Invasive Animals Cooperative Research Centre

Assessment and prioritisation of risk for forty exotic animal species

Marion Massam, Win Kirkpatrick and Amanda Page

GOVERNMENT OF WESTERN AUSTRALIA
Department of Agriculture and Food
Invasive Animals CRC

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"Together, create and apply solutions"

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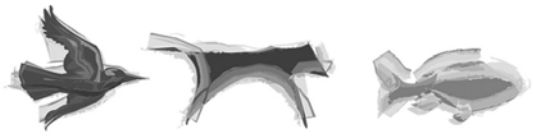

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Contents

Summary

This report documents work contributing to a project commissioned by the Invasive Animals Cooperative Research Centre to validate and refine risk assessment models used in decisions to import and manage introduced vertebrate species.

The intent of the project was to:

- increase predictive accuracy, scientific validation and adoption of risk assessment models for the import and keeping of exotic vertebrates
- reduce the risk of new vertebrate pests establishing introduced populations in Australia.

Risk assessments conducted for 40 species

The Bomford 2008 models were explored for their ability to reasonably predict, across a wide range of species and risk levels, risks of potential pest establishment (in the wild) and adverse impacts. Risk assessments were conducted for Australia for 40 introduced vertebrate species. These species comprised 17 mammals, one bird, 11 reptiles and 11 amphibians. They range from species internationally recognised as invasive to species perceived to present low risks, and include:

- species not in Australia to date
- species not in Australia but detected at the border
- captive or pet species kept in Australia, including some that have been detected in the wild
- 'sleeper' or other species with isolated populations in the wild in Australia, including livestock species
- species well established in the wild in Australia.

The Australian Bird and Mammal Model (Bomford 2008) was used for mammals and birds to assess the risk of species establishing wild populations and becoming pests if introduced to Australia, by calculating Vertebrate Pests Committee (VPC) Threat Categories. Three methods were used for reptiles and amphibians to calculate the risk of species establishing populations in the wild (Establishment Risk Ranks, ERRs): two versions of the Australian Bird and Mammal Model (Bomford 2008) and the Australian Reptile and Amphibian Model. Our comparison of these models showed that the Reptile and Amphibian Model — based on exhaustive analyses of reptile and amphibian establishment data from overseas — produced ERRs consistent with the Australian Bird and Mammal Model, but was generally more precautionary.

Our results produced further evidence for the validation of the Bomford 2008 Australian Bird and Mammal Model and the Australian Reptile and Amphibian Model. The models enabled us to assign different risk ranks to species within families. In addition, Serious or Extreme ranks were assigned to species that have already established introduced populations in Australia (including the livestock species assessed: chital, red and fallow deer, domestic sheep, ostrich). The models also enabled us to assign the rank of Extreme to species recognised internationally as invasive.

Species were also prioritised, by combining threat categories with invasion pathway and Australian-specific information. The high-priority species were then evaluated against relevant goals, objectives and actions from the *Australian Pest Animal Strategy*.

New methods developed to enhance model use

We developed methods to more efficiently assign VPC Threat Categories and ERRs to introduced species, and documented our methods to reduce the three types of uncertainty (process, assessors, and organism) in risk assessments.

We assigned DAFWA Threat Categories to reptiles and amphibians, based on the structure of the original Australian Bird and Mammal Model, the existing VPC conventions for assignment of threat categories and the precautionary approach. We also considered adverse impact factors and predicted effects on Australian species and primary production and included this information in assigning Alternative Threat Categories to reptiles and amphibians.

As an indicator of the level of assessment uncertainty, each assessment document included the number of references used, along with the median number of references for the relevant taxonomic class.

Recommendations

All recommendations should be considered in the current review of the *VPC Guidelines for the Import, Movement and Keeping of Exotic Vertebrates in Australia* (NRMSC 2004) and by agencies responsible for invasive species management. These recommendations will reduce uncertainty in assessments, but we warn that risk assessments, for which the three types of uncertainty (process, assessors and organism) have been reduced to a minimum, require significant resourcing.

1. We recommend continued use and improvement of the Bomford risk assessment models.

2. Given the amount of time needed to gain experience in risk assessments and to train new staff, and the need to ensure the independence of assessments, there needs to be:

    - sharing of risk assessment information via a community of expertise

    - processes to ensure assessments are independent and to rationalise resourcing requirements across the country, by having a nationally agreed approach for a single risk assessment system, each species assessed once, by an accredited, independent assessor.

