non-wildlife hosts there is a low prevalence of infection with wildlife-adapted cryptosporidial organisms (Ryan & Power 2012).
- *C. muris* infection was detected in the faeces of bilbies at a captive breeding colony. Stress associated with a high density of bilbies in enclosures may have predisposed some of the bilbies to infection with this organism. *C. muris* was found in the faeces of one mouse trapped in the enclosures, and it was thought likely that bilbies acquired the infection from mice via faecal contamination of food and water (Warren *et al.* 2003).
- One study determined that free-ranging long-nosed bandicoots and southern brown bandicoots in northern Sydney were shedding cryptosporidial oocysts at a prevalence of 12.2%. This frequency is similar to other marsupial species thought to act as reservoirs for *Cryptosporidium* (Dowle *et al.* 2012).

Giardia duodenalis (syn. *G. lamblia/G. intestinalis*)
- These protozoal parasites cause abdominal discomfort and diarrhoea in immune-competent patients, but may be chronic and life-threatening in those that are immune-compromised. Giardia infection is common in a wide range of mammalian hosts and subclinical carrier status can occur.
- Faeco-oral transmission, via contaminated drinking/recreational water (Figure 6).

- *G. duodenalis* is considered a species complex. There are at least 7 distinct assemblages (A-G) based on genetic analyses (Tangtrongsup & Scorza 2010). Host specificity was believed to be minimal, but there have been varying results concerning the cross-species infection potential of *Giardia* spp. Not all small animal isolates cause disease in humans. Assemblage A has been found in infected humans and other primates, dogs, cats, livestock, rodents, and other wild mammals.
- Assemblage B has been found in infected humans and other primates, dogs, and some species of wild mammals. There are specific genotypes of *Giardia* that commonly infect dogs (assemblages C and D) and cats (assemblage F).
- One survey detected 21% prevalence of *G. duodenalis* infection in Tasmanian wildlife, including 62% prevalence in southern brown bandicoots and EBBs (Bettiol *et al.* 1997).
- A pilot study of experimentally infected EBBs indicated susceptibility to infection with *G. duodenalis* from a human source; however, no clinical signs were observed in the animals (Bettiol *et al.* 1997).

Release Assessment

Many pathogens are already present on French and Phillip Islands. Many animals, both domestic and wild, are colonized by *Salmonella* spp, usually harbouring the bacteria in their gastrointestinal tracts without apparent signs of illness. *Giardia* and *Campylobacter* in particular are unlikely to change with EBB introduction. Many are host specific. Spread of bacteria is dependent on a number of factors including temperature, rainfall, etc. These pathogens are more likely to be introduced by humans, pets and livestock than EBBs and consequently the likelihood of introduction (release) of novel forms of these organisms by EBBs is assessed as **low.**

Exposure Assessment

Transmission of these pathogens is most frequently via ingestion of material that is contaminated with faeces (see Figure 6).

The highest incidence of faecal shedding of enteric pathogens from animals is frequently during periods of stress. For instance, in sheep, high levels of faecal shedding of *C. jejuni* coincided with spring lambing, movement of ewes onto pasture after weaning, and autumn weaning (Altekruse & Tollefson 2003). In Victoria, cattle may shed more *Salmonella* spp. during the summer calving period (L. Horstmann *pers. comm.*). As translocation is a stressful event EBBs harbouring any of these organisms are more likely to shed them during the translocation and release period.

As depicted in Figure 6, animals could come into contact with EBB faeces in grasslands and burrows. Hunters or scavengers could come in contact with EBB entrails and faeces. Little penguins (*Eudyptula minor*) could come in contact if they step in faeces and then groom it off. EBBs have been reintroduced to fenced reserves containing other native wildlife (e.g. rodents, kangaroos, wallabies, possum spp. echidnas, bird spp.) and no disease or wildlife issues have been noted, though these have not been actively monitored. Eastern grey kangaroos (*Macropus giganteus*), swamp wallabies and brushtail possum numbers have increased with high reproductive rates in the presence of EBBs (population release due to the removal of foxes and a fence inhibiting migration).

In comparison with the existing sources of these widespread organisms these scenarios have a low likelihood of significantly increasing the exposure of resident wildlife on both

islands. Consequently the exposure assessment for enteric pathogens as a result of the introduction of EBBs is assessed as **low**.

Consequence Assessment

Wildlife could potentially contract a new strain of bacteria, but this is unlikely to have a population impact. The consequence assessment is, therefore, also **low**.

Risk Estimation

Considering the above, the risk that introducing EBBs to Phillip and French Islands would increase the risk from these widespread enteric organisms to resident wildlife (including long-nosed potoroos and little penguins), domestic animals and people is assessed as **LOW**.

Estimate of Uncertainty in this Risk Assessment

There is a **low to moderate** level of uncertainty in this risk assessment given the knowledge gaps listed in Table 12.

Table 12: Knowledge gaps and measures to reduce uncertainty

KNOWLEDGE GAPS	MEASURES NEEDED TO REDUCE UNCERTAINTY
Normal gastro-intestinal microflora of EBBs	Baseline data for healthy gut flora of EBBs. Not a high priority or cost-benefit, but could be useful for the future.
Current exposure of resident wildlife to these enteric organisms	Faecal analyses - look at information collected from little penguin study, survey wildlife at destination locations (vet reports on wildlife and domestic species).
Transmission rates/virulence of these organisms	Would require targeted research but, given the results of the risk assessment, a low priority for the current purpose.
Which organisms are endemic and which introduced.	

Risk Management

Workshop Group Participants: Simon Firestone, Jasmin Hufschmid, Marissa Parrott

Current Diagnostic, Treatment, Control and Preventative Measures
Salmonella & Campylobacter

Reduce risk of infection by quarantining zoo animals from domestic animals where possible, minimise stress, check animals for signs of disease/scouring, reduce other endoparasites via parasiticide treatment, only release healthy-appearing animals and practice biosecurity/hygiene (e.g. wash hands, clean boxes).

Diagnosis
- Diagnosis is based on isolation of the organism from aseptically collected tissue at necropsy, or from faeces or rectal swabs.
- As many animals are asymptomatic carriers, other evidence of disease compatible with salmonellosis/campylobacteriosis must be present to confirm a diagnosis.

Treatment
- There are no published reports of the efficacy of antibiotics in the treatment of enteric pathogens in Peramelids.
- Microbial culture and sensitivity testing is likely to provide a useful means of determining the most effective antibiotic to use in clinical cases.
- Asymptomatic carriers should not be treated.

Control
- These organisms are susceptible to most disinfectants.

Prevention
- Maintenance of adequate rodent control measures in captive facilities.
- Prevent human exposure to enteric pathogens through hand-washing after animal contact.

E.coli and *Yersinia* sp

Diagnosis
- Diagnosis is based on isolation and culture of these organisms from aseptically collected tissue at necropsy, or from a lesion biopsy collected while an affected animal is under anaesthesia.

Treatment
- There are no published reports of the efficacy of antibiotics in the treatment of these pathogens in Peramelids.
- Microbial culture and sensitivity testing is likely to provide a useful means of determining the most effective antibiotic to use in clinical cases.

Control
- Gram-negative bacteria such as *Yersinia* spp. and *E. coli* may be difficult to inactivate using disinfectants. They are considered resistant to chlorhexidine. Virkon S® is effective, as is 1:100 dilution of household bleach.

Prevention
- Minimise exposure of individuals to environmental stressors.
- Management considerations prior to release (parasite management, pre-release husbandry):
  - Choice of habitat at release site
  - Vegetation for shelter/nest-building (type and quality)
  - Food supply (soil moisture, invertebrate density)
  - Season of release
    - Food supply for release animals (soil moisture, invertebrate density)
    - Temperature/rainfall and its impact on the animals themselves

Cryptosporidium

Diagnosis
- Faecal specimens are examined microscopically using different techniques (e.g. acid-fast staining, direct fluorescent antibody, and/or enzyme immunoassays). Commercial products (DFA, IFA, EIA, and rapid tests) are available for detection of *Cryptosporidium* sp. antigens (e.g. Merifluor® Cryptosporidium/Giardia, Meridian Bioscience Inc.). However, these tests are not validated for use in animals (Johnston *et al.* 2003).
- Direct faecal DNA extraction can identify organisms to species level.

Treatment

- Several drugs are commonly used to treat cryptosporidiosis in humans (e.g. nitazoxanide or paromomycin); very few have been effectively used in animals.
- None are completely effective in terms of both clinical and parasitological response.

Control

- Oocysts are resistant to common disinfectants, and the parasite is difficult to eradicate from contaminated environments. Bleach applied at a high concentration (6%) for 2 hours inactivates 92% of oocysts.
- *Cryptosporidium* oocysts can be efficiently inactivated by thermal treatment at 56°C for at least 20 minutes (Shahiduzzaman & Daugschies, 2012).

Prevention

- Maintain rodent control programmes in captive institutions.
- Hand-washing after animal contact is essential.
- Maintain strict biosecurity protocols during captive breeding programmes, to minimise risk of transmission or infection from other captive birds/mammals held in the institution.

Giardia

Diagnosis

- The primary diagnostic tests for Giardia include direct smear or wet mount examination for trophozoites, microscopic examination for cysts after centrifugal faecal flotation (zinc sulfate solutions are used at Melbourne Zoo), or IFA detection of antigens by enzyme-linked immunosorbent assay (ELISA).
- Commercial products (DFA, EIA, and rapid tests) are available for detection of Giardia sp. antigens, e.g. Merifluor® Cryptosporidium/Giardia, Meridian Bioscience Inc., SNAP® Giardia test (IDEXX Laboratories) are not validated for use in wildlife.
- Direct faecal DNA extraction can identify organisms to species level.

Treatment

- Fenbendazole (50g/kg PO SID x 3-10 days), or
- Metronidazole (15-25mg/kg PO SID-BID for 5-7 days (Tangtrongsup and Scorza, 2010).

Control

- Manual collection of faeces will reduce infectivity of an environment. Cysts are resistant to common disinfectants, and the parasite is difficult to eradicate from contaminated environments (Tangtrongsup & Scorza, 2010).
- Quaternary ammonium compounds are recommended disinfectants (e.g. Trigene® Ceva Animal Health Pty Ltd).

Prevention

- Maintain rodent control programmes in captive institutions.
- Hand-washing after animal contact is essential.
- Maintain strict biosecurity protocols during captive breeding programmes, to minimise risk of transmission of infection from other captive birds and mammals held in the institution.

Environmental, Agent and Host Factors that may influence transmission

Environmental sources (pre-EBB):

- Water ways
- Soil and reptile hosts
- Domestic animal and livestock (dairy cows) hosts
- Effluent and sewage run off
- Wildlife gut flora

Table 13: Factors that may influence transmission of enteric pathogens

ENVIRONMENT FACTORS INFLUENCING TRANSMISSION	AGENT FACTORS INFLUENCING NEGATIVE CONSEQUENCES TO HOST	HOST FACTORS INFLUENCING SUSCEPTIBILITY TO DISEASE
High rainfall/flooding	Virulence	Density
Temperature high or low	Requirement of vectors/intermediate hosts	Immunological status
Little penguin burrow microclimate		Age
Habitat site		Habitat preference
		Stress (nutritional, seasonal, reproductive)
		Seasonal migration

Figure 6: Transmission pathways for enteric organisms from EBB to Wildlife
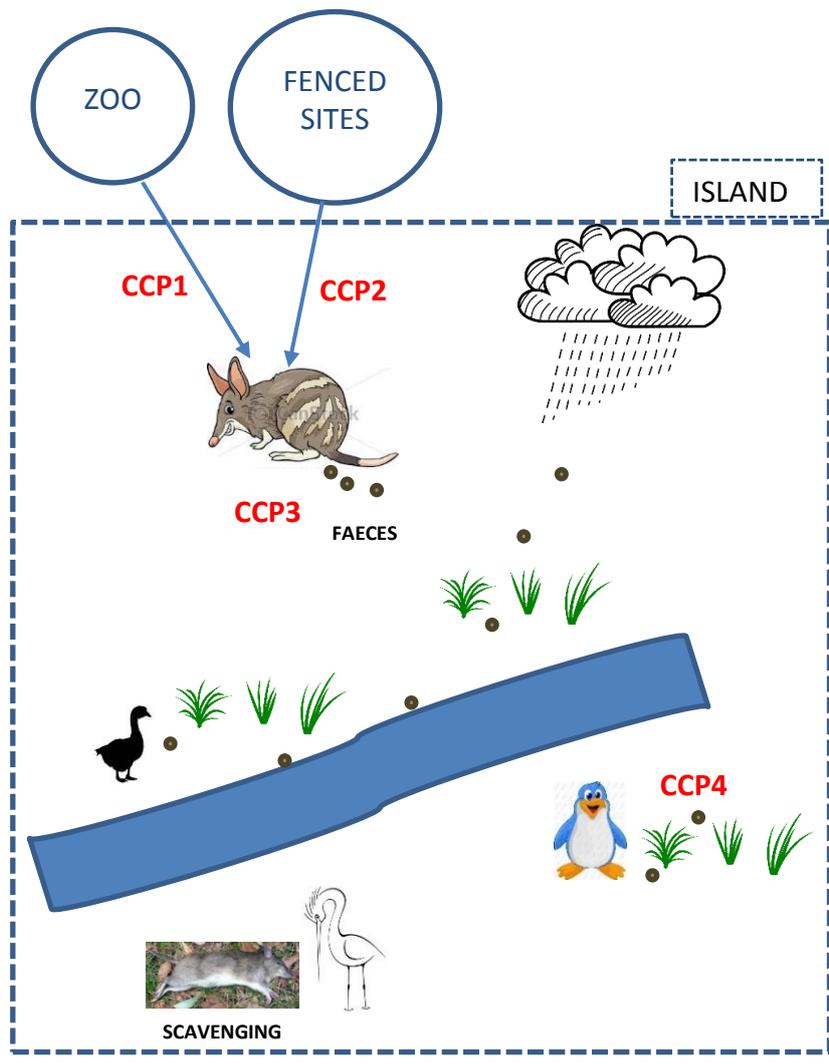
Table 14: Risk Management Option Evaluation for Enteric Pathogens

CCP#	MITIGATION OPTIONS	EFFECTIVENESS*	FEASIBILITY*	EXPLANATION	RECOMMENDATION
1	A. Faecal screening /culture of all pre-release captive EBBs	L	H	Intermittent shedding Culture can have low sensitivity	Yes. Could be considered expensive (Gribbles), but small research project could be run by students/collaboration to determine baselines, which will be useful later
1	B. General health checks x 2	L	H	Hard to pick up enteric infection unless severe. Could be subclinical.	Yes. Continue with health checks for other reasons, but may not be effective for bacteria (unless clinically effected)
1	C. Quarantine/biosecurity /hygiene	H	H	Likely to prevent infection.	Yes. Continue with current program
1	D. Minimise stress	L	M	Stress does not affect exposure.	No for enteric bacteria, but continue to minimise stress as best practice welfare
1	E. Treat endoparasites	L	H	Effective for parasite burden, but for bacteria it is an ancillary measure	No. Not effective for bacteria flora, but treat parasites for other reasons

CCP#	MITIGATION OPTIONS	EFFECTIVENESS*	FEASIBILITY*	EXPLANATION	RECOMMENDATION
1	F. Antibiotic treatment	L (neg)	H	Could do more harm than good, ineffective, will not eliminate carrier state, could disrupt healthy flora, could lead to antibiotic resistance	No.
2	A. Pre-release free ranging EBBs Health checks	L	H	Hard to pick up enteric infection unless severe. Could be subclinical.	No. Continue with health checks for other reasons, but may not be effective for bacteria (unless clinically effected)
2	B. Endoparasite treatment	L	H	Effective for parasite burden, but for bacteria it is an ancillary measure	No. Treat parasites for other reasons, but little/no effect on bacterial flora
2	C. Hold after treatment with parasiticides	H	L	Could determine if parasites have gone but there is a risk to wild animals through stress by quarantining.	No.

CCP#	MITIGATION OPTIONS	EFFECTIVENESS*	FEASIBILITY*	EXPLANATION	RECOMMENDATION
				Enclosure space not available	
2	D. Hygiene/biosecurity	L	H	Likely to prevent infection during short-term transfer only	Yes. Continue with current program, little chance of transfer of bacteria in short transit time.
2	E. Antibiotic treatment	L (neg)	H	Could do more harm than good, ineffective, will not eliminate carrier state, could disrupt healthy flora, could lead to antibiotic resistance	No.
3.1	A. Post-release EBB monitoring of general health	L	H	Hard to pick up enteric infection unless severe. Could be subclinical.	No. Continue with health checks for other reasons, but may not be effective for bacteria (unless clinically effected)
3.2	B. Faecal swabs/screening	L	M	Shedding is intermittent and may be missed	Yes. Useful if an issue is recorded

CCP#	MITIGATION OPTIONS	EFFECTIVENESS*	FEASIBILITY*	EXPLANATION	RECOMMENDATION
3.3	C. Post-mortem	M	M	May not find bodies or find them in time to determine cause of death. If found in time, PM effective if clinical infection is present	Yes. Post mortem any bodies found
3.4	D. Post-release monitoring other wildlife/little penguins (existing programs)	M	H	Can determine new diseases in population	Yes. Continue with current monitoring regimes
4.1	A. Investigate disease outbreaks if they occur	H	M	Detection easy, treatment dependent on the issue	Yes. If outbreaks observed, investigate (irrespective of EBBs)

Implementation and Review

Table 15: Risk Management Implementation and Review Action Plan for Enteric Pathogens

MANAGEMENT TARGET	GOALS	ACTIONS	FREQUENCY	RESPONSIBILITY	SUCCESS MEASURE(S)	DATA REQUIRED
Enteric pathogens	Negligible to low risk of introduction of new strains	Pre-release captive EBBs – Faecal screening/culture	1	Zoos Victoria	All animals screened	Faecal sample analysis
		Captive general health checks	2	Zoos Victoria	All animals screened	General health parameters
		Captive Quarantine/biosecurity /hygiene	ongoing	Zoos Victoria/captive sites	Guidelines followed (Lynch 2015, Appendix 7)	-
		Fenced/island EBB general health check	1	Mt Rothwell, Phillip Island Nature Parks, Zoos Victoria	All animals screened	General health parameters
		Fenced/island EBBs Hygiene/biosecurity during transit	during transit	Mt Rothwell, Phillip Island Nature Parks, Zoos Victoria,	Guidelines followed (Lynch 2015, Appendix 7)	-

Management Target	Goals	Actions	Frequency	Responsibility	Success measure(s)	Data required
				Conservation Volunteers		
		Fenced/island faecal screening/ swabs	1	Zoos Victoria	All animals screened	Swabs/faeces results
	High chance of early detections of any issues	Post-release EBBs Monitoring general health	3+ times/year	Phillip Island Nature Parks, Zoos Victoria	No detectible enteric disease	General heath parameters
		Faecal swabs/screening	Once every 6 months following release	Phillip Island Nature Parks, Zoos Victoria	All animals screened if trapped	Swabs/faeces results
		Post-mortem of any bodies	opportunistic	Zoos Victoria	-	Cause of death/bacteria if present
		Other wildlife/little penguins Monitoring (existing programs) pre and post EBB release, monitoring of long-	Project based	Phillip Island Nature Parks, Parks Victoria	Faecal samples screened	General health parameters + faecal samples

Management Target	Goals	Actions	Frequency	Responsibility	Success measure(s)	Data required
		nosed potoroos and little penguins				
		Investigate disease outbreaks if they occur	Respond to outbreaks if they occur	Phillip Island Nature Parks, Parks Victoria, Zoos Victoria	Outbreak detected and fully investigated	Cause of disease

Risk Assessment for Ectoparasites (Fleas, Ticks & Mites)

Workshop Group Participants: Ian Beveridge, Mark Hawes, Richard Hill, Jasmin Hufschmid, Simon Firestone, Georgia Kerr, Marissa Parrott

Justification for Hazard Status

Bandicoots are likely to carry ectoparasites, including mites, fleas and ticks. Due to a relative lack of host specificity, these have the potential to be transmitted to other wildlife species after release. High ectoparasite loads can cause disease in some animals, and act as vectors for a range of rickettsial diseases (*Bartonella*), trypanosomes, *Babesia* and *Theileria*. *Sarcoptes scabiei* might be the worst of these in terms of consequence for the host, but this would only be relevant if they didn't already occur on the islands. It does occur on French Island, but its presence on Phillip Island is uncertain. It hasn't been seen in dogs from Phillip Island, but Obendorf (1983) reports finding *Sarcoptes* in Phillip Island koalas. Studies have found trypanosome species (*Lewisii*) in bandicoots in the Northern Territory and Tasmania, which may not be species-specific (Bettiol *et al.* 1998, Reiss *et al.* 2015). Passive surveillance of blood smears from mainland EBBs has so far not detected any trypanosomes.

