Contents

National Risk Assessment: MODERATE

RISK ASSESSMENT FOR AUSTRALIA: # African Pygmy Hedgehog (*Atelerix albiventris*)

Class - Mammalia**, Order -** Eulipotyphla**, Family -** Erinaceidae**, Genus -** *Atelerix*.

SPECIES: *Atelerix albiventris* (Wagner, 1841) **Synonyms:** *Erinaceus albiventris* (Wagner, 1841) *Atelerix adansoni* (Rochebrune, 1883) *Atelerix atratus* (Rhoads, 1896) *Atelerix diadematus* (Fitzinger, 1867) *Atelerix faradjius* (J. A. Allen, 1922) *Atelerix heterodactylus* (Sundevall, 1842) *Atelerix hindei* (Thomas, 1910) *Atelerix kilimanus* (Thomas, 1918) *Atelerix langi* (J. A. Allen, 1922) *Atelerix pruneri* (Wagner, 1841) *Atelerix sotikae* (Heller, 1910) *Atelerix spiculus* (Thomas & Wroughton, 1907) *Atelerix spinifex* (Thomas, 1918) **Subspecies:** Monotypic **Common Names:** African Pygmy Hedgehog African Hedgehog Four-toed Hedgehog	**Species description:** The African pygmy hedgehog is a small mammal with a pointed muzzle and short legs whose back and sides are covered in spines that measure between 0.5 and 1.5 centimetres in length. The African hedgehog weighs between 250 and 600 grams and measures, on average, 21 centimetres in length from head to tail. They usually have dark ears and muzzle, and the body is speckled with grey, brown and white on the back and sides while the underparts are white (Deef, 2019). African hedgehogs can exhibit albinism, with the lack of pigmentation resulting in a totally white colouration and pink eyes. Albinism in the wild is rare but is often a trait selectively bred for in captive populations (NSW Department of Primary Industries). **General information:** The African pygmy hedgehog is found across a wide swathe of central Africa, from Gambia and Senegal in the west, to Somalia in the east, in eastern Africa, as far south as Mozambique. The African pygmy hedgehog is bred and sold as a pet in North America and the United Kingdom. The African pygmy hedgehog belongs to the Erinaceidae family. This family includes the European hedgehog (*Erinaceus eruopaeus*) which has established feral populations in New Zealand and some Scottish islands. Once established in a new environment, hedgehogs negatively impact native species due to their voracious, omnivorous appetite, affecting insects, snails, lizards and ground-nesting birds, particularly shore birds, as hedgehogs raid their nests and eat the eggs and chicks (NSW Department of Primary Industries). The African pygmy hedgehog is found at elevations as high as 2,000 metres but is more common in lowland areas. It prefers grassy environments or open woodland and prefers to shelter in dry rocky or grassy areas, avoiding dense forest and swampland (Santana, 2010). Generally, this species requires dry shelters in matted grass, leaf litter, a rocky crevice, or a hole in the ground (Nowak, 1999). It can be found in human habitation, such as gardens, food stores, and cultivated fields (Reeve, 1994). The African pygmy hedgehog tends to prefer temperatures between 24 and 30 °C. Although African pygmy hedgehogs do aestivate through the summer, this is not thought to be connected to a rise in temperature, but rather to a lack of available food. Aestivation rarely lasts for more than 6 weeks (Santana, 2010).

	The African pygmy hedgehog female reaches sexual maturity around 1 year of age and on average gives birth to 1 litter a year. The female gives birth to a litter of two to ten young, with an average of 5 per litter. The young are born in a nest and are blind and naked at birth (NSW Department of Primary Industries and Bedford, 2000). All hedgehogs have the potential to seriously damage the Australian economy due to their ability to harbour exotic animal diseases such as foot and mouth disease. Other endemic diseases carried by hedgehogs include Salmonella, Q fever and Toxoplasmosis which are all capable of being transmitted to humans (NSW Department of Primary Industries). **Longevity:** A wild African pygmy hedgehog typically lives for 2-3 years while a captive African pygmy hedgehog can live up to 10 years (Raymond, 2001). **Conservation status:** **IUCN:** Least Concern **CITES:** Not listed
DATE OF ASSESSMENT: Oct 2021 (Jodi Buchecker) **EIC ENDORSEMENT:** 22/04/22 **Risk assessment model used for the assessment:** Bomford 2008, Mammals and Birds	**The risk assessment model:** Models for assessing the risk that exotic vertebrates could establish in Australia have been developed for mammals, birds (Bomford 2003, 2006, 2008), reptiles and amphibians (Bomford et al 2005, Bomford 2008). Developed by Dr Mary Bomford for the Bureau of Rural Sciences (BRS), the model uses criteria that have been demonstrated to have significant correlation between a risk factor and the establishment of populations of exotic species and the pest potential of those species that do establish. For example, a risk factor for establishment is similarity in climate (temperature and rainfall) within the species' distribution overseas and Australia. For pest potential, the species' overseas pest status is a risk factor. The model is published as 'Risk assessment models for the establishment of exotic vertebrates in Australia and New Zealand' (Bomford 2008) and is available online on the PestSmart website https://pestsmart.org.au/wp-content/uploads/sites/3/2020/06/Risk_Assess_Models_2008_FINAL.pdf **CLIMATE**: In 2021 a new version of the Climatch program used to assess similarity in climate was released by the Australian Bureau of Agricultural Resource Economics and Sciences (ABARES): CLIMATCH v2.0. The increase in resolution in this new version (from 50 km to 20 km) required recalibration of Climate Match Scores. See Table 1. Sixteen climate parameters (variables) of temperature and rainfall are used to estimate the extent of similarity between data from meteorological stations located within the species' world distribution and stations in Australia. Worldwide, data from approximately 19000 locations are available for analysis. The number of locations used in an analysis will vary according to the size of the species' distribution and the number of meteorological stations located within that distribution. To represent the climate match visually, the map of Australia is divided into 19236 grid squares, each measured in 0.2 degrees in both longitude and latitude.

	CLIMATCH v2.0 calculates a match for each Australian grid by comparing data from all meteorological stations within the species' distribution (excluding any populations in Australia) and allocating a score ranging from ten for the highest level match to zero for the poorest match. Levels of climate match are used in the risk assessment for questions B1 (scores are summed to give a cumulative score), C6, and C8. Climatch v2.0 can be accessed on the ABARES website, agriculture.gov.au/abares. The direct URL is https://climatch.cp1.agriculture.gov.au/.

Bird and Mammal Model:

FACTOR	SCORE	DETAIL
STAGE A: RISKS POSED BY CAPTIVE OR RELEASED ANIMALS		
A1. Risk to people from individual escapees (0–2) *Assess the risk that individuals of the species could harm people. (NB, this question only relates to aggressive behaviour shown by escaped or released individual animals. Question C11 addresses the risk of harm from aggressive behaviour if the species establishes a wild population).* *Aggressive behaviour, size, plus the possession of organs capable of inflicting harm, such as sharp teeth, claws, spines, a sharp bill, or toxin-delivering apparatus may enable individual animals to harm people. Any known history of the species attacking, injuring or killing people should also be taken into account. Assume the individual is not protecting nest or young.*	0	*All other animals posing a lower risk of harm to people (ie animals that will not make unprovoked attacks causing injury requiring medical attention, and which, even if cornered or handled, are unlikely to cause injury requiring hospitalisation).* Small animal often kept as a pet in North America and the United Kingdom. The African pygmy hedgehog will typically "ball up" if people get too close, rather than bite or attack.
A2. Risk to public safety from individual captive animals (0–2) *Assess the risk that irresponsible use of products obtained from captive individuals of the species (such as toxins) pose a public safety risk (excluding the safety of anyone entering the animals' cage/enclosure or otherwise coming within reach of the captive animals)*	0	*Nil or low risk (highly unlikely or not possible).*
STAGE A PUBLIC SAFETY RISK SCORE **SUM A1 - A2 (0-4)**	0	**Not dangerous**

STAGE B: PROBABILITY ESCAPED OR RELEASED INDIVIDUALS WILL ESTABLISH FREE-LIVING POPULATIONS		
Model 1: FOUR-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)		
B1. Degree of climate match between species overseas range and Australia (1–6) *Map the selected mammal or bird species' overseas range, including its entire native and exotic (excluding Australia) ranges over the past 1000 years.* *Use CLIMATCH v2.0, Value X = sum of classes 6 – 10, see Table 1.*	2	*Low climate match to Australia* Value X = 4,069 Climate Match Score = 2
B2. Exotic population established overseas (0–4) *An established exotic population means the introduced species must have bred outside of captivity and must currently maintain a viable free-living population where the animals are not being intentionally fed or sheltered, even though they may be living in a highly disturbed environment with access to non-natural food supplies or shelter.*	0	*No exotic population ever established.* There is no record found of the African pygmy hedgehog establishing exotic population overseas.
B3. Overseas range size score (0–2) < 1 = 0; 1– 70 = 1; >70 = 2 *Estimate the species overseas range size* including currently and the past 1000 years; natural and introduced range in millions of square kilometres*	1	*Overseas range between 1 to 70 million square kilometres.* Approximately 8.5 million km^2.
B4. Taxonomic Class (0–1) *Bird = 0; mammal = 1*	1	*Mammal*
B. ESTABLISHMENT RISK SCORE **SUM OF B1- B4 (1–13)**	4	**Low establishment risk**
Model 2: Seven-Factor Model For Birds And Mammals (Bomford 2008)		
B5. Diet score (0–1) *Specialist = 0; generalist = 1*	1	*Generalist with a broad diet of many food types.* Generalist omnivore. Main diet contains insects, supplemented with small snakes,

		bird eggs, snails, amphibians, worms (Deef, 2019).
B6. Habitat score (0–1) *Undisturbed or disturbed habitat*	1	*Can survive and breed in human-disturbed habitats (including grazing and agricultural lands, forests that are intensively managed or planted for timber harvesting and/or urban–suburban environments) without access to undisturbed (natural) habitats.* Can be found in human habitation, such as gardens, food stores, and cultivated fields (Reeve, 1994).
B7. Migratory score (0–1) *Always migratory = 0; non-migratory = 1*	1	*Non-migratory*
B. ESTABLISHMENT RISK SCORE SUM OF B1- B7 (1–16)	7	**Moderate establishment risk**
STAGE C: PROBABILITY AN ESTABLISHED SPECIES WILL BECOME A PEST		
C1. Taxonomic group (0–4)	0	*Other group.* No taxonomic group similar.
C2. Overseas range size including current and past 1000 years, natural and introduced range (0–2) *Estimate the species overseas range size (including current and past 1000 years, natural and introduced range) in millions of square kilometres*	0	*Overseas geographic range less than 10 million square kilometres.* Approximately 8.5 million km^2
C3. Diet and feeding (0–3)	1	*Mammal that is a non-strict carnivore (mixed animal-plant matter in diet).* Generalist omnivore: main diet contains insects, supplemented with small snakes, bird eggs, snails, amphibians, worms (Deef, 2019).
C4. Competition with native fauna for tree hollows (0–2)	0	*Does not use tree hollows.* Not known to use tree hollows. Shelters in matted grass, leaf litter, a rocky crevice, or a hole in the ground (Nowak, 1999).
C5. Overseas environmental pest status (0–3)	0	*Never reported as an environmental pest in any country or region.*

Has the species been reported to cause declines in abundance of any native species of plant or animal or cause degradation to any natural communities in any country or region of the world?		
C6. Climate match to areas with susceptible native species or communities (0–5) *Identify any native Australian animal or plant species or communities that could be susceptible to harm by the exotic species if it were to establish a wild population here.*	5	*The species has more than 691 grid squares within the highest four climate match classes that overlap the distribution of any susceptible native species or ecological communities = 5* Examples of susceptible native species or ecological communities include (DAWE Protected Matters Search Tool): *Calidris ferruginea* (Curlew Sandpiper) – Critically Endangered *Egernia rugosa* (Yakka Skink) – Vulnerable
C7. Overseas primary production pest status (0–3) *Has the species been reported to damage crops or other primary production in any country or region of the world?*	0	*No reports of damage to crops or other primary production in any country or region.*
C8. Climate match to susceptible primary production (0–5) *Assess Potential Commodity Impact Scores for each primary production commodity listed in Table 9, based on species' attributes (diet, behaviour, ecology), excluding risk of spreading disease which is addressed in Question C9.* *0 = 0; 1-19 = 1; 20-49 = 2; 50-99 = 3; 100-149 = 4; ≥150 = 5*	0	Total Commodity Damage Score = 0 (see Table 2)
C9. Spread disease (1–2) *Assess the risk that the species could play a role in the spread of disease or parasites to other animals*	2	*All mammals (likely or unknown effect on native species and on livestock and other domestic animals).* The African pygmy hedgehog is a mammal and is known to carry salmonella, Q fever and toxoplasmosis (NSW DPI).

C10. Harm to property (0–3) *Assess the risk that the species could inflict damage on buildings, vehicles, fences, roads, equipment or ornamental gardens by chewing or burrowing or polluting with droppings or nesting material.*	0	*$0.* Nil harm
C11. Harm to people (0–5) *Assess the risk that, if a wild population established, the species could cause harm to or annoy people. Aggressive behaviour, plus the possession of organs capable of inflicting harm, such as sharp teeth, tusks, claws, spines, a sharp bill, horns, antlers or toxin delivering organs may enable animals to harm people. Any known history of the species attacking, injuring or killing people should also be taken into account (see Stage A, Score A1).*	0	*Nil risk.*
C. PEST RISK SCORE **SUM C 1 TO C 11 (1–37)**	8	**Low pest risk**
STAGE A. PUBLIC SAFETY RISK RANK – RISK TO PUBLIC SAFETY POSED BY CAPTIVE OR RELEASED INDIVIDUALS *0 = Not dangerous; 1 = Moderately dangerous; ≥ 2 = Highly dangerous*	0	Not dangerous
STAGE B. ESTABLISHMENT RISK RANK – RISK OF ESTABLISHING A WILD POPULATION **MODEL 1: FOUR-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)** *≤ 5 = low establishment risk; 6-8 = moderate establishment risk; 9-10 = serious establishment risk; ≥ 11-13 = extreme establishment risk*	4	Low establishment risk
STAGE B. ESTABLISHMENT RISK RANK – RISK OF ESTABLISHING A WILD POPULATION **MODEL 2: SEVEN-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)**	7	Moderate establishment risk

≤ 6 = low establishment risk; 7-11 = moderate establishment risk; 12-13 = serious establishment risk; ≥14 = extreme establishment risk		
STAGE C. PEST RISK RANK - RISK OF BECOMING A PEST FOLLOWING ESTABLISHMENT *< 9 = low pest risk; 9-14 = moderate pest risk; 15-19 = serious pest risk; > 19 = extreme pest risk*	8	Low pest risk

ENVIRONMENT AND INVASIVES COMMITTEE THREAT CATEGORY	**MODERATE**

World distribution map (IUCN Red List) and World distribution map indicating where meteorological data was sourced for the climate analysis (see B1):

Figure 1 - World Distribution Map - IUCN Red List

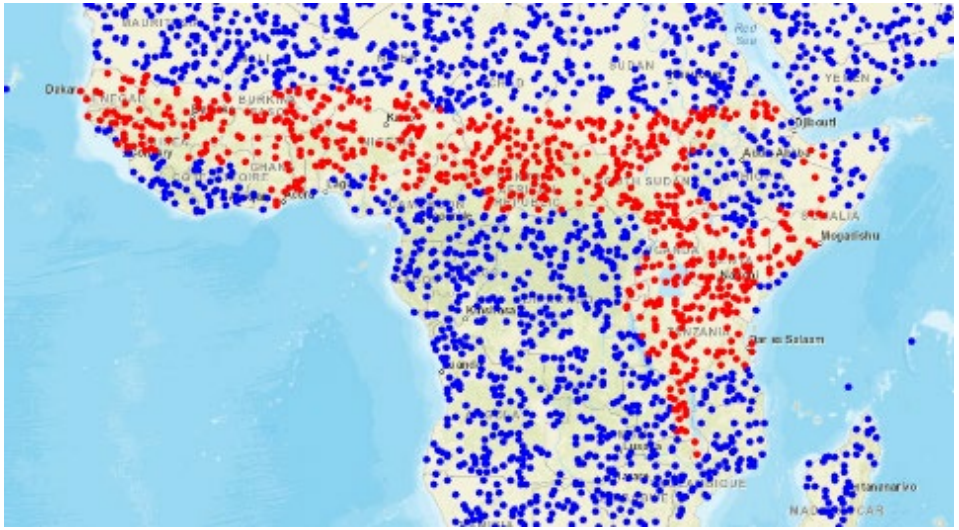
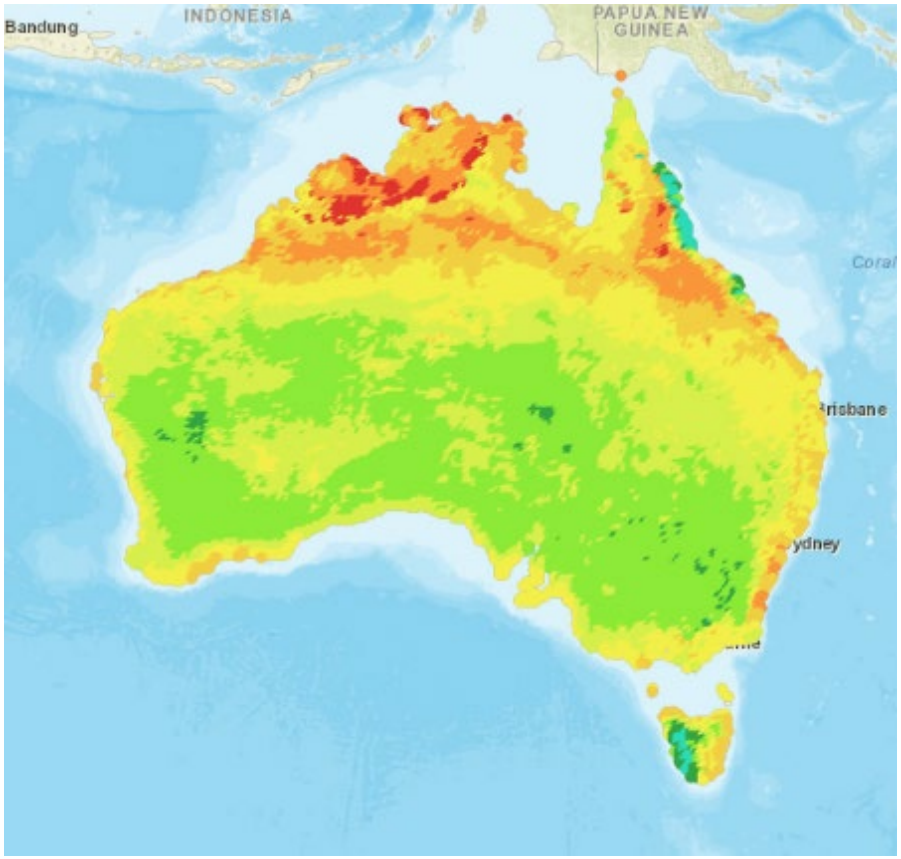


Figure 2 - World Distribution Map - Climatch

Climate match between world distribution of species and Australia:

Areas of Australia where the climate appears suitable for *Atelerix albiventris*

Value X = 4,069



Score	Color	Count
0		0
1		68
2		164
3		6682
4		4699
5		3554
6		2492
7		1305
8		272
9		0
10		0

Species: Atelerix albiventris (African Pygmy Hedgehog)
Algorithm: Closest Standard Score
706 source features selected
19236 target features selected
Approximate selected area: 8,379,736 km^2

Table 1: ABARES recalibration thresholds

Climate Match Score (CMS)	Climatch (50 km) Closest Standard Match Sum Level 6 (Value X)	2021 Recalibrated Climatch v2.0 (20 km) Closest Standard Match Sum Level 6 (Value X)
1 (Very low)	< 100	< 691
2 (Low)	100-599	691-4137
3 (Moderate)	600-899	4138-6209
4 (High)	900-1699	6210-11735
5 (Very high)	1700-2699	11736-18642
6 (Extreme)	≥ 2700	≥ 18643

Table 2: Susceptible Australian Primary Production – Calculating Total Commodity Damage Score

The commodity value index scores in this table are derived from Australian Bureau of Statistics 2005 – 2006 data. The values will require updating if significant change has occurred in the value of the commodity (Bomford 2008).

Industry	**Commodity Value Index 1 (CVI based on best available date)**	**Potential Commodity Impact Score (PCIS 0-3)**	**Climate Match to Commodity Score (CMCS 0–5)**	**Commodity Damage Score (CDS columns 2 X 3 X 4)**
Cattle (includes dairy and beef)	*11*			
Timber (includes native and plantation forests)	*10*			
Cereal grain (includes wheat, barley sorghum etc)	*8*			
Sheep (includes wool and sheep meat)	*5*			
Fruit (includes wine grapes)	*4*			
Vegetables	*3*			
Poultry and eggs	*2*			
Aquaculture(includes coastal mariculture)	*2*			
Oilseeds (includes canola, sunflower etc)	*1*			
Grain legumes (includes soybeans)	*1*			
Sugarcane	*1*			
Cotton	*1*			
Other crops and horticulture (includes nuts tobacco and flowers etc)	*1*			
Pigs	*1*			
Other livestock (includes goats, deer, camels, rabbits)	*0.5*			
Bees (included honey, beeswax and pollination)	*0.5*			
Total Commodity Damage Score (TCDS)				0

NB The Commodity Value Index scores in this table are derived from Australian Bureau of Statistics 2005–2006 data and will need to be updated if these values change significantly.

Assess Potential Commodity Impact Scores for each primary production commodity listed in Table 9, based on species' attributes (diet, behaviour, ecology), excluding risk of spreading disease which is addressed in Question C9, and pest status worldwide as:

0. *Nil (species does not have attributes to make it capable of damaging this commodity)*
1. *Low (species has attributes making it capable of damaging this or similar commodities and has had the opportunity but no reports or other evidence that it has caused damage in any country or region*
2. *Moderate–serious (reports of damage to this or similar commodities exist but damage levels have never been high in any country or region and no major control programs against the species have ever been conducted OR the species has attributes making it capable of damaging this or similar commodities but has not had the opportunity)*
3. *Extreme (damage occurs at high levels to this or similar commodities and/or major control programs have been conducted against the species in any country or region and the listed commodity would be vulnerable to the type of harm this species can cause).*

Climate Match to Commodity Score (0–5)

- *None of the commodity is produced in areas where the species has a climate match within the highest eight climate match classes (ie classes 10, 9, 8, 7, 6, 5, 4 and 3) = 0*
- *Less than 10% of the commodity is produced in areas where the species has a climate match within the highest eight climate match classes = 1*
- *Less than 10% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes (ie classes 10, 9, 8, 7, 6 and 5) = 2*
- *Less than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes AND less than 10% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes (ie classes 10, 9 and 8) = 3*
- *Less than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes BUT more than 10% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes = 4*
- *OR More than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes BUT less than 20% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes = 4*
- *More than 20% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes OR overseas range unknown and climate match to Australia unknown = 5.]*

Table 3: Assigning species to EIC Threat Categories (shaded cells relate to assignment of reptiles and amphibians to EIC Threat Categories based on an assessed establishment risk and an allocated pest risk of extreme) – adapted from Bomford 2008

Establishment Risk	Pest Risk	Public Safety Risk	EIC Threat Category	Implication for any proposed import into Australia	Implication for keeping and movement in Australia
Extreme	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**	Prohibited, unless sufficient risk management measures exist to reduce the potential risks to an acceptable level	Limited to those collections approved for keeping particular EXTREME Threat species
Extreme	Serious	Highly, Moderately or Not Dangerous	**EXTREME**		
Extreme	Moderate	Highly, Moderately or Not Dangerous	**EXTREME**		
Extreme	Low	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Serious	Highly, Moderately or Not Dangerous	**EXTREME**		
Moderate	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Moderate	Highly, Moderately or Not Dangerous	**SERIOUS**	Import restricted to those collections approved for keeping SERIOUS Threat species	Limited to those collections approved for keeping particular SERIOUS Threat species
Serious	Low	Highly, Moderately or Not Dangerous	**SERIOUS**		
Moderate	Serious	Highly, Moderately or Not Dangerous	**SERIOUS**		
Moderate	Moderate	Highly Dangerous	**SERIOUS**		
Moderate	Low	Highly Dangerous	**SERIOUS**		
Low	Extreme	Highly, Moderately or Not Dangerous	**SERIOUS**		
Low	Serious	Highly, Moderately or Not Dangerous	**SERIOUS**		
Low	Moderate	Highly Dangerous	**SERIOUS**		
Low	Low	Highly Dangerous	**SERIOUS**		
Moderate	Moderate	Moderately or Not Dangerous	**MODERATE**	Import restricted to those collections approved for keeping MODERATE Threat species	Limited to those collections approved for keeping particular MODERATE Threat species
Moderate	Low	Moderately or Not Dangerous	**MODERATE**		
Low	Moderate	Moderately or Not Dangerous	**MODERATE**		
Low	Low	Moderately Dangerous	**MODERATE**		
Low	Low	Not Dangerous	**LOW**	Import permitted	May be limited to those collections approved for keeping particular LOW Threat species
Any Value	Any Value	Unknown	**EXTREME until proven otherwise**	Prohibited, unless sufficient risk management measures exist to reduce the potential risks to an acceptable level	Limited to those collections approved for keeping particular EXTREME Threat species
Unknown	Any Value	Any Value	**EXTREME until proven otherwise**		
Any Value	Unknown	Any Value	**EXTREME until proven otherwise**		
Unassessed	Unassessed	Unassessed	**EXTREME until proven otherwise**		

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NSW Department of Primary Industries African hedgehog (*Atelerix albiventris*) Fact S0heet: https://www.dpi.nsw.gov.au/biosecurity/vertebrate-pests/nia/key-new-incursions-species/new-incursions/african-hedgehog

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National Risk Assessment: EXTREME

RISK ASSESSMENT FOR AUSTRALIA: **Hog Deer (*Axis porcinus*)**

Class - Mammalia**, Order -** Artiodactyla**, Family -** Cervidae**, Genus -** *Axis*.

