



Escaping captivity: The biological invasion risk from vertebrate species in zoos



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ABSTRACT

Worldwide, invasive alien species increasingly contribute to environmental change and are a massive drain on social and economic resources. In Australia, the detection of new vertebrate incursions (i.e., alien species not currently established) has increased over the last decade. In other parts of the world, zoos have been identified as one of the influential pathways for the establishment of alien vertebrate species. We quantified the number of vertebrate species released (escaped and stolen) from Australian zoos between 1870 and 2010. The majority of reported releases (185 out of 230) have occurred since 1985. Most of the species (77.9%), which have escaped, or been stolen, from Australian zoos have only ever been released once. In sum, escapes were much more common (89%) than thefts. Compared to the other three vertebrate classes (amphibians, birds, mammals) reptiles experienced a significantly greater proportion of thefts than expected by chance. Almost half of all escapes (46%) were bird species. Birds also had the lowest retrieval rate, and therefore posed the greatest potential risk to establishment and subsequent invasion. We used phylogenetic logistic regression models to assess the association of evolutionary traits correlated with the propensity of a bird species for escaping. There was only weak evidence of phylogenetic signal (association among related species) in the tendency of a bird to escape. Bird species were significantly more likely to have escaped if their current total collection size was larger. There was no relationship between escape and the type of holding (aviary versus free-range/open-pond), or life history traits (adult body size and geographic breeding range size). Zoos are a prominent part of our culture and play a valuable role in education and conservation. Captive animals, including those in zoos, are subject to release, through both intentional and unintentional pathways, however, the establishment of alien species associated with Australian zoos is extremely low. We conclude that, in Australia, the risk of introduction by alien species from zoos is low, and substantially less than other 'backyard' and illegal sources of private species keeping and trade.

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1. Introduction

Invasive alien species are a key driver of human induced environmental change and global species extinctions (Vitousek et al., 1997; McGeoch et al., 2010; Simberloff et al., 2013), and a massive drain on international economic resources (Pimentel et al., 2001; Hulme, 2009; Marbuah et al., 2014). In Australia, a recent conservative estimate of the annual direct economic impact of widespread terrestrial alien vertebrate pests (excluding their considerable environmental and social costs) was AU\$743 million, with annual research and management costs exceeding AU\$122 million (Gong et al., 2009). In addition, the detection of new vertebrate incursions (i.e., alien species not currently established in

Australia) has increased over the last decade (Henderson et al., 2011). Whereas, the majority of new alien vertebrate species detections (c. two-thirds) were intercepted by border security agencies (illegally smuggled or unintentionally stowed-away), a substantial number (76 species of 186 in total) had escaped (or were stolen) from post-border collections, or confiscated from the illegal pet trade (Henderson et al., 2011).

The potential for any animal to be released from captivity poses a number of post-border biosecurity risks (Hulme et al., 2008), and releases of alien species can pose severe economic, environmental and social threats (Pyšek and Richardson, 2010). The term release covers a variety of circumstances, which differ in their degree of human intention. These circumstances can range from unforeseen events, such as an environmental accident that compromises the integrity of a confinement barrier, to an owner who, in times of hardship (e.g., financial or psychological), opens the collection

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gates. However, in most circumstances releases of zoo animals, in particular, are either unintentional escapes or intentional thefts.

The keeping of wild animals dates back to their earliest domestication, which became commonly practiced around 12 k years ago (Vigne, 2011). However, the exhibition of captive animals did not arise until after the urbanization of civilization around 5 k years ago (Kisling, 2001). Queen Hatshepsut of Egypt is recorded to have constructed a zoological garden for the ceremonial display of large-bodied wild animals around 3.5 k years ago (Livingston, 1974). Similar exhibitions were established by rulers in China, India and Africa as a display of their wealth and power (Kisling, 2001). In the ancient Mediterranean region, there was keen interest in alien species for exhibition in menageries and gardens, and for their slaughter in the arenas. An international trade developed in particular species that could be maintained in captivity (Jennison, 1937). From the 15th century, European explorers discovered an enormous range of new species during their global explorations, and established zoos in Britain and continental Europe on their return. The popular modern zoological collection, for public viewing, arose in the early part of the 19th century with the cities of London, Paris and Dublin opening zoos within a few years of each other (Strehlow, 2001). By 2011, 837 zoos worldwide, which were International Species Information System (ISIS) members, contained 3955 alien terrestrial vertebrate species; 58% were birds, 25% were mammals, 11% were reptiles and 6% were amphibians (Conde et al., 2013).