Release Assessment:

Fleas (*Pygiopsylla hoplia; Stephanocircus dasyure*)

EBBs from some fenced free-ranging populations have very heavy flea burdens. Of 52 EBBs examined at necropsy in 1988-89, four were considered to have died primarily as a result of heavy ectoparasite burden (Lenghaus *et al.* 1990). Presence of fleas and "blood meals" apparent in the coat of the bandicoots were indicators of heavy burden. Histologically, severe ectoparasitism was associated with a moderate, diffuse infiltration of lymphocytes and eosinophils in the dermis (Ladds 2009e).

Australian flea species are host-adapted but not host specific, therefore potential host range may be broad. The role of these flea species as disease vectors is not well-understood.

Ticks

The ticks *Ixodes holocyclus* and (rarely) *I. cornuatus* may cause fatal paralysis in domestic pets released into tick-infested environments (Jackson *et al.* 2007). Northern brown bandicoots, *Isoodon macrourus,* released into tick-infested enclosures showed a reduced growth rate, a reduced haematocrit value and an increased total white cell count when compared with bandicoots released into tick-free enclosures (Gemmell *et al*. 1991).

Mites (unidentified sarcoptid mite, unidentified *Demodex* spp., *Haemolaelaps marsupialis*, *Petauralges* sp., *Ornithonyssus bacoti*)

It is generally believed that sarcoptic mange in Australia was introduced by settlers and their dogs, and subsequently became a major disease burden to native wildlife (Fraser *et al.* 2016). A captive EBB infested with a mite from within the genus *Petauralges* exhibited rump alopecia and dorsal hyperkeratosis (MZ case 910320). A wild southern brown bandicoot with generalized alopecia and exudative skin lesions was found to have a heavy burden of a *Sarcoptes*-like mite (HS case 92/0593). While mites of a *Demodex*-like species have been detected in clinically normal EBBs, *Ornithonyssus bacoti* (the tropical rat mite) has been detected in captive bilbies (Buchecker & Kleinig 2002).

Overall, it is likely that EBBs will carry a range of ectoparasites if untreated. Therefore the risk assessment for ectoparasites in the absence of pre-translocation treatment is assessed

as **high**. If parasite treatment occurs pre-release, this would most likely drop down to low (see risk management).

Exposure Assessment:
Fleas
The life cycles of Australian flea species has been well-described. As an example, in the life cycle of *Ctenocephalides* spp. (dog and cat fleas), eggs are laid on the host, and drop off into the environment. After 2-12 days, eggs hatch into larvae. The larvae ingest the blood-containing excrement of adult fleas and then undergo two moults. At the third moult, white larvae spin a whitish-grey cocoon, in which pupae develop. Pupae can delay emergence from the cocoon for up to one year. Vibration, heat, and CO_2 stimulate emergence. Once adult fleas emerge from the larval cocoon, they seek a new host (i.e. fleas live in the environment and jump onto nearby hosts).

Ticks
The life cycle of *Ixodes holocyclus* consists of four stages: egg, larva, nymph and adult. Ticks hatch as larvae. Larvae search for a blood meal from a host, feed for four to six days, then drop from the host and moult to become an eight-legged nymph. Nymphs require a second blood meal before they can moult again to become an adult. Female adults then require a further blood meal of up to ten days before dropping off to lay eggs in leaf litter.

Habitat fragmentation and landscape conversion may favour high population densities of small mammals, mainly rodents, which are crucial as hosts for tick larvae and nymphs as well as important reservoirs for many tick transmitted pathogens.

Ixodes holocyclus has been collected from rodents (bush rat, *Rattus fuscipes*, swamp rat, *R. lutreolus*, black rat, *R. rattus*), wombats, cats and dogs in Gippsland and *I. cornuatus* from bush rat, wombats, cats and dogs in central Victoria (Jackson *et al.* 2007). The known distribution of the two species was established from specimens in museum collections and suggested that a boundary between the two may exist in eastern Gippsland. The area immediately to the east of Melbourne is considered climatically suitable for *I. holocyclus*, although no endemic foci of infection are currently known from this region. The potential distribution of *I. cornuatus* includes east Gippsland and the Otway Ranges, areas in which the tick is not currently known to occur. Northern brown bandicoots and long-nosed bandicoots are considered important in the ecology of *I. holocyclus*.

The role of ixodid ticks as disease vectors is not well-understood. Infected ticks are probably most important in maintaining the life cycle of *C. burnetii,* and of some haemoparasites.

Mites
Close contact is usually required for transmission of mite infestation. It is possible that the route for transmission of *Sarcoptes scabiei* between canids and wombats is indirect, occurring via burrows (Bryant and Reiss, 2008).

Avian species are unlikely to be affected by ectoparasites from EBBs, exposure would most likely be between other mammals (e.g. rats, potoroos, and possums). Fleas have a rapid generation turnover, so can accumulate large numbers quickly, and endemic species are more likely to be affected.

The exposure assessment for fleas is potentially **high** under suitable conditions (high temperature and humidity).

The exposure assessment for ticks is assessed as **moderate** due to the slower generation

time (approximately 1 year), so will take longer to build up numbers to affect other species.

The exposure assessment for mites is assessed as **low,** given that exposure is most likely through direct contact or nest sharing and that endemic species are unlikely to share nests with EBBs.

There may be seasonal variation in ectoparasite numbers, which may affect exposure and transmission probability, e.g. fleas thrive under high temperature and humidity and variations in numbers of certain tick species.

Consequence Assessment:
The vector-borne diseases are likely to be species-specific, so are unlikely to have any significant effect on endemic species. A literature search suggests that trypanosomes may cross species, but are unlikely to cause significant disease in more than the occasional individual.

Sarcoptes scabiei is a zoonosis (Ladds 2009e). Exposure could result in disease in EBBs but infection has so far not been reported in Peramelids. Sarcoptic mange is endemic in common wombat populations throughout their range and relatively common in red fox populations (Fraser *et al.* 2007). Potoroos and other mammals may be affected, but the probability of significant disease due to these ectoparasites is low and the consequences for birds is likely to be negligible. Overall, the consequence is assessed as **low**.

Risk Estimation:
Based on the above, the overall risk of significant impact of fleas, ticks and mites to resident animals on French and Phillip Islands is estimated as **LOW**.

Level of Uncertainty/Measures needed to reduce:
Status of *Sarcoptes* sp. on Phillip Island is not known. Current ectoparasites of potoroos on French Island are also unknown, as well as ectoparasites of possums on French and Phillip Island. Similarly, knowledge of the trypanosome status for wildlife species on French and Phillip Island is unknown.

Risk Management

Current diagnostic treatment, control and preventative measures.

Fleas

Diagnosis
- Presence of fleas in the coat. Visible "blood meals" in the coat indicate a heavy burden.

Treatment
- For adult fleas:
    - 6mg/kg selamectin applied percutaneously appears rapidly effective and is safe (Hufschmid 2008; also used at Melbourne Zoo).
    - 10mg/kg imidacloprid applied percutaneously effectively and safely treated *Pygiopsylla hoplia* in captive EBBs held by Zoos Victoria.

Control
- General measures for cleaning and disinfection should reduce environmental parasite contamination.

Prevention
- To eliminate fleas acquired by captive EBBs from the environment, treat with selamectin/imidacloprid every four weeks.
- Effective quarantine treatment of animals entering a captive/release location is essential. If parasitism is detected in newly-arrived captive animals, treatment should be completed so that infection is eliminated while the bandicoots are housed in their quarantine enclosures.
- Transport boxes and handling bags must be thoroughly cleaned to remove adult fleas, flea eggs and pupae. Effective cleaning is difficult to achieve when wooden transport boxes are used, therefore plastic pet carriers with shredded paper substrate are now used by Zoos Victoria when transporting EBBs between sites. The paper is discarded after use and the transport box cleaned with F10.

Ticks

Diagnosis
- Presence of ticks in the coat. Burdens can be very heavy.

Treatment
- Animals may be treated with topical acaricides, such as fipronil, pyrethrins and selamectin.

Control
- Disinfection techniques have not been described, and are unnecessary. Acaricides are favoured for management.

Prevention
- Effective quarantine treatment of animals entering a captive/release location is essential. If parasitism is detected in newly-arrived captive animals, treatment should be completed so that infection is eliminated while the EBBs are housed in their quarantine enclosures.
- Transport boxes and handling bags must be thoroughly cleaned to remove adult ticks and nymphs. Effective cleaning is difficult to achieve when wooden transport boxes are used, therefore plastic pet carriers with shredded paper substrate are now used by Zoos Victoria when transporting EBBs between sites. The paper is discarded after use and the transport box cleaned with F10.
- Maintenance of adequate rodent control measures in captive facilities.

Mites

Diagnosis
- Presence of mites in the coat.

Treatment
- Acaricides such as selamectin, imidacloprid and fipronil may be used.

Control
- Disinfection techniques have not been described.

Prevention
- Effective quarantine treatment of animals entering a captive/release location is essential. If parasitism is detected in newly-arrived captive animals, therapy should be completed so that infection is eliminated while the bandicoots are housed in their quarantine enclosures.
- Transport boxes and handling bags must be thoroughly cleaned to remove ectoparasites. Effective cleaning is difficult to achieve when wooden transport boxes are used, therefore

plastic pet carriers with shredded paper substrate are now used by Zoos Victoria when transporting EBBs between sites. The paper is discarded after use and the transport box cleaned with F10.

- Maintenance of adequate rodent control measures in captive facilities.
- Close examination of bandicoots for signs of alopecia and dermatitis indicating possible infection with sarcoptic mange should be performed prior to release as well as during post-release monitoring.

Host, Agent and Environmental Factors Influencing Ectoparasitism

Hazard: Fleas affecting endemic wildlife

Environmental sources: EBB

Potential transmission pathways: direct contact, egg/larvae in environment

Table 16: Factors Influencing Flea Infestation

ENVIRONMENT FACTORS INFLUENCING TRANSMISSION	*AGENT FACTORS INFLUENCING NEGATIVE CONSEQUENCES TO HOST*	*HOST FACTORS INFLUENCING SUSCEPTIBILITY TO DISEASE*
High host density	Most likely already present on both islands, so EBBs unlikely to have additional negative effect	Wildlife species (e.g. rats most likely to be affected; possibly possums). Macropods probably not affected.
Moisture levels	Vector potential (*Bartonella*)	Immune-compromised

Hazard: Mites affecting endemic wildlife

Environmental sources: EBB

Potential transmission pathways: direct, indirect (e.g. burrows)

Table 17: Factors Influencing Mite Infestation

ENVIRONMENT FACTORS INFLUENCING TRANSMISSION	*AGENT FACTORS INFLUENCING NEGATIVE CONSEQUENCES TO HOST*	*HOST FACTORS INFLUENCING SUSCEPTIBILITY TO DISEASE*
	Most mites would only cause minor impacts	Immune-compromised
	S. scabiei most likely to be a concern	Wide range of hosts susceptible to infection.
	S. scabiei already present on French Island	

Hazard: Ticks affecting endemic wildlife

Environmental sources: EBB

Potential transmission pathways: environment (multi-host ticks)

Table 18: Factors Influencing Tick Infestation

ENVIRONMENT FACTORS INFLUENCING TRANSMISSION	*AGENT FACTORS INFLUENCING NEGATIVE CONSEQUENCES TO HOST*	*HOST FACTORS INFLUENCING SUSCEPTIBILITY TO DISEASE*
Differences between islands; French Island koala ticks are typically *Ixodes hirsti;* Phillip Island *I. trichosuri, I. hirsti* and *I.tasmani*	*I. holocyclus/cornuatus* could have negative effects on domestic species, but very unlikely that EBBs from southern Victoria carry them	
	Vector potential (*Babesia, Theileria, Hepatozoon*)	

Figure 7: Transmission pathways for Ectoparasites
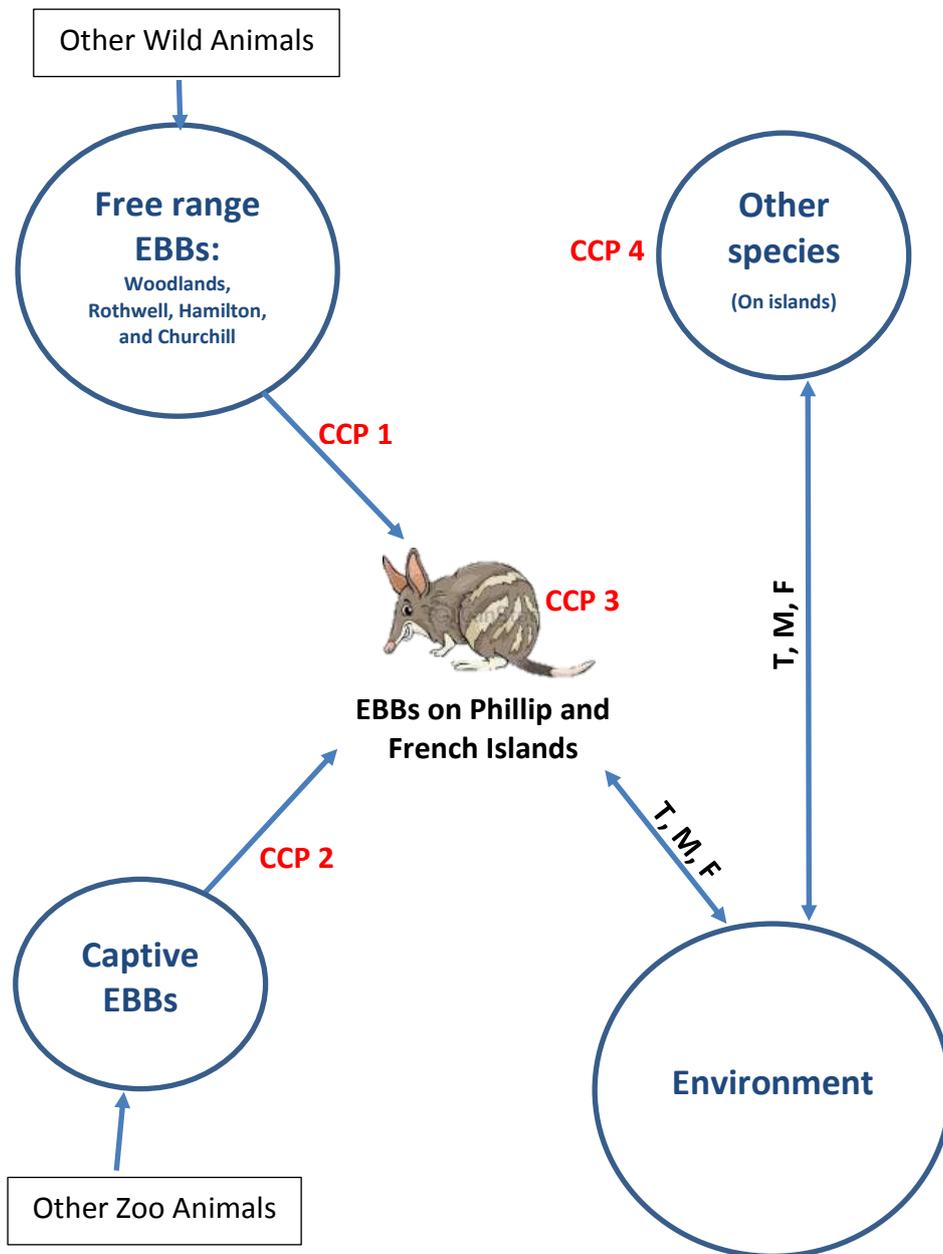
Table 19: Risk Management Option Evaluation for Ectoparasites

Workshop Group Participants: Simon Firestone, Jasmin Hufschmid, Marissa Parrott

CCP#	MITIGATION OPTIONS	EFFECTIVENESS*	FEASIBILITY*	EXPLANATION	RECOMMENDATION
1	A. Pre-release fenced/island EBB health checks	M	H	Many, but not all, endoparasites can be seen	Yes. Continue with health checks
1	B. Ectoparasite treatment	H	H	Effective for majority of parasite burden (though complete elimination of all ectoparasites unlikely)	Yes. Treat parasites
1	C. Hold in quarantine after treatment to ensure treatment effectiveness	M	L	Not feasible based on animals stress/health and holding facilities	No. Could get a good idea from captive studies on effectiveness of treatments
1	D. Hygiene/ biosecurity	H	H	Move into a new box - likely to prevent reinfection following treatment	Yes. Continue with current program
2	A. General health checks x 2	H	H	Ectoparasites can be monitored pre and post-treatment	Yes. Continue with health checks

CCP#	MITIGATION OPTIONS	EFFECTIVENESS *	FEASIBILITY *	EXPLANATION	RECOMMENDATION
2	B. Quarantine/ biosecurity / hygiene	H	H	Likely to prevent infection.	Yes. Continue with current program
2	C. Minimise stress	L	M	Stress does not affect exposure. Could reduce susceptibility	No. Minimise stress as best practice welfare regardless of parasites
2	D. Treat ectoparasites	L	H	Effective for parasite burden though unlikely to eliminate all ectoparasites. Check after a few days	Yes. Treat parasites
3	A. Post-release EBB monitoring of general health	M	H	Record any parasites, or potentially parasite-related lesions seen	Yes. Continue with health checks
3	B. Post-mortem of any bodies	M	M	May not find bodies in time to determine cause of death. Ectoparasites should be obvious unless they have moved off the body	Yes. Post mortem any bodies found
4	A. Post-release monitoring of other wildlife/ little penguins	M	H	Can determine new diseases in the population	Yes. Continue with current monitoring regimes

CCP#	MITIGATION OPTIONS	EFFECTIVENESS *	FEASIBILITY *	EXPLANATION	RECOMMENDATION
	(existing programs)				
4	B. Investigate disease outbreaks if they occur	H	M	Detection easy if it's a large outbreak, treatment dependent on issue	Yes. If outbreaks observed, investigate (irrespective of EBBs!)