Regarding methodology for risk assessments:

3. Qualitative issues, which may be raised by reviewers or assessors in conducting assessments, are not able to be incorporated into the quantitative risk assessment models at present, but should be considered when devising risk management strategies.

4. Mammals assigned to the Low or Moderate VPC Threat Category need to be further considered by the VPC, including their conservation status and the degree of assessment uncertainty.

5. There is an immediate need to seek VPC endorsement (or further development and endorsement) of a method to assign threat categories to reptiles and amphibians.

6. There is a need to further develop a method for including adverse impact factors, including predicted effects on Australian species and primary production, in reptile and amphibian risk assessments.

Regarding future directions to improve assessments and species prioritisation:

7. To further validate the three assessment models, more reptile and amphibian species should be assessed to produce more results across a range of families and threat levels.

8. Further research is required on the nine attributes/factors associated with increased risks of adverse impacts of reptiles and amphibians, in order to improve risk assessments.

9. Research into the use of Bayesian networks to prioritise species on the brink of establishing introduced populations should also be undertaken to assist risk management agencies.

10. A review should be done to identify other species for research, awareness raising, risk assessment, prioritisation and management in the following groups:

    - species that have or could enter the country, as part of an early-warning system
    - species being legally or illegally held in low-security facilities and/or that have been surrendered or reported in the wild
    - species at risk of establishing further introduced populations.

    (Preliminary lists for some of these groups were compiled in this report.)

For priority species, in the context of the Australian Pest Animal Strategy*, we make the following recommendations:*

11. Awareness should be raised about threats posed by high threat-potential species in order to increase reporting of animals in the wild and decrease irresponsible management of captive animals. Based on our prioritisation method (combining threat categories with invasion pathway and Australian-specific information), the highest priority species for which awareness-raising materials seem totally lacking are, in order of priority:

    - mammals and birds: fishing cat, European hare, domestic sheep, oriental small-clawed otter, brown bear, Malayan sun bear, Eurasian lynx and meerkat.
    - reptiles and amphibians: Asiatic painted frog, rhinoceros viper, African bullfrog and clawed frog, flowerpot snake, puff adder, emerald tree boa, ornate box turtle, Romer's tree frog, beauty snake, spiny turtle and western tiger salamander.

12. The management of all captive species posing threats should be in line with the VPC Guidelines (NRMSC 2004), which provides a guide for the minimum level of security measures appropriate to species in each VPC Threat Category. We assessed the fishing cat and oriental small-clawed otter as the highest threat captive exotic mammals most likely to appear in the wild. The boa constrictor was assessed as the captive reptile or amphibian with the highest likelihood of appearing in the wild.

13. The pond slider turtle (one subspecies of which is the red-eared slider) should be a high priority for management across the country, since it is a 'sleeper' species that had the highest

combination of threat ranking versus number of invasion pathways and relevant Australian-specific information of any reptile or amphibian assessed.

14. Removal of animals such as the cane toad, chital, fallow and red deer, feral sheep, European hare and rabbit and red fox at key assets should be assessed for feasibility and cost effectiveness.

15. The Department of Environment, Water, Heritage and the Arts' *Live Import List* should be reviewed with a view to removing assessed species posing extreme threats. The VPC Guidelines (NRMSC 2004) recommend that species in the Extreme category should not be allowed to enter, or be kept in any state or territory, and so should not be on this list. Other high-risk species on the list should be reviewed and risk management requirements upgraded accordingly, particularly in light of the uncertainties surrounding reptile and amphibian assessments, or consideration given to their removal from the list.

16. National Surveillance List — possible additions to guard against the establishment of further species new to Australia include: African bullfrog and clawed frog, Asiatic painted frog, beauty snake, black-spined toad, boa constrictor, brown bear, corn snake, emerald tree boa, Eurasian lynx, fishing cat, Malayan sun bear, meerkat, oriental small-clawed otter, ornate box turtle, puff adder, rhinoceros viper, Romer's tree frog, spiny turtle, stoat and western tiger salamander.

17. National Alert List — possible additions to prevent further spread of wild populations, and for assessment of eradication feasibility include: chital, fallow and red deer, domestic sheep, flowerpot snake, ostrich and pond slider.

18. List of Established Species of National Significance - possible additions include: cane toad, European hare and rabbit and red fox.

Towards a single risk assessment system

As concluded at a recent national workshop on risk assessment processes in Australia, implementation is needed of 'a nationally agreed approach for a single risk assessment system, each species assessed once, by an accredited, independent assessor' (Henderson 2009). We hope that the results from this study, particularly those for managing potential sources of uncertainty, will add to the further development of such a system, endorsed by all relevant groups.