SPECIES:	**Species description:**
Axis porcinus (Zimmermann, 1780) **Synonyms:** *Cervus porcinus* (Zimmermann, 1780) *Hyelaphus porcinus* (Zimmermann, 1780) *Axis oryzus* (Keelart, 1852) *Axis porcinus calamianensis* (Heude, 1888) *Axis porcinus kuhli* (Temminck, 1836) **Subspecies:** *Axis porcinus porcinus* (Zimmermann, 1780) *Axis porcinus annamiticus* (Heude, 1888) **Common Names:** Hog Deer Indian Hog Deer Indochina Hog Deer Indochinese Hog Deer Thai Hog Deer Paddy-field Deer	Hog deer are relatively small yet powerful cervids. Bucks weigh between 40-55 kilograms (with some weighing up to 95 kilograms) whereas does weigh between 30-40 kilograms. Bucks are on average 35% heavier than does (Handbook of Mammals of the World). They have stocky muscular bodies, and, by contrast, their limbs are noticeably short and delicate. The hindlimbs are longer than the forelimbs, raising the rump to a height greater than the shoulders. Adult hog deer are dark olive brown with white-tipped guard hairs and their coat is relatively course. Fawns are born a sandy-yellow colour with cream horizontally distributed spots along their flanks. Fawns gain their adult pelage at about 6 months. In summer, adults often change coat and fawn-like spots are visible. Hog deer faces are short and wedge-shaped. Hog deer rhinarium is always bare and brown and they have unusually large round ears (fringed with white hairs). Their tails are quite bushy. Only males grow antlers, which are shed and regrown annually from their second year. Males in their first year do not possess antlers, and at 2 years of age possess two 'spikes'; usually only males aged 3 years and older grow points (up to a maximum of 3 on each antler, but occasionally more) (Scroggie et al., 2012). The backward pointing antlers reach approximately 30–35 centimetres in length (Vishvanath, 2014). When alarmed, hog deer make a whistling vocalisation or a warning bark (Animal Diversity Web). **General information:** Hog deer occur in riverine and flood-plain grasslands of Pakistan, India, Bangladesh, Nepal, Bhutan, China, Myanmar, Thailand, Loas, Vietnam and Cambodia. They are also known to inhabit Sri Lanka (possibly introduced, though this is disputed by some authors) and are introduced to Australia (IUCN Red List). All extant subpopulations of hog deer in Australia are on the South Coast of Victoria. There are two managed subpopulations at reserves on Sunday Island and at Blond Bay. Additionally, there are scattered groups on private land between Wilson's Promontory and Orbost. These subpopulations derive from releases made in 1865 (Scroggie et al., 2012). Despite these populations existing since 1865, the Australian Deer Association reports that Victoria's population is "struggling" even though legal hunting has been restricted to the month of April since the mid-1970s. They

	also note that the hog deer in these areas have low fecundity, are “stunted” when mature and that they are often in poor condition over the summer and winter months. They reason, as hog deer evolved in a semi-tropical environment, that the cold and wet weather typical of Victoria in winter has led to hog deer population numbers being kept in check. The Climatch map developed for this risk assessment indicates a low climate match with this area of Australia, so only a marginal population surviving there is not surprising. Scroggie et al., (2012) also report that the relatively constant annual harvest during 1997–2011 in Victoria suggests that the size of the hog deer population has not changed substantially in that time. Ramsey et al., (2019) however, report low genetic variability and low effective population size; so inbreeding depression could also be contributing to the lack of population increase in Victoria. Hog deer are generally solitary. They are sometimes seen feeding in small groups where food is plentiful and small family groups are not uncommon. They are sedentary and do not migrate. Measured densities range from 0.1 per kilometres squared in riverine forest, to 16.5 per kilometres squared in savanna, and 35 per kilometres squared in grassland floodplains (Dhungel and O’Gara 1991; Seidensticker, 1976). Hog deer feed nocturnally and are both a grazer and a browser but seem to prefer grazing (Animal Diversity Web). Johnsingh et al., (2004) considered hog deer to be an obligate grassland species in the Terai Arc Landscape of India, and studies in India and Nepal have shown a preference for grasslands dominated by certain grasses (Biswas 2004 and references therein; IUCN). Males are territorial and mark their territory with glandular secretions. During the breeding season, males become extremely aggressive towards other males, however challenges do not usually result in harm. Males mate with as many females as possible (polygynous). Sexual maturity is reached at 8-12 months and, in the wild, breeding season is from August until October (breeding season is known to vary slightly from these parameters in captive populations) (Scoggie et al., 2012). Gestation is approximately 8 months, with most births (of either a single fawn or twins) in May to July. Newly born fawns are left in dense grass thickets or reed beds where they remain concealed from predators for several days while the mother feeds. She returns only periodically to suckle the young, who are precocial at birth and weaned at about 6 months (Animal Diversity Web). Hog deer and Chital deer (*Axis axis*) have been known to hybridise as have hog deer and Sika deer (*Cervus nippon*) (Mayze & Moore, 1990). Hog deer are capable swimmers and often enter water when threatened. Instead of leaping like other deer, when threatened, they will run with a trotting gait and with their head held low (Animal Diversity Web). **Longevity:** Approximately 12-15 years in the wild (Mayze & Moore, 1990). 20 years in captivity, 10 years in the wild (Animal Diversity Web). The maximum recorded longevity in captivity is 22.9 years (AnAge).

	Conservation status: **IUCN:** Endangered **CITES:** Appendix III
DATE OF ASSESSMENT: Oct 2021 (Jodi Buchecker) **EIC ENDORSEMENT:** 22/04/22 **Risk assessment model used for the assessment:** Bomford 2008, Mammals and Birds	**The risk assessment model:** Models for assessing the risk that exotic vertebrates could establish in Australia have been developed for mammals, birds (Bomford 2003, 2006, 2008), reptiles and amphibians (Bomford et al 2005, Bomford 2008). Developed by Dr Mary Bomford for the Bureau of Rural Sciences (BRS), the model uses criteria that have been demonstrated to have significant correlation between a risk factor and the establishment of populations of exotic species and the pest potential of those species that do establish. For example, a risk factor for establishment is similarity in climate (temperature and rainfall) within the species' distribution overseas and Australia. For pest potential, the species' overseas pest status is a risk factor. The model is published as 'Risk assessment models for the establishment of exotic vertebrates in Australia and New Zealand' (Bomford 2008) and is available online on the PestSmart website https://pestsmart.org.au/wp-content/uploads/sites/3/2020/06/Risk_Assess_Models_2008_FINAL.pdf **CLIMATE**: In 2021 a new version of the Climatch program used to assess similarity in climate was released by the Australian Bureau of Agricultural Resource Economics and Sciences (ABARES): CLIMATCH v2.0. The increase in resolution in this new version (from 50 km to 20 km) required recalibration of Climate Match Scores. See Table 1. Sixteen climate parameters (variables) of temperature and rainfall are used to estimate the extent of similarity between data from meteorological stations located within the species' world distribution and stations in Australia. Worldwide, data from approximately 19000 locations are available for analysis. The number of locations used in an analysis will vary according to the size of the species' distribution and the number of meteorological stations located within that distribution. To represent the climate match visually, the map of Australia is divided into 19236 grid squares, each measured in 0.2 degrees in both longitude and latitude. CLIMATCH v2.0 calculates a match for each Australian grid by comparing data from all meteorological stations within the species' distribution (excluding any populations in Australia) and allocating a score ranging from ten for the highest level match to zero for the poorest match. Levels of climate match are used in the risk assessment for questions B1 (scores are summed to give a cumulative score), C6, and C8. Climatch v2.0 can be accessed on the ABARES website, agriculture.gov.au/abares. The direct URL is https://climatch.cp1.agriculture.gov.au/.

Bird and Mammal Model:

FACTOR	SCORE	DETAIL
STAGE A: RISKS POSED BY CAPTIVE OR RELEASED ANIMALS		

A1. Risk to people from individual escapees (0–2) *Assess the risk that individuals of the species could harm people. (NB, this question only relates to aggressive behaviour shown by escaped or released individual animals. Question C11 addresses the risk of harm from aggressive behaviour if the species establishes a wild population).* *Aggressive behaviour, size, plus the possession of organs capable of inflicting harm, such as sharp teeth, claws, spines, a sharp bill, or toxin-delivering apparatus may enable individual animals to harm people. Any known history of the species attacking, injuring or killing people should also be taken into account. Assume the individual is not protecting nest or young.*	1	*Animal that is unlikely to make an unprovoked attack, but which can cause serious injury (requiring hospitalisation) or fatality if cornered or handled.* Smallish, shy deer. Females unlikely to cause serious injury but males in full antler (even though their antlers are relatively small compared to other deer species) have the potential to cause injury.
A2. Risk to public safety from individual captive animals (0–2) *Assess the risk that irresponsible use of products obtained from captive individuals of the species (such as toxins) pose a public safety risk (excluding the safety of anyone entering the animals' cage/enclosure or otherwise coming within reach of the captive animals)*	0	*Nil or low risk (highly unlikely or not possible).*
STAGE A PUBLIC SAFETY RISK SCORE **SUM A1 - A2 (0-4)**	1	**Moderately dangerous**
STAGE B: PROBABILITY ESCAPED OR RELEASED INDIVIDUALS WILL ESTABLISH FREE-LIVING POPULATIONS		
Model 1: FOUR-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)		
B1. Degree of climate match between species overseas range and Australia (1–6) *Map the selected mammal or bird species' overseas range, including its entire native and exotic (excluding Australia) ranges over the past 1000 years.* *Use CLIMATCH v2.0, Value X = sum of classes 6 – 10, see Table 1.*	4	*High climate match to Australia* Value X = 9,843 Climate Match Score = 4

B2. Exotic population established overseas (0–4) *An established exotic population means the introduced species must have bred outside of captivity and must currently maintain a viable free-living population where the animals are not being intentionally fed or sheltered, even though they may be living in a highly disturbed environment with access to non-natural food supplies or shelter.*	4	*Exotic population established on a larger island (> 50 000 km^2) or anywhere on a continent (including elsewhere on the land mass where the natural distribution of the animal is, if this population is due to human introduction and is geographically separate from the natural range of the species).* Introduced populations exist in Sri Lanka, the United States of America (Texas, Florida and Hawaii) (Animal Diversity Web; Ultimate Ungulate). In Australia, introduced populations exist in the coastal regions of south and east Gippsland, Victoria (Australian Deer Association; Ramsey, 2019; Scroggie, 2014) and possibly also in New South Wales (PestSmart).
B3. Overseas range size score (0–2) < 1 = 0; 1– 70 = 1; >70 = 2 *Estimate the species overseas range size* including currently and the past 1000 years; natural and introduced range in millions of square kilometres*	1	*Overseas range between 1 to 70 million square kilometres.* Approximately 3 million km^2
B4. Taxonomic Class (0–1) *Bird = 0; mammal = 1*	1	*Mammal*
B. ESTABLISHMENT RISK SCORE **SUM OF B1- B4 (1–13)**	10	**Serious establishment risk**
Model 2: Seven-Factor Model For Birds And Mammals (Bomford 2008)		
B5. Diet score (0–1) *Specialist = 0; generalist = 1*	1	*Generalist with a broad diet of many food types.* Generalist grazer. Both a grazer and a browser but seem to prefer grazing (Animal Diversity Web). Johnsingh et al., (2004) considered hog deer to be an obligate grassland species in the Terai Arc Landscape of India, and studies in India and Nepal have shown a preference for grasslands dominated by cogon grass (*Imperata cylindrica*) (Biswas, 2004 and references therein).
B6. Habitat score (0–1) *Undisturbed or disturbed habitat*	1	*Can survive and breed in human-disturbed habitats (including grazing and agricultural lands, forests that are intensively managed or planted for timber harvesting and/or urban–suburban environments) without access to undisturbed (natural) habitats.*

		Can live in disturbed habitat. Hog deer are known to inhabit cinnamon plantations in Sri Lanka (Vishvanath, 2014).
B7. Migratory score (0–1) *Always migratory = 0; non-migratory = 1*	1	*Non-migratory*
B. ESTABLISHMENT RISK SCORE SUM OF B1- B7 (1–16)	13	**Serious establishment risk**
STAGE C: PROBABILITY AN ESTABLISHED SPECIES WILL BECOME A PEST		
C1. Taxonomic group (0–4)	4	*Mammal in one of the orders that have been demonstrated to have detrimental effects on prey abundance and/or habitat degradation (Artiodactyla) = 2.* *Mammal in one of the families that are particularly prone to cause agricultural damage (Cervidae) = 2*
C2. Overseas range size including current and past 1000 years, natural and introduced range (0–2) *Estimate the species overseas range size (including current and past 1000 years, natural and introduced range) in millions of square kilometres*	0	*Overseas geographic range less than 10 million square kilometres.* Approximately 3 million km^2
C3. Diet and feeding (0–3)	3	*Mammal that is primarily a grazer or browser.*
C4. Competition with native fauna for tree hollows (0–2)	0	*Does not use tree hollows.*
C5. Overseas environmental pest status (0–3) *Has the species been reported to cause declines in abundance of any native species of plant or animal or cause degradation to any natural communities in any country or region of the world?*	2	*Moderate environmental pest in any country or region.* In Hawaii, hog deer populations are blamed for ecological damage (Animal Diversity Web). In Wilsons Promontory National Park (Victoria, Australia), hog deer have caused environmental damage, through grazing, trampling, and by forming wallows in drainage lines (Parks Victoria).

C6. Climate match to areas with susceptible native species or communities (0–5) *Identify any native Australian animal or plant species or communities that could be susceptible to harm by the exotic species if it were to establish a wild population here.*	5	*The species has more than 691 grid squares within the highest four climate match classes that overlap the distribution of any susceptible native species or ecological communities = 5* Examples of susceptible native species or ecological communities include (DAWE Protected Matters Search Tool): White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland – Critically Endangered *Petrogale lateralis* (Warru, Central Australian Rock-wallaby) – Vulnerable
C7. Overseas primary production pest status (0–3) *Has the species been reported to damage crops or other primary production in any country or region of the world?*	1	*Minor pest of primary production in any country or region.* The hog deer is a minor pest of primary production. It is reported to be a pest in Sri Lanka particularly in cinnamon plantations (Vishvanath, 2014).
C8. Climate match to susceptible primary production (0–5) *Assess Potential Commodity Impact Scores for each primary production commodity listed in Table 9, based on species' attributes (diet, behaviour, ecology), excluding risk of spreading disease which is addressed in Question C9.* *0 = 0; 1-19 = 1; 20-49 = 2; 50-99 = 3; 100-149 = 4; ≥150 = 5*	3	Total Commodity Damage Score = 64 (see Table 2)
C9. Spread disease (1–2) *Assess the risk that the species could play a role in the spread of disease or parasites to other animals*	2	*All mammals (likely or unknown effect on native species and on livestock and other domestic animals).*
C10. Harm to property (0–3) *Assess the risk that the species could inflict damage on buildings, vehicles, fences, roads, equipment or ornamental gardens by chewing or burrowing or polluting with droppings or nesting material.*	2	*$11 - $50 million.* Damage to gardens and fencing has been reported (Parks Victoria). Also, hod deer can be involved in causing car accidents (though as small and shy, damage likely minor).

C11. Harm to people (0–5) *Assess the risk that, if a wild population established, the species could cause harm to or annoy people. Aggressive behaviour, plus the possession of organs capable of inflicting harm, such as sharp teeth, tusks, claws, spines, a sharp bill, horns, antlers or toxin delivering organs may enable animals to harm people. Any known history of the species attacking, injuring or killing people should also be taken into account (see Stage A, Score A1).*	3	*Moderate risk, injuries or harm moderate but unlikely to be fatal and few people at risk. Moderate Risk = 3.* Small/shy deer, unlikely to cause serious harm, however males have (relatively small) antlers so potential to cause injury. Hog deer can be involved in causing car accidents (though small and shy so harm likely minor and few people exposed). Deer species are known to carry the parasite *Cryptosporidium*. This parasite can contaminate drinking water reservoirs and cause infection in humans (cryptosporidiosis).
C. PEST RISK SCORE SUM C 1 TO C 11 (1–37)	25	**Extreme pest risk**
STAGE A. PUBLIC SAFETY RISK RANK – RISK TO PUBLIC SAFETY POSED BY CAPTIVE OR RELEASED INDIVIDUALS *0 = Not dangerous; 1 = Moderately dangerous; ≥ 2 = Highly dangerous*	1	Moderately dangerous
STAGE B. ESTABLISHMENT RISK RANK – RISK OF ESTABLISHING A WILD POPULATION **MODEL 1: FOUR-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)** *≤ 5 = low establishment risk; 6-8 = moderate establishment risk; 9-10 = serious establishment risk; ≥ 11-13 = extreme establishment risk*	10	Serious establishment risk
STAGE B. ESTABLISHMENT RISK RANK – RISK OF ESTABLISHING A WILD POPULATION **MODEL 2: SEVEN-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)** *≤ 6 = low establishment risk; 7-11 = moderate establishment risk; 12-13 = serious establishment risk; ≥14 = extreme establishment risk*	13	Serious establishment risk

STAGE C. PEST RISK RANK - RISK OF BECOMING A PEST FOLLOWING ESTABLISHMENT *< 9 = low pest risk; 9-14 = moderate pest risk; 15-19 = serious pest risk; > 19 = extreme pest risk*	25	Extreme pest risk

ENVIRONMENT AND INVASIVES COMMITTEE THREAT CATEGORY	**EXTREME**

World distribution map (Ultimate Ungulate and IUCN Red List) and World distribution map indicating where meteorological data was sourced for the climate analysis (see B1):

Figure 1 - World Distribution Map - IUCN Red List

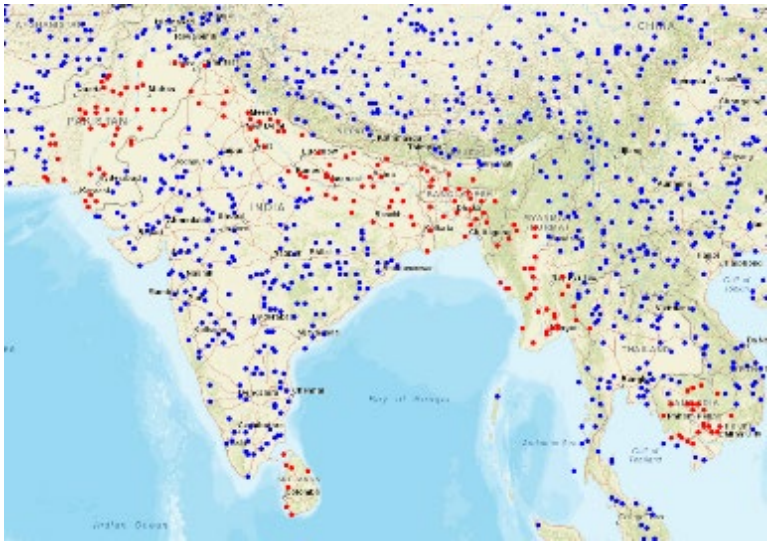


Figure 2 - World Distribution Map - Climatch

Figure 3 – Hawaii United States Map – Climatch

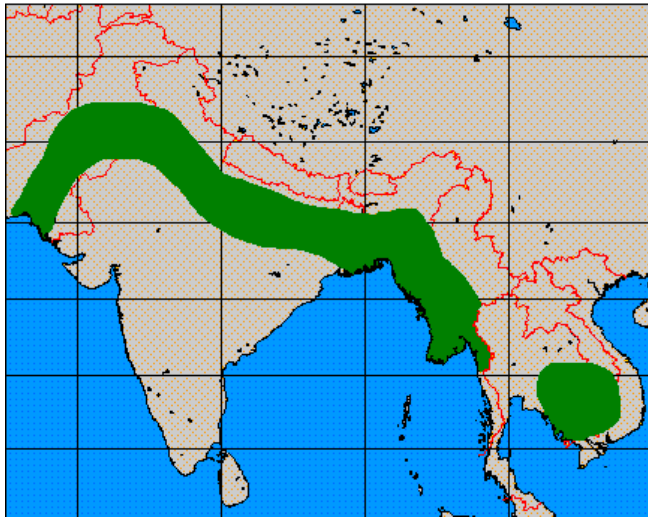
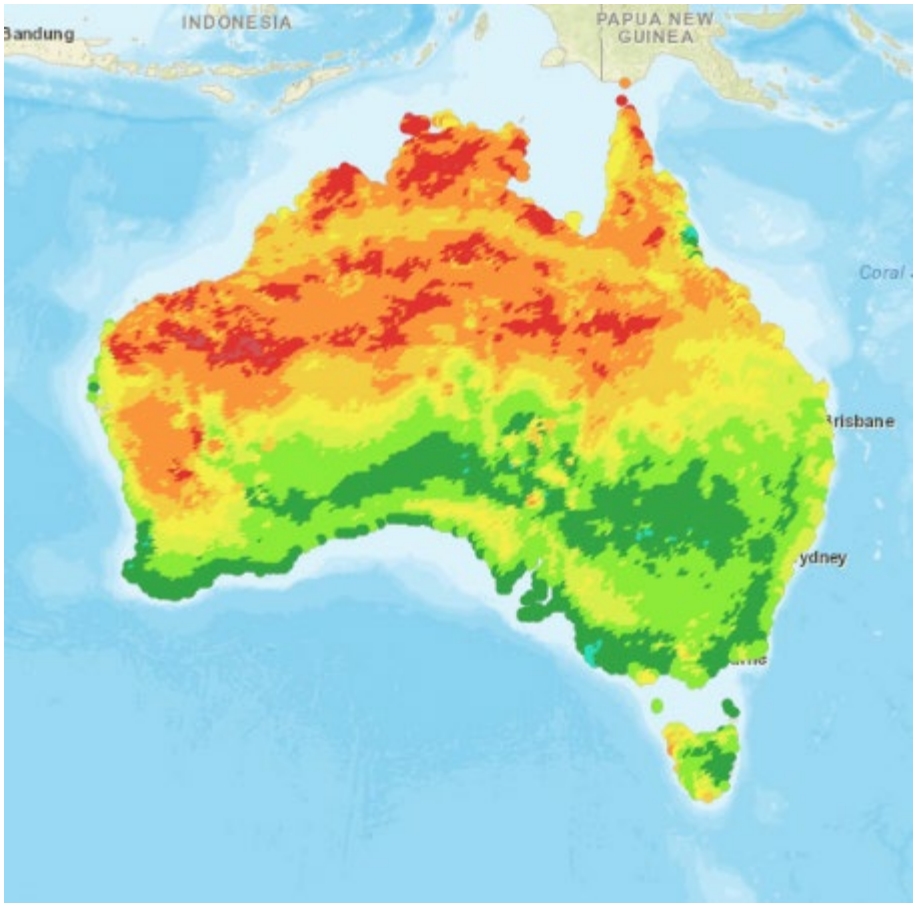


Figure 4 – Hog Deer established populations map

Climate match between world distribution of species and Australia:

Areas of Australia where the climate appears suitable for *Axis porcinus*

Value X = 9,843



Score	Color	Count
0		0
1		33
2		2240
3		3518
4		1828
5		1774
6		3337
7		4890
8		1556
9		60
10		0

Species: Axis porcinus (Hog Deer)
Algorithm: Closest Standard Score
187 source features selected
19236 target features selected
Approximate selected area: 2,399,730 km^2

Table 1: ABARES recalibration thresholds

Climate Match Score (CMS)	Climatch (50 km) Closest Standard Match Sum Level 6 (Value X)	2021 Recalibrated Climatch v2.0 (20 km) Closest Standard Match Sum Level 6 (Value X)
1 (Very low)	< 100	< 691
2 (Low)	100-599	691-4137
3 (Moderate)	600-899	4138-6209
4 (High)	900-1699	6210-11735
5 (Very high)	1700-2699	11736-18642
6 (Extreme)	≥ 2700	≥ 18643

Table 2: Susceptible Australian Primary Production – Calculating Total Commodity Damage Score

The commodity value index scores in this table are derived from Australian Bureau of Statistics 2005 – 2006 data. The values will require updating if significant change has occurred in the value of the commodity (Bomford 2008).