Implementation and Review Action Plan

Workshop Group Participants: Mark Hawes, Richard Hill, Jasmin Hufschmid, Georgia Kerr

Table 20: Implementation and Review Action Plan for Ectoparasites

MANAGEMENT TARGET	GOALS	ACTIONS	FREQUENCY	RESPONSIBILITY	SUCCESS MEASURE(S)
Captive translocations	Minimise number of ectoparasites on EBBs pre-release	Treat with Selamectin and Moxidectin Physical removal of ticks.	Twice, 14 days apart	Zoos Victoria	Visual inspection for general ectoparasites at 14 days
Wild translocations	Minimise number of ectoparasites on EBBs pre-release	Treat with Selamectin and Moxidectin Inspect for lesions consistent with *Sarcoptes scabei*	once	DEWLP, Mt Rothwell, Phillip Island Nature Parks, Zoos Victoria	Treatment will bring parasites down to low-negligible levels, consequence of transfer is low whereas the risk of additional investigation to EBBs high. Practicality of a second treatment for

		Physical removal of ticks			ectoparasites or visual inspection is low.

Risk Assessment for Ross River Virus

Workshop Group Participants: Paul Eden, Michael Lynch and Simon Firestone.

Justification for Hazard Status

Ross River Virus is an arbovirus requiring a mosquito vector for transmission between vertebrates. The main concern with this virus is its impacts on human health. Clinical signs in people include arthralgia, with or without arthritis, fatigue, fever, myalgia, and maculopapular rash. Macropods (kangaroos and wallabies) are thought to be the main animal reservoir (Cutcher *et al.* 2013). Other reservoir species may include possums, foxes, birds and rodents. Disease has not been reported in EBBs to date.

Known clinical signs in animals are limited to three species: brushtail possums, domestic mice and horses (Boyd *et al.* 2001). Brushtail possums infected experimentally with Ross River Virus exhibited the following clinical signs: wobbly gait, lethargy, loss of appetite and in some cases, death.

Pathology associated with infection in wildlife species has only been described in three brushtail possums exhibiting clinical signs (*Boyd et al*. 2001). Haemorrhagic and oedematous meninges and petechial haemorrhages of the occipital lobe of the brain were seen. Mild congestion of the liver and blood filled pulmonary alveolar spaces were also present. Animals were in good body condition.

Recent cases of Ross River Virus on French Island have heightened public concern for the human health implications of this viral disease. As marsupials can act as a significant reservoir host for Ross River Virus (Old & Deane, 2005, Potter *et al.* 2014, Harley *et al.* 2001) it is prudent to consider available evidence to assess, as far as possible, the potential for EBBs to increase the risk of this disease for the resident human and animal populations on French and Phillip Islands.

Release Assessment

Harley *et al.* (2001) report results from serological testing from a variety of domestic and native animals and suggest that macropods (kangaroos and wallabies) may be an important reservoir host although there is no compelling evidence that marsupial species are any better at acting in this role than say, the horse. Serum samples from 22 EBBs resident at Melbourne Zoo were tested for Ross River Virus and returned negative results (M. Lynch *pers. comm*.). Samples tested were collected from animals over the 2010/2011 summer as this was a peak time for Ross River Virus cases recorded in Victoria for humans and horses. Additional serum samples collected from 75 other zoo collection mammals at this time revealed nine animals with positive antibody titres. This suggests that there was potential for the EBBs to be exposed to Ross River Virus at Melbourne Zoo, but no positive results were found in this species. As Ross River Virus is already present on French and Phillip Islands and, given the results of this serological survey and the absence of any reports of this disease in EBBs, the likelihood of EBBs introducing this disease hazard to the proposed destination sites is assessed as **negligible**.

Exposure Assessment

The current prevalence of Ross River Virus in mammals on French and Phillip Islands is unknown. However, given the presence of Ross River Virus and its mosquito vectors on

French Island the likelihood that EBBs would be exposed to Ross River Virus following translocation is assessed as **moderate**. The likelihood that, once exposed, EBBs would increase the likelihood of human or domestic animals is assessed as **negligible (initially) and low** to **negligible** as the bandicoot population grows.

Consequence Assessment

The consequence of Ross River Virus infection on humans and other susceptible non-reservoir species is assessed as **moderate to high.**

Risk Estimation

Although the consequence of Ross River Virus to humans and other susceptible species is moderate to high, the likelihood of EBBs contributing to this risk based on current evidence is **low to negligible**.

Level of Uncertainty

The level of uncertainty in this risk assessment is **low to moderate**. Knowledge gaps and research needed to lower the level of uncertainty are listed in Table 20.

Table 21: Knowledge gaps and measures to reduce uncertainty

KNOWLEDGE GAPS	MEASURES NEEDED TO REDUCE UNCERTAINTY
Duration of viraemia in EBBs after infection	*Experimental infections – not warranted at this time*
Prevalence of infection in wild EBB populations compared to coexisting mammals	*Field studies to define epidemiology of Ross River Virus and the role of EBBs in the transmission of this virus*

Risk Management

Current diagnostic treatment, control and preventative measures.
Diagnosis

- Serology and virus neutralisation tests (AWHN 2015).

Treatment

- Antiviral medications unlikely to be indicated for use in EBBs

Control

- Mosquito control is the most effective method of minimising viral activity.

Prevention

- There are no measures available to reduce risk of infection in free-ranging wildlife.
- Occurrence of a cluster of cases in animals held in close proximity to a captive EBB population might prompt consideration of strategic use of physical and chemical mosquito control measures.

Host, Agent and Environmental Factors Influencing Ross River Virus

Hazard: RRV affecting people

Environmental sources: all mammal species at destination sites including EBB, could be reservoir hosts; most important source of infection are most likely to be macropods.

Potential transmission pathways: mosquitoes

Table 22: Factors Influencing Ross River Virus

ENVIRONMENT FACTORS INFLUENCING TRANSMISSION	AGENT FACTORS INFLUENCING NEGATIVE CONSEQUENCES TO HOST	HOST FACTORS INFLUENCING SUSCEPTIBILITY TO DISEASE
Rainfall and temperature e.g. wet and warm summers	Unknown	Exposed skin
		Activity at dawn and dusk
		Immunocompromised

Figure 8: Transmission pathways for Ross River Virus
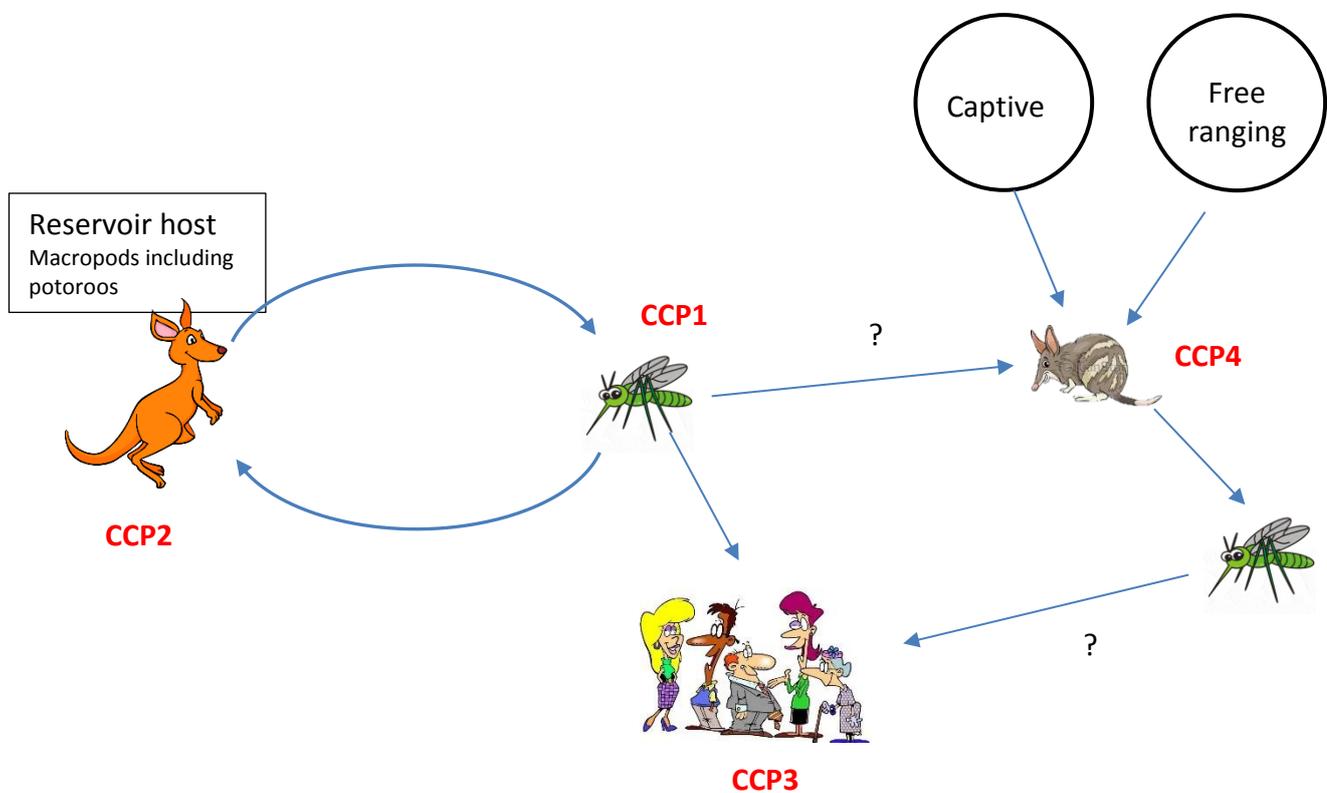
Table 23: Risk Management Option Evaluation for Ross River Virus

CCP#	MITIGATION OPTIONS	EFFECTIVENESS *	FEASIBILITY *	EXPLANATION	RECOMMENDATION
1	Mosquito control, removing stagnant water bodies	H	L	Difficult to control mosquitoes across a large environment	No.
2/3/4	Immunity through vaccination of wildlife, people and EBBs	M	L	Increase likelihood of survival from infection/disease

No currently identified vaccine for marsupials or people, would require research and clinical trials

Challenges in maintaining vaccination of wild populations | No. |

Implementation and Review

The virus has a seasonal incidence, with case numbers peaking in summer and autumn. Local government authorities around Australia are responsible for undertaking mosquito management programs using an integrated approach. This includes monitoring mosquito populations, generating warnings when viral activity has increased, and implementing a range of cultural, physical and chemical control methods to reduce mosquito numbers. Bass Coast Shire Council reports that it is working with Phillip Island Nature Parks to ensure that problem sites for mosquito larvae are "treated to reduce risk", however, local authorities have the capacity to maintain broad-scale treatment programs (e.g. Bass Coast Shire Council Mosquito Control). In most regions, disease prevention continues to rely heavily on personal protection measures, such as insect repellents, promoted by local health authorities (Cutcher *et al.* 2013).

Ross River Virus is already present on French and Phillip Islands. No pre-release management or treatment is currently available for EBBs or useful and there are no plausible management actions post release.

EBB Risk Communications Plan

Workshop Group Participants: Amy Coetsee, Jenny Hibble, Richard Hill, Georgia Kerr, Duncan Sutherland, Alison Pitt

As shown in Figure 1, effective communication with all relevant stakeholders is central to the success of a wildlife Disease Risk Analysis. During the DRA workshop the following initial objectives and identification of stakeholders was developed. More detail can be added to this (see Appendix 1) in the event that a decision to proceed with the translocation of EBBs to French and Phillip Islands is made.

Objectives

Communicate the DRA process.

Communities on both islands should understand the rigour of the DRA process. Include in any communication: a list of participants and their expertise, range of populations considered (humans, livestock, companion animals, wildlife including little penguins and long-nosed potoroos), two day rigorous and structured workshop, IUCN accredited process, independent CBSG facilitation, multiple organisations represented, each possible disease considered for risk likelihood and consequences; process evaluated risk to EBBs as well as other wildlife, humans, livestock and companion animals.

Communicate the key results (only considers disease risk).

Types of communications:
Shouldn't be presented in isolation better to present as part of the overall translocation risk planning. Communication can be:

- ○ Active: open sessions
- ○ Passive: leaflet, information sheets outlining processes and key results, or a detailed report

Stakeholder groups

- Media
- French Island:
  - ○ Active: French Island Community Association (FICA), Landcare, Parks Victoria, EBB recovery team
  - ○ Passive: Friends of French Island, broader community (FICA to decide?), DELWP region, Victorian National Parks Association, Zoos Victoria, Translocation Evaluation Panel, Gregory Andrews, Westernport CMA, Mornington Peninsula Westernport Biosphere, SBB recovery team.
- Phillip Island:
  - ○ Active: Phillip Island Nature Parks board, EBB recovery team
  - ○ Passive: Shire, DELWP, Bass Coast Landcare network, Conservation society, vets, Victorian National Parks Association, Translocation Evaluation Panel,

Zoos Victoria, broader community (residents and transients), Community Advisory Group

The DRA should be submitted to the Translocation Evaluation Panel at the time of submitting an application seeking approval to translocate EBBs to French and/or Phillip Island. The TEP will also require a letter of endorsement/support of the DRA process from DELWP to assist the application

Risks

There is a risk that this DRA on its own, may increase community concern (i.e. bring to people's attention something they might not have considered). We recommend that this DRA is presented to communities as part of the overall risk assessment for the translocation to French and Phillip Islands i.e. presented as a subset of all the risk assessment work done around the translocation.

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Appendix 1: Processes and Tools Used in this DRA

Risk Communication

Purpose
- To engage with relevant experts, influencers and other stakeholders in a way that will maximise the quality of the analysis and probability that recommendations arising will be implemented

Questions:
- Who has an interest in, who has knowledge of value to, and who can influence the implementation of recommendations arising from the DRA?

Process
A small group with relevant knowledge of stakeholder interests (*Amy Coetsee, Jenny Hibble, Richard Hill, Georgia Kerr, Alison Pitt and Duncan Sutherland*) began the development of a communications plan with the following steps:

Step 1: State the objectives of the Communications Plan

Step 2: Identify the stakeholder groups

Step 3: For each group identify contact name(s), organisation, position (title), e-mail address, information to provide, information to obtain

Step 4: Report to plenary and seek further input

Step 5: Note information gaps

Step 6: Identify responsibility for plan implementation

It was not feasibly or necessary to complete this plan for this report. The draft developed at the workshop and included in this report will be fleshed out by Zoos Victoria in consultation with its partners in the EBB Recovery Team in the event that a decision is made to proceed with the translocation of EBBs to French and Phillip Islands.

Problem Description

Purpose:
- Outlines the background and context of the problem (the 'big picture')
- Identifies the goal, scope and focus of the DRA
- States assumptions and limitations
- Specifies the acceptable risk

Question:
- What is the specific question for this DRA and what kind of risk analysis is needed?

Process
A draft Problem Description was developed by Zoos Victoria staff (*Drs. Amy Coetsee, Kate Bodley, Michael Lynch*) with input from members of the EBB Recovery Group (*Richard Hill, Drs. Marissa Parrott and Duncan Sutherland*) prior to the workshop and distributed to all invitees as background briefing papers. The intention was to create a 'level playing field' in which all participants had access to the same information and to ensure, as far as possible,

that relevant published and unpublished information was readily available for discussion and peer review. Further work to critique and refine this information was pursued over the course of the workshop. Participants also identified key information gaps and noted these for future research prioritisation (Appendix 3).

Hazard Identification

Purpose:
- Identify all relevant hazards
- Establish a basis for ranking the importance of each hazard within the context of the defined problem.
- Exclude hazards with zero or negligible probability of release (introduction) or exposure.

Question:
- *What can cause disease or the project to fail in the population of concern?*

Process
A review of relevant literature and unpublished information on the diseases of EBBs was included in the briefing papers. Workshop participants were asked to review this list and add any additions based on their personal experience and expertise. This updated list (Table 2) was subjected to the following prioritization process:

The workshop participants were allocated into small working groups, each focussed on one of the following three populations of interest:

1. Eastern barred bandicoots
2. Wildlife on French and Phillip Islands
3. Humans and domestic animals (including livestock and pets)

…with representatives from the two proposed destination islands represented on the latter two groups and veterinarians with wildlife disease expertise allocated to each group.

Using the hazard list in Table 2, the group followed a two -step prioritization process:

- Step 1: For each population of interest (EBB, Wildlife and Humans & Domestic Animals) the group was asked to allocate a consensus score of 0-3 (in which 0= negligible likelihood/consequence and 3 = high likelihood/high consequence) and multiply the scores for Likelihood x Consequence for each hazard to provide an overall ranking with highest score equating to highest rank (see template below).

		Consequence			
		High (3)	Medium (2)	Low (1)	Negligible (0)
Likelihood	High (3)				
	Medium (2)				
	Low (1)				
	Negligible (0)				

- Step 2: In the event that this process identified more high priority diseases to subject to detailed risk analysis a paired ranking process (Miller & Jakob-Hoff 2014) is applied in which experts compare the potential impact of each hazard with each other hazard, listing them in order of highest to lowest impact considering the following questions:
  - *Which hazards should be subjected to a detailed risk assessment in the workshop (balancing value of expertise in the room, time available and priority for the workshop goal)?*
  - *Which additional hazards require detailed risk assessment post-workshop (selections based on the likely contribution of such risk analyses to the informed decision for which this DRA has been instigated)?*
- However, in the case of the current DRA this step was redundant as only four disease hazards were identified for full risk assessment.

Risk Assessment

Purpose
- Explain the justification for conducting a detailed risk assessment for the selected hazards.
- Assess the likelihood of introduction of the hazard into the area of concern (in this case French and Phillip Islands).
- Assess the likelihood that the species of interest (in this case EBBs or resident wildlife domestic animals and people) will be exposed to the hazard in the area of concern.
- Assess the consequence(s) of such exposure.
- Determine whether there is need to apply risk mitigation measures.

Questions:
- *What is the likelihood and what are the consequences of an identified hazard occurring within a particular pathway or event?*

Process

To enable all participants to have a common understanding of the translocation pathway, a generic graphical representation of this pathway was created and used as a basis for consideration of potential risk pathways for the focal hazards (Figure 2).

Given that all diseases involve an interaction between the hazardous agent, the host and their environment and, based on the known biological characteristics of each selected hazard and focal host species (EBBs, Wildlife, People and Domestic Animals), the groups, using their combined experience and specialist expertise, listed:

- All potential environmental sources
- Potential transmission pathways for the hazard to the host
- Environmental factors that could influence the likelihood of transmission
- Agent factors that can influence the likelihood of transmission and negative consequences to the host
- Host factors that can influence susceptibility to disease if exposed to the hazard

Using this background and the draft material in the briefing notes, each hazard was subjected to risk assessment following a consistent structure:

- Justification for Hazard Status
- Release Assessment
- Exposure Assessment
- Consequence Assessment
- Risk Estimation

Risk Management

Purpose:
- To review potential risk mitigation options and assess their relative effectiveness and feasibility.
- To make recommendations to mitigate the risks associated with the identified hazards.