Acronyms

APAS	Australian Pest Animals Strategy
AQIS	Australian Quarantine and Inspection Service
ARAZPA Inc	Zoo and Aquarium Association
BRS	Bureau of Rural Sciences
DEWHA	Australian Government Department of the Environment, Water, Heritage and the Arts
ERR	Establishment Risk Rank
IA CRC	Invasive Animals Cooperative Research Centre
PRR	Pest Risk Rank
PSRR	Public Safety Risk Rank
VPC	Vertebrate Pests Committee

Glossary

Alternative Threat Category	Category assigned to a reptile or amphibian by this study only. Derived from the Public Safety Risk and Establishment Risk Ranks, according to the Vertebrate Pests Committee (VPC) Threat Category Table (Appendix B), plus arbitrary increase of one rank based on presence of the most important adverse impact factors (1 and 5), or maximum scoring for predicted effects on Australian species or primary production. These categories have not been endorsed by VPC (see Appendix H).
DAFWA Threat Category	Category assigned to a reptile or amphibian by this study only. Derived from the Public Safety Risk Rank and Establishment Risk Rank, according to the VPC Threat Category Table (Appendix B). However, in cases where the assigned threat category was Low or Moderate, the precautionary approach was used to elevate species to the Extreme DAFWA Threat Category, because adverse impacts are not assessed in this process. These categories have not been endorsed by VPC (see Appendix H).
DEWHA Live Import List	*List of Specimens taken to be Suitable for Live Import*, made under the *Environment Protection and Biodiversity Conservation*

	Act 1999 and managed by the Department of the Environment, Water, Heritage and the Arts (DEWHA 2009b).
Establishment Risk Rank	Ranking derived from the Establishment Risk Score, used to predict the risk of escaped or released individuals establishing a free-living population. For reptiles and amphibians, the use of the two highest of these rankings (Extreme and Serious) has been endorsed by the VPC.
introduced species	A non-indigenous plant or animal deliberately or accidentally introduced into a new habitat that is outside its natural geographical distribution. 'Exotic species' is an alternative term.
invasive species	An exotic species that establishes a wild population and spreads beyond the place of introduction and becomes abundant (Richardson et al 2000).
Pest Risk Rank	Ranking derived from the Pest Risk Score, used to predict the risk an established species will become a pest.
precautionary approach	Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation (Burgman et al 2009).
Public Safety Risk Rank	Ranking derived from the Public Safety Risk Score, used to predict the risks posed to humans by captive or released individuals. For reptiles and amphibians, these rankings have not been endorsed by VPC.
risk assessment	The process of identifying hazardous events, in this case the establishment of new exotic vertebrate pest species in Australia, and estimating the likelihood that such events will occur and the probable consequences if they do.
sleeper species	Species undergoing a lag phase prior to a period of rapid population increase and spread.
DAFWA Threat Category	Ranking assigned to a reptile or amphibian by this study only and derived from a combination of the Public Safety Risk Rank, Establishment Risk Rank, and Checklist of adverse impacts and predicted adverse impacts on Australian species. For reptiles and amphibians, these rankings have not been endorsed by the VPC.
VPC Guidelines	*VPC Guidelines for the Import, Movement and Keeping of Exotic Vertebrates in Australia*, outlining a national approach within the context of Australian Government, state and territory legislation to minimise the risks posed by the introduction, keeping and movement of introduced vertebrates. Produced by the VPC and endorsed by the Natural Resource Management Standing Committee in 2004. The 2004 version updates previous guidelines published in 1983 and 1991.
VPC List	VPC's *List of Exotic Vertebrate Animals in Australia* (VPC 2007). This is a definitive list of the exotic vertebrates that have been assigned to threat categories and which can be legally held under state and territory legislation.