Industry	**Commodity Value Index 1 (CVI based on best available date)**	**Potential Commodity Impact Score (PCIS 0-3)**	**Climate Match to Commodity Score (CMCS 0–5)**	**Commodity Damage Score (CDS columns 2 X 3 X 4)**
Cattle (includes dairy and beef)	*11*	1	1	11
Timber (includes native and plantation forests)	*10*	1	3	30
Cereal grain (includes wheat, barley sorghum etc)	*8*	2	1	16
Sheep (includes wool and sheep meat)	*5*	1	1	5
Fruit (includes wine grapes)	*4*			
Vegetables	*3*			
Poultry and eggs	*2*			
Aquaculture(includes coastal mariculture)	*2*			
Oilseeds (includes canola, sunflower etc)	*1*	1	0	0
Grain legumes (includes soybeans)	*1*	1	1	1
Sugarcane	*1*	1	1	1
Cotton	*1*			
Other crops and horticulture (includes nuts tobacco and flowers etc)	*1*			
Pigs	*1*			
Other livestock (includes goats, deer, camels, rabbits)	*0.5*			
Bees (included honey, beeswax and pollination)	*0.5*			
Total Commodity Damage Score (TCDS)				64

Assess Potential Commodity Impact Scores for each primary production commodity listed in Table 9, based on species' attributes (diet, behaviour, ecology), excluding risk of spreading disease which is addressed in Question C9, and pest status worldwide as:

0. *Nil (species does not have attributes to make it capable of damaging this commodity)*
1. *Low (species has attributes making it capable of damaging this or similar commodities and has had the opportunity but no reports or other evidence that it has caused damage in any country or region*
2. *Moderate–serious (reports of damage to this or similar commodities exist but damage levels have never been high in any country or region and no major control programs against the species have ever been conducted OR the species has attributes making it capable of damaging this or similar commodities but has not had the opportunity)*
3. *Extreme (damage occurs at high levels to this or similar commodities and/or major control programs have been conducted against the species in any country or region and the listed commodity would be vulnerable to the type of harm this species can cause).*

Climate Match to Commodity Score (0–5)

- *None of the commodity is produced in areas where the species has a climate match within the highest eight climate match classes (ie classes 10, 9, 8, 7, 6, 5, 4 and 3) = 0*
- *Less than 10% of the commodity is produced in areas where the species has a climate match within the highest eight climate match classes = 1*
- *Less than 10% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes (ie classes 10, 9, 8, 7, 6 and 5) = 2*
- *Less than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes AND less than 10% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes (ie classes 10, 9 and 8) = 3*
- *Less than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes BUT more than 10% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes = 4*
- *OR More than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes BUT less than 20% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes = 4*
- *More than 20% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes OR overseas range unknown and climate match to Australia unknown = 5.]*

Table 3: Assigning species to EIC Threat Categories (shaded cells relate to assignment of reptiles and amphibians to EIC Threat Categories based on an assessed establishment risk and an allocated pest risk of extreme) – adapted from Bomford 2008

Establishment Risk	Pest Risk	Public Safety Risk	EIC Threat Category	Implication for any proposed import into Australia	Implication for keeping and movement in Australia
Extreme	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**	Prohibited, unless sufficient risk management measures exist to reduce the potential risks to an acceptable level	Limited to those collections approved for keeping particular EXTREME Threat species
Extreme	Serious	Highly, Moderately or Not Dangerous	**EXTREME**		
Extreme	Moderate	Highly, Moderately or Not Dangerous	**EXTREME**		
Extreme	Low	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Serious	Highly, Moderately or Not Dangerous	**EXTREME**		
Moderate	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Moderate	Highly, Moderately or Not Dangerous	**SERIOUS**	Import restricted to those collections approved for keeping SERIOUS Threat species	Limited to those collections approved for keeping particular SERIOUS Threat species
Serious	Low	Highly, Moderately or Not Dangerous	**SERIOUS**		
Moderate	Serious	Highly, Moderately or Not Dangerous	**SERIOUS**		
Moderate	Moderate	Highly Dangerous	**SERIOUS**		
Moderate	Low	Highly Dangerous	**SERIOUS**		
Low	Extreme	Highly, Moderately or Not Dangerous	**SERIOUS**		
Low	Serious	Highly, Moderately or Not Dangerous	**SERIOUS**		
Low	Moderate	Highly Dangerous	**SERIOUS**		
Low	Low	Highly Dangerous	**SERIOUS**		
Moderate	Moderate	Moderately or Not Dangerous	**MODERATE**	Import restricted to those collections approved for keeping MODERATE Threat species	Limited to those collections approved for keeping particular MODERATE Threat species
Moderate	Low	Moderately or Not Dangerous	**MODERATE**		
Low	Moderate	Moderately or Not Dangerous	**MODERATE**		
Low	Low	Moderately Dangerous	**MODERATE**		
Low	Low	Not Dangerous	**LOW**	Import permitted	May be limited to those collections approved for keeping particular LOW Threat species
Any Value	Any Value	Unknown	**EXTREME until proven otherwise**	Prohibited, unless sufficient risk management measures exist to reduce the potential risks to an acceptable level	Limited to those collections approved for keeping particular EXTREME Threat species
Unknown	Any Value	Any Value	**EXTREME until proven otherwise**		
Any Value	Unknown	Any Value	**EXTREME until proven otherwise**		
Unassessed	Unassessed	Unassessed	**EXTREME until proven otherwise**		

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National Risk Assessment: EXTREME

RISK ASSESSMENT FOR AUSTRALIA: Water Buffalo (*Bubalus bubalis*)

Class - Mammalia**, Order -** Artiodactyla**, Family -** Bovidae**, Genus -** *Bubalus*.

SPECIES: *Bubalus bubalis* (Linnaeus, 1758) **Subspecies:** 1. Bubalus bubalis bubalis (Linnaeus, 1758) 2. Bubalus bubalis kerabau (Fitzinger, 1860) **Synonyms:** **1. Bubalus bubalis bubalis (Linnaeus, 1758)** *Bubalus bubalis semindus* (Kerr, 1792) **2. Bubalus bubalis kerabau (Fitzinger, 1860)** *Bubalus bubalis carabanensis* (Castillo, 1971) *Bos bubalus* (Linnaeus, 1758) **Common Names:** **1. Bubalus bubalis bubalis (Linnaeus, 1758)** River Buffalo	**Species description:** The wild Asian buffalo, from which the domestic water buffalo originates, is a large and powerful animal. Individual wild Asian buffalo stand at 1.5–1.9 metres at the shoulder. Wild Asian buffalo have a body length ranging from 2.4–3.6 metres with males (bulls) weighing up to 1,200 kilograms and females (cows) weighing 800 kilograms (Roth, 2004). In contrast, domestic water buffalo are often smaller in size, having been bred for tractability. Typical weights for domestic water buffalo range from 250 kilograms in China, to 300 kilograms in Burma and 500–600 kilograms in Laos (Ligda, 1998). Water buffalo have sparse hair that is ashy grey or black. Their relatively long tail is bushy at the tip. Their legs are often dirty white up to the knees. Adult buffalo are almost hairless, and their skin colour varies with weather conditions. It is often difficult to ascertain skin colour as the animals are usually covered with mud. Domestic varieties range in colour from black to ashy grey to reddish. For example, in Indonesia, the domestic water buffalo has black and white hair (Ligda, 1998). Calves have a reddish coat that darkens with age. Both sexes have horns, although the females are usually smaller than the male's. Horns of both sexes are heavy-set at the base, ribbed, and triangular in cross-section (Roth, 2004). There are two broad types of domestic water buffalo recognised by the shape of their horns: the river-type from western Asia (with curled horns) and the swamp-type from eastern Asia (with swept-back horns) (Department of Environment and Heritage, 2004). Australia has a mix of both, with the swamp-type dominating. Feral water buffalo in Australia are usually light to dark grey, but the natural population also contains numbers of pink, albinoid and piebald types (grey and white patches) (Lemke, 1994). **General information:** Water buffalo have been associated with people since prehistoric times. It is one of the oldest species of domesticated livestock and continues to be used as a source of milk and meat, and as a draft animal. Until recently all water buffalo were considered to be one species. Recent taxonomic revision has defined *B. bubalis* as the domestic Water Buffalo, and *B. arnee* as the Wild Water Buffalo. This risk assessment considers only the domestic Water Buffalo (*B. bubalis*), and the term "water buffalo" refers to this species unless otherwise specified.

2. Bubalus bubalis kerabau (Fitzinger, 1860) Swamp Buffalo Asian Water Buffalo Asiatic Water Buffalo Water Buffalo Domestic Water Buffalo Carabao	The wild Asian buffalo originally ranged from eastern Nepal and India to Indochina and what is now Malaysia where they were found at elevations up to 2,800 metres in Nepal (Roth, 2004). By the mid-20th century, the original wild herds had been substantially reduced and eliminated from much of their range. In 1990, it was believed that remnant wild populations were restricted to a few small herds in India, Nepal and Thailand. The total wild population was estimated to be fewer than 4,000 animals. Due to interbreeding with domestic cattle, it is also possible that no purebred wild Asian buffalo remain. Interbreeding with domestic buffalo is the major threat to wild Asian buffalo. Diseases and parasites (transmitted by domestic livestock) and competition for food and water between wild buffalo and domestic stock are also significant threats (Massicot, 2004; Roth, 2004). The water buffalo appears to have been one of the earliest domesticated animals in Asia. Evidence of their existence in prehistoric time dates from around 4000 BC (Diamond, 1997). They were introduced to the Near East and north Africa as domestic animals around 600 AD, before being brought to Europe in the Middle Ages. Herds still exist in Italy and Bulgaria (Ligda, 1998). More recently, water buffalo have been introduced as farmed animals into the United States, South America, Central America, Australia and Oceania. Between 1825 and 1843, about 80 water buffalo were transported from South-East Asia to Melville Island and Cobourg Peninsula (in what is now the Northern Territory, Australia) to provide the remote settlements with meat. When these settlements were abandoned in the mid-1800s, the water buffalo were left to roam and soon colonised the permanent and semi-permanent swamps and freshwater springs of the “Top End”. By the late 19th century, large numbers of water buffalo could be found on the northern flood plains and Melville Island. From about 1886, a small buffalo harvesting industry developed and the animals were shot for their hides (Lever, 1985). During the first half of the 20th century, harvesting buffalo for their hides continued. There were also some exports of live animals and attempts at re-domestication. By 1955–56, nearly 400,000 buffalo had been shot for hides and a further 140,000 had been slaughtered for pet food and human consumption (Lever, 1985). However, the prices for buffalo products were subject to fluctuation; business interest tended to wax and wane in line with prices, while feral water buffalo numbers continued to increase. A safari hunting industry, which developed in the “Top End” during the 1960s, had little impact on buffalo numbers. By the 1970s, feral buffalo numbers were so high that they were destroying wetlands and harbouring diseases that could affect native species and livestock; the most significant of these diseases being brucellosis (*Brucella abortus*) and bovine tuberculosis (*Mycobacterium bovis*). A water buffalo eradication program was initiated for environmental reasons and as part of the Brucellosis and Tuberculosis Eradication Campaign (BTEC), which commenced in the 1970s.

	During the 1980s, it was estimated some 350,000 water buffalo lived in the Top End of the Northern Territory. However, the BTEC almost eradicated them from the wild. In Kakadu National Park, Northern Territory, the number was reduced from about 20,000 animals in 1988 to less than 250 animals in 1996. The current population of water buffalo in the Northern Territory is now estimated at 80,000 animals (Clive McMahon, pers. comm. 2008). Feral water buffalo have never been a major problem in Queensland, Australia. A survey of water buffalo in 1981–82 suggested low population levels, with only a few sightings in north Queensland and the Gulf, and a single report from south-west Queensland (Mitchell et al., 1982). At the time of the survey, up to 200 bulls were thought to exist in the State (Mitchell et al., 1982). In 2005, a survey again confirmed that feral water buffalo were restricted to small areas of the state. Currently there are no exact figures for feral water buffalo in Queensland. Water buffalo are occasionally sighted in the far north region of Burke Shire. Up to 12 animals a year are reported, with higher numbers in dry years when they may travel from the Northern Territory in search of food. There is likely to be many more water buffalo in this region, as water buffalo are only sighted when they are moving through or feeding out in the open. "There is a considerable area of inaccessible country to the west of Burketown, to the north of Doomadgee and along the coast, with numerous large lakes and lagoons that could harbour buffalo" (Russell Cunningham, Burke Shire Ranger, pers. comm. 2008). Apart from water buffalo kept in zoos, there are a small number of water buffalo dairy farms on the Atherton Tableland and at Maleny on the Sunshine Coast. In Queensland, there are approximately 1,800 registered farmed water buffalo (Robert Collins, DPI&F, pers. comm. 2008). Domestic water buffalo are farmed for meat and hides in small numbers in all states. There is also a growing market for water buffalo milk (Victorian Department of Primary Industries, 2000). There are approximately 15,000–20,000 head of domestic water buffalo in Australia (Australian Buffalo Industry Council, 2008). Wild Asian buffalo are found in tropical and subtropical forests and in wet grasslands. Wild Asian buffalo are heavily dependent on water and spend a considerable time wallowing in rivers or mud holes. They are more frequently encountered in riverine forests and grasslands, marshes and swamps (Roth, 2004). Domestic water buffalo are found in similar tropical and subtropical environments to their wild ancestors. However, their range can extend if they are provided with adequate shelter. With suitable protection, farmed water buffalo have been able to tolerate most conditions in southern Australia (Lemke, 1994). In Australia, most feral water buffalo are found in the "Top End" of the Northern Territory. They inhabit wetlands and floodplains where they have access to food and water. In low-rainfall years, many buffalo die, and the

	survivors are restricted to more permanent wetlands in the northern part of their range. After a series of wet years, the population builds, with densities of up to 34 animals per square kilometre (DEH, 2004). In the wet season, water buffalo tend to graze flood plains at dawn and dusk. Around mid-morning they move to water to drink and wallow, before returning to graze from mid-afternoon until dark (Roth, 2004). They retreat to upland savannah woodlands for nurseries and overnight camps, and for grazing recently germinated annual grasses (Petty et al., 2007). In drier times, feral buffalos prefer to graze at night, spending most of the day in wallows (Roth, 2004). During the late dry season, buffalo will graze perennial grasses on savannah woodlands (Petty et al., 2007). Water buffalo are more sensitive to heat than most bovids because they have fewer sweat glands. Wallowing in mud helps keep the water buffalo cool. Wallowing also serves to cake the animal with mud, thereby protecting it from biting insects (Roth, 2004). Water Buffalo eat a range of grasses and other plants but also chew the bark off trees to obtain minerals (DEH, 2004). In the wet season (November–April), water buffalo graze aquatic grasses and grass-like wetland plants. They eat a broader range of food in the dry season, feeding on grasses, herbs and the leaves of plants like pandanus. Males consume up to 30 kilograms of dry matter each day (DEH, 2004). Water buffalo are known to eat a wider range of forage than cattle and are physiologically better adapted to poor quality feed compared to cattle (Lemke, 1994). The river-type water buffalo has 50 chromosomes whereas the swamp-type has 48 chromosomes. The two types can interbreed, and all offspring are fertile. Females reach sexual maturity at 18 months to 2 years whereas males reach it at 3 years. After a gestation period between 300-340 days, 1 calf is born (rarely 2). Weaning of young occurs at 6-9 months. Cows can reproduce for 15–18 years, however bulls decline in fertility after 6–7 years but may remain active for longer (Ingawale & Dhoble, 2004; Soysal et al., 2005). Although water buffalo are considered to be slow breeders, research in Australia indicates that weaning can be carried out as late as 12 months of age without any effect on the mother's conception times (Ligda, 2004). This suggests that water buffalo may have high reproduction rates when nutrition levels are high, and predation is low. The mating period in Australia peaks around March (Roth, 2004). During most of the Australian dry season (May–October), males and females form separate herds. Females form clans, consisting of mothers and daughters, of roughly 30 individuals. Females and calves, led by one of the older cows, occupy the forested plains, where food and shade are most plentiful. Each clan has a home range varying from 170–1,000 hectares, which may overlap with the range of other clans. Clans may come together at night to form a herd of up to 500 animals at a communal resting area. At the age of three, males leave the female herds, often forming bachelor herds. Bachelor herds may number up to 10 individuals. These herds typically have slightly larger ranges than the ranges of female clans, and male

	ranges will overlap those of the female clans. Males inhabit more open plains with little shade, or slopes with drier vegetation. Older bulls are often solitary but have been observed in female herds year-round. Older bulls and young males ejected from the herds may wander thousands of kilometres in search of new territories (Roth, 2004). Water buffalo can cause significant environmental damage. Their habit of wallowing stirs up mud, making the water body unsuitable for many aquatic plants and animals. They consume substantial amounts of grass and other plants and compete for food with native wildlife. As they move from one wetland area to another they create “swim channels”. These channels intersect with tidal creeks, allowing saltwater to move into freshwater wetlands, often killing plants and animals’ intolerant to saltwater (DEW, 2006). Habitat degradation by water buffalo can also impact on native fauna and waterholes. It is believed that habitat reduction and degradation decrease nesting activity in magpie geese (*Anseranas semipalmata*), crocodiles (Northern Territory Government, 2007) and on endangered species such as the Gouldian finch (*Erythrura gouldiae*) (O’Malley, 2006). Water buffalo have been the primary cause of two major “ecological cascades” in Kakadu National Park. The first cascade occurred between 1960 and 1985, when water buffalo populations increased exponentially and reached the area’s maximum carrying capacity. Due to high levels of grazing, vegetation damage and soil compaction, water buffalo severely affected vegetation structure and composition in the main habitat types of flood plains, monsoon rainforests, savannah woodlands and open forest. Across all habitat types, there was a significant decrease in biomass (both green and litter) and a decrease in vegetative cover. In the flood plains, there was an increase in saltwater channels, a loss of freshwater vegetation and siltation of some ponds. Monsoon rainforests and savannah woodlands experienced a decrease in fire fuel loads and an increase in weeds (Petty et al., 2007). The second cascade, from 1985 to 1994, corresponded with BTEC and a rapid decline in buffalo numbers. This sudden reversal in grazing pressure caused significant changes in vegetation ground cover and biomass (Petty et al., 2007). There is anecdotal evidence that *Mimosa pigra*, a weed of national significance, became much more abundant soon after water buffalo were removed by the BTEC campaign. In some areas, however, flood plains largely reverted to their natural state; there were fewer water buffalo wallows, the water cleared, there was less salt intrusion, and plants such as red water lilies, grasses and sedge plants (valuable food for native animals) reappeared. However, rehabilitation work in these areas is often costly, requiring weed control, as well as the ongoing removal of water buffalo (DEW, 2006; Findlayson et al., 1997). Savannah woodlands experienced a rapid increase in biomass and change in plant species, which subsequently increased fires; and the lasting impact in monsoon rainforests was an increase in weed abundance (Petty et al., 2007).

	The direct effect of water buffalo on ground-level vegetation and soils in Kakadu National Park indirectly altered competitive relationships between trees, grasses and forbs, and produced significant changes to fuel loads and fire regimes which, in turn, further altered species composition and overall structure of the savannah. The simple removal of water buffalo was not enough of an impetus for Kakadu National Park's savannah system to revert to its previous state. Feral water buffalo have been recorded as a pest in Sri Lanka where they cause damage to various agricultural crops, mainly in the dry zone (Bambaradeniya et al., 2005). Feral water buffalo populations also exist in Brazil, where they are a threat to important wetlands in the Amazon Basin (Kane, 1989; Thornback, 1983). **Longevity:** Up to 25 years in the wild; 29 years in captivity (Roth, 2004). **Conservation status:** **IUCN RedList:** Not listed (wild form *B. arnee* has a fragmented distribution in parts of Asia and is listed as Endangered) **CITES:** Not listed (wild form *B. arnee* listed as CITES: Appendix III)
DATE OF ORIGINAL ASSESSMENT: 2008 (updated 2016) and 2011 **DATE OF CURRENT ASSESSMENT:** May 2021 (Jodi Buchecker) **EIC ENDORSEMENT:** 22/04/22 **Risk assessment model used for the assessment:** Bomford 2008, Mammals and Birds	**The risk assessment model:** Models for assessing the risk that exotic vertebrates could establish in Australia have been developed for mammals, birds (Bomford 2003, 2006, 2008), reptiles and amphibians (Bomford et al 2005, Bomford 2008). Developed by Dr Mary Bomford for the Bureau of Rural Sciences (BRS), the model uses criteria that have been demonstrated to have significant correlation between a risk factor and the establishment of populations of exotic species and the pest potential of those species that do establish. For example, a risk factor for establishment is similarity in climate (temperature and rainfall) within the species' distribution overseas and Australia. For pest potential, the species' overseas pest status is a risk factor. The model is published as 'Risk assessment models for the establishment of exotic vertebrates in Australia and New Zealand' (Bomford 2008) and is available online on the PestSmart website https://pestsmart.org.au/wp-content/uploads/sites/3/2020/06/Risk_Assess_Models_2008_FINAL.pdf **CLIMATE**: In 2021 a new version of the Climatch program used to assess similarity in climate was released by the Australian Bureau of Agricultural Resource Economics and Sciences (ABARES): CLIMATCH v2.0. The increase in resolution in this new version (from 50 km to 20 km) required recalibration of Climate Match Scores. See Table 1. Sixteen climate parameters (variables) of temperature and rainfall are used to estimate the extent of similarity between data from meteorological stations located within the species' world distribution and stations in Australia. Worldwide, data from approximately 19000 locations are available for analysis. The number of locations used in an analysis will vary according to the size of the species' distribution and the number of meteorological stations located within that distribution. To represent the climate match visually, the map of Australia is divided into 19236 grid squares, each measured in 0.2 degrees in both longitude and latitude.

