Biological Conservation 197 (2016) 247–253

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/bioc

Discussion

Koala translocations and *Chlamydia*: Managing risk in the effort to conserve native species

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ARTICLE INFO

Article history:
Received 16 July 2015
Received in revised form 12 February 2016
Accepted 18 March 2016
Available online 2 April 2016

Keywords:
Koalas
Chlamydia
Translocation
Molecular typing
Conservation
Disease

ABSTRACT

Translocation of the koala (*Phascolarctos cinereus*) has been a controversial measure that has been utilised for over a century in the southern states of Australia. Recently, translocation has been suggested as an option in the management of some declining northern koala populations. Infectious diseases present within donor and recipient populations are important factors that must be considered when planning any wildlife translocation. In the koala, infectious diseases, caused by the bacterial pathogen *Chlamydia pecorum*, are one of the key threats to koala conservation. In recent years, significant progress has been made in understanding the biology and epidemiology of koala *C. pecorum* infections revealing complex patterns of infection and disease and the potential for 'spill-over' from *C. pecorum* infected livestock. Here, in light of this new epidemiological data, we provide a discussion of risk assessment and management in the context of enzootic chlamydial infections. We conclude that without careful investigation and management, significant risk of pathogen transfer is likely, especially for larger and more distant translocations. Thus, for such a programme to be appropriate, they must: 1) perform adequate molecular screening methods for *Chlamydia* at both donor and recipient sites; 2) implement risk mitigation strategies that avoid transmission of *Chlamydia* genotypes that are not enzootic to the recipient site; and 3) assess and mitigate risk associated with potential transmission between koalas and livestock. Standardised and comprehensive veterinary procedures are crucial in the assessment and management of disease and infection transmission risk, and telemetric monitoring is essential for the post-release monitoring of both translocated and resident koalas at the recipient site and subsequent evaluation of programme success.

1. Introduction

Wildlife translocation (defined as the human-managed movement of individuals of a species from one area for re-release in another in order to 'establish, re-establish, or augment' a population [Griffith et al., 1989]) is being increasingly used to mitigate anthropogenic impacts such as fragmentation, habitat loss and rapid climate change (Thomas, 2011). Premature translocations often fail or complications manifest due to a lack of understanding of infectious disease dynamics in the recipient population, the translocated animals, and to the larger host community (Cunningham, 1996; Kock et al., 2010).

Translocation is a controversial measure that is becoming increasingly recognised as a politically acceptable and practical means of managing free-ranging koala (*Phascolarctos cinereus*) populations in Australia. In the southern states of Australia, koalas originally translocated onto koala-free islands were so successful that they were then utilised for reintroduction of animals (translocations) to mainland habitat. Eventually, however, these same practices were employed primarily to prevent overbrowsing of koala food trees associated with explosions in koala numbers (Copley, 1994; Martin and Handasyde, 1990; Short, 2009). In declining northern koala populations under threat from urban development, this conservation tool has recently been suggested as the only viable option to protect the most at-risk koalas in intense urban development areas in south-east Queensland (Callaghan et al., 2014). Indeed, two large government-funded projects involving koala translocations have been conducted in the past 5 years (Callaghan et al., 2014; Department of Transport and Main Roads, 2015), the long-term results of which are still yet to be published. Globally, in other wildlife species, there is evidence to suggest that if translocation is conducted inappropriately, an increased susceptibility to disease threats can occur in resident and/or translocated animals (Kock et al., 2010). While translocation of koalas has been suggested as the best approach to saving animals at risk of displacement through habitat clearing, the implications for disease transmission have been largely overlooked. The purpose of this commentary then, is to consider the purpose and risks of koala translocation in the context of chlamydial disease, a threat to koala health that may: 1) influence the success of translocation events and/or; 2) increase the risk of disease in the resident koala population, thereby creating a net negative

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http://dx.doi.org/10.1016/j.biocon.2016.03.018
0006-3207/

effect for koala conservation. We also make key recommendations for mitigating these risks when translocation of koalas is considered to be necessary in the circumstances.

Other factors such as habitat carrying capacity, habitat diversity and refugia, connectivity, genetics, natural geographic barriers, regional population conservation, are important considerations for koala translocation, and must also be considered, however, these are beyond the scope of this paper.

2. A history of koala translocation and the associated issues

The koala is a unique arboreal marsupial and iconic representative of Australia's biodiversity. Despite widespread esteem for this marsupial, concerning evidence is mounting that koala numbers are in decline. Indeed, the United States of America Government has listed the koala as a 'threatened species' under the US *Endangered Species Act* since 2000 (Tabbart, 2012). In Australia, ongoing studies of northern koala populations (i.e. Queensland and New South Wales), by koala management authorities (i.e. state and local governments) and research groups strongly suggest that koala numbers are in decline and that localised extinctions of regional populations are, or will soon be, occurring (Rhodes et al., 2011). In recognition of this decline, the status of the koala in these states and the Australian Capital Territory (ACT) was recently reclassified as "vulnerable to extinction" (Environment Protection and Biodiversity Conservation Act 2014). On the other hand, koala populations in southern states (i.e. Victoria and South Australia) suffer from localised overpopulation and lack of genetic diversity, causing a vastly different profile of vulnerability and population instability. In the early 20th Century, koala numbers in these states experienced severe declines due primarily to hunting and land clearing (Warneke, 1978). Today, management of koalas in these populations continues to be a significant and controversial issue both politically and ecologically.