VPC Threat Category	Ranking assigned to a bird or mammal derived from a combination of the Public Safety Risk Rank, Establishment Risk Rank, and Pest Risk Rank, according to Appendix B. These categories have been endorsed by VPC.
VPC Extreme Threat Category	Species in this category should not be allowed to enter, nor be kept in any state or territory. However, any collection containing Extreme Threat Species should be subject to approval by the relevant state or territory authority on a case-by-case basis as meeting best practice standards for keeping of the species concerned and to standards acceptable to the appropriate jurisdictions. The keeping and movement of specimens in this category will also have to be conducted in compliance with any conditions placed on the species by DEWHA and AQIS at the time of import (VPC Guidelines) (NRMSC 2004). (Using the precautionary approach, any species that has not been assessed previously should be considered to be in the Extreme Threat Category and should be treated accordingly, until a risk assessment is conducted.)
VPC Serious Threat Category	Species in this category may be introduced and/or should be kept only in collections approved by the relevant state/territory authority as being primarily kept for (1) public display and education purposes, and/or for (2) genuine scientific research approved by the relevant state/territory authority, and as meeting best practice for the purposes of keeping the species concerned (NRMSC 2004). NB: The term 'Serious' is interchangeable with the term 'High', which has been used in some risk assessment documentation for vertebrates in Australia.
VPC Moderate Threat Category	Species in this category should be restricted to collections approved and registered by the relevant state/territory authority for the keeping of Moderate Threat Species. States/territories may continue to impose any additional restrictions on acquisition and keeping of Moderate Threat Species (NRMSC 2004).
VPC Low Threat Category	Species in this category, relative to other species, have a low risk of becoming a problem for the environment, primary industry or public safety (NRMSC 2004).

1 Introduction

1.1 Pest animal problems and policies

Since European settlement, many species of exotic vertebrates have become established in Australia as a result of deliberate or accidental releases (NRMSC 2004). Pest animals have many impacts in Australia, including damage to crops, livestock industries and native plants and animals. They also act as reservoirs for diseases and have varied social impacts (NRMMC 2007).

One of the three goals of the *Australian Pest Animals Strategy* (APAS, NRMMC 2007) is to manage the impacts of established pest animals. Invasive birds, rabbits, wild dogs, mice, foxes and feral pigs are conservatively estimated to have annual economic impacts of over $744 million (Gong et al 2009). The economic impacts of other significant pests (such as feral cats, feral deer and donkeys) as well as environmental and social impacts make the overall costs much greater.

Another of the goals of the APAS is to prevent the establishment of new pest animals. Potential pest species could establish via a number of pathways: species are detected after having entered Australia as accidental hitchhikers, or after being intentionally smuggled in as part of illegal trade. Applications are frequently made for the legal import of further exotic species for domestic, conservation, research or commercial purposes (Bomford 2008).

In addition, there are potentially high-risk species already in Australia in captivity that need to be managed to prevent them finding their way into the wild and establishing viable populations (boa constrictors and corn snakes are examples). There are also species in the wild that can be considered ‘sleepers’, in that they constitute a potential future risk of having a population explosion (eg pond slider turtles). Finally, some species such as deer are relatively widespread in the wild and, without management, still have the potential to spread to further parts of Australia.

To minimise the risks of new pests establishing, governments are attempting to put in place policies and legislation to control the entry and management of known and potential pest species that are not native to Australia. Simons and De Poorter (2009) comment that addressing invasive exotic species at the national level, including pre-import risk assessment of live species, is most effective when operating within an overall strategic framework in which practical implementation, overall vision, and legal and institutional arrangements are mutually supportive.

The Vertebrate Pests Committee’s (VPC) *Guidelines for the Import, Movement and Keeping of Exotic Vertebrates in Australia* (VPC Guidelines) outline a national approach within the context of Commonwealth, state and territory legislation, to minimise the risks posed by introduced invasive animals (NRMSC 2004). Among other things, the VPC Guidelines propose that decisions relating to the import, movement and keeping be underpinned by the application of the Bomford risk assessment process and other processes as considered appropriate.

These risk assessment processes consider three aspects:

- risks posed to humans by captive or released individuals, expressed as the Public Safety Risk Rank (PSRR)
- risk of a species establishing populations in the wild, expressed as the Establishment Risk Rank (ERR)

- risk that an established species will become a pest, expressed as the Pest Risk Rank (PRR).

These risk ranks are combined and the overall threat is assigned and expressed as a VPC Threat Category: Extreme, Serious, Moderate or Low. The VPC Guidelines suggest management strategies for each threat category, as detailed in the glossary of this report.

Since the current version of the VPC Guidelines was produced, the need for credible, consistent and rigorous risk assessment processes for use across all groups of potential invasive species has only increased. The need for thorough risk assessment processes was reinforced during a risk assessment workshop (Henderson 2009) attended by representatives from the Australian Government, each state and territory government, the VPC, Murray-Darling Basin Authority, Zoo and Aquarium Association (ARAZPA Inc), the Invasive Animals Cooperative Research Centre (IA CRC) and New Zealand's Department of Conservation and Environmental Risk Management Authority. Management of high-risk species already in Australia was another top-priority issue identified during the workshop (Henderson 2009).