	CLIMATCH v2.0 calculates a match for each Australian grid by comparing data from all meteorological stations within the species' distribution (excluding any populations in Australia) and allocating a score ranging from ten for the highest level match to zero for the poorest match. Levels of climate match are used in the risk assessment for questions B1 (scores are summed to give a cumulative score), C6, and C8. Climatch v2.0 can be accessed on the ABARES website, agriculture.gov.au/abares. The direct URL is https://climatch.cp1.agriculture.gov.au/.

FACTOR	**SCORE**	**DETAIL**
STAGE A: RISKS POSED BY CAPTIVE OR RELEASED ANIMALS		
A1. Risk to people from individual escapees (0–2) *Assess the risk that individuals of the species could harm people. (NB, this question only relates to aggressive behaviour shown by escaped or released individual animals. Question C11 addresses the risk of harm from aggressive behaviour if the species establishes a wild population).* *Aggressive behaviour, size, plus the possession of organs capable of inflicting harm, such as sharp teeth, claws, spines, a sharp bill, or toxin-delivering apparatus may enable individual animals to harm people. Any known history of the species attacking, injuring or killing people should also be taken into account. Assume the individual is not protecting nest or young.*	2	*Animal that sometimes attacks when unprovoked and/or is capable of causing serious injury (requiring hospitalisation) or fatality.* Large animal with large horns that will sometimes attack unprovoked and can cause serious injury (requiring hospitalisation) or fatality.
A2. Risk to public safety from individual captive animals (0–2) *Assess the risk that irresponsible use of products obtained from captive individuals of the species (such as toxins) pose a public safety risk (excluding the safety of anyone entering the animals' cage/enclosure or otherwise coming within reach of the captive animals)*	0	*Nil or low risk (highly unlikely or not possible) .* The risk to public safety from irresponsible use of products obtained from water buffalo is low.
STAGE A PUBLIC SAFETY RISK SCORE **SUM A1 - A2 (0-4)**	2	**Highly dangerous**

STAGE B: PROBABILITY ESCAPED OR RELEASED INDIVIDUALS WILL ESTABLISH FREE-LIVING POPULATIONS		
Model 1: FOUR-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)		
B1. Degree of climate match between species overseas range and Australia (1–6) *Map the selected mammal or bird species' overseas range, including its entire native and exotic (excluding Australia) ranges over the past 1000 years.* *Use CLIMATCH v2.0, Value X = sum of classes 6 – 10, see Table 1.*	3	*Moderate climate match to Australia* Value X = 5,711 Climate Match Score = 3
B2. Exotic population established overseas (0–4) *An established exotic population means the introduced species must have bred outside of captivity and must currently maintain a viable free-living population where the animals are not being intentionally fed or sheltered, even though they may be living in a highly disturbed environment with access to non-natural food supplies or shelter.*	4	*Exotic population established on a larger island (> 50 000 km^2) or anywhere on a continent (including elsewhere on the land mass where the natural distribution of the animal is, if this population is due to human introduction and is geographically separate from the natural range of the species).* Introduced free-ranging populations noted in Sri Lanka, Papua New Guinea, Indonesia, Andaman Islands, Tunisia, north-eastern Argentina and Brazil (Jesser et al., 2008; Long, 2003). Not included in this scoring: In Australia, feral populations occur in the northern regions of Western Australia, the Northern Territory and Queensland. Water buffalo were originally introduced to Australia from Timor in the 1820s, with subsequent introductions in the 1840s and 1860s. Large herds of water buffalo were established by the mid-1870s (Long 2003).
B3. Overseas range size score (0–2) < 1 = 0; 1– 70 = 1; >70 = 2 *Estimate the species overseas range size* including currently and the past 1000 years; natural and introduced range in millions of square kilometres*	1	*Overseas range between 1 to 70 million square kilometres.* Range is estimated to be >8 million km^2.
B4. Taxonomic Class (0–1) *Bird = 0; mammal = 1*	1	*Mammal*
B. ESTABLISHMENT RISK SCORE	9	**Serious establishment risk**

SUM OF B1- B4 (1–13)		
Model 2: Seven-Factor Model For Birds And Mammals (Bomford 2008)		
B5. Diet score (0–1) *Specialist = 0; generalist = 1*	1	*Generalist with a broad diet of many food types.* Not a specialist (grazer and browser).
B6. Habitat score (0–1) *Undisturbed or disturbed habitat*	1	*Can survive and breed in human-disturbed habitats (including grazing and agricultural lands, forests that are intensively managed or planted for timber harvesting and/or urban–suburban environments) without access to undisturbed (natural) habitats.* Can live in disturbed habitat.
B7. Migratory score (0–1) *Always migratory = 0; non-migratory = 1*	1	*Non-migratory*
B. ESTABLISHMENT RISK SCORE **SUM OF B1- B7 (1–16)**	12	**Serious establishment risk**
STAGE C: PROBABILITY AN ESTABLISHED SPECIES WILL BECOME A PEST		
C1. Taxonomic group (0–4)	4	*Mammal in one of the orders that have been demonstrated to have detrimental effects on prey abundance and/or habitat degradation (Artiodactyla) = 2. Mammal in one of the families that are particularly prone to cause agricultural damage (Bovidae) = 2.*
C2. Overseas range size including current and past 1000 years, natural and introduced range (0–2) *Estimate the species overseas range size (including current and past 1000 years, natural and introduced range) in millions of square kilometres*	0	*Overseas geographic range less than 10 million square kilometres.* Range is estimated to be >8 million km^2.
C3. Diet and feeding (0–3)	3	*Mammal that is primarily a grazer or browser.*
C4. Competition with native fauna for tree hollows (0–2)	0	*Does not use tree hollows.*
C5. Overseas environmental pest status (0–3)	3	*Major environmental pest in any country or region.*

Has the species been reported to cause declines in abundance of any native species of plant or animal or cause degradation to any natural communities in any country or region of the world?		Feral water buffalo populations exist in Brazil, where they are a threat to important wetlands in the Amazon Basin (Kane, 1989; Thornback, 1983). Water buffalo can cause significant environmental impact by trampling flood plain environments; causing extensive damage to freshwater swamps; eating out native grasses; compacting soil; and changing the structure of monsoon forest and wetlands (Braithwaite et al., 1984; cited in Long, 2003; Calder, 1981; Considine, 1985).
C6. Climate match to areas with susceptible native species or communities (0–5) *Identify any native Australian animal or plant species or communities that could be susceptible to harm by the exotic species if it were to establish a wild population here.*	5	*The species that has more than 691 grid squares within the highest four climate match classes that overlap the distribution of any susceptible native species or ecological community = 5.* Water buffalo are noted for trampling the nesting grounds of the rare Pig-nosed Turtle (*Carettochelys inscuplta*) on the shores of billabongs and rivers (Georges and Kennett, 1990 cited in Long, 2003). Habitat degradation by water buffalo can also impact on native fauna and waterholes. It is believed that this habitat reducation and degradation decreases nesting activity in magpie geese (*Anseranas semipalmata*), crocodiles (Northern Territory Government, 2007) and on endangered species such as the Gouldian finch (*Erythrura gouldiae*) (O'Malley, 2006).
C7. Overseas primary production pest status (0–3) *Has the species been reported to damage crops or other primary production in any country or region of the world?*	1	*Minor pest of primary production in any country or region.* Water buffalo are commonly used in farming but can be a pest to agriculture by overgrazing and trampling pasture and contributing to soil erosion and salinity problems. Minor pest to agriculture in northern Australia. Feral water buffalo have been recorded as a pest in Sri Lanka where they cause damage to various agricultural crops, mainly in the dry zone (Bambaradeniya et al., 2005).
C8. Climate match to susceptible primary production (0–5) *Assess Potential Commodity Impact Scores for each primary production commodity listed in Table 9, based on species' attributes (diet, behaviour, ecology), excluding risk of spreading disease which is addressed in Question C9.* *0 = 0; 1-19 = 1; 20-49 = 2; 50-99 = 3; 100-149 = 4; ≥150 = 5*	3	Total Commodity Damage Score = 59.5 (see Table 2)

C9. Spread disease (1–2) *Assess the risk that the species could play a role in the spread of disease or parasites to other animals*	2	*All mammals (likely or unknown effect on native species and on livestock and other domestic animals).*
C10. Harm to property (0–3) *Assess the risk that the species could inflict damage on buildings, vehicles, fences, roads, equipment or ornamental gardens by chewing or burrowing or polluting with droppings or nesting material.*	2	*$11-$50 million*. Damage to fences, equipment, and roads
C11. Harm to people (0–5) *Assess the risk that, if a wild population established, the species could cause harm to or annoy people. Aggressive behaviour, plus the possession of organs capable of inflicting harm, such as sharp teeth, tusks, claws, spines, a sharp bill, horns, antlers or toxin delivering organs may enable animals to harm people. Any known history of the species attacking, injuring or killing people should also be taken into account (see Stage A, Score A1).*	4	*Injuries or harm severe or fatal but few people at risk: Serious risk = 4.* Water buffalo are unlikely to make unprovoked attacks, although may charge and trample humans or inflict damage with their horns. Injuries are likely to be serious and may potentially result in death.
C. PEST RISK SCORE SUM C 1 TO C 11 (1–37)	27	**Extreme pest risk**
STAGE A. PUBLIC SAFETY RISK RANK – RISK TO PUBLIC SAFETY POSED BY CAPTIVE OR RELEASED INDIVIDUALS *0 = Not dangerous; 1 = Moderately dangerous; ≥ 2 = Highly dangerous*	2	Highly dangerous
STAGE B. ESTABLISHMENT RISK RANK – RISK OF ESTABLISHING A WILD POPULATION **MODEL 1: FOUR-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)**	9	Serious establishment risk

≤ 5 = low establishment risk; 6-8 = moderate establishment risk; 9-10 = serious establishment risk; ≥ 11-13 = extreme establishment risk		
STAGE B. ESTABLISHMENT RISK RANK – RISK OF ESTABLISHING A WILD POPULATION **MODEL 2: SEVEN-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)** *≤ 6 = low establishment risk; 7-11 = moderate establishment risk; 12-13 = serious establishment risk; ≥14 = extreme establishment risk*	12	Serious establishment risk
STAGE C. PEST RISK RANK - RISK OF BECOMING A PEST FOLLOWING ESTABLISHMENT *< 9 = low pest risk; 9-14 = moderate pest risk; 15-19 = serious pest risk; > 19 = extreme pest risk*	27	Extreme pest risk

ENVIRONMENT AND INVASIVES COMMITTEE THREAT CATEGORY	**EXTREME**

World distribution map of wild type (*Bubalus arnee*) (IUCN Red List), distribution of feral Water Buffalo (*Bubalus bubalis*) (CABI) and World distribution map indicating where meteorological data was sourced for the climate analysis (see B1):

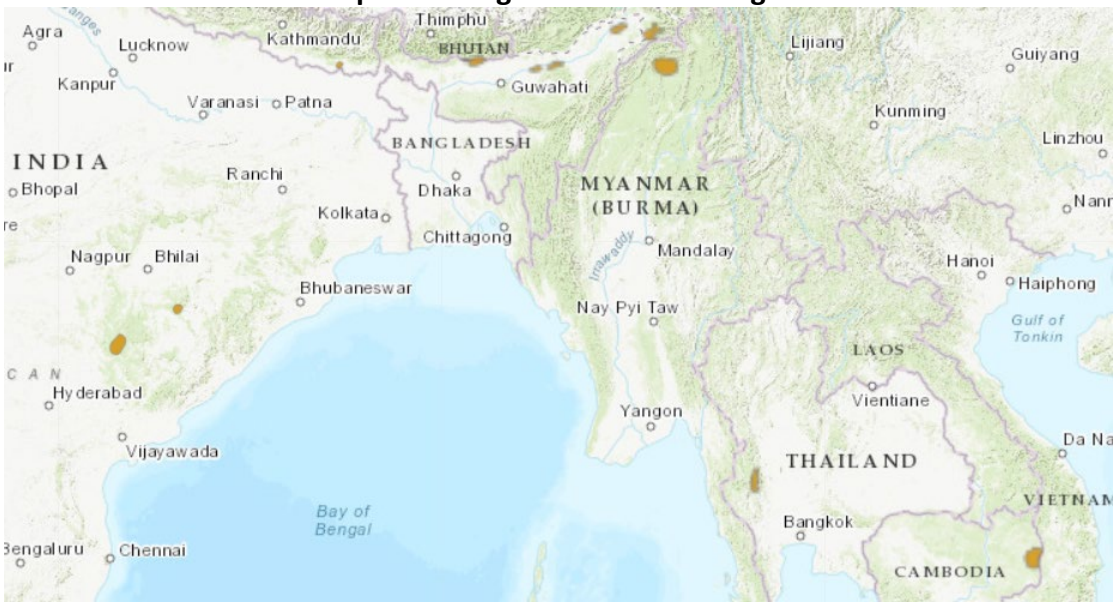


Figure 1 - World Distribution Map - IUCN Red List

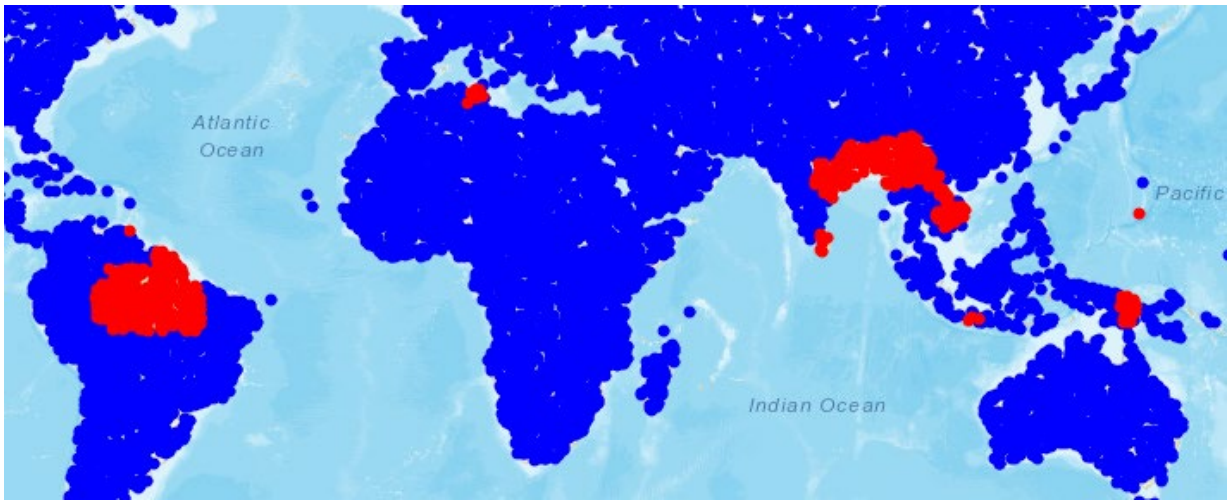
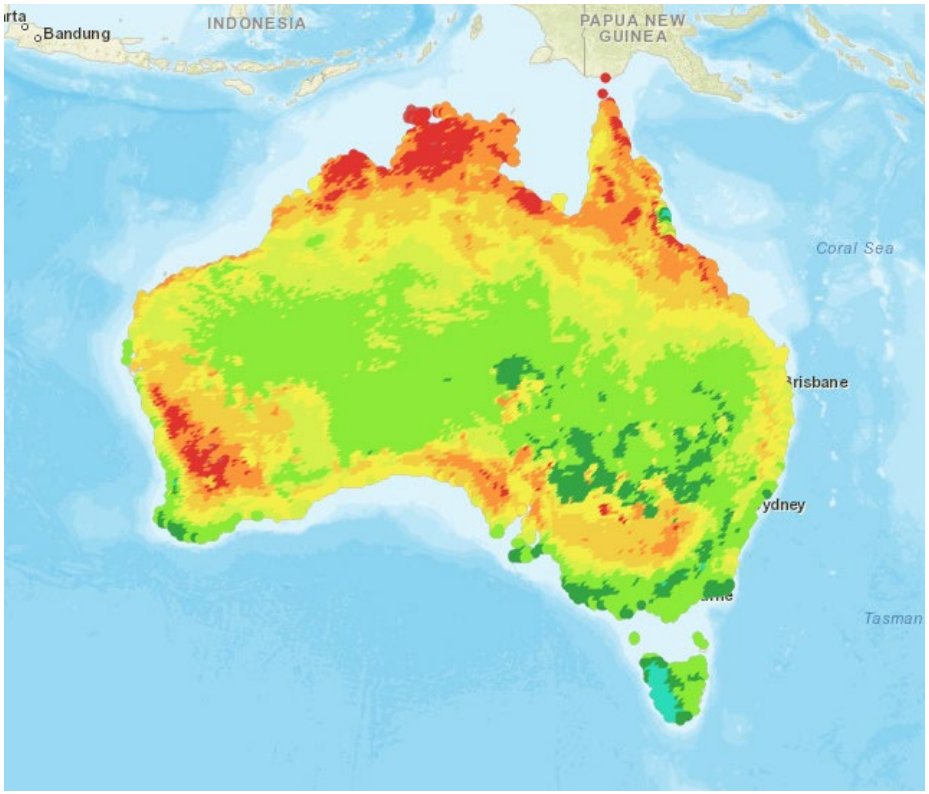


Figure 2- World Distribution Map - Climatch

Climate match between world distribution of species and Australia:

Areas of Australia where the climate appears suitable for *Bubalus bubalis*

Value X = 5,711



Score	Color	Count
0		0
1		66
2		809
3		6521
4		3349
5		2780
6		3024
7		1820
8		846
9		21
10		0

Species: Bubalus bubalis (Water Buffalo)
Algorithm: Closest Standard Score
569 source features selected
19236 target features selected
Approximate selected area: 7,251,916 km^2

Table 1: ABARES recalibration thresholds

Climate Match Score (CMS)	Climatch (50 km) Closest Standard Match Sum Level 6 (Value X)	2021 Recalibrated Climatch v2.0 (20 km) Closest Standard Match Sum Level 6 (Value X)
1 (Very low)	< 100	< 691
2 (Low)	100-599	691-4137
3 (Moderate)	600-899	4138-6209
4 (High)	900-1699	6210-11735
5 (Very high)	1700-2699	11736-18642
6 (Extreme)	≥ 2700	≥ 18643

Table 2: Susceptible Australian Primary Production – Calculating Total Commodity Damage Score

The commodity value index scores in this table are derived from Australian Bureau of Statistics 2005 – 2006 data. The values will require updating if significant change has occurred in the value of the commodity (Bomford 2008).

Industry	**Commodity Value Index 1 (CVI based on best available date)**	**Potential Commodity Impact Score (PCIS 0-3)**	**Climate Match to Commodity Score (CMCS 0–5)**	**Commodity Damage Score (CDS columns 2 X 3 X 4)**
Cattle (includes dairy and beef)	*11*	1	4	44
Timber (includes native and plantation forests)	*10*			
Cereal grain (includes wheat, barley sorghum etc)	*8*	1	1	8
Sheep (includes wool and sheep meat)	*5*	1	1	5
Fruit (includes wine grapes)	*4*			
Vegetables	*3*			
Poultry and eggs	*2*			
Aquaculture (includes coastal mariculture)	*2*			
Oilseeds (includes canola, sunflower etc)	*1*			
Grain legumes (includes soybeans)	*1*			
Sugarcane	*1*			
Cotton	*1*			
Other crops and horticulture (includes nuts tobacco and flowers etc)	*1*	2	1	2
Pigs	*1*			
Other livestock (includes goats, deer, camels, rabbits)	*0.5*	1	1	0.5
Bees (included honey, beeswax and pollination)	*0.5*			
Total Commodity Damage Score (TCDS)				59.5

NB The Commodity Value Index scores in this table are derived from Australian Bureau of Statistics 2005–2006 data and will need to be updated if these values change significantly.

Assess Potential Commodity Impact Scores for each primary production commodity listed in Table 9, based on species' attributes (diet, behaviour, ecology), excluding risk of spreading disease which is addressed in Question C9, and pest status worldwide as:

0. *Nil (species does not have attributes to make it capable of damaging this commodity)*
1. *Low (species has attributes making it capable of damaging this or similar commodities and has had the opportunity but no reports or other evidence that it has caused damage in any country or region*
2. *Moderate–serious (reports of damage to this or similar commodities exist but damage levels have never been high in any country or region and no major control programs against the species have ever been conducted OR the species has attributes making it capable of damaging this or similar commodities but has not had the opportunity)*
3. *Extreme (damage occurs at high levels to this or similar commodities and/or major control programs have been conducted against the species in any country or region and the listed commodity would be vulnerable to the type of harm this species can cause).*

Climate Match to Commodity Score (0–5)

- *None of the commodity is produced in areas where the species has a climate match within the highest eight climate match classes (ie classes 10, 9, 8, 7, 6, 5, 4 and 3) = 0*
- *Less than 10% of the commodity is produced in areas where the species has a climate match within the highest eight climate match classes = 1*
- *Less than 10% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes (ie classes 10, 9, 8, 7, 6 and 5) = 2*
- *Less than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes AND less than 10% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes (ie classes 10, 9 and 8) = 3*
- *Less than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes BUT more than 10% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes = 4*
- *OR More than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes BUT less than 20% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes = 4*
- *More than 20% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes OR overseas range unknown and climate match to Australia unknown = 5.]*

Table 3: Assigning species to EIC Threat Categories (shaded cells relate to assignment of reptiles and amphibians to EIC Threat Categories based on an assessed establishment risk and an allocated pest risk of extreme) – adapted from Bomford 2008

Establishment Risk	Pest Risk	Public Safety Risk	EIC Threat Category	Implication for any proposed import into Australia	Implication for keeping and movement in Australia
Extreme	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**	Prohibited, unless sufficient risk management measures exist to reduce the potential risks to an acceptable level	Limited to those collections approved for keeping particular EXTREME Threat species
Extreme	Serious	Highly, Moderately or Not Dangerous	**EXTREME**		
Extreme	Moderate	Highly, Moderately or Not Dangerous	**EXTREME**		
Extreme	Low	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Serious	Highly, Moderately or Not Dangerous	**EXTREME**		
Moderate	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Moderate	Highly, Moderately or Not Dangerous	**SERIOUS**	Import restricted to those collections approved for keeping SERIOUS Threat species	Limited to those collections approved for keeping particular SERIOUS Threat species
Serious	Low	Highly, Moderately or Not Dangerous	**SERIOUS**		
Moderate	Serious	Highly, Moderately or Not Dangerous	**SERIOUS**		
Moderate	Moderate	Highly Dangerous	**SERIOUS**		
Moderate	Low	Highly Dangerous	**SERIOUS**		
Low	Extreme	Highly, Moderately or Not Dangerous	**SERIOUS**		
Low	Serious	Highly, Moderately or Not Dangerous	**SERIOUS**		
Low	Moderate	Highly Dangerous	**SERIOUS**		
Low	Low	Highly Dangerous	**SERIOUS**		
Moderate	Moderate	Moderately or Not Dangerous	**MODERATE**	Import restricted to those collections approved for keeping MODERATE Threat species	Limited to those collections approved for keeping particular MODERATE Threat species
Moderate	Low	Moderately or Not Dangerous	**MODERATE**		
Low	Moderate	Moderately or Not Dangerous	**MODERATE**		
Low	Low	Moderately Dangerous	**MODERATE**		
Low	Low	Not Dangerous	**LOW**	Import permitted	May be limited to those collections approved for keeping particular LOW Threat species
Any Value	Any Value	Unknown	**EXTREME until proven otherwise**	Prohibited, unless sufficient risk management measures exist to reduce the potential risks to an acceptable level	Limited to those collections approved for keeping particular EXTREME Threat species
Unknown	Any Value	Any Value	**EXTREME until proven otherwise**		
Any Value	Unknown	Any Value	**EXTREME until proven otherwise**		
Unassessed	Unassessed	Unassessed	**EXTREME until proven otherwise**		

Adapted from:	Water Buffalo invasive animal risk assessment, Qld Gov. Peter Jesser, Anna Markula and Steve Csurhes, 2008, updated 2016. DPIPWE (2011) Pest Risk Assessment: Water Buffalo (*Bubalus bubalis*). Department of Primary Industries, Parks, Water and Environment. Hobart, Tasmania.	**By:** Jodi Buchecker	**Date:** May 2021

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National Risk Assessment: MODERATE

RISK ASSESSMENT FOR AUSTRALIA: Golden Conure (*Guaruba guarouba*)

Class - Aves**, Order -** Psittaciformes**, Family -** Psittacidae**, Genus -** *Guaruba*.