Questions:
- *What can be done to decrease the likelihood of a hazardous event?*
- *What can be done to reduce the implications once a hazardous event has happened?*

Process:
Considering the translocation pathway and host, pathogen and environmental factors that can influence exposure and disease expression, workshop groups constructed a diagram to graphically represent the potential points of interaction between the host and the hazard from the source to the destination site (Figure 4Figure 7).

This was used as a basis for identifying Critical Control Points (CCPs) on the diagram at which risk management interventions could be made to reduce the likelihood of exposure or reduce the impact on the host if exposure occurs (see template below).

CCP #	CONTROL POINT	MITIGATION OPTIONS	EFFECTIVENESS	FEASIBILITY	EXPLANATION	RECOMMENDATION
1						
2						

Each CCP was marked and numbered on the Risk Pathways diagram.

For each CCP, all the possible measures that could be put in place to interrupt the risk pathway and mitigate the identified risk were listed (brainstormed).

CCPs were then tabulated with their risk mitigation options using the following template:

Options Evaluation Template with Examples

CCP #	MITIGATION OPTIONS	EFFECTIVENESS	FEASIBILITY	EXPLANATION	RECOMMENDATION
1	A	H	H		YES
	B	M	H		Possible*
	C	M	L		No
2	A	L	H		No
	B	M	L		No
3	A	H	L		No
	B	M	M		Possible*
	C	L	L		No
	D	M	H		YES
4	etc				

Using a scale of low, medium and high, the groups evaluated the effectiveness and feasibility of each risk mitigation option.

On this basis, recommendations were then made on which options the group considered must be in place to minimise the disease risk to a low level.

Implementation and Review

Purpose

- Formulate an action plan
- Include a timeline for monitoring, evaluation and review of risk management actions
- Allocate responsibilities and, as much as possible, budget estimates

Questions

- *How will the selected risk management actions be implemented?*
- *On review, are the risk management actions having the desired effect? If not, how can they be improved?*

Process

There were two action plans addressed by this step:

1. Implementation of the risk management recommendations identified in the previous step

For each Risk Management recommendation groups agreed on:

- Practical steps needed to apply the recommended measures
- Goal of each measure
- How success will be measured
- Data to be collected to evaluate success
- Over time frame/frequency
- Person responsible for driving implementation of this recommendation
- Person responsible for evaluating success

For ease of reference these recommendations are included in the 'Risk Management' section of the report.

2. Completion of this DRA post-workshop.

For the completion of the Risk Analysis the whole group addressed the following:

- Person(s) responsible for coordination of inputs
- The tasks to be completed
- For each task:
    - Actions required
    - Deadline
    - Responsibility

This is captured in the 'Implementation and Review' section of the report.

Appendix 2: Potential in-contact species at source and destination sites

Species that are present at source sites and may have contact with *Perameles gunnii*

Churchill Island
Terrestrial Mammals:
Black rat *Rattus rattus*
Brushtail possums *Trichosurus Vulpecula*
House mouse *Mus musculus*
Red-neck wallabies *Macropus rufogriseus*
Swamp wallabies *Wallabia bicolor*
Water rat *Hydromys chrysogaster*
Domestic Dog
Guninea pigs
Highland cattle
Horses
Pig
Sheep
Birds:
Cape barren geese *Cereopsis novaehollandiae*
Shorebirds
Domestic poultry (geese, chickens, peacocks)

Hamilton Community Parklands
Terrestrial Mammals:
Black rat *Rattus rattus*
Brown rat *Rattus norvegicus*
Brushtailed possum *Trichosurus vulpecula*
Eastern grey kangaroo *Macropus giganteus*
European rabbit *Oryctolagus cuniculus*
House mouse *Mus musculus*
Ringtailed possum *Pseudocheirus peregrinus*
Short-beaked echidna *Tachyglossus aculeatus*
Swamp rat *Rattus lutreolus*
Swamp wallaby *Wallabia bicolor*
Birds:
Black swan *Cygnus atratus*
Dusky moorhen *Gallinula tenebrosa*
Eurasian coot *Fulica atra*
Little eagle *Hieraaetus morphnoides*
Purple swamp hen *Porphyrio porphyrio*
Straw-necked ibis *Threskiornis spinicollis*
Swamp harrier *Circus approximans*
Wedge-tailed eagle *Aquila audax*

Zoos Victoria properties
Terrestrial Mammals:
Black rat *Rattus rattus*
Brown rat *Rattus norvegicus*
Brushtailed possum *Trichosurus vulpecula*
Eastern grey kangaroo *Macropus giganteus*
European rabbit *Oryctolagus cuniculus*
House mouse *Mus musculus*
Ringtailed possum *Pseudocheirus peregrinus*
Birds:
Brolga *Grus rubicunda*
Emu *Dromaius novaehollandiae*

Mt Rothwell
Terrestrial Mammals:
Black rat *Rattus rattus*
Brown rat *Rattus norvegicus*
Brushtailed possum *Trichosurus vulpecula*
Brush-tailed rock wallaby *Petrogale penicillata*
Eastern grey kangaroo *Macropus giganteus*
Eastern quoll *Dasyurus viverrinus*
European rabbit *Oryctolagus cuniculus*
House mouse *Mus musculus*
Long-nosed potoroo *Potorous tridactylus*
Red-necked wallaby *Macropus rufogriseus*
Ringtailed possum *Pseudocheirus peregrinus*
Rufous bettong *Aepyprymnus rufescens*
Short-beaked echidna *Tachyglossus aculeatus*
Southern brown bandicoot *Isoodon obesulus*
Spotted tailed quoll *Dasyurus maculatus*
Sugar glider *Petaurus breviceps*
Swamp wallaby *Wallabia bicolor*
Tasmanian pademelon *Thylogale billardierii*
Domestic dog and dingo
Birds:
Black-shouldered kite *Elanus axillaris*
Brown Goshawk *Accipiter fasciatus*
Little eagle *Hieraaetus morphnoides*
Wedge-tailed eagle *Aquila audax*
Whistling kite *Haliastur sphenurus*

Woodlands Historic Park
Terrestrial Mammals:
Black rat *Rattus rattus*
Brown hare *Lepus capensis*
Brown rat *Rattus norvegicus*
Brushtailed possum *Trichosurus vulpecula*
Eastern grey kangaroo *Macropus giganteus*
European rabbit *Oryctolagus cuniculus*
House mouse *Mus musculus*
Ringtailed possum *Pseudocheirus peregrinus*
Sambar deer *Rusa unicolor*
Short-beaked echidna *Tachyglossus aculeatus*
Swamp wallaby *Wallabia bicolor*
Birds:
Australian raven *Corvus coronoides*
Black-shouldered kite *Elanus axillaris*
Brown Goshawk *Accipiter fasciatus*
Dusky moorhen *Gallinula tenebrosa*
Eurasian coot *Fulica atra*
Little eagle *Hieraaetus morphnoides*
Little raven *Corvus mellori*
Purple swamphen *Porphyrio porphyrio*
Wedge-tailed eagle *Aquila audax*
Whistling kite *Haliastur sphenurus*

Species list of terrestrial mammals present on Phillip Island and French Island

Phillip Island

Terrestrial mammals
Black rat *Rattus rattus*
Brown hare *Lepus capensis*
Brushtail possum *Trichosurus vulpecula*
European rabbit *Oryctolagus cuniculus*
Fallow Deer *Dama dama* (domestic)
Feral cat *Felis catus*
House mouse *Mus musculus*
Koala *Phascolarctos cinereus*
Red fox *Vulpes vulpes* (no sightings since August, 2015)
Red necked wallaby *Macropus rufogriseus*
Ringtail possum *Pseudocheirus peregrinus*
Short-beaked echidna *Tachyglossus aculeatus*
Swamp wallaby *Wallabia bicolor*
Tammar wallaby *Macropus eugenii*
Water rat *Hydromys chrysogaster*
Alpacas/llamas
Cattle (beef cattle grazing)
Horses
Sheep
Domestic pets: dogs and cats

French Island

Terrestrial mammals
Bush rat *Rattus fuscipes*
European rabbit *Oryctolagus cuniculus*
Fallow Deer *Dama dama*
Feral cat *Felis catus*
Feral goat *Capra hircus*
House mouse *Mus musculus*
Koala *Phascolarctos cinereus*
Long-nosed potoroo *Potorous tridactylus*
Sambar deer *Cervus unicolor*
Short-beaked echidna *Tachyglossus aculeatus*
Swamp Rat *Rattus lutreolus*
Water rat *Hydromys chrysogaster*
Alpacas/llamas
Cattle (beef cattle grazing)
Domestic goat
Domestic pig
Horses
Sheep
Domestic pets: dogs and cats

Avifauna on Phillip Island and French Island (those considered more likely to contact *Perameles gunnii*)

Phillip Island

Ground-nesting birds
Black swan *Cygnus atratus*
Cape Barren goose *Cereopsis novaehollandiae*
Dusky moorhen *Gallinula tenebrosa*
Eurasian Coot *Fulica atra*
Masked lapwing *Vanellus miles*
Purple swamphen *Porphyrio porphyrio*
Straw-necked ibis *Threskiornis spinicollis*

Raptors and owls
Barn owl *Tito javanica*
Black-shouldered kite *Elanus axillaris*
Brown Goshawk *Accipiter fasciatus*
Nankeen kestrel *Falco cenchroides*
Peregrine falcon *Falco peregrinus*
Powerful owl *Ninox strenua*
Southern boobook *Ninox novaeseelandiae*
Swamp harrier *Circus approximans*
Wedge-tailed eagle *Aquila audax*
Whistling kite *Haliastur sphenurus*
White-bellied sea eagle *Haliaeetus leucogaster*

Seabirds
Little penguin *Eudyptula minor*
Short-tailed shearwater *Ardenna tenuirostris*

Other birds
Australian raven *Corvus coronoides*
Kelp gull *Larus dominicanus*
Little raven *Corvus mellori*
Pacific gull *Larus pacificus*
Silver gull *Chroicocephalus novaehollandiae*
Domestic Chickens (free-range egg farming)
Domestic geese and ducks

French Island

Ground-nesting birds
Black swan *Cygnus atratus*
Cape Barren goose *Cereopsis novaehollandiae*
Dusky moorhen *Gallinula tenebrosa*
Eurasian Coot *Fulica atra*
Masked lapwing *Vanellus miles*
Purple swamphen *Porphyrio porphyrio*
Straw-necked ibis *Threskiornis spinicollis*

Raptors and owls
Barn owl *Tito javanica*
Black-shouldered kite *Elanus axillaris*
Brown Goshawk *Accipiter fasciatus*
Nankeen kestrel *Falco cenchroides*
Peregrine falcon *Falco peregrinus*
Southern boobook *Ninox novaeseelandiae*
Swamp harrier *Circus approximans*
Wedge-tailed eagle *Aquila audax*
Whistling kite *Haliastur sphenurus*
White-bellied sea eagle *Haliaeetus leucogaster*

Seabirds
Short-tailed shearwater *Ardenna tenuirostris*

Other birds
Australian raven *Corvus coronoides*
Indian peafowl *Pavo cristatus*
Little raven *Corvus mellori*
Pacific gull *Larus pacificus*
Silver gull *Chroicocephalus novaehollandiae*
Domestic Chickens (free-range egg farming)
Domestic geese and ducks

Appendix 3: Information Gaps Influencing Degree of Uncertainty of this DRA

The following key information gaps were identified during the DRA workshop and provide a basis for prioritising future research to reduce the level of uncertainty in the expert judgements made in this risk analysis:

INFORMATION GAP
Cause of EBB population fluctuations and the role of disease
Threatened status of EBB parasites (should they be treated prior to moving?)
Is the disease status of different EBB populations equal?
Population impacts of toxoplasmosis on EBB
Can EBBs be a reservoir of Ross River Virus
Is the rufous bettong *Capillaria* sp at Mt Rothwell the same *Capillaria* sp causing lung lesions in some EBB?
Threshold cat densities to achieve reduced environmental contamination with *T. gondii*
Salmonella status of destination wildlife
Detection of *T. gondii* in the environment – estimating environmental contamination
Influence of pathogens such as *T. gondii* on increasing susceptibility to predation
Review of ectoparasite treatment effectiveness (to better understand treatment in wild to wild translocations).

Appendix 4: Diagnostic testing

DISEASE	DIAGNOSTIC TEST	SPECIFICITY	SENSITIVITY
Bandicoot Papillomatosis Carcinomatosis Virus 1 Bandicoot Papillomatosis Carcinomatosis Virus 2	Detection of DNA by PCR/ sequencing using tissues/swab samples: **not currently available.** Testing could be developed if required	High	High
Peramelid Herpesvirus-1	Detection of DNA by PCR/ sequencing. Tissues/swab samples tested at Faculty of Veterinary and Agricultural Sciences, The University of Melbourne, Parkville, VIC	High	Moderate
Encephalomyocarditis virus	Serology: virus neutralization assay available at Department of Primary Industries, Elizabeth Macarthur Agricultural Institute, Menangle, NSW	High	High
Ross River Fever Virus	Serology: virus neutralization assay available at the Victorian Department of Economic Development, Jobs, Transport & Resources, AgriBio, Bundoora, VIC	High	High
Coxiella burnettii	Serology (CFT) available at Department of Primary Industries, Parks, Water and Environment (DPIPWE) Mount Pleasant Laboratories, Prospect, TAS	High	Moderate
Leptospira interrogans	Serology for full VLE panel available at Gribbles Veterinary Pathology Clayton VIC: MAT for 10 serovars (Australis, Bataviae, Canicola, Grippotyphosa, Hardjo, Hebdomadis, Iceterohaemorrhagiae, Copenhageni, Pomona and Tarassovi). Other serovars can be requested as needed	High	High
Bacterial pathogens (*Pasteurella multocida, Erysipelothrix rhusiopathiae, Pseudomonas aeruginosa*)	Culture diagnosis from lesion, available at Gribbles Veterinary Pathology Clayton VIC	High, but dependent upon correct site selection, sampling technique and sample handling	High, but dependent upon correct site selection, sampling technique and sample handling
Salmonella spp., *Campylobacter* spp)	Culture diagnosis from faecal screening available at Gribbles Veterinary Pathology Clayton VIC	High	Moderate – will be increased if multiple samples are examined, as shedding may be intermittent
Chlamydia spp.	Detection of DNA by PCR/ sequencing. Tissues/swab samples tested at Asia Pacific Centre for Animal Health, Faculty of Veterinary Science, University of Melbourne, Werribee VIC	Moderate. May be difficult to attribute clinical significance to organisms that are detected	High
Mycobacterium spp.	Culture diagnosis from a lesion (culture may take up to 3m) Molecular diagnosis (detection of DNA by PCR + sequencing), performed at the Victorian Infectious Diseases Laboratory Mycobacterium Reference Laboratory, Parkville VIC	High High	High High

DISEASE	DIAGNOSTIC TEST	SPECIFICITY	SENSITIVITY
Cryptococcus spp.	Serology: Latex Cryptococcal Antigen Test (LCAT). Available through the Department of Veterinary Anatomy and Pathology, Faculty of Veterinary Science University of Sydney NSW	High	High
Dermatophytes	Culture of fungal organisms from lesions available at Gribbles Veterinary Pathology Clayton VIC	High	High
Toxoplasma gondii	Serology: MAT (IgG) available at DPIPWE, Mount Pleasant Laboratories, Prospect, TAS (submit through Gribbles)	High	High
Cryptosporidium spp., *Giardia* spp.	Examination of preserved or fresh faecal samples	High	Moderate – sensitivity will be increased if repeated samples are examined
Sarcocystis spp., *Klossiella* spp., *Spirometra erinacei*	Histologic examination of tissue lesions available at Gribbles Veterinary Pathology Clayton VIC	High	High
Eimeria spp.	Examination of faecal samples using $ZnSO_4$ centrifugal flotation method, to detect oocysts – performed within ZV veterinary facilities	High	Moderate. Oocyst shedding is variable
Ectoparasites	Detecting presence of parasites, or parasite-related lesions in the coat/skin during physical examination	High	Low-moderate, if parasite burden is low
Helminth parasites	Examination of faecal samples using $ZnSO_4$ centrifugal flotation method, to detect ova	High	Moderate
Haemoparasites	Examination of Giemsa-stained thin blood smears available at Gribbles Veterinary Pathology Clayton VIC	Moderate	Moderate. Sensitivity may be increased by examination of thick buffy coat smears
	Molecular analysis (DNA extraction, PCR and sequencing): **not yet developed for Peramelid haemoparasites**	High	High

References

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Appendix 5: Synopses of Diseases of Low to Negligible Risk for this Translocation

Infectious Diseases

Viral Diseases

Bandicoot Papillomatosis Carcinomatosis Virus 1 (BPCV-1); Bandicoot Papillomatosis Carcinomatosis Virus 2 (BPCV-2)

Clinical Signs and Pathology
- Progressively debilitating syndrome characterized by irregular thickenings and masses over the skin of the digits, body, pouch, and mucocutaneous junctions of lips and conjunctivae.
- Histologically classified as papillomatous hyperplasia.

Transmission
- The observed pattern of disease in captive *P. bougainville* populations suggests that disease is possibly transmitted through direct contact.

Diagnosis
- PCR from tissues.

Treatment
- No successful treatment.

Control
- No studies of disinfectant efficacy have been reported to date.
- Papillomaviruses and polyomaviruses are non-enveloped viruses, and therefore are resistant to many disinfectants. Studies investigating control of human papillomavirus types have reported that commonly-used clinical disinfectants have no effect on infectivity.

Prevention
- Specific guidelines have not been reported.
- Virus-positive individuals must be kept physically separated from negative individuals to prevent direct transmission.
- Care must also be taken to prevent indirect transmission through fomites.
- The role of vectors in the transmission of these viruses is unknown.
- Minimize exposure of individuals to environmental stressors:
  - Management considerations prior to release (parasite management, pre-release husbandry)
  - Choice of habitat at release site:
    - Vegetation for shelter/nest-building (type and quality)
    - Food supply (soil moisture, invertebrate density)
  - Season for release
    - Food supply for release animals (soil moisture, invertebrate density)
    - Temperature/rainfall and its impact on the animals themselves.

Epidemiological Factors
- BPCV-1 and BPCV-2 have been identified in two Peramelid species in Western Australia only.

- Both viruses have genomic properties of both the Papillomaviridae and Polyomaviridae.
- The mammalian papillomaviruses tend to be species-specific viruses; however, the mammalian polyomaviruses typically cause subclinical infections in their natural and immunocompetent hosts but may cause severe disease in the immunocompromised host. They may cause tumour formation when introduced into an unnatural host.