1.2 Risk assessment models

Dr Mary Bomford of the Bureau of Rural Sciences (BRS) developed risk assessment models for mammals and birds (Bomford 2003, 2006, 2008), and reptiles and amphibians (Bomford et al 2005, Bomford 2006, 2008) that are currently used by the Australian Government and various state and territory jurisdictions around Australia. These models in general use factors for which there is strong evidence of a correlation with establishment success, such as climate match, history of establishment elsewhere and taxonomic group. This approach is strongly endorsed by Simons and De Poorter (2009), who emphasised the need for conducting science-based risk assessments, appropriate to the specific context, before decisions were made concerning the proposed importation of live, non-native animal species into a country.

The risk assessment models for mammals and birds, including the Australian Bird and Mammal Model used in this study, were developed from analyses of successful and failed introductions of exotic mammals and birds to Australia. However, it was not possible to do this for exotic reptiles and amphibians, because too few exotic species in these taxa have been introduced to Australia. Instead, a model to assess the risk of establishment success for these taxa was developed based on exhaustive analyses of reptile and amphibian establishment data (Bomford et al 2005, 2009; Bomford 2006, 2008) for Britain, Florida and California, where reasonably large numbers of exotic reptiles and amphibians have been introduced. This Australian Reptile and Amphibian Model was based on the assumption that the results of these analyses would also apply to introductions of species in these taxa to Australia (Bomford et al 2005).

In addition, while there is sufficient reliable information upon which to develop a quantitative method for assessing the risks of adverse impacts (public safety and pest risks) of new mammal and bird species (discussed in detail in Bomford 2003), the same is not true for reptiles and amphibians. This is because there has been limited research in this area, and because introductions of exotic species have often coincided with other changes, such as habitat disturbance and destruction and the impacts of other introduced species (Bomford et al 2005).

Review indicates that an increased risk of adverse impacts is associated with reptiles and amphibians that have nine attributes/factors, including: having adverse impacts elsewhere, being generalist feeders and being predatory, although the absence of such factors does not mean that the species can be taken to pose a low risk of harm (Bomford et al 2005). Other contributing factors can increase

the level of uncertainty in predicting pest potential; for example, species that display new behaviour patterns in response to new environments.

Bomford et al 2005 suggested that these nine factors could be used as the basis for a checklist to make a qualitative assessment of the threat of impacts posed by the establishment of new reptile and amphibian species in Australia. The concept of using non-quantitative tools for supplementary purposes is also supported by Simons and De Poorter (2009). Bomford (2008) comments that 'such an assessment would be particularly desirable if decisions were being made on whether to import species that score a risk of establishment of Moderate or higher in the quantitative models', as these are the species most likely to establish introduced populations and potentially become pests.

1.3 VPC list of exotic vertebrates

As part of the national approach to minimise the risks posed by introduced invasive animals, the VPC maintains a definitive list of the exotic vertebrates that have been assigned to threat categories and can be legally held under state and territory legislation: the VPC's *List of Exotic Vertebrate Animals in Australia* (VPC List, VPC 2007).

This list was to be the main reference source for Australian Government, state and territory authorities on the movement and keeping of exotic vertebrate animals in Australia. However, so far only 20 per cent of the VPC's list of around 700 species has been assessed using the currently available models.

1.4 Project aims

This report documents work carried out for a project commissioned by the IA CRC to validate and refine risk assessment models used in decisions to import and manage introduced vertebrate species.

The intent of the project was to:

- increase predictive accuracy, scientific validation and adoption of risk assessment models for the import and keeping of exotic vertebrates
- reduce the risk of new vertebrate pests establishing introduced populations in Australia.

This project is a continuation of risk assessment work commissioned by BRS (Massam and Kirkpatrick 2004; Kirkpatrick and Massam 2005, 2008a, 2008c; Massam et al in prep). A need was identified to further explore the ability of the Bomford models to reasonably predict public safety, establishment and pest risks across a wider range of bird and mammal species and risk levels. The relative ability of the models to assess risks of reptiles and amphibians establishing in the wild was also investigated across a range of species and risk levels.

1.5 Achievements

Risk assessments for Australia were conducted for 40 introduced species (17 of which are on the VPC List), comprising 17 mammals, one bird, 11 reptiles and 11 amphibians. Chapter 2 describes the general methodology used for the assessments, and techniques that we refined to reduce the three

types of uncertainty (process, assessors and organism) in risk assessments. Streamlined methods were developed to:

- more efficiently assign VPC Threat categories and ERRs
- incorporate reviewers' qualitative comments into risk assessment documents
- document numbers of references used for assessments, as an indicator of the level of uncertainty
- assign DAFWA Threat Categories to reptiles and amphibians
- consider adverse impact factors and predicted effects on Australian species and primary production of reptiles and amphibians to assign Alternative Threat Categories
- combine information on invasion pathways and Australian-specific data with VPC Threat Categories or Alternative Threat Categories to prioritise the species assessed.