SPECIES: *Guaruba guarouba* (Gmelin, 1788) **Synonyms:** *Psittacus guarouba* (Gmelin, 1788) *Aratinga guarouba* (Gmelin, 1788) *Aratinga guarouba guarouba* (Gmelin, 1788) **Subspecies:** Monotypic **Common Names:** Golden Conure Golden Parakeet Golden Parrot Queen of Bavaria Conure Yellow Conure	**Species description:** The golden parakeet, also known as the Queen of Bavaria Parakeet (Reynolds, 2003), is a striking medium-sized (34 centimetres) parakeet. The golden parakeet is golden-yellow with an all-yellow tail and outer wings that are mainly yellow and green (Birdlife International). It has a large horn-colored (grey) beak, pale pink to white bare eye rings, brown irises, and pink legs. Males and females have identical external appearance. Juveniles are duller in colour with less yellow and more green in their plumage. The juvenile's head and neck are mostly green, the back is green and yellow, the upper side of tail is mostly green, the breast is greenish, the eye rings are pale-gray, and the legs are brown (Reynolds, 2003). **General information:** The golden parakeet is endemic to Brazil. It is recorded between the Tocantins, lower Xingú and Tapajós rivers in the Amazon Basin of Pará (Birdlife International; Laranjeiras, 2011; Vilarta, 2021). Golden parakeets are a social species, living, feeding, sleeping, and breeding together. In the wild, golden parakeets have a varied diet, feeding on fruits such as mango, muruci, açai, flowers, buds, seeds, and crop plants, particularly maize (Birdlife International; Laranjeiras, 2008). The golden parakeet's breeding system is almost unique amongst parrots. Pairs are aided by a number of helpers who assist in raising the young (Birdlife International). Once the golden parakeet reaches sexual maturity at the age of 3 years, the breeding season starts in November and runs through February. They nest high in the trees, in deeper than average nesting cavities, and lay an average of 4, 37.1 by 29.9 millimetres white eggs, which they aggressively guard. The incubation period is around 30 days, in which the male and female take turns incubating. In the first few years of sexual maturity, golden parakeets tend to lay infertile clutches until the ages of 6 to 8. In captivity, golden parakeets resume breeding when their chicks are taken from them (Yasmashita, 2003). **Longevity:** Lifespan 10 – 23 years (Animal Life Expectancy) **Conservation status:**

	IUCN: Vulnerable **CITES:** Appendix I
DATE OF ORIGINAL ASSESSMENT: March 2011 **DATE OF CURRENT ASSESSMENT:** Sep 2021 (Jodi Buchecker) **EIC ENDORSEMENT:** 22/04/22 **Risk assessment model used for the assessment:** Bomford 2008, Mammals and Birds	**The risk assessment model:** Models for assessing the risk that exotic vertebrates could establish in Australia have been developed for mammals, birds (Bomford 2003, 2006, 2008), reptiles and amphibians (Bomford et al 2005, Bomford 2008). Developed by Dr Mary Bomford for the Bureau of Rural Sciences (BRS), the model uses criteria that have been demonstrated to have significant correlation between a risk factor and the establishment of populations of exotic species and the pest potential of those species that do establish. For example, a risk factor for establishment is similarity in climate (temperature and rainfall) within the species' distribution overseas and Australia. For pest potential, the species' overseas pest status is a risk factor. The model is published as 'Risk assessment models for the establishment of exotic vertebrates in Australia and New Zealand' (Bomford 2008) and is available online on the PestSmart website https://pestsmart.org.au/wp-content/uploads/sites/3/2020/06/Risk_Assess_Models_2008_FINAL.pdf **CLIMATE**: In 2021 a new version of the Climatch program used to assess similarity in climate was released by the Australian Bureau of Agricultural Resource Economics and Sciences (ABARES): CLIMATCH v2.0. The increase in resolution in this new version (from 50 km to 20 km) required recalibration of Climate Match Scores. See Table 1. Sixteen climate parameters (variables) of temperature and rainfall are used to estimate the extent of similarity between data from meteorological stations located within the species' world distribution and stations in Australia. Worldwide, data from approximately 19000 locations are available for analysis. The number of locations used in an analysis will vary according to the size of the species' distribution and the number of meteorological stations located within that distribution. To represent the climate match visually, the map of Australia is divided into 19236 grid squares, each measured in 0.2 degrees in both longitude and latitude. CLIMATCH v2.0 calculates a match for each Australian grid by comparing data from all meteorological stations within the species' distribution (excluding any populations in Australia) and allocating a score ranging from ten for the highest level match to zero for the poorest match. Levels of climate match are used in the risk assessment for questions B1 (scores are summed to give a cumulative score), C6, and C8. Climatch v2.0 can be accessed on the ABARES website, agriculture.gov.au/abares. The direct URL is https://climatch.cp1.agriculture.gov.au/.

Bird and Mammal Model:

FACTOR	**SCORE**	**DETAIL**
STAGE A: RISKS POSED BY CAPTIVE OR RELEASED ANIMALS		
A1. Risk to people from individual escapees (0–2) *Assess the risk that individuals of the species could harm people. (NB, this question only relates to aggressive behaviour*	0	*All other animals posing a lower risk of harm to people (ie animals that will not make unprovoked attacks causing injury requiring medical attention, and which, even if cornered or handled, are unlikely to cause injury requiring hospitalisation).*

shown by escaped or released individual animals. Question C11 addresses the risk of harm from aggressive behaviour if the species establishes a wild population). *Aggressive behaviour, size, plus the possession of organs capable of inflicting harm, such as sharp teeth, claws, spines, a sharp bill, or toxin-delivering apparatus may enable individual animals to harm people. Any known history of the species attacking, injuring or killing people should also be taken into account. Assume the individual is not protecting nest or young.*		Medium-sized parrakeet that is unlikely to make an unprovoked attack causing injury. The golden parakeet will bite if cornered or handled but is unlikely to cause an injury requiring hospitalisation.
A2. Risk to public safety from individual captive animals (0–2) *Assess the risk that irresponsible use of products obtained from captive individuals of the species (such as toxins) pose a public safety risk (excluding the safety of anyone entering the animals' cage/enclosure or otherwise coming within reach of the captive animals)*	0	*Nil or low risk (highly unlikely or not possible).*
STAGE A PUBLIC SAFETY RISK SCORE **SUM A1 - A2 (0-4)**	0	**Not dangerous**
STAGE B: PROBABILITY ESCAPED OR RELEASED INDIVIDUALS WILL ESTABLISH FREE-LIVING POPULATIONS		
Model 1: FOUR-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)		
B1. Degree of climate match between species overseas range and Australia (1–6) *Map the selected mammal or bird species' overseas range, including its entire native and exotic (excluding Australia) ranges over the past 1000 years.* *Use CLIMATCH v2.0, Value X = sum of classes 6 – 10, see Table 1.*	1	*Very Low climate match to Australia* Value X = 47 Climate Match Score = 1
B2. Exotic population established overseas (0–4) *An established exotic population means the introduced species must have bred outside of captivity and must currently*	0	*No exotic population ever established.* There are no records found of the golden parakeet establishing any exotic populations.

maintain a viable free-living population where the animals are not being intentionally fed or sheltered, even though they may be living in a highly disturbed environment with access to non-natural food supplies or shelter.		
B3. Overseas range size score (0–2) < 1 = 0; 1– 70 = 1; >70 = 2 *Estimate the species overseas range size* including currently and the past 1000 years; natural and introduced range in millions of square kilometres*	1	*Overseas range between 1 to 70 million square kilometres.* Approximately 1.5 million km^2
B4. Taxonomic Class (0–1) *Bird = 0; mammal = 1*	0	*Bird*
B. ESTABLISHMENT RISK SCORE **SUM OF B1- B4 (1–13)**	2	**Low establishment risk**
Model 2: Seven-Factor Model For Birds And Mammals (Bomford 2008)		
B5. Diet score (0–1) *Specialist = 0; generalist = 1*	1	*Generalist with a broad diet of many food types.* Generalist fruit and seed eater. The golden parakeet feeds on fruit, berries, seeds and nuts and, seasonally, on crops (especially maize, which ripens immediately before fledging) (Birdlife International; Laranjeiras, 2008).
B6. Habitat score (0–1) *Undisturbed or disturbed habitat*	1	*Can survive and breed in human-disturbed habitats (including grazing and agricultural lands, forests that are intensively managed or planted for timber harvesting and/or urban–suburban environments) without access to undisturbed (natural) habitats.* Require access to undisturbed (natural) habitats to survive and breed. However, the species is not as forest dependent as several other non-threatened Psittacid species in its home region. The golden parakeet is capable of commuting between multiple forest-patches and moving around non-forest landscapes (A. C. Lees *in litt*., 2013).
B7. Migratory score (0–1) *Always migratory = 0; non-migratory = 1*	0	*Always migratory.*

		Nomadic in lowland humid forest (Birdlife International).
B. ESTABLISHMENT RISK SCORE SUM OF B1- B7 (1–16)	4	**Low establishment risk**
STAGE C: PROBABILITY AN ESTABLISHED SPECIES WILL BECOME A PEST		
C1. Taxonomic group (0–4)	2	*Bird in one of the taxa that are particularly prone to cause agricultural damage (Psittaciformes) = 2.* The golden parakeet is in the Family Psittacidae, however, there are no native species in the same genus within Australia.
C2. Overseas range size including current and past 1000 years, natural and introduced range (0–2) *Estimate the species overseas range size (including current and past 1000 years, natural and introduced range) in millions of square kilometres*	0	*Overseas geographic range less than 10 million square kilometres.* Approximately 1.5 million km^2
C3. Diet and feeding (0–3)	0	*Not a mammal.*
C4. Competition with native fauna for tree hollows (0–2)	1	*Can nest or shelter in tree hollows.* Nests in tree hollows with tree-cavities used for nesting and roosting (Birdlife International).
C5. Overseas environmental pest status (0–3) *Has the species been reported to cause declines in abundance of any native species of plant or animal or cause degradation to any natural communities in any country or region of the world?*	0	*Never reported as an environmental pest in any country or region.* No reports found of this species being an environmental pest.
C6. Climate match to areas with susceptible native species or communities (0–5)	2	*The species has no grid squares within the highest two climate match classes (ie in classes 9 and 10) that overlap the distribution of any susceptible native species or communities,*

Identify any native Australian animal or plant species or communities that could be susceptible to harm by the exotic species if it were to establish a wild population here.		*and has 1 – 62 grid squares within the highest four match classes (ie classes 7 – 10) that overlap the distribution of any susceptible native species or communities.* Examples of susceptible native species or ecological communities include (DAWE Protected Matters Search Tool): *Cyclopsitta coxeni* (Coxen's Fig-Parrot) – Critically Endangered *Lathamus discolor* (Swift Parrot) – Critically Endangered
C7. Overseas primary production pest status (0–3) *Has the species been reported to damage crops or other primary production in any country or region of the world?*	1	*Minor pest of primary production in any country or region.* The golden parakeet is a minor primary production pest as it feeds seasonally on crops (especially maize) (Birdlife International).
C8. Climate match to susceptible primary production (0–5) *Assess Potential Commodity Impact Scores for each primary production commodity listed in Table 9, based on species' attributes (diet, behaviour, ecology), excluding risk of spreading disease which is addressed in Question C9.* *0 = 0; 1-19 = 1; 20-49 = 2; 50-99 = 3; 100-149 = 4; ≥150 = 5*	1	Total Commodity Damage Score = 9 (see Table 2)
C9. Spread disease (1–2) *Assess the risk that the species could play a role in the spread of disease or parasites to other animals*	2	*All birds (likely or unknown effect on native species and on livestock and other domestic animals).*
C10. Harm to property (0–3) *Assess the risk that the species could inflict damage on buildings, vehicles, fences, roads, equipment or ornamental gardens by chewing or burrowing or polluting with droppings or nesting material.*	0	*$0.* Nil or low risk
C11. Harm to people (0–5)	0	*Nil risk.*

Assess the risk that, if a wild population established, the species could cause harm to or annoy people. Aggressive behaviour, plus the possession of organs capable of inflicting harm, such as sharp teeth, tusks, claws, spines, a sharp bill, horns, antlers or toxin delivering organs may enable animals to harm people. Any known history of the species attacking, injuring or killing people should also be taken into account (see Stage A, Score A1).		
C. PEST RISK SCORE SUM C 1 TO C 11 (1–37)	9	**Moderate pest risk**
STAGE A. PUBLIC SAFETY RISK RANK – RISK TO PUBLIC SAFETY POSED BY CAPTIVE OR RELEASED INDIVIDUALS *0 = Not dangerous; 1 = Moderately dangerous; ≥ 2 = Highly dangerous*	0	Not dangerous
STAGE B. ESTABLISHMENT RISK RANK – RISK OF ESTABLISHING A WILD POPULATION **MODEL 1: FOUR-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)** *≤ 5 = low establishment risk; 6-8 = moderate establishment risk; 9-10 = serious establishment risk; ≥ 11-13 = extreme establishment risk*	2	Low establishment risk
STAGE B. ESTABLISHMENT RISK RANK – RISK OF ESTABLISHING A WILD POPULATION **MODEL 2: SEVEN-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)** *≤ 6 = low establishment risk; 7-11 = moderate establishment risk; 12-13 = serious establishment risk; ≥14 = extreme establishment risk*	4	Low establishment risk
STAGE C. PEST RISK RANK - RISK OF BECOMING A PEST FOLLOWING ESTABLISHMENT	9	Moderate pest risk

< 9 = low pest risk; 9-14 = moderate pest risk; 15-19 = serious pest risk; > 19 = extreme pest risk		

ENVIRONMENT AND INVASIVES COMMITTEE THREAT CATEGORY	**MODERATE**

World distribution map (IUCN Red List) and World distribution map indicating where meteorological data was sourced for the climate analysis (see B1):

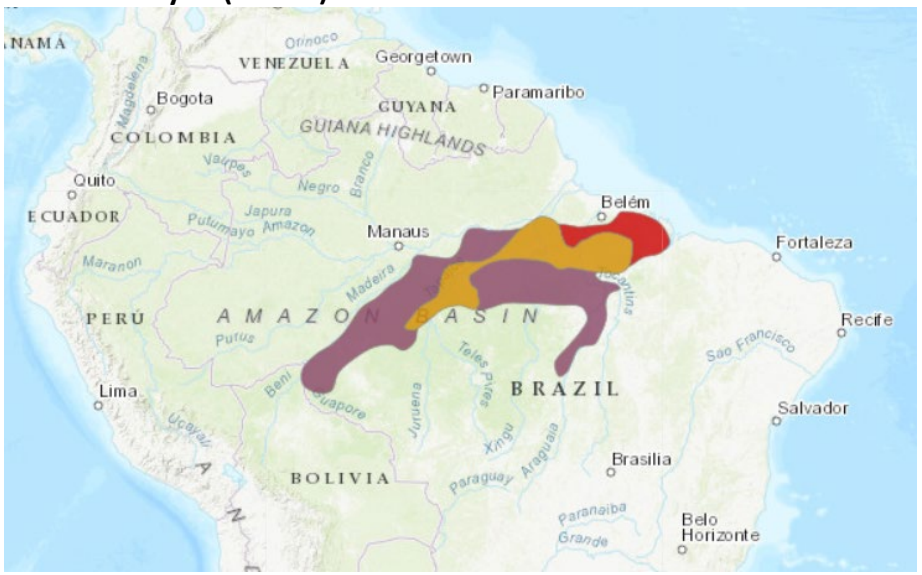


Figure 1 - World Distribution Map - IUCN Red List

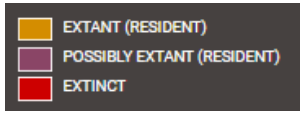


Figure 2 – IUCN Red List Key

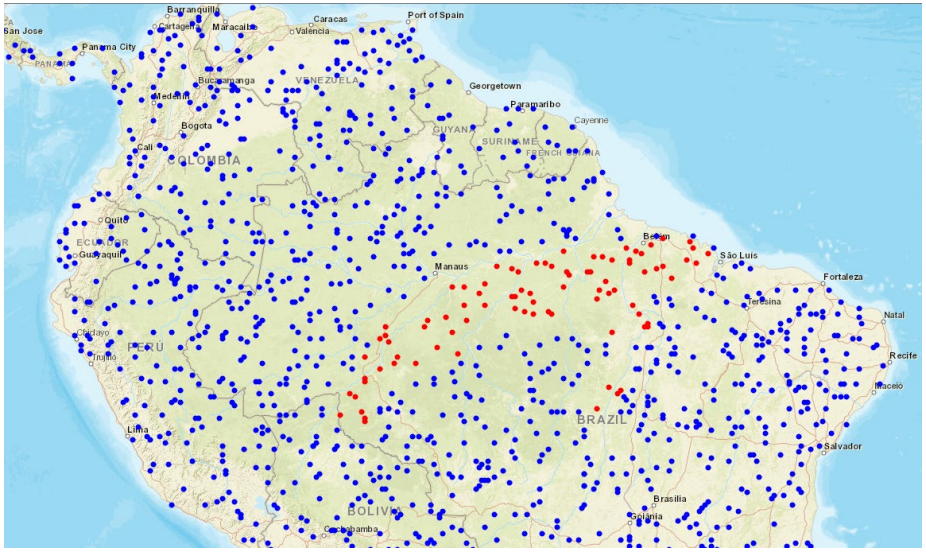
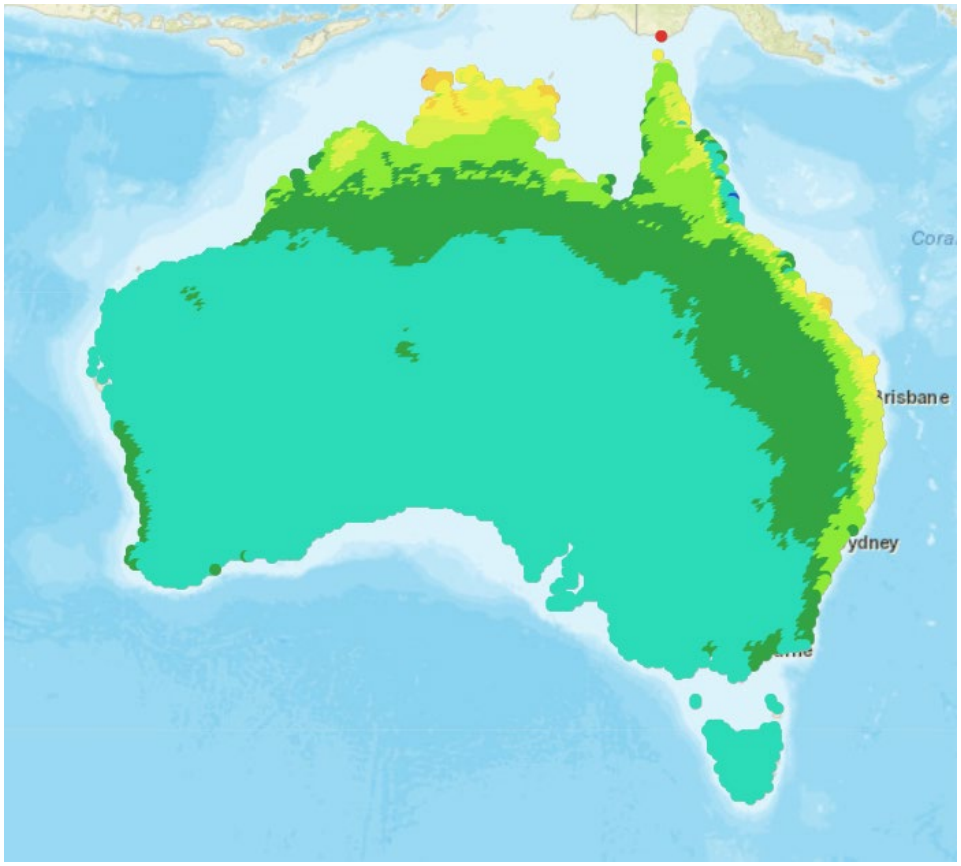


Figure 3 - World Distribution Map - Climatch

Climate match between world distribution of species and Australia:

Areas of Australia where the climate appears suitable for *Guaruba guarouba*

Value X = 47



Score	Color	Count
0		1
1		12710
2		4038
3		1619
4		561
5		260
6		45
7		1
8		1
9		0
10		0

Species: Guaruba guarouba (Golden Conure)
Algorithm: Closest Standard Score
86 source features selected
19236 target features selected
Approximate selected area: 1,498,658 km^2

Table 1: ABARES recalibration thresholds

Climate Match Score (CMS)	Climatch (50 km) Closest Standard Match Sum Level 6 (Value X)	2021 Recalibrated Climatch v2.0 (20 km) Closest Standard Match Sum Level 6 (Value X)
1 (Very low)	< 100	< 691
2 (Low)	100-599	691-4137
3 (Moderate)	600-899	4138-6209
4 (High)	900-1699	6210-11735
5 (Very high)	1700-2699	11736-18642
6 (Extreme)	≥ 2700	≥ 18643

Table 2: Susceptible Australian Primary Production – Calculating Total Commodity Damage Score

The commodity value index scores in this table are derived from Australian Bureau of Statistics 2005 – 2006 data. The values will require updating if significant change has occurred in the value of the commodity (Bomford 2008).

Industry	**Commodity Value Index 1 (CVI based on best available date)**	**Potential Commodity Impact Score (PCIS 0-3)**	**Climate Match to Commodity Score (CMCS 0–5)**	**Commodity Damage Score (CDS columns 2 X 3 X 4)**
Cattle (includes dairy and beef)	*11*			
Timber (includes native and plantation forests)	*10*			
Cereal grain (includes wheat, barley sorghum etc)	*8*	1	1	8
Sheep (includes wool and sheep meat)	*5*			
Fruit (includes wine grapes)	*4*	1	0	0
Vegetables	*3*			
Poultry and eggs	*2*			
Aquaculture(includes coastal mariculture)	*2*			
Oilseeds (includes canola, sunflower etc)	*1*	1	0	0
Grain legumes (includes soybeans)	*1*	1	0	0
Sugarcane	*1*			
Cotton	*1*			
Other crops and horticulture (includes nuts tobacco and flowers etc)	*1*	1	1	1
Pigs	*1*			
Other livestock (includes goats, deer, camels, rabbits)	*0.5*			
Bees (included honey, beeswax and pollination)	*0.5*			
Total Commodity Damage Score (TCDS)				9

NB The Commodity Value Index scores in this table are derived from Australian Bureau of Statistics 2005–2006 data and will need to be updated if these values change significantly.