References

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Peramelid Herpesvirus-1

Clinical Signs and Pathology
- Herpesvirus infection is lifelong, being characterized by a primary infection event (with or without acute disease), followed by subclinical latency, and episodes of disease recrudescence during periods of stress/immunocompromise.
- Macropod Herpesvirus-3 (MaHV-3, a gammaherpesvirus) has been associated with outbreaks of respiratory disease in macropods. Signs included ataxia, nasal and ocular discharges, inappetence, lethargy, recumbency and death.
- Pathology at necropsy: widespread visceral necrosis and inflammation.

Transmission
- Via direct contact.

Diagnosis
- Virus isolation
- PCR
- Serology

Treatment
- No successful treatment.
- Supportive care for clinically-affected animals.

Control
- No studies of disinfectant efficacy have been reported to date.
- Gammaherpesviruses are enveloped viruses, therefore are presumed to be unstable in the environment and should be susceptible to common disinfectant strategies.

Prevention
- Specific guidelines have not been reported.
- Herpesvirus-positive individuals must be kept physically separated from negative individuals to prevent direct transmission.
- Care must also be taken to prevent indirect transmission through fomites.
- The role of vectors in the transmission of these viruses is unknown.

- Minimize exposure of individuals to environmental stressors:
  - Management considerations prior to release (parasite management, pre-release husbandry)
  - Choice of habitat at release site:
    - Vegetation for shelter/nest-building (type and quality)
    - Food supply (soil moisture, invertebrate density)
  - Season for release
    - Food supply for release animals (soil moisture, invertebrate density)
    - Temperature/rainfall and its impact on the animals themselves

Epidemiological Factors
- Herpesviruses have largely been detected in captive populations; however, they have potential to negatively impact free-ranging populations, also.
- Herpesvirus infection is widespread among a range of Australian marsupial species, and has been detected in bandicoots.
- In the common wombat, age and body condition score were identified as significant predictors for the presence of herpesvirus infection. It was proposed that the association between poor body condition and detection of herpesvirus DNA in wombats may be explained by a higher rate of new/reactivated infection as a consequence of immunosuppression associated with another disease process. Progressive urbanisation and habitat destruction were identified as possible causes, leading to higher levels of stress and increased potential of disease transmission.

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Encephalomyocarditis virus (EMCV)

Clinical Signs and Pathology
- The most common clinical presentation was sudden death.
- The gross pathologic changes were diffuse or focal pallor of the myocardium with occasional marked pulmonary congestion. Necrotising, non-suppurative myocarditis is consistently present.

Transmission
- Recommendations for EMCV control in zoological collections primarily involve reducing rodent numbers and preventing contamination of food and water with rodent excreta. However, the epizootiology of EMCV is poorly understood, and the role of rodents in the spread of EMCV has not been established conclusively.

Diagnosis
- Serology
- Gross and microscopic necropsy changes

Treatment
- No successful treatment.

Control
- EMCV is a picornavirus – a non-enveloped virus that may remain infectious for days, even in a hostile environment.
- Recommended disinfection techniques include: treatment at 60°C for 30 min, solutions containing 0.5 ppm of chlorine, and iodine-based disinfectants.

Prevention
- An inactivated EMCV vaccine has been developed in Australia.
- Recommendations for EMCV control in zoological collections primarily involve reducing rodent numbers and preventing contamination of food and water with rodent excreta.

Epidemiological Factors
- Epizootiology of EMCV is poorly understood, and the role of rodents in the spread of EMCV has not been established conclusively.
- EMCV has often been described as a potential zoonotic agent. However, an association between human infection and disease has not been clearly established.
- Both native and non-native rodents are present on Phillip Island and on French Island; however, the geographic distribution of disease probably depends on both prevalence of rodent host and presence of pathogenic strains in the reservoir host. *EMCV has not been reported in Victoria.*

References

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Bacterial Diseases

Erysipelothrix rhusiopathiae
Clinical Signs and Pathology
- Disease caused by *E. rhusiopathiae* manifests in a similar way in animals and humans. Erysipelas and polyarthritis are typical forms of infection in animals. Erysipeloid, a local skin infection or cellulitis, is a common presentation in humans.
- Acute erysipelas in swine is characterised by sudden death or general signs of septicaemia. Subacute erysipelas shows signs that are less severe than the acute form, and is characterized by cutaneous lesions. The chronic form of infection is characterised most commonly by signs of local arthritis or proliferative endocarditis.

Transmission
- The domestic pig is the most important reservoir of E. *rhusiopathiae.* It is estimated that 30–50% of healthy swine harbour the organism in their tonsils and other lymphoid tissues. Carriers can discharge the organism in their faeces, urine, saliva

and nasal secretions, creating an important source of infection. Soil, bedding, food and water can be contaminated by infected pigs, leading to the indirect transmission of the organism.
- Over 30 species of wild birds and at least 50 species of wild mammals are known to harbour *E. rhusiopathiae*, providing an extensive reservoir.

Diagnosis
- Diagnosis is based on isolation of the organism from aseptically collected tissue at necropsy or from a lesion biopsy collected while an affected animal is under anaesthesia.

Treatment
- There are no published reports of the efficacy of antibiotics in the treatment of these pathogens in Peramelids.
- In humans, cases of erysipeloid can be effectively treated with oral penicillin.

Control
- *E. rhusiopathiae* can be killed by commonly available disinfectants.

Prevention
- In pigs, disease is controlled by sound husbandry, herd management, good sanitation and immunisation procedures.
- Eryvac® vaccine (Zoetis Inc. Australia) is available for use in pigs in Australia.

Epidemiological Factors
- The organism is ubiquitous and is a pathogen or a commensal in a wide variety of wild and domestic animals, birds (including little penguins) and fish.
- Two serotypes that are commonly associated with erysipelas in pigs in Australia are infrequently detected in other animals.
- Two serotypes that were detected in Peramelids were found to be distinct from those causing disease in other species.
- Disease in Peramelids may associated with septicaemia (ARWH 2007 case 87/1910; MZ 2006 Case MZ 539).

References

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Mycobacterium ulcerans
Clinical Signs and Pathology
- *M. ulcerans* infection causes slowly progressive skin ulceration.
- The only non-human cases that have been reported occur in a range of mammal species in Victoria, including koalas, common ringtail possums, common brushtail

possums, a mountain brushtail possum, a long-footed potoroo, horses, domestic dogs, an alpaca and a domestic cat.

Transmission
- The precise mode(s) of transmission and environmental reservoir(s) of *M. ulcerans* are unresolved.

Diagnosis
- Diagnosis is based on isolation of the organism (via PCR) from aseptically collected tissue at necropsy or from a lesion biopsy collected while an affected animal is under anaesthesia.

Treatment
- Surgical excision of isolated lesions followed by prolonged treatment course using appropriate tuberculocidal drugs.

Control
- Resistant to many disinfectants. Suitable disinfectants include iodine 10%, alcohol 70%, and 10% phenolic disinfectants. Minimum contact time is 30 minutes.

Prevention
- The environmental reservoir and mode of transmission of *M. ulcerans* remain obscure, making it difficult to recommend prevention strategies.
- The geographically restricted epidemiology of *M. ulcerans* transmission means that risk is negligible outside endemic areas (coastal Victoria: east Gippsland, Phillip Island, Frankston-Langwarrin and the Bellarine Peninsula).

Epidemiological Factors
- There was a large, localised outbreak of *M. ulcerans* among humans on Phillip Island 1992-1995.
- Proximity to wetlands is a recognised risk factor for infection, and several studies have explored the role of aquatic invertebrate species as potential vectors and/or reservoirs.
- In Victoria, but not elsewhere so far, there is evidence that mosquitoes and possibly other biting insects may transmit the infection.
- Faeces of possums may contain *M. ulcerans* DNA, therefore possums may be an environmental reservoir for *M. ulcerans* in south-eastern Australia. The way in which *M. ulcerans* might be transmitted from an animal to humans is not clear.

References

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Veitch MGK, Johnson PDR, Flood PE, Leslie DE, Street AC and Hayman JA (1997) A large localized outbreak of *Mycobacterium ulcerans* infection on a temperate southern Australian island. *Epidemiology and Infection*. **119**, 313-318.

Non-tuberculous mycobacteria (NTM)

Consist of mycobacterial species other than those of the *Mycobacterium tuberculosis* complex and *Mycobacterium leprae*. While *Mycobacterium ulcerans* is a non-tuberculous mycobacterium it is excluded from this discussion (see more detailed description above).

Clinical Signs and Pathology

- Clinical disease due to NTM infection covers a broad spectrum of manifestations, including pulmonary disease, lymphadenitis, skin and soft tissue infection, and even dissemination in immunocompromised hosts. However, the most common disease manifestation of NTM infection is pulmonary involvement.

Transmission

- Given the appropriate host setting (e.g. immunosuppression or underlying pulmonary disease), disease can occur following environmental NTM exposure.

Diagnosis

- Diagnosis is based on isolation of the organism (culture, PCR) from aseptically collected tissue at necropsy or from a lesion biopsy.

Treatment

- Surgical excision of isolated lesions followed by prolonged treatment course using appropriate tuberculocidal drugs.

Control

- Mycobacterial organisms may be resistant to a range of disinfectants. Environmental treatment is generally not required. In cases where animals are suspected to have shed large numbers of organisms into substrate (e.g. from the gastrointestinal tract), removal of enclosure substrate may be required.

Prevention

- Maintain strict biosecurity protocols during captive breeding programmes, to minimise risk of transmission of infection from other captive birds/mammals held in the institution.

Epidemiological Factors

- NTM are ubiquitous in the environment and are found in natural aqueous reservoirs, soil, and potable water.
- Although animals may serve as a reservoir for NTM, direct animal to animal transmission is not thought to occur. However, shared drinking water systems with animals may serve as a source of infection. NTM have a significant impact on birds kept in confinement in zoos, aviaries, and captive breeding programs, and faeces from infected birds (and other animals) that are shedding the organisms via the intestinal tract are a principal source of infection for other animals. Mycobacteria can survive in soil for years. Hence, infected soil and other organic material is a potential source of infection for other animals.

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Leptospira interrogans; Leptospira weilii sv Topaz

Leptospirosis is a notifiable disease within Australia. It is an important zoonotic disease with worldwide distribution.

Clinical Signs and Pathology
- Classical symptoms of leptospirosis include fever, headaches, sweats, chills and myalgia. Some highly pathogenic serovars may cause pulmonary haemorrhaging and death.
- In cattle and pigs, signs of leptospirosis include reproductive failure, abortion, stillbirths, foetal mummification, weak piglets or calves and agalactia.

Transmission
- Animals recovering from leptospirosis may become asymptomatic carriers harbouring virulent leptospires in the renal tubules for extended periods, and shedding infectious leptospires into the environment.
- Species such as mice and rats serve as reservoirs for their host-related serovars (mice for Ballum, Icterohaemorrhagiae and rats for Copenhageni).

Diagnosis
- Diagnosis of leptospirosis depends upon a variety of laboratory assays such as detection of specific antibodies by microscopic agglutination test (MAT), by indirect hemagglutination assay (IHA) or by immuno-enzymatic assays (ELISA). Leptospires or their components may be detected in urine or tissues by culture, dark field microscopy, immuno-staining or PCR.

Treatment
- Leptospires are sensitive to most antibiotics.

Control
- Leptospires are destroyed by heat over 42°C but not by cold or freezing, iodine, chlorine, detergents (including soaps, free fatty acids and bile salts), and desiccation.
- Maintain strict biosecurity protocols during captive breeding programmes, to minimise risk of transmission of infection from other captive birds/mammals held in the institution.
- Maintain rodent control programmes in captive institutions
- Handwashing after animal contact is essential.

Prevention
- Control of the disease in domestic animals is based on prevention, vaccination (where applicable) and treatment.
- In cattle, vaccination is available for sv Hardjobovis or Hardjoprajitno and Pomona, pig vaccines are available for Pomona, Tarassovi and Bratislava.
- In wildlife, vaccination is not possible in most cases. Vaccination will generally only protect for up to six months.
- The use of vaccination can assist greatly in preventing infection and shedding in domestic carrier animals such as pigs and cattle. The incidence of infection in livestock on Phillip Island and French Island is thought to be very low, as a result of vaccination practices in place for livestock (L. Horstmann *pers. comm.*).

Epidemiological Factors
- In Australia, clinical leptospirosis occurs in cattle (serovars Hardjo, Pomona and

Zanoni) and pigs (Pomona, Tarassovi and Bratislava). Sporadic cases occur in sheep (Hardjo), horses (Pomona) and dogs (Copenhageni and Australis). Clinical cases have been reported in humans with sv Hardjo predominating, with some sv Pomona and occasionally sv Tarassovi, in the temperate regions of Australia.

- *L. weilii* sv Topaz is a newly emergent serovar in Australia. It is proposed that this serovar may be indigenous to Australia. Human cases involving sv Topaz infection have occurred dominantly in the far north of Queensland.
- *L. weilii* sv. Topaz infection has been isolated from three native animal species: *I. macrourus, P. nasuta* and the eastern grey kangaroo. Disease has so far been found in a single bandicoot; however, a NSW study population of eastern grey kangaroos revealed that leptospiral antibodies were detected in 47% (41 of 87) of serum samples collected. *L. weilii* sv Topaz was detected in all seropositive kangaroos.
- Antibodies to *L. interrogans* sv Balanica *and sv* Hardjo have been detected in brushtail possums in Victoria, and antibodies to sv Hardjo and Pomona have been detected in wombats in Victoria.
- *L. interrogans* serovar Perameles strain Bandicoot 343 has been detected in *P nasuta* from Queensland. Incidence of *Leptospira* spp. carriage in bandicoots, including EBBs*,* is not known.

References

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Coxiella burnetii

Clinical Signs and Pathology

- This illness is associated with a wide clinical spectrum, from asymptomatic or mildly symptomatic seroconversion to fatal disease.
- In humans, Q fever can manifest as an acute disease (mainly as a self-limited febrile illness, pneumonia, or hepatitis) or as a chronic disease (mainly endocarditis). In contrast, in animals, *Coxiella burnettii* is generally asymptomatic.

Transmission

- Infected ticks are probably most important in maintaining the life cycle of *C. burnetii*. The organism multiplies in the gut cells of ticks and large numbers of C. *burnetii* are shed in tick feces. Ticks may play a significant role in the transmission of *C. burnetii* among the wild vertebrates, especially in rodents, lagomorphs, and wild birds.

- People in contact with farm animals can be infected by inhalation of contaminated aerosols from amniotic fluid or placenta or contaminated wool. Rats may represent a major reservoir of *C. burnetii* from which domestic animals, especially cats, may become infected.

Diagnosis
- In humans, the diagnosis of Q fever relies upon serology. A variety of serological techniques are available, but the indirect microimmunofluorescent antibody test has become the reference technique.
- Isolation of *C. burnetii* is not performed for routine diagnosis in veterinary medicine. Diagnosis of *C. burnetii* in animals is usually established by examination of fixed impressions or smears prepared from the placenta stained by the Stamp, Gimenez or Machiavello methods, associated with serological tests.
- PCR kits are becoming available and provide a specific, sensitive and rapid tool for the detection of *C. burnetii* in various clinical samples.

Treatment
- Antibiotic regimes include use of tetracyclines, fluoroquinolones, rifampicin and trimethoprim-sulfamethoxazole (may be used during pregnancy).

Control
- *C. burnetii* can survive in the environment for prolonged periods. It is more resistant to chemical disinfectants than vegetative bacteria and rickettsiae.
- Liquid suspensions of the bacteria have been shown to be inactivated by 70% ethyl alcohol and by 2% Virkon S® within 30 minutes, but not by 0.5% sodium hypochlorite. It is resistant to UV light.

Prevention
- Maintain rodent control programmes in captive institutions
- Maintain appropriate monitoring and treatment programmes to eliminate translocation of tick-infested animals.
- Handwashing after any animal contact is essential.
- Q fever remains primarily an occupational hazard in persons in contact with domestic animals such as cattle, sheep and, less frequently, goats. Persons at risk from Q fever include farmers, veterinarians, abattoir workers, those in contact with dairy products, and personnel working with *C. burnetii*-infected animals. Humans working in high risk occupations should be vaccinated.
- Appropriate tick control strategies and good hygiene practice can decrease environmental contamination.

Epidemiological Factors
- Disease reservoirs are extensive, but only partially known, and include mammals, birds, and arthropods, mainly ticks. Although over 40 tick species can be naturally infected with *C. burnetii,* they appear to not be important in the maintenance of infections in livestock or humans.
- A quantitative PCR has been used to detect *C. burnetii* in ticks and wildlife species in northern Queensland. *C burnetii* DNA was detected in blood and ticks of eight mammal species studied, including *I. macrourus*.

- Evidence of *C. burnetii* exposure was detected in ticks and blood of *P. bougainville* living on offshore islands in Western Australia.
- Bandicoots are frequently implicated as a wildlife reservoir; however, risk of exposure from wildlife reservoirs appears to be low. Incidence of carriage in bandicoots, including EBBs, is not known.

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Pasteurella multocida

An opportunistic pathogenic bacterium with an extensive mammalian and avian host range.

Clinical Signs and Pathology

- In squirrel gliders, clinical signs are associated with skin or dental abscessation or with neurological signs.
- Ringtail possums develop septicaemia, usually secondary to cat bites. It has been isolated from a variety of pathologic processes in human patients also, commonly following animal bites.
- In squirrel gliders: otitis media/interna, meningitis, maxillary or cerebral abscess with multi-organ bacterial emboli. Suppurative panniculitis, acute interstitial pneumonia and pyogranulomatous lymphadenitis have been reported.
- Two EBBs that were released onto French Island during 2012 (MZ B10435 and MZ B10436) were found dead with evidence of systemic infection (septicaemia and peritonitis) and identifiable bite wounds that were consistent with cat predation. Lesions were not cultured, so the bacterial pathogen/s cannot be identified.

Transmission

- For many animals, it is considered as a normal oral, or respiratory tract resident which, following some predisposing stress, may flare to produce pathologic lesions and, often, fulminating septicemia and death. However, it is not clear whether the organism is present as part of the normal flora of Australian marsupials. Australian marsupials may be exposed from contact with organisms from other animal species, or following bite wounds.

Diagnosis

- Diagnosis is based on isolation of the organism from aseptically collected tissue at necropsy or from a lesion biopsy collected while an affected animal is under anaesthesia.

Treatment

- There are no published reports of the efficacy of antibiotics in the treatment of *Pasteurella* spp. in Peramelids.
- Microbial culture and sensitivity testing is likely to provide a useful means of determining the most effective antibiotic to use in clinical cases.

Control

Phenolic disinfectants, 1% sodium hypochlorite, 70% ethanol and iodine are effective against *Pasteurella* spp. *Pasteurella* spp. are inactivated by UV radiation, moist heat (121°C for at least 20 min), and dry heat (165-170°C for 2 h).

Prevention
- Reducing interaction between EBBs and predators.

Epidemiological Factors
- *Pasteurella multocida* is the predominant bacterial species isolated in cat bite wounds.
- *P. multocida* infections in marsupials have been reported in a red kangaroo (*Macropus rufus*),
  bandicoots and wombats, ringtail possums with septicaemia secondary to cat bites, and in eight cases of neurological disease affecting possums and gliders at Healesville Sanctuary, Victoria.