Regardless of the locality, the common denominator that has the greatest impact on koala conservation is land clearing, leading to loss of habitat and habitat connectivity (Melzer et al., 2000). Urbanisation of koala populations, as a result of land clearing, also contributes to downstream threats to the koala such as motor vehicle trauma and dog attacks (Griffith et al., 2013). Infectious diseases, primarily caused by the bacterial pathogen *Chlamydia pecorum*, are also a significant threat to koala conservation (Polkinghorne et al., 2013). *C. pecorum* is primarily a sexually transmitted infection in koalas; however there is anecdotal evidence for vertical transmission. Ocular infections by this pathogen can lead to debilitating blindness while urogenital tract infections lead to cystitis and/or ascending infections of the reproductive tract and sterility (Wan et al., 2011). Epidemiological surveys of koala populations indicate that *C. pecorum* infections in mainland koala populations are widespread (Kollipara et al., 2013a) with only a limited number of populations showing little or no evidence of infection. Challenging efforts to manage these populations for disease, however, is the observation that there is a disconnection between infection and disease. Some koala populations are seemingly unaffected despite a high prevalence of infection while other infected populations display a high prevalence of disease with close to 60% of koalas affected by chlamydial disease at some geographical sites (Kollipara et al., 2013a; Patterson et al., 2015). Although much is still to be learnt about chlamydial disease pathogenesis, a growing number of molecular epidemiology studies completed by our group (Bachmann et al., 2015; Jelocnik et al., 2013; Kollipara et al., 2013a; Marsh et al., 2011) and others (Higgins et al., 2012) suggest that koala *C. pecorum* strains are genetically diverse which, in part, may hold the key to why certain populations are more impacted by chlamydial infection. However, direct evidence is still lacking, and other environmental factors, such as co-infections with virulent KoRV variants (Xu et al., 2013), or host genetic differences may also contribute.

Translocations of koalas have had the highest reported success of all vertebrate translocations attempted in Australia (Short, 2009), and have been employed for over 120 years (Hrdina and Gordon, 2004; Lee and Martin, 1988; Martin and Handasyde, 1990; Seymour et al., 2001; Taylor et al., 1997; Warneke, 1978). The earliest records of koala translocations involve movement of animals from the Victorian and South Australian mainland to Phillip Island, French Island and Kangaroo Island (islands off the coast of southern Australia), where small numbers were introduced by local residents in the 1870s, 1890s, and 1920s respectively (Martin and Handasyde, 1990; Fig. 1). These translocations appear to have been unsanctioned and the motives are unclear. At least some of the earlier translocations of koalas were motivated by a concern for the species' status at the time these translocations were carried out, though many others appeared to have been largely for aesthetic reasons. These translocations were so "successful" that over-browsing and death of trees was occurring to a significant extent on some islands — on Kangaroo Island by 1948, only 20 years after koalas were introduced. It soon became apparent that translocations back away from these marooned island populations would be required to reduce the impact of localised over-browsing (Lee and Martin, 1988; Philpott, 1965; Whisson et al., 2008; Fig. 1). Successful island populations, in turn, served the role of 'koala arks' to restart populations on the southern mainland where localised extinctions had occurred, mainly due to hunting (Martin and Handasyde, 1990; Whisson et al., 2008; Fig. 1).

In northern populations in Queensland, translocations of up to 900 koalas occurred in the 1920s and 1930s (Hrdina and Gordon, 2004). This included introductions of koalas from the mainland to establish populations on Magnetic Island and St Bees Island in central Queensland, and then from these islands onto nearby Brampton Island, Newry Island and Rabbit Island (Hrdina and Gordon, 2004; Jackson, 2007; Fig. 1), though some of this history is contradicted in other anecdotal reports (Lee et al., 2013). Interestingly, koalas on Queensland islands have not inflicted habitat damage to the extent of their southern counterparts and there have been no records of translocations from islands back to the mainland (Melzer and Ellis, 2009). These translocations at the time were mostly for aesthetic reasons; however, recent utilisations and proposals of translocations in Queensland are largely associated with land-clearing.

The translocation of koalas in response to substantial habitat loss, usually associated with urban development, is controversial, but nevertheless seen as necessary by governments, scientists and conservations groups alike in compassionately managing displaced koalas. This is particularly so when remnants of koala habitat are completely obliterated by land-clearing, leaving no suitable habitat remaining and no safe paths of egress for affected koalas.

Current legislation relating to koala translocation varies between Australian states, with Victoria and South Australia commonly utilising the method, whereas New South Wales takes a more conservative approach, allowing translocations only if a koala is in immediate danger (NSW Environment and Heritage, 2008), and Queensland prohibits the translocation of koalas other than for scientific purposes (Queensland Department of Environment and Heritage Protection). This creates a quandary for the management of severely affected koala populations and an urgent need for review of the relevant regulations. The imperative to avoid the spread of infectious diseases, particularly in respect of *Chlamydia* strains or genotypes that may be highly pathogenic, remains an important issue in the translocation debate. Other factors that have vexed the debate and contributed to the slow progress in refining the regulations and policy are:

1) The view that approval of translocation as acceptable tool to manage koalas under threat will facilitate urban development and consequent habitat loss that otherwise might not be approved.
2) That negative impacts on genetic make-up of local or regional koala populations could occur following translocations if natural barriers to genetic mixing are not considered.
3) That sufficient investigation of donor and recipient sites and their respective koala populations will not occur, and that translocation programmes or events will be reactive and poorly managed and inadequately evaluated for success and long-term ecological impacts.