Assess Potential Commodity Impact Scores for each primary production commodity listed in Table 9, based on species' attributes (diet, behaviour, ecology), excluding risk of spreading disease which is addressed in Question C9, and pest status worldwide as:

0. *Nil (species does not have attributes to make it capable of damaging this commodity)*
1. *Low (species has attributes making it capable of damaging this or similar commodities and has had the opportunity but no reports or other evidence that it has caused damage in any country or region*
2. *Moderate–serious (reports of damage to this or similar commodities exist but damage levels have never been high in any country or region and no major control programs against the species have ever been conducted OR the species has attributes making it capable of damaging this or similar commodities but has not had the opportunity)*
3. *Extreme (damage occurs at high levels to this or similar commodities and/or major control programs have been conducted against the species in any country or region and the listed commodity would be vulnerable to the type of harm this species can cause).*

Climate Match to Commodity Score (0–5)

- *None of the commodity is produced in areas where the species has a climate match within the highest eight climate match classes (ie classes 10, 9, 8, 7, 6, 5, 4 and 3) = 0*
- *Less than 10% of the commodity is produced in areas where the species has a climate match within the highest eight climate match classes = 1*
- *Less than 10% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes (ie classes 10, 9, 8, 7, 6 and 5) = 2*
- *Less than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes AND less than 10% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes (ie classes 10, 9 and 8) = 3*
- *Less than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes BUT more than 10% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes = 4*
- *OR More than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes BUT less than 20% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes = 4*
- *More than 20% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes OR overseas range unknown and climate match to Australia unknown = 5.]*

Table 3: Assigning species to EIC Threat Categories (shaded cells relate to assignment of reptiles and amphibians to EIC Threat Categories based on an assessed establishment risk and an allocated pest risk of extreme) – adapted from Bomford 2008

Establishment Risk	Pest Risk	Public Safety Risk	EIC Threat Category	Implication for any proposed import into Australia	Implication for keeping and movement in Australia
Extreme	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**	Prohibited, unless sufficient risk management measures exist to reduce the potential risks to an acceptable level	Limited to those collections approved for keeping particular EXTREME Threat species
Extreme	Serious	Highly, Moderately or Not Dangerous	**EXTREME**		
Extreme	Moderate	Highly, Moderately or Not Dangerous	**EXTREME**		
Extreme	Low	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Serious	Highly, Moderately or Not Dangerous	**EXTREME**		
Moderate	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Moderate	Highly, Moderately or Not Dangerous	**SERIOUS**	Import restricted to those collections approved for keeping SERIOUS Threat species	Limited to those collections approved for keeping particular SERIOUS Threat species
Serious	Low	Highly, Moderately or Not Dangerous	**SERIOUS**		
Moderate	Serious	Highly, Moderately or Not Dangerous	**SERIOUS**		
Moderate	Moderate	Highly Dangerous	**SERIOUS**		
Moderate	Low	Highly Dangerous	**SERIOUS**		
Low	Extreme	Highly, Moderately or Not Dangerous	**SERIOUS**		
Low	Serious	Highly, Moderately or Not Dangerous	**SERIOUS**		
Low	Moderate	Highly Dangerous	**SERIOUS**		
Low	Low	Highly Dangerous	**SERIOUS**		
Moderate	Moderate	Moderately or Not Dangerous	**MODERATE**	Import restricted to those collections approved for keeping MODERATE Threat species	Limited to those collections approved for keeping particular MODERATE Threat species
Moderate	Low	Moderately or Not Dangerous	**MODERATE**		
Low	Moderate	Moderately or Not Dangerous	**MODERATE**		
Low	Low	Moderately Dangerous	**MODERATE**		
Low	Low	Not Dangerous	**LOW**	Import permitted	May be limited to those collections approved for keeping particular LOW Threat species
Any Value	Any Value	Unknown	**EXTREME until proven otherwise**	Prohibited, unless sufficient risk management measures exist to reduce the potential risks to an acceptable level	Limited to those collections approved for keeping particular EXTREME Threat species
Unknown	Any Value	Any Value	**EXTREME until proven otherwise**		
Any Value	Unknown	Any Value	**EXTREME until proven otherwise**		
Unassessed	Unassessed	Unassessed	**EXTREME until proven otherwise**		

Adapted from:	Tasmanian Risk Assessment for Queen of Bavaria Parakeet provided by: Jensz, K., Finley, L. and Baker, G.B. (2011) Risk Assessment of the import of birds into Tasmania. Latitude 42 Environment Consultants Pty Ltd. Hobart, Tasmania.	**By:** Jodi Buchecker	**Date:** Sep 2021

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National Risk Assessment: EXTREME

RISK ASSESSMENT FOR AUSTRALIA: White-tailed Deer (*Odocoileus virginianus*)

Class - Mammalia**, Order -** Artiodactyla**, Family -** Cervidae**, Genus -** *Odocoileus*.

SPECIES: *Odocoileus virginianus* (Zimmermann, 1780) **Synonyms:** *Dama virginianus* (Zimmermann, 1780) *O. v. mayensis* (Unknown) *O. v. venatoria* (Goldman & Kellogg, 1940) *O. v. virginianus* (Zimmermann, 1777) **Subspecies:** *O. v. acapulcensis* (Caton, 1877) *O. v. borealis* (Miller, 1990) *O. v. cariacou* (Boddaert, 1784) *O. v. carminis* (Goldman & Kellogg, 1940) *O. v. chiriquensis* (J.A. Allen, 1910) *O. v. clavium* (Barboyr & Allen, 1922) *O. v. couesi* (Coues & Yarrow, 1875) *O. v. curassavicus* (Hummelinck, 1940) *O. v. dacotensis* (Goldman & Kellogg, 1940) *O. v. goudotti* (Gay & Gervais, 1846) *O. v. gymnotis* (Wiegmann, 1833) *O. v. hiltonensis* (Goldman & Kellogg, 1940) *O. v. leucurus* (Douglas, 1829)	**Species description:** White-tailed deer are named for the white underside of their tails which is visible when they hold it erect when they run. White fur is also located in a band behind the nose, over the chin and throat, in circles around the eyes, inside the ears, and on the upper insides of the legs. The coat colour of white-tailed deer varies seasonally (adults have a bright reddish-brown coat in the summer and a duller greyish brown coat in winter), with age (young have white spots on reddish coats) and sometimes due to locality or subspecies. Scent glands (used for intraspecies communication) are located between the 2 toes on all 4 feet, on the outside of each hind leg, and on the inside of each hind leg (at the hock). Secretions are particularly strong during the rutting season. Males possess antlers which are shed from mid-summer to early-autumn and grow out again mid-late autumn. Their antlers lose their velvet late-summer/early-autumn. White-tailed deer have acute hearing and good eyesight but depend mainly on their sense of smell to detect danger (Animal Diversity Web; Animalia). White-tailed deer vary in size depending upon region (Innes, 2013). Weight range can from 52 to 140 kilograms (Animalia; Animal Diversity Web). Young white-tailed deer are born at a weight of 1.5 to 2.5 kilograms. White-tailed deer can grow to a length between 160 to 240 centimetres (Animalia; Animal Diversity Web) and a height between 80 to 100 centimetres (Animalia). **General information:** White-tailed deer occur from southern Canada south through most of the United States of America (USA) and Mexico to South America (Peru, Ecuador, Bolivia, Colombia, northern Brazil, Venezuela, and the Guianas). The southernmost populations in the neotropics may represent other species (Molina and Molinari, 1999). White-tailed deer are absent from much of southwestern USA and has been introduced in former Czechoslovakia, Finland and New Zealand (Animal Diversity Web; IUCN). “Few mammalian species occupy such a wide range of latitudes or inhabit such a diverse array of habitats as the white-tailed deer” (Miller, 2003).

O. v. macrourus (Rafinesque, 1817) *O. v. mcilhennyi* (Miller, 1928) *O. v. margaritae* (Osgood, 1910) *O. v. mexicanus* (Gmelin, 1788) *O. v. miquihuanensis* (Goldman & Kellogg, 1940) *O. v. nelsoni* (Merriam, 1898) *O. v. nemoralis* (Hamilton-Smith, 1827) *O. v. nigribarbis* (Goldman and Kellogg, 1940) *O. v. oaxacensis* (Goldman & Kellogg, 1940) *O. v. ochrourus* (Bailey, 1932) *O. v. osceola* (Bangs, 1896) *O. v. peruvianus* (Gray, 1874) *O. v. rothschildi* (Thomas, 1902) *O. v. seminolus* (Goldman & Kellog, 1940) *O. v. sinaloae* (J.A. Allen, 1903) *O. v. taurinsulae* (Goldman & Kellogg, 1940) *O. v. texanus* (Mearns, 1898) *O. v. thomasi* (Merriam, 1898) *O. v. toltecus* (Saussure, 1860) *O. v. tropicalis* (Cabrera, 1918) *O. v. ustus* (Trouessart, 1910) *O. v. venatorius* (Goldman & Kellogg, 1940) *O. v. veraecrucis* (Goldman & Kellogg, 1940) *O. v. virginianus* (Zimmermann, 1780) *O. v. yucatanensis* (Hays, 1872) **Common Names include:**	From IUCN: Multiple subspecies have been identified (Smith, 1991): • *O. v. acapulcensis* - Type locality Acapulco, Guerrero, México. • *O. v. borealis* - Type locality Booksport, Maine, USA. • *O. v. cariacou* - Type locality Guyane, coastal French Guiana. • *O. v. carminis* - Type locality Botellas Cañón, Sierra del Carmen, northern Coahuila, Mexico. • *O. v. chiriquensis* - Type locality Boquerón, Chiriqui, Panamá. • *O. v. clavium* - Type locality Big Pine Key, Florida, USA. • *O. v. couesi* - Type locality Rancho Santuario, northwestern Durango, México. • *O. v. curassavicus* - Type locality Island of Curacao. • *O. v. dacotensis* - Type locality White Earth River, Mountrail Country, North Dakota, USA. • *O. v. goudotti* - Type locality “vits dans les regions elevees de la Nouvelle-Grenade” (lives in the highlands of New Granada). • *O. v. gymnotis* - Type locality British Guiana. • *O. v. hiltonensis* - Type locality Hilton Head Island, Beaufort County, South Carolina, USA. • *O. v. leucurus* - Type locality “the districts adjoining the river Columbia,” USA. • *O. v. macrourus* - Type locality Mer Rouge, Morehouse County, Louisiana, USA. • *O. v. margaritae* - Type locality “vicinity of Puerto Viejo”, Margarita Island, Venezuela. • *O. v. mcilhennyi* - Type locality “near Avery Island, Iberia Parish,” Louisiana, USA. • *O. v. mexicanus* - Type locality Valley of México, México. • *O. v. miquihuanensis* - Type locality Sierra Madre Oriental, near Miquihuana, southwestern Tamaulipas, México. • *O. v. nelsoni* - Type locality San Cristobal, highlands of Chiapas, México. • *O. v. nemoralis* - Type locality restricted to “Central America, round the Gulf of Mexico to Surinam”, further restricted to “From Honduras to Panamá" (Lydekker, 1915). • *O. v. nigribarbis* - Type locality Blackbeard Island, McIntoch County, Georgia, USA. • *O. v. oaxacensis* - Type locality “mountains 15 miles west of Oaxaca, México”. • *O. v. ochrourus* - Type locality Coolin, south end of Priest Lake, Idaho, USA.

White-tailed Deer White-tail Deer Whitetail Deer Key Deer Toy Deer Virginia Deer Columbian White-tailed Deer Coues' White-tailed Deer Hilton Head white-tailed deer Blackbeard Island white-tailed deer Bulls Island white-tailed deer Hunting Island white-tailed deer Guatemalan White-tailed deer	• *O. v. osceola* - Type locality Citronelle, Citrus County, Florida, USA. • *O. v. peruvianus* - Type locality Ceuchupate, Perú. • O. v. rothschildi - Type locality Island of Coiba, Veraguas, Panamá. • *O. v. seminolus* - Type locality "ten miles northeast of Everglades", Collier County, Florida, USA. • *O. v. sinaloae* - Type locality Escuinapa, southern Sinaloa, México. • *O. v. taurinsulae* - Type locality Bull's Island, Charleston County, South Carolina, USA. • *O. v. texanus* - Type locality Fort Clark, Kinney County, Texas, USA. • *O. v. thomasi* - Type locality Huehuetan, Chiapas, México. • *O. v. toltecus* - Type locality Orizaba, Veracruz, México. • *O. v. tropicalis* - Type locality "La María, en el Valle del Dagua", Colombia. • *O. v. ustus* - Type locality "El Pelado, au nord de Quito (4,100 m), sur la frontiere de Colombie" (El Pelado, north of Quito (4,100 metres), south of the Colombian border). • *O. v. venatorius* - Type locality Hunting Island, Beufort County, South Carolina, USA. • *O. v. veraecrucis* - Type locality Chijol, northern Veracruz, México. • *O. v. virginianus* - Type locality Wisconsin, USA. • *O. v. yucatanensis* - Type locality "throughout Yucatán and the southern part of México". In some areas translocations have led to intermixing of subspecies (Cronin, 1992; Geist, 1998), and, where they coexist, subspecies are known to interbreed (Cronin, 1988). Leberg and Ellsworth (1999) concluded that translocations have had substantial and persistent effects on the genetic composition of white-tailed deer populations in the Southeast based upon mitochondrial DNA and allozyme variation. White-tailed deer can survive in a variety of terrestrial habitats, from the hammock swamps and deep saw grass of Florida to the big woods of northern Maine. They also inhabit brushy areas, farmlands and desolate areas of the west (such as the thorn brush and deserts of southern Texas and Mexico). Ideal habitat contains dense thickets where they can hide and move about, with nearby forest edges (which furnish food) (Animal Diversity Web). They are therefore considered an "edge species", as they thrive in environments where cover and food are juxtaposed. The ability to survive in a variety of habitats, due to their flexible diet, allows them to migrate seasonally and stray far from their home ranges (Schipansky *et al.*, 2018). Migration between summer and winter ranges tends to be more pronounced where there are

	marked differences in seasonal weather patterns, such as in northern or mountainous areas, particularly in regions with deep snow (Innes, 2013). White-tailed deer are active throughout the day and night but are most active at dusk and dawn (Cypher, 1988). They are generalist browsers and grazers consuming the leaves, stalks, flowers, fruits, and seeds of grasses and forbs. They also eat buds, fruits, seeds (particularly acorns), stems, leaves and bark of trees and shrubs (Hewitt, 2011). They may opportunistically eat birds, fish, insects and sometimes consume aquatic vegetation (Geist, 1998). White-tailed deer have large reproductive potential (DeYoung, 2011). They are polygynous and bucks fight fiercely during the mating season (rut), with winners able to mate with does in the area. Breeding season timing is linked to photoperiod, with a general continuum in breeding season timing associated with latitude. White-tailed deer in northern regions of the USA tend to breed in November, whereas the breeding season in southern regions may be as late as January or February (Ditchkoff, 2011). White-tailed deer near the equator breed year-round (Geist, 1998). Most white-tailed deer attain sexual maturity and can breed as yearlings (DeYoung, 2011; Miller, 2003). Females enter oestrus in the autumn and give birth to 1 to 3 fawns after a 7-month gestation (Ditchkoff, 2011). **Longevity:** Maximum longevity in captivity is 23 years with few animals living more than 5-10 years in the wild (AnAge). Innes (2013) states that white-tailed deer may live 20 years or more, but few live more than 10 years. 10 years in wild, 16 years captivity (Animal Diversity Web). **Conservation status:** **IUCN:** Least Concern The Key deer is listed as Endangered throughout its range. The Columbian white-tailed deer is listed as Endangered in portions of the Columbia River Basin (Innes, 2013). **CITES:** Not listed *O. v. mayensis* is listed in Appendix III.
DATE OF ASSESSMENT: Nov 2021 (Jodi Buchecker) **EIC ENDORSEMENT:** 22/04/22 **Risk assessment model used for the assessment:**	**The risk assessment model:** Models for assessing the risk that exotic vertebrates could establish in Australia have been developed for mammals, birds (Bomford 2003, 2006, 2008), reptiles and amphibians (Bomford et al 2005, Bomford 2008). Developed by Dr Mary Bomford for the Bureau of Rural Sciences (BRS), the model uses criteria that have been demonstrated to have significant correlation between a risk factor and the establishment of populations of exotic species and the pest potential of those species that do establish. For example, a risk factor for establishment is similarity in climate (temperature and rainfall) within the species' distribution overseas and Australia. For pest potential, the species' overseas pest status is a risk factor.

Bomford 2008, Mammals and Birds	The model is published as 'Risk assessment models for the establishment of exotic vertebrates in Australia and New Zealand' (Bomford 2008) and is available online on the PestSmart website https://pestsmart.org.au/wp-content/uploads/sites/3/2020/06/Risk_Assess_Models_2008_FINAL.pdf **CLIMATE**: In 2021 a new version of the Climatch program used to assess similarity in climate was released by the Australian Bureau of Agricultural Resource Economics and Sciences (ABARES): CLIMATCH v2.0. The increase in resolution in this new version (from 50 km to 20 km) required recalibration of Climate Match Scores. See Table 1. Sixteen climate parameters (variables) of temperature and rainfall are used to estimate the extent of similarity between data from meteorological stations located within the species' world distribution and stations in Australia. Worldwide, data from approximately 19000 locations are available for analysis. The number of locations used in an analysis will vary according to the size of the species' distribution and the number of meteorological stations located within that distribution. To represent the climate match visually, the map of Australia is divided into 19236 grid squares, each measured in 0.2 degrees in both longitude and latitude. CLIMATCH v2.0 calculates a match for each Australian grid by comparing data from all meteorological stations within the species' distribution (excluding any populations in Australia) and allocating a score ranging from ten for the highest level match to zero for the poorest match. Levels of climate match are used in the risk assessment for questions B1 (scores are summed to give a cumulative score), C6, and C8. Climatch v2.0 can be accessed on the ABARES website, agriculture.gov.au/abares. The direct URL is https://climatch.cp1.agriculture.gov.au/.

Bird and Mammal Model:

FACTOR	**SCORE**	**DETAIL**
STAGE A: RISKS POSED BY CAPTIVE OR RELEASED ANIMALS		
A1. Risk to people from individual escapees (0–2) *Assess the risk that individuals of the species could harm people. (NB, this question only relates to aggressive behaviour shown by escaped or released individual animals. Question C11 addresses the risk of harm from aggressive behaviour if the species establishes a wild population).* *Aggressive behaviour, size, plus the possession of organs capable of inflicting harm, such as sharp teeth, claws, spines, a sharp bill, or toxin-delivering apparatus may enable individual animals to harm people. Any known history of the species attacking, injuring or killing people should also be*	1	*Animal that is unlikely to make an unprovoked attack, but which can cause serious injury (requiring hospitalisation) or fatality if cornered or handled.* Although wary and shy, white-tailed deer are large deer that can weigh up to 140 kilograms. Males have large antlers and are known to be aggressive, sometimes attacking humans when in rut (Hubbard, 2009).

taken into account. Assume the individual is not protecting nest or young.		
A2. Risk to public safety from individual captive animals (0–2) *Assess the risk that irresponsible use of products obtained from captive individuals of the species (such as toxins) pose a public safety risk (excluding the safety of anyone entering the animals' cage/enclosure or otherwise coming within reach of the captive animals)*	0	*Nil or low risk (highly unlikely or not possible).*
STAGE A PUBLIC SAFETY RISK SCORE **SUM A1 - A2 (0-4)**	1	**Moderately dangerous**
STAGE B: PROBABILITY ESCAPED OR RELEASED INDIVIDUALS WILL ESTABLISH FREE-LIVING POPULATIONS		
Model 1: FOUR-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)		
B1. Degree of climate match between species overseas range and Australia (1–6) *Map the selected mammal or bird species' overseas range, including its entire native and exotic (excluding Australia) ranges over the past 1000 years.* *Use CLIMATCH v2.0, Value X = sum of classes 6 – 10, see Table 1.*	5	*Very high climate match to Australia* Value X = 16,279 Climate Match Score = 5
B2. Exotic population established overseas (0–4) *An established exotic population means the introduced species must have bred outside of captivity and must currently maintain a viable free-living population where the animals are not being intentionally fed or sheltered, even though they may be living in a highly disturbed environment with access to non-natural food supplies or shelter.*	4	*Exotic population established on a larger island (> 50 000 km^2) or anywhere on a continent (including elsewhere on the land mass where the natural distribution of the animal is, if this population is due to human introduction and is geographically separate from the natural range of the species).* The white-tailed deer has been introduced in former Czechoslovakia, Finland, New Zealand (South Island) and Slovakia (Animalia; IUCN; New Zealand Government).
B3. Overseas range size score (0–2) < 1 = 0; 1– 70 = 1; >70 = 2	1	*Overseas range between 1 to 70 million square kilometres.*

Estimate the species overseas range size including currently and the past 1000 years; natural and introduced range in millions of square kilometres*		Approximately 19 million km^2
B4. Taxonomic Class (0–1) *Bird = 0; mammal = 1*	1	*Mammal*
B. Establishment Risk Score **Sum of B1- B4 (1–13)**	11	**Extreme establishment risk**
Model 2: Seven-Factor Model For Birds And Mammals (Bomford 2008)		
B5. Diet score (0–1) *Specialist = 0; generalist = 1*	1	*Generalist with a broad diet of many food types*. generalist browsers and grazers. As herbivores, white-tailed deer feed on grass, bark, leaves, twigs, shrubs, nuts, fruit of most vegetation, lichens, and other fungi (Animalia; National Geographic).
B6. Habitat score (0–1) *Undisturbed or disturbed habitat*	1	*Can survive and breed in human-disturbed habitats (including grazing and agricultural lands, forests that are intensively managed or planted for timber harvesting and/or urban–suburban environments) without access to undisturbed (natural) habitats.* White-tailed deer can survive in a variety of terrestrial habitats, including farmlands (Animal Diversity Web). The species thrives in close association with man and his agricultural and industrial pursuits. The white-tailed deer's requirements are met in practically every ecological type including grasslands, prairies and plains, mountains, hardwoods, coniferous and tropical forests, deserts, and even in woodlots associated with farmland. In the United States, it reaches its largest densities in hardwood forests and bushlands (Teer, 1984).
B7. Migratory score (0–1) *Always migratory = 0; non-migratory = 1*	1	*Facultative migrant in its native range.* Sometimes migratory. White-tailed deer exhibit multiple types of migratory strategies: they may be nonmigratory (year-round residents), obligate migrators (migrating every year), or conditional migrators (migrating some years but not others). Migration between summer and winter ranges tends to be more pronounced where there are marked differences in seasonal weather patterns, such as in northern or mountainous areas, particularly in regions with deep snow (Innes, 2013; IUCN; Schipansky *et al.*, 2018).

B. ESTABLISHMENT RISK SCORE SUM OF B1- B7 (1–16)	14	**Extreme establishment risk**
STAGE C: PROBABILITY AN ESTABLISHED SPECIES WILL BECOME A PEST		
C1. Taxonomic group (0–4)	4	*Mammal in one of the orders that have been demonstrated to have detrimental effects on prey abundance and/or habitat degradation (Artiodactyla) = 2.* *Mammal in one of the families that are particularly prone to cause agricultural damage (Cervidae) = 2.*
C2. Overseas range size including current and past 1000 years, natural and introduced range (0–2) *Estimate the species overseas range size (including current and past 1000 years, natural and introduced range) in millions of square kilometres*	1	*Overseas geographic range 10–30 million square kilometres.* Approximately 19 million km^2
C3. Diet and feeding (0–3)	3	*Mammal that is a primarily a grazer or browser.* A 2011 review of white-tailed deer diets throughout the species' range concluded that white-tailed deer consumed a variety of vegetation: 46% browse, 24% forbs, 11% mast, 8% grass, 4% agricultural crops, 2% cacti, 2% fungi, and 3% other items (Hewitt, 2011).
C4. Competition with native fauna for tree hollows (0–2)	0	*Does not use tree hollows*
C5. Overseas environmental pest status (0–3) *Has the species been reported to cause declines in abundance of any native species of plant or animal or cause degradation to any natural communities in any country or region of the world?*	3	*Major environmental pest in any country or region.* Studies have shown that heavy white-tailed deer foraging is correlated with increases in non-native plant abundance and declines in native plant abundance. As white-tailed deer forage selectively, they can influence plant species composition and diversity by consuming palatable species. This may allow unpalatable species to gain dominance and eventually alter plant community dynamics and succession (Cote, 2011; Eschtruth, 2008). In their home ranges, overabundant populations commonly reduce tree diversity in temperate and boreal forests. Also, white-tailed deer effect plant growth. They exert cascading effects on animals by modifying the composition and structure of habitats and competing directly for resources with other herbivores (Cote, 2004).