- For many animals, it is considered as a normal oral, or respiratory tract resident which, following some predisposing stress, may flare up to produce pathologic lesions and, often, fulminating septicemia and death. However, it is not clear whether the organism is present as part of the normal flora of Australian marsupials.

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Chlamydia spp.

Specifically: four *Chlamydiales* types were identified in *P. bougainville* with ocular disease. Organisms were identified by gene sequencing, and included a strain of *Chlamydia pecorum* different from strains previously found in koalas and several new *Chlamydiales* genotypes.

Clinical Signs and Pathology
- In *P. bougainville*, ocular infection resulted in corneal opacity, conjunctivitis, ocular discharge, and blepharitis. Histologic lesions have not been described (biopsy samples were not collected from affected bandicoots).
- In koalas, the presence of 'wet bottom' in males, and the presence of reproductive tract pathology in females, are significantly associated with *C. pecorum* infection.
- *C. pecorum* also causes a range of clinically important diseases in economically significant livestock species (cattle, sheep, goats, and pigs) manifesting as encephalomyelitis, reduced fertility, vaginitis and endometritis, enteric infections, mastitis, pneumonia, conjunctivitis, and arthritis.

Transmission
- In koalas, transmission is generally thought to occur by direct contact or aerosol. This can include faecal-oral transmission during pap feeding by dependent young, direct transfer of

infected discharges from the eyes and urogenital tract and venereal transmission. Invertebrate vectors are also capable of carrying and transmitting organisms.

- Despite the fact that *C. pecorum* is a major pathogen of domesticated animals with a worldwide distribution, still little is known about its transmission and the factors associated with *C. pecorum* infection in these hosts.

Diagnosis

- Swabs from conjunctivae/other ocular tissues to detect and identify Chlamydiales using PCR.

Treatment

- Ocular lesions in *P. bougainville* responded to systemic and topical tetracyclines.

Control

- Chlamydiae are susceptible to most detergents and disinfectants.

Prevention

- Maintain strict biosecurity protocols during captive breeding programmes, to minimise risk of transmission of infection from other captive birds/mammals held in the institution.
- There are no measures available to reduce risk of infection in free-ranging wildlife.

Epidemiological Factors

- Chlamydiosis is a well-described disease in free-ranging koalas in eastern Australia; however, the prevalence and pathogenicity of *Chlamydiales* infections in other Australian native species is largely unknown.
- In 2011, *Chlamydia pecorum* was detected in two koalas from French Island, a location considered previously free of Chlamydia infection. The sequence types were most closely related to published isolates of livestock rather than koala origin, suggesting potential cross-species transmission of *C. pecorum.*
- There is growing evidence to suggest that *C. pecorum* infection is endemic in livestock worldwide. *C. pecorum* is known to be prevalent in Australian sheep.

- Contact between bandicoots and koalas is likely to be infrequent (D. Sutherland *pers. comm.*). Livestock will be contacted more frequently.
- There are no reports of chlamydial disease affecting EBBs*.

References

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Warren K, Swan R, Bodetti T, Friend T, Hill S and Timms P (2005) Ocular Chlamydiales infections of Western Barred Bandicoots *(Perameles bougainville)* in Western Australia. *Journal of Zoo and Wildlife Medicine* **36**, 100-102.

Fungal Diseases

Dermatophytes: *Trichophyton* spp.
Clinical Signs and Pathology

- Clinical ringworm has been reported in kangaroos, wallaroos, and wallabies.
- In kangaroos, ringworm may present as an area of alopecia with minor reddening of the skin and 'little else'. In kangaroo joeys, in the 'classic' form there are discrete,

sometimes multiple areas of alopecia with no erythema. In the more severe, generalised form quite large areas may be involved and the skin is roughened and thickened with associated alopecia.

- Microscopic findings in ringworm appear to be similar across species. Skin changes are most prominent in hair follicles, which show ortho- and parakeratotic hyperkeratosis, acanthosis and dilatation. Follicular lumens may be full of neutrophils, fungal spores and hyphae.

Transmission

- People and animals become infected by dermatophytes after contact with spores (conidia).
- Some dermatophytes (anthropophilic species) are adapted to humans, and are generally transmitted from person to person. Others (zoophilic species) are adapted to animals.
- A few (geophilic) species normally live in the environment, but occasionally act as parasites.
- The zoophilic and geophilic species may be transmitted from animals to humans.

Diagnosis

Fungal culture is required to identify the causal fungus.

Treatment

Dermatophyte infections are treated with a variety of topical and oral antifungal drugs.

Control

- Dermatophyte spores are susceptible to benzalkonium chloride, dilute chlorine bleach (1% sodium hypochlorite), enilconazole (0.2%), formaldehyde and some strong detergents. In one study, Virkon S® prevented the growth of Microsporum canis from 87% of contaminated hairbrushes.
- The mechanical removal of any material containing keratin, such as shed skin and hairs, facilitates disinfection. Vacuuming is considered to be the best method in many cases. Dusting may also be appropriate. After mechanical removal, washable surfaces should be cleaned thoroughly with detergent and water.
- Dermatophytes are susceptible to high heat. Moist heat of 121°C, applied for at least 20 minutes, or dry heat of 165-170°C for 2 hours, are reported to be effective.

Prevention

- Maintain strict biosecurity protocols during captive breeding programmes, to minimise risk of transmission of infection from other captive birds/mammals held in the institution.
- There are no measures available to reduce risk of infection in free-ranging wildlife.
- Effective quarantine treatment of animals entering a captive/release location is essential. If parasitism is detected in newly-arrived captive animals, therapy should be completed so that infection is eliminated while the bandicoots are housed in their quarantine enclosures.
- To prevent infected animals from transmitting dermatophytes to others, they should be isolated until the infection has resolved. The premises should be cleaned and disinfected. Some environments (e.g., barns) may be difficult or impossible to decontaminate completely.

Epidemiological Factors
- Ringworm in wildlife species is of particular interest because of its zoonotic aspects, and the occurrence of clinical disease in wildlife carers.
- In several extensive surveys of Australian native mammals, various fungi, including some potentially pathogenic species (notably *Trichophyton* sp. and *Microsporum* sp.) were isolated, but in no case was isolation associated with clinical disease.
- A *Trichophyton* spp. has been isolated from bilbies in a captive colony.

References

Ladds PW (2012) Pathology of macropods. In: *Proceedings of a Wildlife Pathology Short Course*: 254-282. Revised by Barker IK. Camden, NSW.

Lynch M (2008) Bandicoots and Bilbies. In: *Medicine of Australian Mammals*: 439-464. L. Vogelnest and R. Woods (Eds.). CSIRO Publishing, Collingwood.

Centre for Food Security and Public Health (2013) Dermatophytosis, Iowa State University, accessed 18 January 2017 < http://bit.ly/2jud7sB >

Cryptococcus spp.

Clinical Signs and Pathology
- In one EBBs (MZ case 961022), the renal medulla contained a well-circumscribed focus of mild inflammation with large numbers of *Cryptococcus* spp. yeasts.
- In koalas, clinical cryptococcosis may be manifested as:
  - inappetence and weight loss;
  - nasal discharge and occasionally facial distortion
  - pulmonary disease is usually manifested as severe dyspnea
  - neurological signs have included blindness, nystagmus, a whole–body tilt and seizures.
- Grossly, lesions have been described as pale, firm nodules or as pale, gelatinous foci.

Transmission
- In cases of cryptococcosis, the most likely route of infection is through inhalation of airborne cryptococcal organisms from the environment.

Diagnosis
- Smears prepared from nasal discharges, cerebrospinal fluid, fine needle aspirates, impression smears, exudates from lesions, or macerated tissue dissolved in potassium hydroxide may allow rapid diagnosis by identification of characteristic yeasts.
- The latex–cryptococcal antigen test (LCAT) can be used to detect soluble cryptococcal capsular polysaccharide antigen in body fluid samples.

Treatment
- Successful treatment depends on early diagnosis, and requires long periods of therapy using appropriate antifungals.

Control
- *C. neoformans* is effectively killed by 70% ethyl alcohol and is susceptible to phenolic compounds, formaldehyde, glutaraldehyde, iodophors, and sodium hypochloride (1%).

Prevention
- Avoid contact between captive EBBs and known sources of cryptococcal organisms.
- There are no measures available to reduce risk of infection in free-ranging wildlife

Epidemiological Factors
- Cryptococcosis is caused by the *Cryptococcus neoformans* complex, including *C. neoformans* and *C. gattii.*
- The relatively high incidence of disease caused by *C. gattii* in koalas is believed to be the result of exposure to high environmental burdens of the organism.
- *C. gattii* has a well–recognised association with a number of *Eucalyptus* spp. trees, particularly the river red gum (*E. camaldulensis*) The presence of dead wood in tree hollows was found to be an important substrate for the organism.
- Infected animals do not themselves cause contamination of enclosures.
- Some cases of cryptococcosis in captive animals have been attributed to use of a mulch from Eucalyptus leaves/twigs as enclosure substrate.

References

Lynch M (2008) Bandicoots and Bilbies. In: *Medicine of Australian Mammals*: 439-464. L. Vogelnest and R. Woods (Eds.). CSIRO Publishing, Collingwood.

Blanshard W and Bodley K (2008) Koalas. In: *Medicine of Australian Mammals*: 227-328. L. Vogelnest and R. Woods (Eds.). CSIRO Publishing, Collingwood

Protozoal Diseases

Sarcosystis spp

Clinical Signs and Pathology
- In Australian native mammals and birds, *Sarcocystis* infections appear to be innocuous.

Transmission
- The life cycle and definitive hosts are not well-understood. All *Sarcocystis* spp. are assumed to have a carnivore definitive host and a carnivore and/or omnivore intermediate host.

Diagnosis
- Sarcocysts are found in tissues at necropsy. In birds, sarcocysts are overwhelmingly found in skeletal muscle, and occasionally in myocardium. In mammals, they are found in skeletal muscle, myocardium and gastrointestinal tissues.

Treatment
- No treatments are described.

Control
- Sarcocystis sporocysts are highly resistant to disinfecting agents. Heat treatment has been found to be the most effective means of killing *S. neurona* sporocysts in the environment.

Prevention
- Specific prevention measures are not necessary.

Epidemiological Factors
- Peramelids may act as intermediate hosts (IH).

- Infection in IH is often asymptomatic; however, disease may occur in livestock IH following ingestion of sporocysts from faeces of definitive host (DH) - predator species, including canids.

References

Ladds P (2009) Protozoal diseases in terrestrial mammals. In: *Pathology of Australian Native* Wildlife: 197-230. CSIRO Publishing, Collingwood, Australia.

Ladds P (2009) Protozoal Diseases in Birds. In: *Pathology of Australian Native* Wildlife: 235-260. CSIRO Publishing, Collingwood, Australia.

Munday BL and Mason RW (1978) Sarcocystis and related organisms in Australian wildlife: I. Survey findings in mammals. *Journal of Wildlife Diseases* **14**, 417-433.

Coccidiosis*: Eimeria* spp.

Clinical Signs and Pathology

- Coccidia from the genus *Eimeria* are frequently detected in the intestine and caecum of EBBs. Clinically significant infections appear to be very rare; however, disease may be seen in young animals (MZ 2006 cases MZP/40, A30171) or in animals suffering chronic stress/immunosuppression.
- Gross lesion found at necropsy are typically those of a severe haemorrhagic enteritis. Histologically, there may be proliferative enteritis associated with coccidial organisms. Focal hepatic/splenic necrosis may occur, associated with accumulations of schizonts.

Transmission

- Coccidia are transmitted directly through the faecal-oral route. Environmentally-resistant oocysts are passed in the faeces, and become infective after a short period of development (sporulation).

Diagnosis

- Large numbers of a small, unsporulated coccidian oocyst are frequently detected during examination of faeces from *P. gunnii*. Older faecal samples may contain oocysts that have sporulated to form four sporocysts.

Treatment

- Treatment with toltrazuril 10-20mg/kg PO has failed to eliminate infection. Trimethoprim-sulfadiazine (5mg/kg of trimethoprim component PO SID x 7 days) has also failed to eliminate infection.

Control

- Peroxide-based disinfectants (e.g. Virkon) have some efficacy against oocysts.
- UV exposure is effective (including direct sunlight)
- Environmental cleaning should focus on mechanical removal of faeces.

Prevention

- Minimize exposure of individuals to environmental stressors:
  - Management considerations prior to release (parasite management, pre-release husbandry)
  - Choice of habitat at release site:
    - Vegetation for shelter/nest-building (type and quality)
    - Food supply (soil moisture, invertebrate density)

- Season for release
    - Food supply for release animals (soil moisture, invertebrate density)
    - Temperature/rainfall and its impact on the animals themselves.
- Manual collection of faeces will reduce infectivity of an environment. Areas with boggy/poorly-drained soils should be avoided or measures undertaken to address these issues, so that survival of infective oocysts is reduced.

- Further research is required to better ascertain the pathogenicity of *Eimeria* in EBBs*.*

Epidemiological Factors
- All animals, particularly herbivores, appear to be natural hosts for coccidian species; there is a high degree of host specificity observed.
- In macropods, overcrowding and damp conditions enhance survival of oocysts leading to accumulation in the environment.
- Within managed animal populations, stress may occur when there is overstocking of enclosures (e.g. due to high intraspecific and interspecific competition for nesting sites and for food). Examples of stressors in zoos include forced proximity with humans and exposure to uncomfortable temperatures or substrates.
- Oocysts survive longer when the environment is cool and moist, therefore seasonal variations have been seen in oocyst shedding by EBBs.

References

AWHN (2011) Coccidiosis in Kangaroos Fact Sheet. *Australian Wildlife Health Network,* accessed 17 January 2017 < http://bit.ly/2k2cFoL >

Lynch M (2008) Bandicoots and Bilbies. In: *Medicine of Australian Mammals*: 439-464. L. Vogelnest and R. Woods (Eds.). CSIRO Publishing, Collingwood.

Norman, R J deB (1991). *Physaloptera peramelis* infection in the Eastern Barred Bandicoot (*Perameles gunnii*): taxonomy and pathogenicity. A report on a research project for a Diploma of Wildlife Medicine and Husbandry, University of Sydney (unpublished).

Klosiella quimrensis
Clinical Signs and Pathology
- In Peramelids, *K. quimrensis* appears minimally pathogenic. In *P. bougainville*, it has been indirectly associated with mild, multifocal interstitial lymphohistiocytic nephritis.

Transmission
- The complete life cycle of the organism remains unknown.

Diagnosis
- There is no method for antemortem diagnosis. Histology of multiple sections of kidney tissue, collected at necropsy, is the gold standard for definitive diagnosis.

Treatment
- No treatments are described.

Control
- Disinfection techniques have not been described.

Prevention
- Specific prevention measures are not necessary.

Epidemiological Factors
- A range of *Klossiella* species are parasitic in marsupial hosts.

References
Bennett MD, Woolford L, O'Hara AJ, Nicholls PK, Warren KS, Friend JA and Swan RA (2007) *Klossiella quimrensis* (Apicomplexa: Klossiellidae) causes renal coccidiosis in western barred bandicoots *Perameles bougainville* (Marsupialia: Peramelidae) in Western Australia. *Journal of Parasitology* **93,** 89-92.

Helminthiases

Capillaria spp.

Clinical Signs and Pathology
1. Intestinal disease and glossitis: infection appears clinically inapparent in most cases, and parasites may be an incidental finding during necropsy. Animals may present with signs of illness consistent with enteritis (diarrhoea, weight loss, hypothermia, lethargy). Parasitic glossitis, parasitism of the lips and oesophagus, parasitic gastritis and parasitic enteritis may be findings at necropsy.
2. Verminous pneumonia associated with presence of migrating larvae: HS nematode larvae were isolated from lung tissue and identified as *Capillaria* spp. This may be a different capillarid species to that frequently detected in the gastrointestinal tract, and its origin is not known.

Transmission
- Life cycle is suggested as being indirect, via an insect or annelid intermediate host. In that case, it is likely that there will be a low risk of transmission between IH and non-Peramelid DH. However, several species of *Capillaria* are believed to occur in EBBs. None have been defined to species level, and details of life cycle and transmission are not known.

Diagnosis
- Capillarid ova are frequently detected during examination of faecal samples from EBBs (using the zinc sulphate flotation method).
- Adult worms may be detected in the gastrointestinal tract during necropsy examination. Histologic examination of tissues will reveal presence of nematode larvae with associated inflammatory reaction.

Treatment
- Effective treatment has proved difficult. High-dose avermectin therapy (400ug/kg moxidectin), administered on two occasions pre-release, has been proposed.

Control
- *Capillaria* spp. ova are highly resistant and may survive in substrate for years.

Prevention
- Development of an effective anthelmintic regime pre-release will assist with control. Strategic pre-release treatment with avermectins may reduce risk of clinical disease.
- Minimize exposure of individuals to environmental stressors:

- o Management considerations prior to release (parasite management, pre-release husbandry)
- o Choice of habitat at release site:
  - ▪ Vegetation for shelter/nest-building (type and quality)
  - ▪ Food supply (soil moisture, invertebrate density)
- • Season for release
  - ▪ Food supply for release animals (soil moisture, invertebrate density)
  - ▪ Temperature/rainfall and its impact on the animals themselves.

Epidemiological Factors

1. Intestinal disease and glossitis: clinical illness has been detected in animals. A number of these animals presented with a history that suggested stress/concurrent disease may have played a role. They may present with signs of illness consistent with enteritis (diarrhoea, weight loss, hypothermia, lethargy).
   - • MZ B00094: a 12 week-old EBBs bred in captivity and recently weaned and moved to new enclosure (parasitic glossitis, enteritis and mild verminous pneumonia),
   - • MZ A90413, MZ A90443: two captive, adult EBBs that had suffered a period of severe stress (parasitic glossitis, parasitic enteritis)
   - • MZ B20406, MZ B10444: adult EBBs suffering concurrent disease following release (lingual nematodiasis, verminous pneumonia – both animals had concurrent toxoplasmosis)
2. Verminous pneumonia associated with presence of migrating larvae:
   - • Again, clinical illness has been detected in animals. Many had a history that suggested stress/concurrent disease may have played a role in development of clinically significant parasitism:
     - o MZ B00094 (see notes above) and MZ B20405 (died in poor condition following release onto French Island. Migrating parasite larva was detected in lung tissue; also gastric nematodiasis (*Physaloptera peramelis*) and a focal necrotic lesion containing protozoal organisms, possibly *Toxoplasma* spp.).
     - o WORZ B20070: captive, adult EBBs died with chronic multifocal pneumonia that included presence of larval nematodes.
     - o WORZ B20074: animal died with evidence of neoplastic disease affecting liver, spleen, lung, adrenal, bladder. In addition, there were small, curved, filarial nematodes resulting in bronchiolar pneumonia.
     - o HS B30389: nematode larvae were isolated from lung tissue and identified as likely *Capillaria* spp. This was thought to be a different capillarid species to that frequently detected in the gastrointestinal tract, and its origin is not known.