Results are presented in Chapter 3 and Appendices E-I, providing further evidence for the validation of the Bomford (2008) Australian Bird and Mammal Model and the Australian Reptile and Amphibian Model.

Chapter 4 discusses our methodology and results, and evaluates high-priority species against relevant APAS goals, objectives and actions. Preliminary lists of some of the species that should be subject to awareness-raising activities, risk assessment and prioritisation are presented. Recommendations for future research and exotic animal management in Australia are also presented.

2 Methods

2.1 Species selection

We conducted risk assessments for Australia on 40 exotic species comprising 17 mammals, one bird, 11 reptiles and 11 amphibians (Appendix A). Only a single bird was included, as 54 birds have been assessed previously in projects funded by BRS (Massam et al in prep). Separate analyses were conducted for the merino, dorper and damara breeds of the domestic sheep (*Ovis aries*), for *O. aries* as an overall species (ie with no breeds distinguished) and for its ancestor (see Section 2.4).

Species were selected to reflect a wide range of the characteristics/criteria below (and see Appendix A) to analyse the risk assessment models' performance, including:

- the degree of invasiveness of the species, indicated by international recognition in invasive species databases
- the presence of the species overseas in the pet, food, skin, medicine or other similar trade
- the status of the species as a game animal
- the existence of introduced populations of the species overseas
- the existence of introduced populations of the species in countries neighbouring Australia
- the existence of planned or actual proposals for import of the species into Australia
- whether the species is on the Department of Environment, Water, Heritage and the Arts' *List of Specimens taken to be Suitable for Live Import* (DEWHA Live Import List)
- previous detection of the species entering Australia
- whether the species is present in Australasia in accredited zoo collections
- whether the species is present in Australasia in (legal or illegal) captivity or is known to have been seized from, or surrendered by, keepers holding them illegally
- whether or not the species is a livestock animal
- whether or not the species has established introduced populations in Australia
- whether or not the taxonomic order or family has representatives in Australia that have not been assessed fully by the models
- the risk results predicted for the species.

2.2 Data used in analyses

To objectively compare risk assessment results, only data from outside Australia were used in the analyses. Even if data were available for species that had established introduced populations in

Australia, or which caused adverse impacts here, this information was not used in the assessment, but was documented for use by others.

All assessments were completed using the version of CLIMATE adapted by BRS for use on Microsoft Windows PCs (Bureau of Rural Sciences 2006). CLIMATE contains data for 16 temperature and rainfall variables imported from BIOCLIM for 9460 meteorological stations worldwide.

2.3 Risk assessment model for birds and mammals

The Australian Bird and Mammal Model (Bomford 2008, pp 16–28) was used for mammals and birds to assess the risk they pose if introduced to Australia. This model is used to calculate three risk scores:

A. Risks to public safety posed by captive or released individuals.

B. Risk of establishment.

C. Risk of becoming a pest.

Each type of risk is assessed and scored progressively by means of a series of questions, with two questions for stage A, four or seven for stage B, and 11 for stage C. The risk scores are then converted to three risk ranks: Public Safety Risk Rank (PSRR), Establishment Risk Rank (ERR) and Pest Risk Rank (PRR). The VPC Threat Category (Low, Moderate, Serious or Extreme) is then determined from the various combinations of a species' three risk ranks using the VPC Threat Category Table (Appendix B) from the VPC Guidelines (Natural Resource Management Standing Committee 2004).

Two versions of the Australian Bird and Mammal Model were used to assign ERRs to birds and mammals: Model 1 uses the first four factors/questions from stage B of the model (as per the recommendation of Bomford 2008, p14), which deals with the risk of escaped or released individuals establishing a free-living population:

1. Climate match score for Australia.
2. Exotic population established overseas.
3. Overseas distribution size.
4. Taxonomic class.

The three additional questions from stage B are added for Model 2 (Bomford 2008, pp 20):

5. Diet.
6. Habitat use.
7. Migratory behaviour.

For both versions, an Establishment Risk Score is calculated by summing the scores for each question. The ERR (Low, Moderate, Serious or Extreme) is then determined using the published cut-off thresholds (Bomford 2008). Where there was a difference between the results, the higher result was used.