		The rapidly rising population of white-tailed deer pose a more significant threat to forest habitats across the eastern USA than global warming, according to a new study by The Nature Conservancy (TNC). U.S. Forest Service researchers have noted that even if areas with high deer densities were managed to reduce the impact of deer, there may be long-lasting legacy effects (Royo, 2010). Webster (2005) found severe and lasting impacts at Smoky Mountain National Park (USA) to be so complete that some plants such as trilliums were unlikely to recolonize local areas on their own. Deer are also well-documented vectors for the dispersal of non-native exotic plants (Knight *et al*., 2009; Baiser *et al*., 2008; Williams and Ward, 2006).
C6. Climate match to areas with susceptible native species or communities (0–5) *Identify any native Australian animal or plant species or communities that could be susceptible to harm by the exotic species if it were to establish a wild population here.*	5	*The species has more than 691 grid squares within the highest four climate match classes that overlap the distribution of any susceptible native species or ecological communities = 5* Examples of susceptible native species or ecological communities include (DAWE Protected Matters Search Tool): White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland – Critically Endangered *Petrogale lateralis centralis* (Warru, Central Australian Rock-wallaby) – Vulnerable
C7. Overseas primary production pest status (0–3) *Has the species been reported to damage crops or other primary production in any country or region of the world?*	3	*Major pest of primary production in any country or region.* In parts of their range conservation practices have proved so successful current white-tailed deer populations far exceed their cultural carrying capacity and the animal may be considered a nuisance. At high population densities farmers can suffer economic damage by deer feeding on cash crops, especially corn and orchards. It has become nearly impossible to grow some crops in some areas unless very burdensome deer-deterring measures are taken (McShea, 1997; Miller, 2003). The National Agricultural Statistics Service (NASS) reported that the estimated loss in field crops, nuts, fruits, and vegetables in 2001 was near $765 million. See also C8.

C8. Climate match to susceptible primary production (0–5) *Assess Potential Commodity Impact Scores for each primary production commodity listed in Table 9, based on species' attributes (diet, behaviour, ecology), excluding risk of spreading disease which is addressed in Question C9.* *0 = 0; 1-19 = 1; 20-49 = 2; 50-99 = 3; 100-149 = 4; ≥150 = 5*	5	Total Commodity Damage Score = 309 (see Table 2) From Innes (2013): In agricultural areas, crops are an important food source (Geist, 1998; Miller, 2003). Orchards, nurseries, vineyards, and lawns are also common food sources wherever available. High-quality forages, such as crops and mast, compose large portions of white-tailed deer diets if available. Crops are "exceedingly important" to white-tailed deer during summer and fall in the Midwest and along riparian areas in northwestern portions of the species' range (Hewitt, 2011). Because they are highly digestible and nutritious, most agricultural crops are preferred when available, regardless of the availability of naturally occurring foods (Cypher, 1988). A review stated that white-tailed deer are better adapted to browsing and select plants with higher nutritional quality than cattle, which have better ability to digest low-quality grasses, thus making forage competition minimal (Chaikina, 2006). However, white-tailed deer and cattle diets overlap somewhat (range: 15%-60%) depending upon location, duration and type of grazing (continuous vs. rotational), and time of year (Chaikina, 2006). Overlap may increase as forage becomes less available, typically in winter and early spring (Bryant, 1981; Chaikina, 2006; Fulbright, 2006). Domestic sheep and domestic goats compete more directly with white-tailed deer for forage than cattle because their diets overlap more (Bryant, 1981; Fulbright, 2006). A review stated that competition between livestock and white-tailed deer is particularly severe in habitats that are overgrazed (Fulbright, 2006).
C9. Spread disease (1–2) *Assess the risk that the species could play a role in the spread of disease or parasites to other animals*	2	*All mammals (likely or unknown effect on native species and on livestock and other domestic animals).* White-tailed deer harbor diseases that may be fatal to other ruminants (Geist, 1998).
C10. Harm to property (0–3) *Assess the risk that the species could inflict damage on buildings, vehicles, fences, roads, equipment or ornamental gardens by chewing or burrowing or polluting with droppings or nesting material.*	3	*More than $50 million.* Orchards, nurseries, vineyards, and lawns are common food sources (Hewitt, 2011).

		Often involved in road accidents. Motor vehicle collisions with deer are a serious problem in many parts of the animal's range, especially at night and during rutting season. Vehicular damage can be substantial in some cases (Insurance Information Institute). In the USA, such collisions increased from 200,000 in 1980 to 500,000 in 1991 (Cote, 2004). By 2009, the insurance industry estimated 2.4 million deer–vehicle collisions had occurred over the past two years, estimating damage cost to be over 7 billion US dollars (Insurance Information Institute).
C11. Harm to people (0–5) *Assess the risk that, if a wild population established, the species could cause harm to or annoy people. Aggressive behaviour, plus the possession of organs capable of inflicting harm, such as sharp teeth, tusks, claws, spines, a sharp bill, horns, antlers or toxin delivering organs may enable animals to harm people. Any known history of the species attacking, injuring or killing people should also be taken into account (see Stage A, Score A1).*	5	*Injuries or harm moderate, severe or fatal and many people at risk: Extreme risk = 5.* Although wary and shy, white-tailed deer are large deer that can weigh up to 140 kilograms. Males have large antlers and are known to be aggressive, sometimes attacking humans when in rut (Hubbard, 2009). Often involved in road accidents, injuring and killing people in home ranges. Motor vehicle collisions with deer are a serious problem in many parts of the animal's range, especially at night and during rutting season, causing injuries and fatalities among both deer and humans (Insurance Information Institute). In the USA, such collisions increased from 200,000 in 1980 to 500,000 in 1991 (Cote, 2004). By 2009, the insurance industry estimated 2.4 million deer–vehicle collisions had occurred over the past 2 years, resulting in approximately 300 human deaths (Insurance Information Institute). Disease: White-tailed deer can serve as hosts of ticks known to be vectors of human diseases, such as Lyme disease and ehrlichiosis (Diefenbach, 2011). SARS-CoV-2: Analyses of SARS-CoV-2 spike protein affinities suggest multiple animal species endemic to the USA, including white-tailed deer are potentially susceptible to SARS-CoV-2. The possibility exists that animal reservoirs of SARS-CoV-2 could emerge. Of particular concern are wildlife species that are both abundant and live in close association with humans. The geographic distribution of white-tailed deer encompasses most of North America and these animals are particularly abundant near urban population centres in the eastern USA. Antibodies were detected in 152 of 624 white-tailed deer samples (40%) from

		2021 suggesting that white-tailed deer had been exposed to SARS-CoV-2 (Chandler *et al.*, 2021).
C. PEST RISK SCORE SUM C 1 TO C 11 (1–37)	34	**Extreme pest risk**
STAGE A. PUBLIC SAFETY RISK RANK – RISK TO PUBLIC SAFETY POSED BY CAPTIVE OR RELEASED INDIVIDUALS *0 = Not dangerous; 1 = Moderately dangerous; ≥ 2 = Highly dangerous*	1	Moderately dangerous
STAGE B. ESTABLISHMENT RISK RANK – RISK OF ESTABLISHING A WILD POPULATION **MODEL 1: FOUR-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)** *≤ 5 = low establishment risk; 6-8 = moderate establishment risk; 9-10 = serious establishment risk; ≥ 11-13 = extreme establishment risk*	11	Extreme establishment risk
STAGE B. ESTABLISHMENT RISK RANK – RISK OF ESTABLISHING A WILD POPULATION **MODEL 2: SEVEN-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)** *≤ 6 = low establishment risk; 7-11 = moderate establishment risk; 12-13 = serious establishment risk; ≥14 = extreme establishment risk*	14	Extreme establishment risk
STAGE C. PEST RISK RANK - RISK OF BECOMING A PEST FOLLOWING ESTABLISHMENT *< 9 = low pest risk; 9-14 = moderate pest risk; 15-19 = serious pest risk; > 19 = extreme pest risk*	34	Extreme pest risk

ENVIRONMENT AND INVASIVES COMMITTEE THREAT CATEGORY	**EXTREME**

World distribution map (IUCN Red List and GBIF) and World distribution map indicating where meteorological data was sourced for the climate analysis (see B1):

Figure 1- World Distribution Map - IUCN Red List

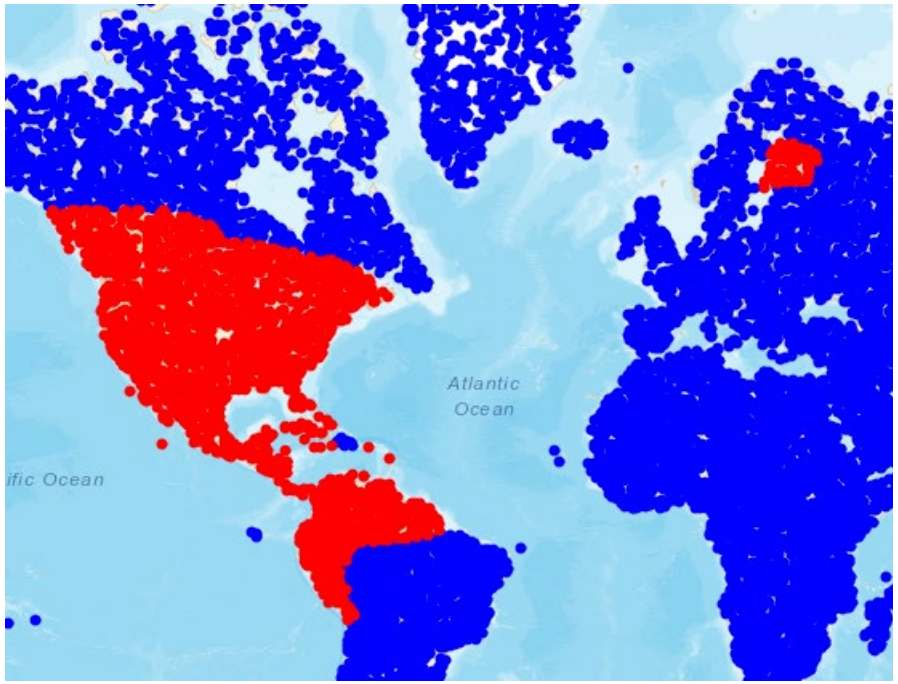


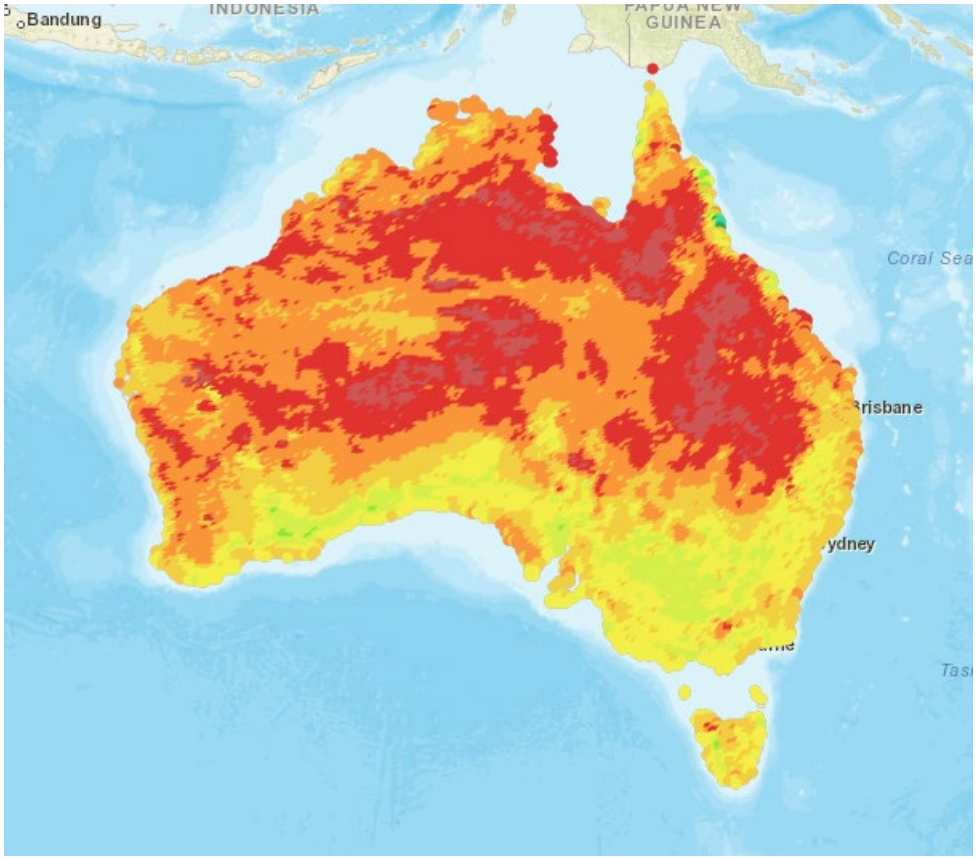
Figure 2 - World Distribution Map - Climatch

Figure 3 - World Georeferenced records (GBIF) – All referenced locations

Climate match between world distribution of species and Australia:

Areas of Australia where the climate appears suitable for *Odocoileus virginianus*

Value X = 16,279



Score	Color	Count
0		0
1		2
2		2
3		24
4		850
5		2079
6		2967
7		6507
8		5595
9		1207
10		3

Species: Odocoileus virginianus (White-tailed Deer)
Algorithm: Closest Standard Score
2337 source features selected
19236 target features selected
Approximate selected area: 19,851,964 km^2

Table 1: ABARES recalibration thresholds

Climate Match Score (CMS)	Climatch (50 km) Closest Standard Match Sum Level 6 (Value X)	2021 Recalibrated Climatch v2.0 (20 km) Closest Standard Match Sum Level 6 (Value X)
1 (Very low)	< 100	< 691
2 (Low)	100-599	691-4137
3 (Moderate)	600-899	4138-6209
4 (High)	900-1699	6210-11735
5 (Very high)	1700-2699	11736-18642
6 (Extreme)	≥ 2700	≥ 18643

Table 2: Susceptible Australian Primary Production – Calculating Total Commodity Damage Score

The commodity value index scores in this table are derived from Australian Bureau of Statistics 2005 – 2006 data. The values will require updating if significant change has occurred in the value of the commodity (Bomford 2008).

Industry	**Commodity Value Index 1 (CVI based on best available date)**	**Potential Commodity Impact Score (PCIS 0-3)**	**Climate Match to Commodity Score (CMCS 0–5)**	**Commodity Damage Score (CDS columns 2 X 3 X 4)**
Cattle (includes dairy and beef)	*11*	1	4	44
Timber (includes native and plantation forests)	*10*	3	4	120
Cereal grain (includes wheat, barley sorghum etc)	*8*	2	3	48
Sheep (includes wool and sheep meat)	*5*	1	4	20
Fruit (includes wine grapes)	*4*	2	3	24
Vegetables	*3*	2	3	18
Poultry and eggs	*2*			
Aquaculture (includes coastal mariculture)	*2*			
Oilseeds (includes canola, sunflower etc)	*1*	2	3	6
Grain legumes (includes soybeans)	*1*	2	3	6
Sugarcane	*1*	2	5	10
Cotton	*1*	1	4	4
Other crops and horticulture (includes nuts tobacco and flowers etc)	*1*	3	3	9
Pigs	*1*			
Other livestock (includes goats, deer, camels, rabbits)	*0.5*			
Bees (included honey, beeswax and pollination)	*0.5*			
Total Commodity Damage Score (TCDS)				309

Assess Potential Commodity Impact Scores for each primary production commodity listed in Table 9, based on species' attributes (diet, behaviour, ecology), excluding risk of spreading disease which is addressed in Question C9, and pest status worldwide as:

0. *Nil (species does not have attributes to make it capable of damaging this commodity)*
1. *Low (species has attributes making it capable of damaging this or similar commodities and has had the opportunity but no reports or other evidence that it has caused damage in any country or region*
2. *Moderate–serious (reports of damage to this or similar commodities exist but damage levels have never been high in any country or region and no major control programs against the species have ever been conducted OR the species has attributes making it capable of damaging this or similar commodities but has not had the opportunity)*
3. *Extreme (damage occurs at high levels to this or similar commodities and/or major control programs have been conducted against the species in any country or region and the listed commodity would be vulnerable to the type of harm this species can cause).*

Climate Match to Commodity Score (0–5)

- *None of the commodity is produced in areas where the species has a climate match within the highest eight climate match classes (ie classes 10, 9, 8, 7, 6, 5, 4 and 3) = 0*
- *Less than 10% of the commodity is produced in areas where the species has a climate match within the highest eight climate match classes = 1*
- *Less than 10% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes (ie classes 10, 9, 8, 7, 6 and 5) = 2*
- *Less than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes AND less than 10% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes (ie classes 10, 9 and 8) = 3*
- *Less than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes BUT more than 10% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes = 4*
- *OR More than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes BUT less than 20% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes = 4*
- *More than 20% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes OR overseas range unknown and climate match to Australia unknown = 5.]*

Table 3: Assigning species to EIC Threat Categories (shaded cells relate to assignment of reptiles and amphibians to EIC Threat Categories based on an assessed establishment risk and an allocated pest risk of extreme) – adapted from Bomford 2008

Establishment Risk	Pest Risk	Public Safety Risk	EIC Threat Category	Implication for any proposed import into Australia	Implication for keeping and movement in Australia
Extreme	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**	Prohibited, unless sufficient risk management measures exist to reduce the potential risks to an acceptable level	Limited to those collections approved for keeping particular EXTREME Threat species
Extreme	Serious	Highly, Moderately or Not Dangerous	**EXTREME**		
Extreme	Moderate	Highly, Moderately or Not Dangerous	**EXTREME**		
Extreme	Low	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Serious	Highly, Moderately or Not Dangerous	**EXTREME**		
Moderate	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Moderate	Highly, Moderately or Not Dangerous	**SERIOUS**	Import restricted to those collections approved for keeping SERIOUS Threat species	Limited to those collections approved for keeping particular SERIOUS Threat species
Serious	Low	Highly, Moderately or Not Dangerous	**SERIOUS**		
Moderate	Serious	Highly, Moderately or Not Dangerous	**SERIOUS**		
Moderate	Moderate	Highly Dangerous	**SERIOUS**		
Moderate	Low	Highly Dangerous	**SERIOUS**		
Low	Extreme	Highly, Moderately or Not Dangerous	**SERIOUS**		
Low	Serious	Highly, Moderately or Not Dangerous	**SERIOUS**		
Low	Moderate	Highly Dangerous	**SERIOUS**		
Low	Low	Highly Dangerous	**SERIOUS**		
Moderate	Moderate	Moderately or Not Dangerous	**MODERATE**	Import restricted to those collections approved for keeping MODERATE Threat species	Limited to those collections approved for keeping particular MODERATE Threat species
Moderate	Low	Moderately or Not Dangerous	**MODERATE**		
Low	Moderate	Moderately or Not Dangerous	**MODERATE**		
Low	Low	Moderately Dangerous	**MODERATE**		
Low	Low	Not Dangerous	**LOW**	Import permitted	May be limited to those collections approved for keeping particular LOW Threat species
Any Value	Any Value	Unknown	**EXTREME until proven otherwise**	Prohibited, unless sufficient risk management measures exist to reduce the potential risks to an acceptable level	Limited to those collections approved for keeping particular EXTREME Threat species
Unknown	Any Value	Any Value	**EXTREME until proven otherwise**		
Any Value	Unknown	Any Value	**EXTREME until proven otherwise**		
Unassessed	Unassessed	Unassessed	**EXTREME until proven otherwise**		

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National Risk Assessment: EXTREME

RISK ASSESSMENT FOR AUSTRALIA: # Sambar Deer (*Rusa unicolor*)

Class - Mammalia**, Order -** Artiodactyla**, Family -** Cervidae**, Genus -** *Rusa*.

SPECIES: *Rusa unicolor* (Kerr, 1792) **Synonyms:** *Cervus unicolor* (Kerr, 1792) **Subspecies:** *Rusa unicolor brookei* (Hose, 1893) *Rusa unicolor cambojensis* (Gray, 1861) *Rusa unicolor dejeani* (de Pousargues, 1896) *Rusa unicolor equina* (Cuvier, 1823) *Rusa unicolor hainana* (Xu, 1983) *Rusa unicolor swinholii* (Sclater, 1862) *Rusa unicolor unicolor* (Kerr, 1792) **Common Names:** Sambar Sambar Deer Indian Sambar	**Species description:** Sambar deer are the largest Southeast Asian deer with sizeable antlers (Chatterjee, 2014). Adult sambar stags weigh between 225-320 kilograms whereas sambar hinds are smaller, weighing between 135 and 225 kilograms (Crandall, 1964; Lydekker, 1916). Adult sambar deer's reach a height of approximately 1.5 metres. Sambar deer have a uniformly brown coat, long bushy tail with black tip, and large and round ears. Mature males (stags) have ruffs around their neck. The antlers of sambar deer are smaller than red deer (*Cervus elaphus*) (both in spread and length), have only three tines (branches) and look more robust compared to the red deer. **General information:** Sambar deer are native to the Indian subcontinent, South China, and Southeast Asia (Rai 2019). They are closely related to the red deer of Asia and Europe, Rusa deer (*Cervus timorensis*) of Asia, and Rocky Mountain Elk (*Cervus canadensis nelsoni*) of North America (Chatterjee, 2014). Sambar deer have been successfully introduced to New Zealand, the United States of America (Florida, Texas and California) and Australia (Animal Diversity Web). Sambar deer inhabit both gently sloping and steep forested hillside. They often reside near cultivated areas, such as gardens and plantations but also in thick forests, swamp forests, and open scrub (Animal Diversity Web). They typically leave cover after dark and range widely to find food, returning by dawn (Chatterjee, 2014). In New Zealand, sambar deer are believed to not have as great an impact on the vegetation as other deer species. They primarily graze but are flexible feeders and will, at least in their home range, switch to feeding on leaves, buds flowers and fruits. Sambar deer may not be as selective as other deer species, which can eliminate favoured plant species from the understorey. It may also be because sambar deer also eat a lot of other foods, in addition to shrubs, including native and introduced grasses, flax and reeds (Pest Detective). Males are solitary and very aggressive during breeding season. Females are found in groups of up to 8 individuals. Their mating system is polygynous, with one male mating with as many females as he can. There is no specific breeding season, but breeding most commonly occurs from September through January. Gestation

	is approximately 9 months with generally only 1 fawn is born at a time. Males and females both reach sexual maturity at approximately 2 years (Animal Diversity Web). **Longevity:** In captivity, the maximum recorded longevity for sambar deer is 26 years compared to the wild where longevity is estimated to be 20 years (Animal Diversity Web; Nowak, 1999) **Conservation status:** **IUCN:** Vulnerable **CITES:** Not listed
DATE OF ASSESSMENT: Nov 2021 (Jodi Buchecker) **EIC ENDORSEMENT:** 22/04/22 **Risk assessment model used for the assessment:** Bomford 2008, Mammals and Birds	**The risk assessment model:** Models for assessing the risk that exotic vertebrates could establish in Australia have been developed for mammals, birds (Bomford 2003, 2006, 2008), reptiles and amphibians (Bomford et al 2005, Bomford 2008). Developed by Dr Mary Bomford for the Bureau of Rural Sciences (BRS), the model uses criteria that have been demonstrated to have significant correlation between a risk factor and the establishment of populations of exotic species and the pest potential of those species that do establish. For example, a risk factor for establishment is similarity in climate (temperature and rainfall) within the species' distribution overseas and Australia. For pest potential, the species' overseas pest status is a risk factor. The model is published as 'Risk assessment models for the establishment of exotic vertebrates in Australia and New Zealand' (Bomford 2008) and is available online on the PestSmart website https://pestsmart.org.au/wp-content/uploads/sites/3/2020/06/Risk_Assess_Models_2008_FINAL.pdf **CLIMATE**: In 2021 a new version of the Climatch program used to assess similarity in climate was released by the Australian Bureau of Agricultural Resource Economics and Sciences (ABARES): CLIMATCH v2.0. The increase in resolution in this new version (from 50 km to 20 km) required recalibration of Climate Match Scores. See Table 1. Sixteen climate parameters (variables) of temperature and rainfall are used to estimate the extent of similarity between data from meteorological stations located within the species' world distribution and stations in Australia. Worldwide, data from approximately 19000 locations are available for analysis. The number of locations used in an analysis will vary according to the size of the species' distribution and the number of meteorological stations located within that distribution. To represent the climate match visually, the map of Australia is divided into 19236 grid squares, each measured in 0.2 degrees in both longitude and latitude. CLIMATCH v2.0 calculates a match for each Australian grid by comparing data from all meteorological stations within the species' distribution (excluding any populations in Australia) and allocating a score ranging from ten for the highest level match to zero for the poorest match. Levels of climate match are used in the risk assessment for questions B1 (scores are summed to give a cumulative score), C6, and C8. Climatch v2.0 can be accessed on the ABARES website, agriculture.gov.au/abares. The direct URL is https://climatch.cp1.agriculture.gov.au/.