References

Lenghaus C, Obendorf DL and Wright FH (1990) Veterinary aspects of *Perameles gunnii* biology with special reference to species conservation. In: *Management and Conservation of Small populations*: 89-108. TW Clark and JH Seebeck (Eds.). Chicago Zoological Society, Brookfield, Illinois.

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Physaloptera peramelis
Clinical Signs and Pathology
Ulcerative gastritis may be seen when > 15 adult worms are present, attached to the gastric mucosa.

Histologically, there is severe, granulomatous inflammation of the submucosa.

Transmission
The life cycle is probably indirect, involving arthropod or insect intermediate hosts.

Diagnosis
Typical larvated spirurid ova may be seen following $ZnSO_4$ flotation of faeces.

Treatment
Fenbendazole 10-30mg/kg SID PO x three days has successfully treated this parasite.

Control
- General measures for cleaning and disinfection should reduce environmental parasite contamination. Bleach or ethanol treatment may reduce viability of spirurid eggs, which are believed not to be very resistant in the environment. Control in any environment should focus on mechanical removal of faeces from enclosures.

Prevention
- Manual collection of faeces will reduce infectivity of an environment. Areas with boggy/poorly-drained soils should be avoided or measures undertaken to address these issues, so that survival of infective ova/larvae is reduced. Strategic rotation of spelled enclosures may be required.
- Strategic anthelmintic therapy will effectively eliminate the parasite if ova are detected in faeces.
- Effective quarantine treatment of animals entering a captive/release location is essential. If parasitism is detected in newly-arrived captive animals, therapy should be completed so that infection is eliminated while the bandicoots are housed in their quarantine enclosures.
- Minimize exposure of individuals to environmental stressors:
  - Management considerations prior to release (parasite management, pre-release husbandry)
  - Choice of habitat at release site:
    - Vegetation for shelter/nest-building (type and quality)
    - Food supply (soil moisture, invertebrate density)
  - Season for release
    - Food supply for release animals (soil moisture, invertebrate density)
    - Temperature/rainfall and its impact on the animals themselves.

Epidemiological Factors
- *Physaloptera peramelis* is a spirurid parasite that is found in EBBs from Victoria, *P. nasuta* and *I. obesulus.*

- EBBs from Hamilton Community Parklands are found with infection (e.g. MZ case B20412).
- In general, overcrowding and damp conditions enhance survival of parasite ova, leading to accumulation in the environment.
- Within managed animal populations, stress may occur when there is overstocking of enclosures (e.g. due to high intraspecific and interspecific competition for nesting sites and for food). Examples of stressors in zoos include forced proximity with humans and exposure to uncomfortable temperatures or substrates.

References

Lynch M (2008) Bandicoots and Bilbies. In: *Medicine of Australian Mammals*: 439-464. L. Vogelnest and R. Woods (Eds.). CSIRO Publishing, Collingwood.

Norman, R J deB (1991). *Physaloptera peramelis* infection in the Eastern Barred Bandicoot (*Perameles gunnii*): taxonomy and pathogenicity. A report on a research project for a Diploma of Wildlife Medicine and Husbandry, University of Sydney (unpublished).

Other gastrointestinal helminths: *Strongyloides/Parastrongyloides* spp./*Peramelostrongylus* spp.

Clinical Signs and Pathology

- During necropsy, one juvenile EBBs from Hamilton Community Parklands was found to have numerous pinpoint foci of consolidation scattered throughout its lungs. These foci contained single larval nematodes in a nidus of atelectasis and inflammation. Larvae were considered to be migrating *Strongyloides/Parastrongylus* spp.
- Both *Capillaria* spp. and *Parastrongyloides australis* nematodes were considered the cause of enteritis and diarrhoea in several EBBs from Serendip Sanctuary that were examined at necropsy.
- A heavy burden of *Peramelostrongylus* spp. caused the death of a free-ranging juvenile EBBs, and *P. skedastos* is found in the stomach of EBBs, and migrating larvae of this parasite may cause pulmonary granulomas.

Transmission

- *Strongyloides and Parastrongyloides* are soil-transmitted helminths. The primary mode of infection is through contact with soil that is contaminated with free-living larvae. Infective larvae of Peramelostrongylus are ingested.

Diagnosis

- Parasites may be found in the gastrointestinal tract at necropsy. In freshly isolated faeces direct examination of a thick smear will reveal eggs and/or L1 stages. The eggs are ellipsoid, 40–85 µm in length, with a thin wall containing a larva. For lower intensity infections larvae can be collected from a greater faecal mass by the use of a Baermann funnel, or by using egg concentration techniques.

Treatment

- The avermectin anthelmintics are likely to be effective.

Control
- General measures for cleaning and disinfection should reduce environmental parasite contamination. Control in any environment should focus on mechanical removal of faeces from enclosures.

Prevention
- Manual collection of faeces will reduce infectivity of an environment. Areas with boggy/poorly-drained soils should be avoided or measures undertaken to address these issues, so that survival of infective ova/larvae is reduced. Strategic rotation of spelled enclosures may be required.
- Strategic anthelmintic therapy will effectively eliminate the parasite if ova are detected in faeces. Effective quarantine treatment of animals entering a captive/release location is essential. If parasitism is detected in newly-arrived captive animals, therapy should be completed so that infection is eliminated while the bandicoots are housed in their quarantine enclosures.
- Minimize exposure of individuals to environmental stressors:
  - Management considerations prior to release (parasite management, pre-release husbandry)
  - Choice of habitat at release site:
    - Vegetation for shelter/nest-building (type and quality)
    - Food supply (soil moisture, invertebrate density)
  - Season for release
    - Food supply for release animals (soil moisture, invertebrate density)
    - Temperature/rainfall and its impact on the animals themselves.

Epidemiological Factors
- In general, overcrowding and damp conditions enhance survival of parasite ova and larvae, leading to accumulation in the environment.
- Within managed animal populations, stress may occur when there is overstocking of enclosures (e.g. due to high intraspecific and interspecific competition for nesting sites and for food). Examples of stressors in zoos include forced proximity with humans and exposure to uncomfortable temperatures or substrates.

References

Lynch M (2008) Bandicoots and Bilbies. In: *Medicine of Australian Mammals*: 439-464. L. Vogelnest and R. Woods (Eds.). CSIRO Publishing, Collingwood.

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Sparganosis
Occurs following plerocercoid larval infection with the cestode, *Spirometra erinacei.*

Clinical Signs and Pathology
- Infection in intermediate hosts is mostly sub-clinical.

Transmission
- Infection of paratenic/secondary intermediate hosts (sparganosis) occurs via ingestion of a primary intermediate host (copepods, waterborne crustaceans).

Diagnosis
- Detection of plerocercoids at necropsy.

Treatment
- Surgical removal of masses.

Control
- Disinfection techniques have not been described.

Prevention
- There are no measures available to reduce risk of infection in free-ranging wildlife

Epidemiological Factors
- Adult *S erinacei* occur in a range of carnivores, including domestic dogs, dingoes, foxes and cats.
- Sparganosis occurs in diverse species groups, including humans and in Peramelids (*P. nasuta, I. macrourus*).

References
Ladds P (2009) Helminth Disease in Terrestrial Mammals. In: *Pathology of Australian Native* Wildlife: 227-312. CSIRO Publishing, Collingwood, Australia.

Haemoparasites

Trypanosoma spp., *Hepatozoon* spp.
Clinical Signs and Pathology
- No clinical consequences of infection have been identified.

Transmission
- The complete life cycle of these organisms remains unknown. These haemoparasites may infect humans, domestic animals, and wildlife, and are transmitted by blood-feeding invertebrate vectors.

Diagnosis
- Trypanosomes were detected in erythrocytes on Giemsa-stained blood films from EBBs. As the parasitemia was often low, a concentration technique was used to enhance detection of trypanosomes.
- Hepatozoon gametocytes may be seen when blood films are stained with Leishman stain and acridine orange.

Treatment
- No treatments are described.

Control
- Disinfection techniques have not been described.

Prevention
- Specific prevention measures are not necessary.

Epidemiological Factors

- Trypanosomes were observed in 10% of blood smears from EBBs in Tasmania.
- Of 220 wild EBBs captured in two locations in Tasmania, 55 (25%) had a detectable parasitaemia with gametocytes of the protozoan genus *Hepatozoon*.
- Eight native trypanosome species have been described from Australian indigenous mammals. Recent work has raised the possibility that infection with trypanosomes may be potentiating other disease syndromes in koalas.

References

Bettiol SS, Jakes K, Le DD, and Driessen M (1996) The first record of a member of the genus *Hepatozoon* in the eastern barred bandicoot (*Perameles gunnii*) in Tasmania. *Journal of Parasitology* **82**, 829-830.

Bettiol SS, Jakes K, Le DD, Goldsmid JM and Hocking G (1998) First record of trypanosomes in Tasmanian bandicoots. *Journal of Parasitology* **84**, 538-541.

McInnes LM, Gillett A, Hanger J, Reid SA, Ryan UM (2011) The potential impact of native Australian trypanosome infections on the health of koalas (*Phascolarctos cinereus*). *Parasitology* **138**, 873-83.

Non-Infectious Diseases

Motor Vehicle Trauma

Clinical Signs and Pathology

- Animals may suffer a range of injuries consistent with severe blunt force trauma.

Diagnosis

- Physical examination of injured animals, including radiographs.
- Gross necropsy findings that may be found following motor vehicle trauma include skeletal trauma (fractures), haemoabdomen/haemothorax, pulmonary oedema/haemorrhage, head trauma, acute myonecrosis.

Treatment

- Supportive care including analgesia and fluid support, repair of fractures/wounds as appropriate.

Prevention

- Mitigating measures might include:
  - Fauna exclusion fencing
  - Reduced speed limits and wildlife warning signs
  - Fauna movement structures, e.g. road underpass tunnels

Epidemiological Factors

- Road underpasses have been used to reduce road mortalities in koalas in northern NSW.
- On Phillip Island, road mortality is regarded as the major threat to the koala population, and in some years accounted for > 60% of total koala mortality.
- 52 EBBs from the Hamilton population were necropsied 1988-89, and 22 of these were found to have died from motor vehicle trauma. During the period 1990-1994, 136 EBBs were necropsied, and five animals were found to have died from motor vehicle trauma. It is thought that this reduction in road trauma deaths was the result

of the population having been almost entirely enclosed within a predator-proof fence at Hamilton Community Parklands.

References

Australian Wildlife Registry cases describing MVA trauma in Peramelids 2008-2015: UMEL-27/1, TARZ-9368/1, TARZ-9439/1.

Backhouse G and Crouch A (1990) Koala management in the western Port region, Victoria. In: *Biology of the Koala*: 313-317. AK Lee, KA Handasyde and GD Sanson (Eds.). Surrey Beatty and Sons, Chipping Norton, NSW.

Booth R and McCracken H (1994) Morbidity and mortality report for eastern barred bandicoots, *Perameles gunnii* 1990-1994. Melbourne Zoo (unpublished).

Lenghaus C, Obendorf DL and Wright FH (1990) Veterinary aspects of *Perameles gunnii* biology with special reference to species conservation. In: *Management and Conservation of Small populations*: 89-108. TW Clark and JH Seebeck (Eds.). Chicago Zoological Society, Brookfield, Illinois.

Trauma During Live Trapping

Clinical Signs and Pathology

- EBBs have suffered a range of injuries associated with repetitive digging/scratching while held in mesh traps during trapping surveys.

Diagnosis

- Physical examination of injured animals, including radiographs.
- Gross necropsy findings that may be found following trap trauma include skeletal trauma (fractures), severe abrasions to nails and soft tissues of the front feet, ulceration of the nasal planum, acute myonecrosis.
- Affected animals are frequently found dead in traps.

Treatment

- Supportive care including analgesia and fluid support, repair of fractures/wounds as appropriate.

Prevention

- Mitigating measures might include:
  - Providing adequate bedding inside traps to minimise the risk of hypothermia and stress
  - Providing well-fitted, opaque trap covers that reduce daylight disturbance
  - Redesign of traps to reduce risk of injury, e.g. use of traps made from smooth-sided PVC poly pipe is currently being investigated by Zoos Victoria.
  - Frequent checking of traps, with checks commencing at dawn
  - Traps must be well-maintained.

Epidemiological Factors

- Individuals will vary in their responses to trapping. Designs of traps and trapping procedures must minimise risk for all animals.

References

Necropsy records for Melbourne Zoo cases B10646, B30297, B40268, B50255.

Predation

Clinical Signs and Pathology

- Canids, including foxes: a necropsy survey of EBBs found that most animals that had suffered fox predation showed evidence of a fatal bite to the thorax causing severe subcutaneous haemorrhage. Skin was intact, and there were typically elliptical tears in the intercostal and abdominal musculature. Punctures were often paired, and were typical of canine incisors.
- Cat predation: cats appeared to be a greater threat to EBBs that are of smaller size. Sharp puncture wounds penetrate the skin and soft tissues. Bandicoots may survive the initial attack, but later die from complications of systemic infection.

Diagnosis

- Diagnosis of predation is usually made during necropsy, when gross abnormalities typical for predator-induced injury are found.

Treatment

- Supportive care of injured animals should include treatment with antibiotics that are effective against *Pasteurella multocida.*

Prevention

- Reduce contact between predators and EBBs:
  - predator-proof fencing
  - release into fox-free habitat

Epidemiological Factors

- French Island is fox free but has a population of feral cats.
- No foxes have been detected on Phillip Island since August, 2015. Feral cats are present (D. Sutherland *pers. comm*.).
- Two EBBs that were released onto French Island during 2012 (MZ B10435 and MZ B10436) were found dead with evidence of systemic infection (septicaemia and peritonitis) and identifiable bite wounds that were consistent with cat predation. Lesions were not cultured, so the bacterial pathogen/s cannot be identified.

References

Booth R and McCracken H (1994) Morbidity and mortality report for eastern barred bandicoots, *Perameles gunnii* 1990-1994. Melbourne Zoo (unpublished).

Lenghaus C, Obendorf DL and Wright FH (1990) Veterinary aspects of *Perameles gunnii* biology with special reference to species conservation. In: *Management and Conservation of Small populations*: 89-108. TW Clark and JH Seebeck (Eds.). Chicago Zoological Society, Brookfield, Illinois.

Appendix 6: Churchill Island Disease Risk Analysis

Project: Release of eastern barred bandicoots to Churchill Island.

Author: Michael Lynch, Veterinarian, Melbourne Zoo

Date: May 11th, 2015

Background

As part of recovery efforts for the Eastern Barred Bandicoot, it is proposed that 20 individuals be released at Churchill Island in August 2015. The Churchill Island release is an important trial as to the survival of Eastern Barred Bandicoots in this coastal environment. If successful, then a greater number of bandicoots will be released onto neighbouring Phillip Island. Bandicoots will be sourced from multiple populations; captive animals held at Melbourne Zoo, Werribee Zoo, Serendip Sanctuary and Healesville Sanctuary; free-ranging animals at Woodlands Historic Park and Mt Rothwell Conservation and Research Centre. Translocation of wildlife requires the consideration of risk of disease transmission. The aims of this qualitative analysis are to estimate the magnitude of disease risks, assess the importance of each risk (consequence) and to recommend mitigation measures where appropriate. This document will focus on infectious pathogens as the absence of existing Eastern Barred Bandicoots on Churchill Island makes the consideration of genetic disease not applicable to this discussion.

Methodology

It is necessary to define for the translocation, groups that are potential sources of pathogens and/or groups that may be impacted by disease exposure. I have defined these as:

1. The translocated Eastern Barred Bandicoots
2. Domestic and wild animals resident on Churchill Island
3. Captive animals of multiple species held at Melbourne, Werribee Zoos, Serendip Sanctuary and Healesville Sanctuary
4. Wildlife sharing habitat with bandicoots at Woodlands or Mt Rothwell

This process of disease risk analysis is then:

1. Hazard identification: Compilation of potential pathogens of Eastern Barred Bandicoots and an assessment of the potential of these pathogens to infect non-bandicoot species.
2. Estimation of the likelihood that the translocated bandicoot will be carrying these agents.
3. Assess the likelihood of disease establishment and spread in any of the at-risk populations and the subsequent consequences.
4. Risk to bandicoots from diseases potentially present in animals on Churchill Island.
5. Recommend risk mitigation strategies where appropriate.

Hazard identification and potential for transfer to non-bandicoot species

Generation of a list of potential pathogens to be considered for more detailed risk analysis is a critical step in the risk assessment process. Table 1 lists pathogens that have been reported from bandicoot species, the consequences of infection in bandicoots and the potential for transfer to other species.

Table 24: Bandicoot pathogens (Consequence: S = severe, PS = potentially severe, M = mild/ moderate).

PATHOGEN	CONSEQUENCE OF INFECTION	POTENTIAL FOR TRANSFER FROM BANDICOOT SP. TO NON-BANDICOOT SP.
Viruses		
Papilloma virus	S	Unlikely
Herpesviruses	S	Unlikely
Encephalomyocarditis virus	S	No
Bacteria		
Pseudomonas aeruginosa	PS	No
Proteus mirabilus	PS	No
Pasteurella multocida	PS	No
Erysipelothrix rhusiopathiae	PS	No
Salmonella spp.	PS	Yes
Non TB Mycobacterium spp.	PS	No
Protozoa		
Toxoplasma gondii	S	Yes
Eimeria spp.	M	No
Cryptosporidium muris	M	No
Sarcocystis spp.	M	Yes
Giardia duodenalis	PS	Yes
Fungi & Yeasts		
Trichophyton spp.	PS	Yes
Cryptococcus spp.	PS	Yes
Helminths		

PATHOGEN	CONSEQUENCE OF INFECTION	POTENTIAL FOR TRANSFER FROM BANDICOOT SP. TO NON-BANDICOOT SP.
Marsupostrongylus bronchialis	PS	No
Filostrongylus peramelis	PS	No
Physaloptera peramelis	PS	No
Capillaria (Eucoleus) spp.	M	No
Parastrongyloides spp.	M	No
Mites		
Ornithonyssus bacoti	M	Yes
Petauralges spp.	M	Yes
Sarcoptes-like spp.	PS	Yes
Demodex spp.	M	Yes
Mesostigmata sp.	M	Yes
Haemolaelaps marsupialis	M	Yes
Ticks		
Ixodes spp.	PS	Yes
Fleas		
Pygiopsylla sp.	PS	Yes
Stephanocircus sp.	PS	Yes

The likelihood that the translocated bandicoots will be carrying these pathogens is dependent in part on their source population (Table 2). Assessment of this likelihood is easiest in the captive animals as disease surveillance in this environment is at a high level. The difficulty in recovering bodies for post mortem examination from the free-ranging populations at Woodlands and Mt Rothwell results in a greater level of uncertainty around disease status at these sites. One consideration for the zoo environment is the proximity of a diverse range of animal species and therefore the need for strict biosecurity measures to isolate animals that are part of captive breeding and release programs. Figure 1 illustrates that transfer of disease from zoo collection animals can occur via indirect means by use of non-dedicated equipment and from keeper's hands and clothing. Similar hazards exist for staff capturing animals from Woodlands and Mt Rothwell if they are using equipment or wearing clothes that have had contact with domestic animals or has been used for other wildlife capture and transport without appropriate sterilization.