In Europe, zoos have been identified as the second most important known pathway (following the pet trade) for the introduction of escaped alien vertebrate species (Hulme et al., 2008). However, these introductions are dwarfed by the number of species intentionally released for food/game and fauna improvement. It was also found that European zoos, which did not belong to a professional association, had more non-secure enclosures than zoo association members (Fàbregas et al., 2010). In Australia, alien vertebrate species, particularly mammals, reptiles and amphibians, are not as readily legally available as pets, in comparison to much of Europe and the USA, or non-Western countries. Although no widespread alien vertebrate pest species has ever originated from an Australian zoo, at least, two free-living populations have established via species released from captive collections. In Perth, a wild population of the five-lined palm squirrel (*Funambulus pennanti*), native to south Asia, was descended from captive animals intentionally released into the zoo grounds by the local Acclimatisation Society in 1898 (Long, 2003). In Tasmania, a localised population of the agile wallaby (*Macropus agilis*) originated from a small number of individuals that escaped (or were intentionally released) from a wildlife park in the late 1990s (Pauza et al., 2014). Native to mainland Australia, the introduced population on Tasmania occurs outside its natural geographic range.

Scientific accounts of zoo releases are relatively rare (Fàbregas et al., 2010). Nevertheless, in Australia, as well as the rest of the world, there are numerous records (and anecdotal accounts) of animal releases from zoos (Csurshes, 2003). Examples of these accounts include:

- [1] The Northern Territory (Australia) pig-hunter who ‘accidentally’ shot a pygmy hippo (*Choeropsis liberiensis*) in the Douglas Daly district 200 km south of Darwin, in November-2009. Native to western African it was believed that the female pygmy hippo had escaped from a former private collection on Tipperary Station, which was closed in 2003; 6 years prior to the shooting (<http://www.abc.net.au/news/2009-11-16/nt-man-shoots-pygmy-hippo-by-mistake/1145336>).
- [2] The 25 kg alligator snapping turtle (*Macrochelys temminckii*) discovered in a stormwater drain in a Sydney suburb (Australia) in 2000, after a heavy rain event. Native to waterways in the south-eastern United States, the alligator snapping

turtle is the largest freshwater turtle (by weight) in the world, and it required six council workers and a wheelbarrow to remove the male turtle from the stormwater drain. It was believed that the turtle could have been one of a batch of juveniles stolen from an Australian fauna park near Sydney in 1979; 21 years prior to its recovery (<http://www.theguardian.com/world/2000/nov/29/patrickbarkham>).

- [3] The intentional release of dozens of wild alien carnivores and primates in October-2011 from a preserve in Ohio (United States), following the suicide of the preserve’s owner. The majority of the wild animals, which included over 30 Bengal tigers (*Panthera tigris tigris*) and lions (*Panthera leo*), were fatally controlled, however, a single macaque (*Macaca* sp.) was never recovered (<http://abcnews.go.com/US/zanesville-animal-massacre-included-18-rare-bengal-tigers/story?id=14767017>).

Collectively, these accounts lead to the inference that large species collections can be a prominent pathway for the post-border release of alien (and potentially invasive pest) species (see also Hulme et al., 2008). In the current paper we analyse the historical release of animals (alien and native) from 19 Australian zoos (1870–2010) and provide a quantitative appraisal of the biological invasion risk from vertebrate species in zoo collections. Specifically, we tested for differences among vertebrate classes (amphibians, birds, mammals, reptiles) in their propensity for escaping (and being stolen) from zoo collections, as well as their likelihood of (and time to) retrieval. We also compared characteristics of the different zoo collections, and whether the frequencies of releases have changed through time. For the one vertebrate class which has experienced the majority of zoo escapes (Aves) we quantitatively tested whether a set of putative species-level and collection-level characteristics were associated with a species’ propensity for escaping.

2. Data and methods

2.1. Zoo release data

The list of vertebrate species in Australian zoological collections follows the Zoo and Aquarium Association (ZAA) ‘*Australasian Species Management Program: Regional Census and Plan*’ (Hibbard and Wilkins, 2010). The list of alien species in Australia follows the Australian intergovernmental Vertebrate Pest Committee (VPC, 2007) and sources therein. In Australia, the display (and import) of alien wildlife is legislated for under the *Quarantine Act 1908* and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), with the regulatory authorities of each of the States and Territories controlling the movement (import and export) of alien wildlife within the country. Under the EPBC Act, the Australian Government established the *List of Specimens taken to be Suitable for Live Import* (last updated 26-May-2014: <http://www.environment.gov.au/biodiversity/wildlife-trade/live/import-list>), which regulates the particular species that can be imported into the country through the assessment of potential risks of an alien species to Australia (Bomford, 2008).

Australian State and Territory legislative bodies were contacted (by email and telephone) to determine the number of all exhibited animal licence holders, and the number of those holding alien species. This information was used to determine what proportion of exhibited licence holders, who held alien species, were members of the ZAA. The ZAA is the peak body representing the zoo and aquarium community throughout Australasia, and is a member of the World Association of Zoos and Aquariums. In 2012, there were 38 alien species licences in Australia of which 30 institutions

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