Bird and Mammal Model:

FACTOR	SCORE	DETAIL
STAGE A: RISKS POSED BY CAPTIVE OR RELEASED ANIMALS		
A1. Risk to people from individual escapees (0–2) *Assess the risk that individuals of the species could harm people. (NB, this question only relates to aggressive behaviour shown by escaped or released individual animals. Question C11 addresses the risk of harm from aggressive behaviour if the species establishes a wild population).* *Aggressive behaviour, size, plus the possession of organs capable of inflicting harm, such as sharp teeth, claws, spines, a sharp bill, or toxin-delivering apparatus may enable individual animals to harm people. Any known history of the species attacking, injuring or killing people should also be taken into account. Assume the individual is not protecting nest or young.*	1	*Animal that is unlikely to make an unprovoked attack, but which can cause serious injury (requiring hospitalisation).* Extremely wary and shy but they are large deer (can weigh over 300 kilograms) and stags have large antlers.
A2. Risk to public safety from individual captive animals (0–2) *Assess the risk that irresponsible use of products obtained from captive individuals of the species (such as toxins) pose a public safety risk (excluding the safety of anyone entering the animals' cage/enclosure or otherwise coming within reach of the captive animals)*	0	*Nil or low risk (highly unlikely or not possible).*
STAGE A PUBLIC SAFETY RISK SCORE **SUM A1 - A2 (0-4)**	1	**Moderately dangerous**
STAGE B: PROBABILITY ESCAPED OR RELEASED INDIVIDUALS WILL ESTABLISH FREE-LIVING POPULATIONS		
Model 1: FOUR-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)		
B1. Degree of climate match between species overseas range and Australia (1–6)	4	*High climate match to Australia* Value X = 7,618

Map the selected mammal or bird species' overseas range, including its entire native and exotic (excluding Australia) ranges over the past 1000 years. *Use CLIMATCH v2.0, value X = sum of classes 6 – 10, see Table 1.*		Climate Match Score = 4
B2. Exotic population established overseas (0–4) *An established exotic population means the introduced species must have bred outside of captivity and must currently maintain a viable free-living population where the animals are not being intentionally fed or sheltered, even though they may be living in a highly disturbed environment with access to non-natural food supplies or shelter.*	4	*Exotic population established on a larger island (> 50 000 km^2) or anywhere on a continent (including elsewhere on the land mass where the natural distribution of the animal is, if this population is due to human introduction and is geographically separate from the natural range of the species).* Exotic populations have been established in the United States of America. In Florida: St. Vincent Island (Florida Fish and Wildlife Conservation Commission); California: near Hearst Castle (Miller, 2020); Texas: (Nowak, 1999) and Guam: with sambar deer introduced to Guam during the 1770s, and subsequently establishing in the wild (Conry, 1988; Lever, 1985; Long, 2003). Exotic populations have also been established in New Zealand: introduced in the late 1800s, there has been minimal dispersal since introduction and their range is restricted to coastal Manawatū and near Rotorua in the North Island (IUCN, 2009; Kelton and Skipworth, 1987; King, 2005; Lever, 1985; Long, 2003; Nugent, Fraser et al., 2001) and Bonin Island, Japan (Ogasawara-shoto): introduced in 1853, sambar deer were established for a number of years but no deer have been present for some time (Kaburaki, 1934) as cited in (Kuroda, 1939; Long, 2003). Exotic populations have also been established in Australia however, these statistics are not used for calculating the overseas exotic population score.
B3. Overseas range size score (0–2) < 1 = 0; 1– 70 = 1; >70 = 2 *Estimate the species overseas range size* including currently and the past 1000 years; natural and introduced range in millions of square kilometres*	1	*Overseas range between 1 to 70 million square kilometres.* Approximately 9 million km^2
B4. Taxonomic Class (0–1) *Bird = 0; mammal = 1*	1	*Mammal*

B. ESTABLISHMENT RISK SCORE **SUM OF B1- B4 (1–13)**	10	**Serious establishment risk**
Model 2: Seven-Factor Model For Birds And Mammals (Bomford 2008)		
B5. Diet score (0–1) *Specialist = 0; generalist = 1*	1	*Generalist with a broad diet of many food types.* Generalist grazers and browsers. Depending on local habitat, sambar deer feed on a wide variety of vegetation, including grasses, foliage, browse, fruit, and water plants. They also consume a great variety of shrubs and trees (Geist, 1998).
B6. Habitat score (0–1) *Undisturbed or disturbed habitat*	1	*Can survive and breed in human-disturbed habitats (including grazing and agricultural lands, forests that are intensively managed or planted for timber harvesting and/or urban–suburban environments) without access to undisturbed (natural) habitats.* Can live and breed in disturbed habitats and are known to graze and browse on crops and plantations.
B7. Migratory score (0–1) *Always migratory = 0; non-migratory = 1*	1	*Non-migratory*
B. ESTABLISHMENT RISK SCORE **SUM OF B1- B7 (1–16)**	13	**Serious establishment risk**
STAGE C: PROBABILITY AN ESTABLISHED SPECIES WILL BECOME A PEST		
C1. Taxonomic group (0–4)	4	*Mammal in one of the orders that have been demonstrated to have detrimental effects on prey abundance and/or habitat degradation (Artiodactyla) = 2.* *Mammal in one of the families that are particularly prone to cause agricultural damage (Cervidae) = 2.*
C2. Overseas range size including current and past 1000 years, natural and introduced range (0–2) *Estimate the species overseas range size (including current and past 1000 years, natural and introduced range) in millions of square kilometres*	0	*Overseas geographic range less than 10 million square kilometres.* Approximately 9 million km^2
C3. Diet and feeding (0–3)	3	*Mammal that is a primarily a grazer or browser.*

		Grazes or browses depending upon the forage available at that time (Bentley, 1978; Richardson, 1972,).
C4. Competition with native fauna for tree hollows (0–2)	0	*Does not use tree hollows.*
C5. Overseas environmental pest status (0–3) *Has the species been reported to cause declines in abundance of any native species of plant or animal or cause degradation to any natural communities in any country or region of the world?*	2	*Moderate environmental pest in any country or region.* Environmental impacts include loss of flora and fauna species, loss of vegetation erosion, loss of predator refuges for ground mammals, and their wallowing behaviour leads to loss of ground- layer plants and alteration of drainage patterns. In New Zealand, sambar deer are not thought to have a significant impact on the environment. This is partially due to their restricted range, but also because they tend to occur on forest margins and patches of scrub, and predominantly browse on pasture grassland. It may also reflect their wider dietary preferences, compared to other deer, or be due to relatively low density. It is noted however that males rub bark off trees with their antlers and that they graze and browse forest understorey (Pest Detective). In the Manawatū Region, sambar deer cause considerable damage to pine forests (*Pinus radiata*) by bark stripping, feeding on pine needles, and antler thrashing of trees (Stafford, 1997). On Guam, sambar deer browse favoured shrub and grass species such as *Triphasia trifolia* and *Pennisetum polystachyon* causing a browse line to form on vegetation in some areas, but no other documented negative impacts of the species on other native vegetation (Conry, 1988). In Australia, sambar deer were listed as a potentially threatening process to native vegetation under Victoria's Flora and Fauna Guarantee Act 1988 (FFG Act) in 2007. Rutting and fighting by sambar deer may create patches of bare ground of up to 30 metre in diameter (Bennett, 2012). Bowman (2014) attributed reduced understorey vegetation to sambar deer activity. It has been speculated that removal of vegetation

		by deer causes increased light levels, disrupts moisture dynamics (Department of Sustainability and Environment, 2010) and facilitates weed invasion (Jesser, 2005). The sambar deer is known to adversely impact at least 13 Australian threatened flora species and 12 ecological communities, some of which are threatened, including Alpine Sphagnum Bogs and associated fens. The potential for sambar deer to act as seed dispersers is indicated by their broad diets and large home ranges. In East Gippsland, Victoria, Peel et al. (2005) recorded severe browsing pressure by sambar deer and decline of several species (they list about 50 species "severely and adversely affected" by browsing in East Gippsland). Bartlett (2012) compared the abundance of small vertebrates in areas of high and low sambar deer density. Sites with higher sambar deer densities were associated with reductions in small-mammal species richness and abundances of some small mammals and reptiles.
C6. Climate match to areas with susceptible native species or communities (0–5) *Identify any native Australian animal or plant species or communities that could be susceptible to harm by the exotic species if it were to establish a wild population here.*	5	*The species has more than 691 grid squares within the highest four climate match classes that overlap the distribution of any susceptible native species or ecological communities = 5* Examples of susceptible native species or ecological communities include (DAWE Protected Matters Search Tool): White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland – Critically Endangered *Petrogale lateralis centralis* ((Warru, Central Australian Rock-wallaby) – Vulnerable
C7. Overseas primary production pest status (0–3) *Has the species been reported to damage crops or other primary production in any country or region of the world?*	2	*Moderate pest of primary production in any country or region.* In New Zealand, sambar deer are common grazers on farmland particularly in the Manawatū Region and can damage root and maize crops. They also browse young pine trees and strip bark in plantation forests (Pest Detective). Crop raiding and damage has been reported in some Indian villages (Rai, 2019).

C8. Climate match to susceptible primary production (0–5) *Assess Potential Commodity Impact Scores for each primary production commodity listed in Table 9, based on species' attributes (diet, behaviour, ecology), excluding risk of spreading disease which is addressed in Question C9.* *0 = 0; 1-19 = 1; 20-49 = 2; 50-99 = 3; 100-149 = 4; ≥150 = 5*	5	Total Commodity Damage Score = 229 (see Table 2)
C9. Spread disease (1–2) *Assess the risk that the species could play a role in the spread of disease or parasites to other animals*	2	*All mammals (likely or unknown effect on native species and on livestock and other domestic animals).*
C10. Harm to property (0–3) *Assess the risk that the species could inflict damage on buildings, vehicles, fences, roads, equipment or ornamental gardens by chewing or burrowing or polluting with droppings or nesting material.*	3	*More than $50 million.* Could harm ornamental gardens and have been reported to damage fences (Lindeman & Forsyth, 2008). Motor vehicle collisions with deer are a serious problem in many parts of the animal's range, especially at night and during rutting season (Insurance Information Institute).
C11. Harm to people (0–5) *Assess the risk that, if a wild population established, the species could cause harm to or annoy people. Aggressive behaviour, plus the possession of organs capable of inflicting harm, such as sharp teeth, tusks, claws, spines, a sharp bill, horns, antlers or toxin delivering organs may enable animals to harm people. Any known history of the species attacking, injuring or killing people should also be taken into account (see Stage A, Score A1).*	4	*Injuries or harm severe or fatal but few people at risk: Serious risk = 4.* Large animal with large antlers, however, is shy and wary rather than aggressive. Motor vehicle collisions with deer are a serious problem in many parts of the animal's range, especially at night and during rutting season, causing injuries and fatalities among both deer and humans (Insurance Information Institute). Deer species are known to carry the parasite Cryptosporidium spp. This parasite can contaminate drinking water reservoirs and cause infection in humans (cryptosporidiosis).
C. PEST RISK SCORE **SUM C 1 TO C 11 (1–37)**	30	**Extreme pest risk**
STAGE A. PUBLIC SAFETY RISK RANK – RISK TO PUBLIC SAFETY POSED BY CAPTIVE OR RELEASED INDIVIDUALS	1	Moderately dangerous

0 = Not dangerous; 1 = Moderately dangerous; ≥ 2 = Highly dangerous		
STAGE B. ESTABLISHMENT RISK RANK – RISK OF ESTABLISHING A WILD POPULATION **MODEL 1: FOUR-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)** *≤ 5 = low establishment risk; 6-8 = moderate establishment risk; 9-10 = serious establishment risk; ≥ 11-13 = extreme establishment risk*	10	Serious establishment risk
STAGE B. ESTABLISHMENT RISK RANK – RISK OF ESTABLISHING A WILD POPULATION **MODEL 2: SEVEN-FACTOR MODEL FOR BIRDS AND MAMMALS (BOMFORD 2008)** *≤ 6 = low establishment risk; 7-11 = moderate establishment risk; 12-13 = serious establishment risk; ≥14 = extreme establishment risk*	13	Serious establishment risk
STAGE C. PEST RISK RANK - RISK OF BECOMING A PEST FOLLOWING ESTABLISHMENT *< 9 = low pest risk; 9-14 = moderate pest risk; 15-19 = serious pest risk; > 19 = extreme pest risk*	30	Extreme pest risk

ENVIRONMENT AND INVASIVES COMMITTEE THREAT CATEGORY	**EXTREME**

World distribution map (IUCN Red List and GBIF) and World distribution map indicating where meteorological data was sourced for the climate analysis (see B1):

Figure 1 - World Distribution Map - IUCN Red List

Figure 2 - World Distribution Map – Climatch – home range

Figure 3 - World Distribution Map – Climatch – introduced range United States of America

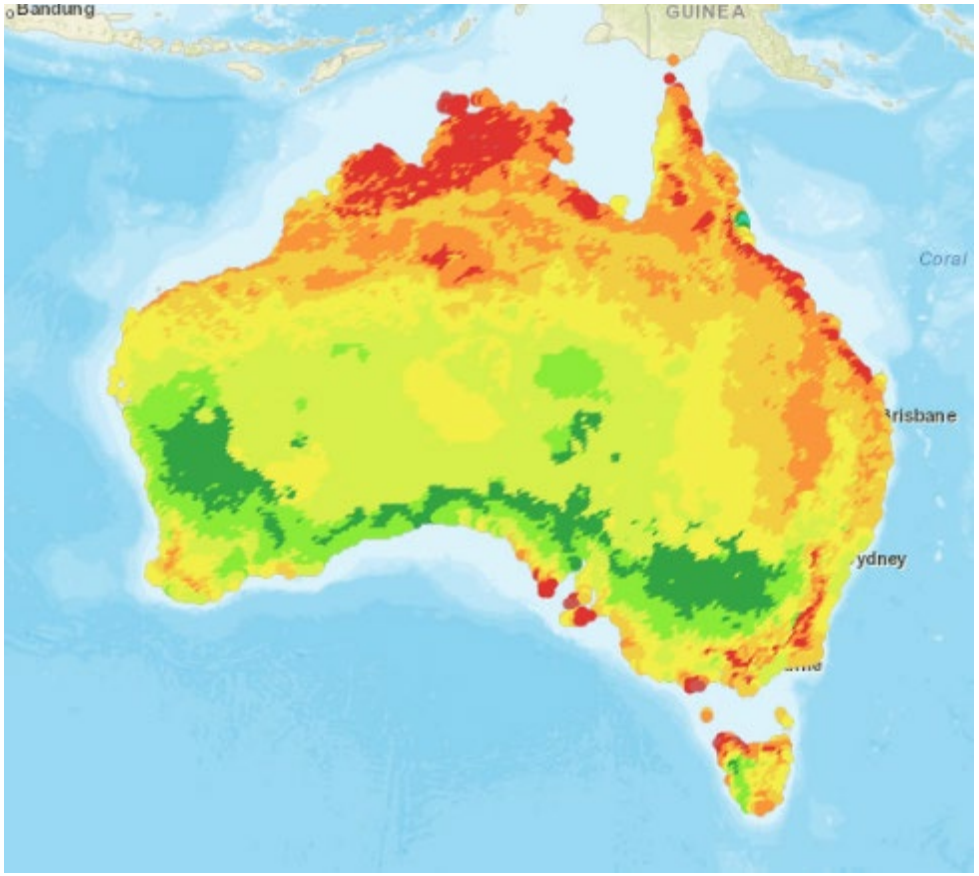
Figure 4 - World Distribution Map – Climatch – introduced range New Zealand

Figure 5 – World Georeferenced records (GBIF) – All referenced locations

Climate match between world distribution of species and Australia:

Areas of Australia where the climate appears suitable for *Rusa unicolor*

Value X = 7618



Score	Color	Count
0		0
1		3
2		1310
3		1547
4		4952
5		3806
6		3869
7		2659
8		1063
9		27
10		0

Species: Rusa unicolor (Sambar Deer)
Algorithm: Closest Standard Score
936 source features selected
19236 target features selected
Approximate selected area: 8,913,491 km^2

Table 1: ABARES recalibration thresholds

Climate Match Score (CMS)	Climatch (50 km) Closest Standard Match Sum Level 6 (Value X)	2021 Recalibrated Climatch v2.0 (20 km) Closest Standard Match Sum Level 6 (Value X)
1 (Very low)	< 100	< 691
2 (Low)	100-599	691-4137
3 (Moderate)	600-899	4138-6209
4 (High)	900-1699	6210-11735
5 (Very high)	1700-2699	11736-18642
6 (Extreme)	≥ 2700	≥ 18643

Table 2: Susceptible Australian Primary Production – Calculating Total Commodity Damage Score

The commodity value index scores in this table are derived from Australian Bureau of Statistics 2005 – 2006 data. The values will require updating if significant change has occurred in the value of the commodity (Bomford 2008).

Industry	**Commodity Value Index 1 (CVI based on best available date)**	**Potential Commodity Impact Score (PCIS 0-3)**	**Climate Match to Commodity Score (CMCS 0–5)**	**Commodity Damage Score (CDS columns 2 X 3 X 4)**
Cattle (includes dairy and beef)	*11*	1	4	44
Timber (includes native and plantation forests)	*10*	1	4	40
Cereal grain (includes wheat, barley sorghum etc)	*8*	2	3	48
Sheep (includes wool and sheep meat)	*5*	1	4	20
Fruit (includes wine grapes)	*4*	2	3	24
Vegetables	*3*	2	3	18
Poultry and eggs	*2*			
Aquaculture (includes coastal mariculture)	*2*			
Oilseeds (includes canola, sunflower etc)	*1*	2	3	6
Grain legumes (includes soybeans)	*1*	2	3	6
Sugarcane	*1*	2	5	10
Cotton	*1*	1	4	4
Other crops and horticulture (includes nuts tobacco and flowers etc)	*1*	3	3	9
Pigs	*1*			
Other livestock (includes goats, deer, camels, rabbits)	*0.5*			
Bees (included honey, beeswax and pollination)	*0.5*			
Total Commodity Damage Score (TCDS)				229

Assess Potential Commodity Impact Scores for each primary production commodity listed in Table 9, based on species' attributes (diet, behaviour, ecology), excluding risk of spreading disease which is addressed in Question C9, and pest status worldwide as:

0. *Nil (species does not have attributes to make it capable of damaging this commodity)*
1. *Low (species has attributes making it capable of damaging this or similar commodities and has had the opportunity but no reports or other evidence that it has caused damage in any country or region*
2. *Moderate–serious (reports of damage to this or similar commodities exist but damage levels have never been high in any country or region and no major control programs against the species have ever been conducted OR the species has attributes making it capable of damaging this or similar commodities but has not had the opportunity)*
3. *Extreme (damage occurs at high levels to this or similar commodities and/or major control programs have been conducted against the species in any country or region and the listed commodity would be vulnerable to the type of harm this species can cause).*

Climate Match to Commodity Score (0–5)

- *None of the commodity is produced in areas where the species has a climate match within the highest eight climate match classes (ie classes 10, 9, 8, 7, 6, 5, 4 and 3) = 0*
- *Less than 10% of the commodity is produced in areas where the species has a climate match within the highest eight climate match classes = 1*
- *Less than 10% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes (ie classes 10, 9, 8, 7, 6 and 5) = 2*
- *Less than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes AND less than 10% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes (ie classes 10, 9 and 8) = 3*
- *Less than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes BUT more than 10% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes = 4*
- *OR More than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes BUT less than 20% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes = 4*
- *More than 20% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes OR overseas range unknown and climate match to Australia unknown = 5.]*

Table 3: Assigning species to EIC Threat Categories (shaded cells relate to assignment of reptiles and amphibians to EIC Threat Categories based on an assessed establishment risk and an allocated pest risk of extreme) – adapted from Bomford 2008

Establishment Risk	Pest Risk	Public Safety Risk	EIC Threat Category	Implication for any proposed import into Australia	Implication for keeping and movement in Australia
Extreme	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**	Prohibited, unless sufficient risk management measures exist to reduce the potential risks to an acceptable level	Limited to those collections approved for keeping particular EXTREME Threat species
Extreme	Serious	Highly, Moderately or Not Dangerous	**EXTREME**		
Extreme	Moderate	Highly, Moderately or Not Dangerous	**EXTREME**		
Extreme	Low	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Serious	Highly, Moderately or Not Dangerous	**EXTREME**		
Moderate	Extreme	Highly, Moderately or Not Dangerous	**EXTREME**		
Serious	Moderate	Highly, Moderately or Not Dangerous	**SERIOUS**	Import restricted to those collections approved for keeping SERIOUS Threat species	Limited to those collections approved for keeping particular SERIOUS Threat species
Serious	Low	Highly, Moderately or Not Dangerous	**SERIOUS**		
Moderate	Serious	Highly, Moderately or Not Dangerous	**SERIOUS**		
Moderate	Moderate	Highly Dangerous	**SERIOUS**		
Moderate	Low	Highly Dangerous	**SERIOUS**		
Low	Extreme	Highly, Moderately or Not Dangerous	**SERIOUS**		
Low	Serious	Highly, Moderately or Not Dangerous	**SERIOUS**		
Low	Moderate	Highly Dangerous	**SERIOUS**		
Low	Low	Highly Dangerous	**SERIOUS**		
Moderate	Moderate	Moderately or Not Dangerous	**MODERATE**	Import restricted to those collections approved for keeping MODERATE Threat species	Limited to those collections approved for keeping particular MODERATE Threat species
Moderate	Low	Moderately or Not Dangerous	**MODERATE**		
Low	Moderate	Moderately or Not Dangerous	**MODERATE**		
Low	Low	Moderately Dangerous	**MODERATE**		
Low	Low	Not Dangerous	**LOW**	Import permitted	May be limited to those collections approved for keeping particular LOW Threat species
Any Value	Any Value	Unknown	**EXTREME until proven otherwise**	Prohibited, unless sufficient risk management measures exist to reduce the potential risks to an acceptable level	Limited to those collections approved for keeping particular EXTREME Threat species
Unknown	Any Value	Any Value	**EXTREME until proven otherwise**		
Any Value	Unknown	Any Value	**EXTREME until proven otherwise**		
Unassessed	Unassessed	Unassessed	**EXTREME until proven otherwise**		

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