Figure 9: Points of potential pathogen transfer associated with Eastern Barred Bandicoots (EBBs)

Zoo collection animals

Boxes and transport materials   Boxes and transport materials

| EBBs from Woodlands, Mt Rothwell & Hamilton | → | EBBs from captive collections | → | EBBs at Churchill Island |

Hands/clothing
Bags/transport boxes

Hands/clothing/Boots
Food and dishes
Bedding/nets/bags

Direct and indirect contacts

Domestic pets/
other wildlife handled

Zoo collection
animals

Domestic and wildlife
species on CI

In regards to transfer of disease to resident animals on Churchill Island, the species present at that location are:

Native mammals: Red necked wallabies (not free ranging and plans to remove them)
Swamp wallaby
Brushtail possum
Water rats

Nesting birds: Masked lapwings
Pied Oyster catchers
Red-capped plover
Cape Barron geese

Farm animals: Cattle
Sheep
Horses
Pig
Guinea Pigs – kept in pens/cages

Introduced species: House mice
                       Black rats

Pathogens likely to be carried by translocated bandicoots

Table two presents the pathogens likely to be present in the translocated bandicoots and an indication of the host range of these pathogens. Based on available knowledge it appears that only fleas and ticks are the likely pathogens capable of being transferred.

Table 25: Likely pathogens in translocated bandicoots and susceptibility of resident species to infection.

SOURCE POPULATION	PATHOGENS LIKELY TO BE PRESENT IN EBBS	THEORETICAL TRANSFER TO RESIDENTS
Captivity (MZ and WORZ)	*Eimera* spp. *Capillaria* spp.	None. Bandicoot-specific pathogens
Woodlands	*Eimera* spp. *Physaloptera peramelis* *Capillaria* spp. *Ixodes* spp.	Ixodes spp to mammals & birds
Mt Rothwell	*Eimera* spp. *Physaloptera peramelis* *Capillaria* spp. *Ixodes* spp. *Pygiopsylla* sp. *Stephanocircus* sp.	*Ixodes* spp. to mammals & birds *Pygiopsylla* sp. to mammals *Stephanocircus* sp to mammals

Likelihood of disease establishment and spread from bandicoots and subsequent consequences.

The *Ixodes* species that have been described in Eastern Barred Bandicoots within the last 20 years have all been from the Western Victorian region. Two species, *Ixodes tasmani* and *I. faecialis* have been found and these are likely to be widespread in their geographical and host range. The status of these species on Churchill Island is unknown. Eastern Barred Bandicoots were historically considered to be one of the natural hosts of the paralysis tick, *Ixodes holocyclus* but this tick is found in coastal Eastern Victoria. The major impact of tick infestations potentially carried by the translocated bandicoots is likely only on the bandicoots themselves. The flea species described from Eastern Barred Bandicoots are not species specific and are widespread geographically in a range of marsupial species. Again these fleas are most likely to have greatest impact upon the bandicoots themselves.

Risk to bandicoots from pathogens in the domestic and wild animal species on Churchill Island

The disease status of resident animals on Churchill Island is unknown, therefore a detailed risk analysis as to the potential impact on bandicoots is not currently possible. Of most likely significance are bacterial enteric (intestinal) pathogens that are common in birds and mammals (e.g. *Salmonella* spp. and *Campylobacter* spp.). The exposure of bandicoots to such pathogens also depends on the overlapping use of habitat between them and resident animals. Of note is that cats, the carrier of the protozoan parasite *Toxoplasma gondii* are not present on the island. This pathogen can result in high mortality rates in infected bandicoots. Ultimately, while it is unlikely that pathogens in Churchill Island resident animals will significantly impact the translocated bandicoots the assessment of this will rely upon monitoring the latter's health, post-release.

Risk mitigation measures

Appropriate biosecurity is the cornerstone of preventing introduction of disease pathogens to captive or free-ranging bandicoot populations. In the zoo setting the prevention of pathogen transfer largely relies on the maintenance of healthy collection animals via existing quarantine, preventative medicine and disease surveillance programs. Specifically Appendix A details biosecurity measures specific to this project.

The removal of ectoparasites by appropriate treatment and transfer to a non-contaminated environment is recommended largely to reduce health impacts on bandicoots. In addition, it is acknowledged that some of these ectoparasites are not species specific and their current status on Churchill Island is unknown. Therefore, this provides an additional prompt to treat these infestations prior to release. This implies that bandicoots will not be transferred from field sites to Churchill Island without receiving a veterinary examination.

Conclusion

The translocation of Eastern Barred Bandicoots from Melbourne Zoo, Werribee Zoo, Serendip Sanctuary, Healesville Sanctuary, Mt Rothwell and Woodlands is an acceptable risk in regards to the potential transfer and impact of disease pathogens. All animals should receive a veterinary examination and be treated for ectoparasites if they are present.

Appendix 7: Zoos Victoria Pre-Release Health Assessment Protocol

Hygiene and Health monitoring

On a daily basis, all food dishes and water bowls are removed, washed and fresh food and water provided. Enclosures are given a thorough clean every 1-2 weeks. This involves replacing the grass hay nesting material and scrubbing nest boxes, logs and walls with F10 disinfectant solution. Large eucalypt branches and grass tussocks are changed as required, generally every 2-3 weeks. The substrate should remain at least 100 mm deep and topped up as required. Changing the substrate is rarely necessary. In the event of an infectious disease, the substrate is replaced after the animal has been treated, to avoid transmission to other individuals.

Bandicoot movement is checked daily though tracks left in the sand at the front of their enclosure. Bandicoots are generally caught every month to obtain a weight, assess body condition, check for injuries or other health problems, and parasites. Weekly checks are advised if a pair has been introduced to check for any signs of aggression or the presence of pouch young, if an animal is losing weight, the diet has been altered, an animal suffers from hair loss or any sign of injury, or juveniles have been recently separated from their mother. Once a female is found to be carrying pouch young she is likely to lose them if handled too frequently, especially once they reach 20 days old. Therefore handling females with pouch young is avoided unless absolutely necessary.

Biosecurity and Translocation Procedures

Project: Translocation of 20 Eastern Barred Bandicoots from Melbourne Zoo, Werribee Zoo, Serendip Sanctuary, Healesville Sanctuary, Woodlands Historic Park and Mt Rothwell to Churchill Island

Capture at Woodlands and Mt Rothwell

Aims:

1. Prevention of disease pathogen transfer from domestic animals and other wildlife to captured bandicoots.

2. Prevention of translocating diseases or parasites with captured bandicoots that may impact other animals at the destination

3. Selection of bandicoots for translocation that are in a suitable state of health

Basic Biosecurity Procedures

Animal transport crates

- Transport boxes that have been used for other species: Before use, clean with soap and water then disinfect using F10 SC (Health and Hygiene PTY, LTD. South Africa) or similar.
- New transport bedding material

Hands and Clothing
- Staff conducting the field capture must be aware of the potential for transfer of pathogens from hands and clothing and take appropriate care. E.g. Wash hands before handling bandicoots. Use bandicoot-only nets and weigh bags. Wear clean clothing if you have been in contact with other wild or domestic animals.

Examination Protocol

All animals captured at Woodlands and Mt Rothwell are to receive a veterinary examination to assess their suitability for translocation. The absence of cats on Churchill Island has reduced the need to collect blood samples for base-line serology so examinations can be performed under light manual restraint while bandicoots are held in calico bags. Examinations must include:

- Measurement of body weight.
- Estimation of body condition. Animals in below average condition should be excluded from the translocation
- Recording of presence or absence of pouch young including number and head length. Animals with pouch young with head length greater than 20mm should not be translocated.
- Assessment of any foot and toe injuries
- Assessment of the animal's age as judged by degree of molar wear. Animals in advanced stages of molar wear should be excluded from the translocation.
- Photograph of occlusion between upper and lower incisors and estimation of set-back of mandibular incisors
- Examination of eye and specifically noting of the presence or absence of lens opacity
- Thorough examination for the presence of ectoparasites (ticks, fleas and mites) and treatment with selamectin at 6mg/kg if present. If treated animals have previously been held in boxes, they must be transferred to a new box with new bedding after treatment.
- Collection of skin punch biopsy from the thin skin of the lateral ear margin.

At Mt Rothwell, bandicoots will be net-caught at night and receive a veterinary examination in the field. If judged suitable for translocation they will have collars applied and held overnight. Prior to release at Churchill Island the bandicoots will be briefly examined again to make sure collars have not been applied too tightly. At Woodlands bandicoots will be captured by trapping and assessed for translocation suitability by a veterinarian on site. If suitable they will be collared and transported to Churchill Island directly for release at disk.

Animals sourced from Melbourne Zoo, Werribee Zoo and Healesville Sanctuary
Aims:

1. Prevention of disease pathogen transfer between zoo collection animals and bandicoots

2. Prevention of disease pathogen transfer between free ranging rodents and birds within the zoo environment to bandicoots

3. Prevention of disease transfer from domestic animals to bandicoots

4. Prevention of translocating diseases or parasites with bandicoots that may impact other animals at the destination

5. Selection of bandicoots for translocation that are in a suitable state of health

Basic Biosecurity Procedures
Enclosure design and use
- Enclosures holding bandicoots should be rodent proof and exclude free-ranging birds
- Bandicoots should not share enclosures with other species

Servicing
- Dedicated footwear (rubber boots) when servicing enclosures
- Disinfectant footbath (Appendix B) to be placed at the exit/entry points of the bandicoot facility. Use this after changing into rubber boots.

Enclosure equipment
- Dedicated cleaning, catching and weighing equipment assigned to each bank of bandicoot enclosures
- Dedicated food and water dishes for bandicoot enclosures. These dishes should be cleaned and dried before reuse.

Hands and Clothing
- Use F10 hand-gel disinfectant before and after servicing bandicoots
- Wear protective scrub top or lab coat when handling bandicoots

Examination Protocol
All animals from the three ZV properties will receive a veterinary examination under anaesthesia a week prior to release. The examination protocol is identical to that applied to bandicoots captured from Woodlands and Mt Rothwell excepting the collection of blood samples for serum storage. This serum may be valuable for retrospective disease investigations if health issues are identified post-release. If judged suitable for translocation, bandicoots will have collars applied at this examination. The collar will be checked the next morning and then again on the day of transfer to Churchill Island.

All ZV bandicoots should have two faecal samples collected within two-weeks of release for endoparasite investigation. This is for recording purposes only as the recovery team current supports a philosophy of allowing the natural bandicoot-specific parasites to be translocated with the animals as part of their microflora.

Animals sourced from Serendip Sanctuary

Aims:

1. Prevention of disease pathogen transfer from domestic animals and wildlife held at this facility to captured bandicoots.

2. Prevention of translocating diseases or parasites with captured bandicoots that may impact other animals at destination

3. Selection of bandicoots for translocation that are in a suitable state of health

Basic Biosecurity Procedures

Servicing

- Dedicated footwear (rubber boots) when servicing enclosures
- Disinfectant footbath (Appendix B) to be placed at the exit/entry points of the bandicoot facility. Use this after changing into rubber boots.

Enclosure equipment

- Dedicated cleaning, catching and weighing equipment assigned to each bank of bandicoot enclosures
- Dedicated food and water dishes for bandicoot enclosures. These dishes should be cleaned and dried before reuse.

Hands and Clothing

- Use F10 hand-gel disinfectant before and after servicing bandicoots
- Wear protective scrub top or lab coat when handling bandicoots

Examination Protocol

All animals from Serendip are to be examined the day before release under light manual restraint while bandicoots are held in calico bags. Examinations as are for the bandicoots from Woodlands and Mt Rothwell. If judged suitable for translocation, bandicoots will have collars attached at this examination and the collar fit checked when boxed up the following day for transfer to Churchill Island.

Footbath Protocol

Boots contaminated with organic debris (substrate, faeces) can serve as a mechanism for transporting infectious agents from one enclosure to another. To reduce this risk we will use a 1% Virkon Solution for all footbaths.

Instructions to make 1% Virkon solution:

- Add 1 tablet of Virkon S to 5 litres of water. Follow SOP located on the ZV intranet site (Virkon SOP)
- 1% Virkon S solutions are *stable for approximately 7 days or until the pink colour fades*.

Protocol for use of Footbaths:

- Boots should be rinsed in water to remove any dirt/sand/substrate before stepping in the Virkon footbath. *Allow boots to contact the Virkon footbath solution for 30 seconds*.

- Footbaths should be covered when not in use (unless indoors), as UV exposure will inactivate the disinfectant solution, rainfall dilutes solution and sun evaporates solution. Keep bath covered with the lid provided, a wooden board or a second tub.

- Footbath solution should be replaced every *7 days or when the pink colour fades.* If in a high traffic area, they may need replacing frequently as they may become contaminated with visible dirt and/or organic matter, which will cause the disinfectant to become ineffective.

Appendix 8: Workshop Program

Day 1: Thursday 4 August, 2016

TIME	TOPIC
8.30	Registration
9.00	Welcome
9.10	Background and goal, scope, focus and question(s) for this workshop; assumptions and limitations; acceptable risk; capture of information gaps
9.40	Introductions and group working agreement
10.10	Coffee break
10.30	Overview of IUCN-SSC/OIE Disease Risk Analysis process and review of workshop programme
	Value and purpose of workshop – elicitation of expert opinion/stakeholder support
	Small group and plenary sessions (presenters, time keepers, recorders)
	Information capture (flip charts, laptops, photos)
	STEP 1: PROBLEM DESCRIPTION
11.00	Discussion of briefing notes – errors and gaps
11.30	**STEP 2: HAZARD IDENTIFICATION (HI)**
	Review hazard list – additions? (whole group)
	Prioritization exercise: consider risk *to* EBBs, risks *from* EBBs to wildlife, domestic animals, people (small groups)
	Translocation pathway (small group)
12.15	LUNCH
1.00	Review of HI step (plenary)
1.30	**STEP 3: RISK ASSESSMENT (high priority hazards)**
	Overview of steps:
	• Identify populations of interest • Hazard risk pathways and CCPs (small group) • Release assessment (discard if negligible) • Exposure assessment (discard if negligible) • Consequence assessment (discard if negligible) • Risk estimation (High, Medium or Low)
	Record basis for each assessment including any citations

2.00	Risk Assessments (hazard focussed small groups)
3.15	Coffee break
3.25	Risk Assessments (small groups continued)
4.40	Risk Assessments review (plenary)
5.10	Discussion of acceptable risk
5.30	Review of day and agenda for day 2
5.40	**END OF DAY 1**

PM Social evening

Day 2: Friday 5 August, 2016

TIME	*TOPIC*
8.30	Introduction to the day
	STEP 4: RISK MANAGEMENT
8.45	Review of risk assessments vs acceptable risk
9.15	Risk management options for each CCP on risk pathway diagram against desired outcome (brainstorm)
10.15	Coffee break
10.45	Risk management assessment: effectiveness and feasibility (operationally and technically) (small groups)
12.20	Review of risk management assessment and research priorities (plenary)
1.00	LUNCH
	STEP 5: IMPLEMENTATION & REVIEW
2.00	Complete Action Plan to implement and monitor results of the risk management plan
3.00	Coffee break
	STEP 6: RISK COMMUNICATION
3.30	Review list of stakeholders and draft communications plan
4.00	Workshop review against Goal and Question(s); next steps
4.25	Workshop evaluation
4.45	Farewell
	END OF WORKSHOP

Appendix 9: Workshop Participants

Name	Organisation	Email address	Relevant Expertise
Alison Pitt	French Island Landcare	fi.llamas@bigpond.com	Chair of French Island Landcare. Community and farming interests on French Island.
Amy Coetsee	Zoos Victoria	ACoetsee@zoo.org.au	Recovery team member since 2005. Completed PhD on EBBs and now manages Zoos Victoria's EBB projects
Dan Harley	Zoos Victoria	dharley@zoo.org.au	Contributes to the design and implementation of several threatened species recovery programs. Involvement in several release programs over the past 20 years. A member of several recovery teams.
Duncan Sutherland	Phillip Island Nature Parks	dsutherland@penguins.org.au	Wildlife ecology researcher on Phillip island; monitoring of EBBs; pest animal management; member of the EBB Recovery Team
Georgia Kerr	Parks Victoria	georgia.kerr@parks.vic.gov.au	Area Chief Ranger for Northern Peninsula, including French Island
Ian Beveridge	The University of Melbourne	ibeve@unimelb.edu.au	Professor in Veterinary Parasitology, 40 years' experience working with helminth and some protozoan parasites of marsupials.
Jasmin Hufschmid	The University of Melbourne	huj@unimelb.edu.au	Wildlife health researcher and lecturer at FVAS, The University of Melbourne. Epi membership ANZCVS; some previous experience with wildlife disease risk

Name	Organisation	Email address	Relevant Expertise
			analysis (e.g. WNS in bats).
Jenny Hibble	PINP vet	hibblej@waterfront.net.au	Veterinarian in general practise with >25 years' experience working with PINP wildlife. Also PINP Animal Ethics Committee Chair.
Marissa Parrott	Zoos Victoria	mparrott@zoo.org.au	Reproductive Biologist with extensive experience of marsupial reproduction, captive breeding and reintroduction. Recovery team member since 2008. Species coordinator for the captive insurance program. Has been involved with risk analyses for other species (e.g. mountain pygmy-possum)
Mark Hawes	Department of Economic Development, Jobs, Transport and Resources	mark.hawes@ecodev.vic.gov.au	Veterinary Pathologist, Department of Economic Development, Jobs, Transport and Resources. State Coordinator for Wildlife Health Australia
Michael Lynch	Melbourne Zoo	mlynch@zoo.org.au	Extensive involvement with EBB program over 20 years. Critical analysis skills gained through my work history and completion of PhD in disease ecology
Natalie Rourke	Zoos Victoria	nrourke@zoo.org.au	Senior veterinarian at Werribee pen Range Zoo for past 10 years. Involved with treating captive and wild EBBs over the last 12 years since studying the Melbourne Zoo veterinary residency program.

Name	Organisation	Email address	Relevant Expertise
Paul Eden	Healesville Sanctuary	peden@zoo.org.au	Head vet at Healesville sanctuary, working with wildlife for 15 years, including work in the field with health assessment of wild native animals.
Rebecca Traub	The University of Melbourne	rebecca.traub@unimelb.edu.au	Associate Professor of Veterinary Parasitology at the University of Melbourne, whose main focus is the epidemiology and molecular diagnosis of parasites of zoonotic significance (direct, food and vector-borne)
Richard Hill	DELWP	Richard.Hill@delwp.vic.gov.au	Chair of the recovery team since 2005 MSc on conservation biology of island rainforest owl. Included review of diseases on island birds.
Richard Jakob-Hoff	CBSG/Auckland Zoo	richard@cbsgaustralasia.org	Wildlife and zoo veterinarian and CBSG facilitator; Conservation Science manager at Auckland Zoo, NZ.
Simon Firestone	The University of Melbourne	simon.firestone@unimelb.edu.au	Veterinary epidemiologist, recently involved in risk analysis of WNS in bats.