The first model uses four factors that are strongly linked to establishment risk in the analyses by Duncan et al (2001) and Forsyth (2004)). The second model includes an additional three factors that many experts suggest are linked to establishment success, but for which there is not such strong quantitative evidence (Bomford 2003 and 2006).

Depending on the results for each stage of the model, it is possible for some streamlining of its use. Figure 2.1 shows the streamlined process we developed.

2.4 Domestic sheep assessment

The separate assessments conducted for the merino, dorper and damara breeds of the domestic sheep presented a number of challenges for the climate analyses and assignment of VPC Threat Categories.

A typical climate analysis uses the species' overseas distribution, including its entire naturally occurring and introduced (excluding Australia for this report) distributions over the past 1000 years. However, literature searches indicated that no naturally occurring populations of domestic sheep have existed in the wild for more than 1000 years. Some records of introduced distributions were available for the overall species and for the merino breed.

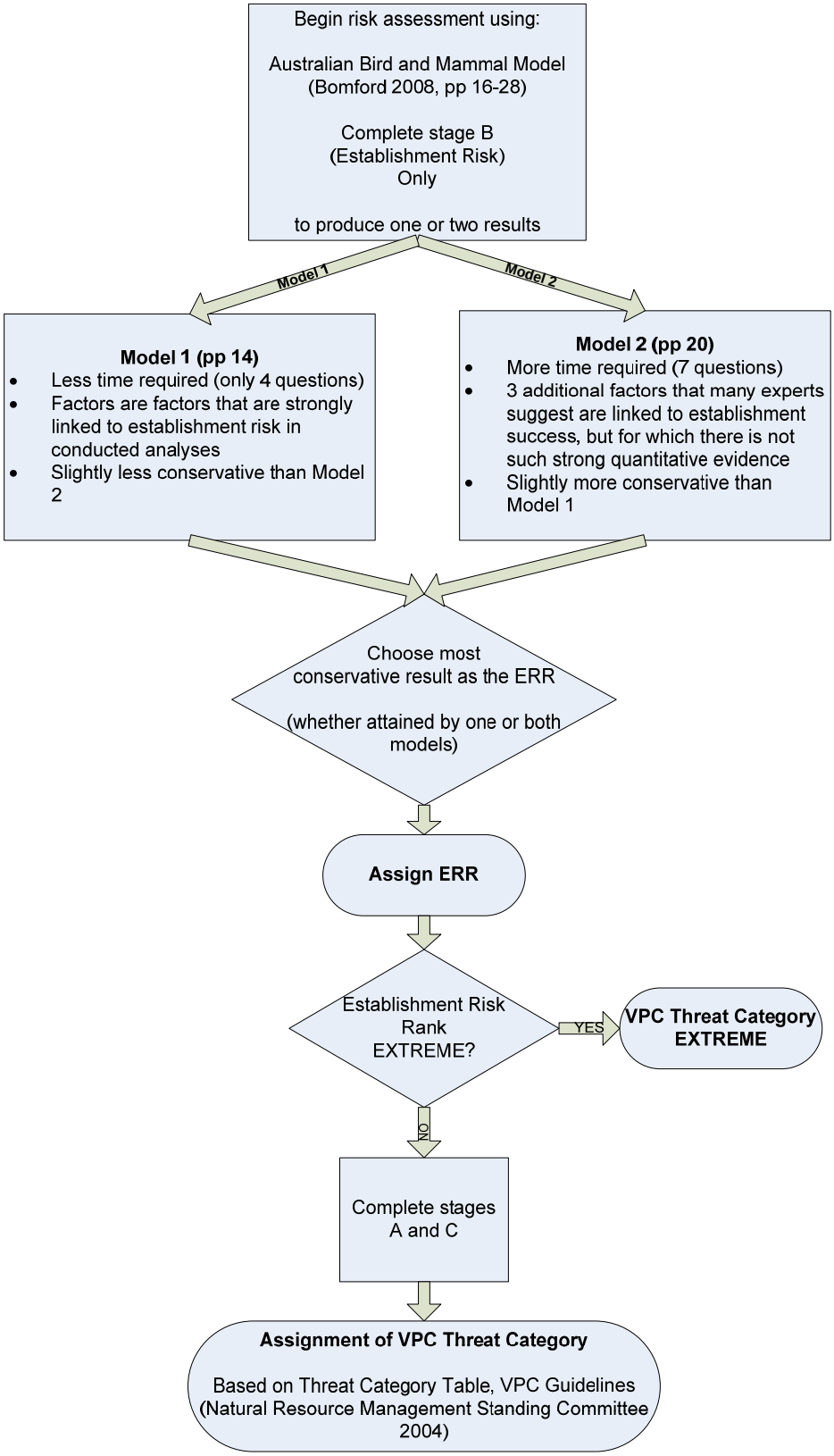
Although the sheep assessment was the first conducted by us for which these circumstances existed, and the first conducted for breeds of a particular species, Bomford (2008) suggests three ways to address this:

- for domesticated species that originated from wild ancestors more than 1000 years ago, the introduced distribution of the species can be used where this is applicable, or
- an approximate estimate can be obtained by using the distribution of the wild ancestor, or
- the distribution of domestic flocks and herds can be used, provided they are living in the open with minimal provision of food supplements and shelter.

Based on these suggestions, we conducted climate analyses on the following sheep 'breeds':

1. Domestic sheep (no breeds distinguished), using introduced distribution records.
2. Mouflon (*O. orientalis*, as the sheep's wild ancestor), using its present day geographical distribution. Several ancestors of domestic sheep are proposed in the literature. The taxonomy is uncertain due to the species' long period of domestication, as well as the existence of several congeneric primitive sheep species. However, this study used the present geographical distribution of the mouflon based on mitochondrial DNA evidence (Hiendleder et al 1998).
3. Merino breed, using the introduced distribution of sheep populations that were documented in the literature as merinos.
4. Damara breed, using the distribution of this breed in South Africa, where it was developed.
5. Dorper breed, using the distribution of this breed in South Africa, where it was developed.

Figure 2.1 Streamlined process for assigning VPC Threat Categories to birds and mammals using the Australian Bird and Mammal Model (Bomford 2008)



Using distribution data where breeds originated was not an option suggested by Bomford (2008). However, these data were used in the present study because they were often the only breed-specific information available. Also, damara and dorper sheep were developed specifically for South African climatic conditions and it was considered that these data could provide useful results.

We could not use distribution data for domestic sheep flocks that were living in the open with minimal provision of food supplements and shelter, because the literature did not clearly distinguish these populations. In addition, the degree of minimal provisions varied between countries, making it difficult to judge when herds could qualify as 'living in the open with minimal provisions'.

The general lack of breed-specific information meant that we were unable to collect sufficient information to complete separate analyses for the three different sheep breeds for stage A (Public Safety Risk) and C (Pest Risk) of the Bird and Mammal Model. This meant that while separate ERRs were calculated for the domestic sheep, the mouflon and the three breeds, a VPC Threat Category could only be assigned to the domestic sheep (no breeds distinguished).

2.5 Risk assessment models for establishment of reptiles and amphibians

Three methods were used to assess the establishment potential of reptiles and amphibians introduced to Australia: two versions of the Australian Bird and Mammal Model and the Australian Reptile and Amphibian Model (Bomford 2008).

2.5.1 Australian Bird and Mammal Model

Two versions of the Australian Bird and Mammal Model were used to assign ERRs to reptiles and amphibians: our Model A uses the first three factors/questions from stage B of the model (as per the recommendation of Bomford 2008, pp 54–55), which deals with the risk of escaped or released individuals establishing a free-living population:

1. Climate match score for Australia.
2. Exotic population established overseas.
3. Overseas distribution size.

The four additional questions from stage B are added for our Model B (Bomford 2008, pp 20):

4. Taxonomic class.
5. Diet.
6. Habitat use.
7. Migratory behaviour.

For both versions, an Establishment Risk Score is calculated by summing the scores for each question. The ERR (Low, Moderate, Serious or Extreme) is then determined using the published cut-off thresholds (Bomford 2006, 2008).

We decided to use Model B even though the factors have not been validated scientifically as correlating with establishment success for reptiles and amphibians. As Bomford (2008) points out 'where no significant effect has been found for a factor, such as for diet, migratory behaviour or a tendency to live in disturbed habitats, this does not mean that the factor does not influence establishment success. Expert opinion, published in the scientific literature, suggests that such factors may well be potentially important.'

2.5.2 Australian Reptile and Amphibian Model

The assessment stages used for determining ERRs in the Australian Reptile and Amphibian Model (Bomford 2008, pp 51–53) are:

A. Climate match risk score.

B. Exotic elsewhere score.

C. Taxonomic family risk score.

An Establishment Risk Score is calculated by summing the scores for each stage. The ERR (Low, Moderate, Serious or Extreme) is then determined using the published cut-off thresholds (Bomford 2006, 2008).

2.5.3 Convention for assignment of ERRs

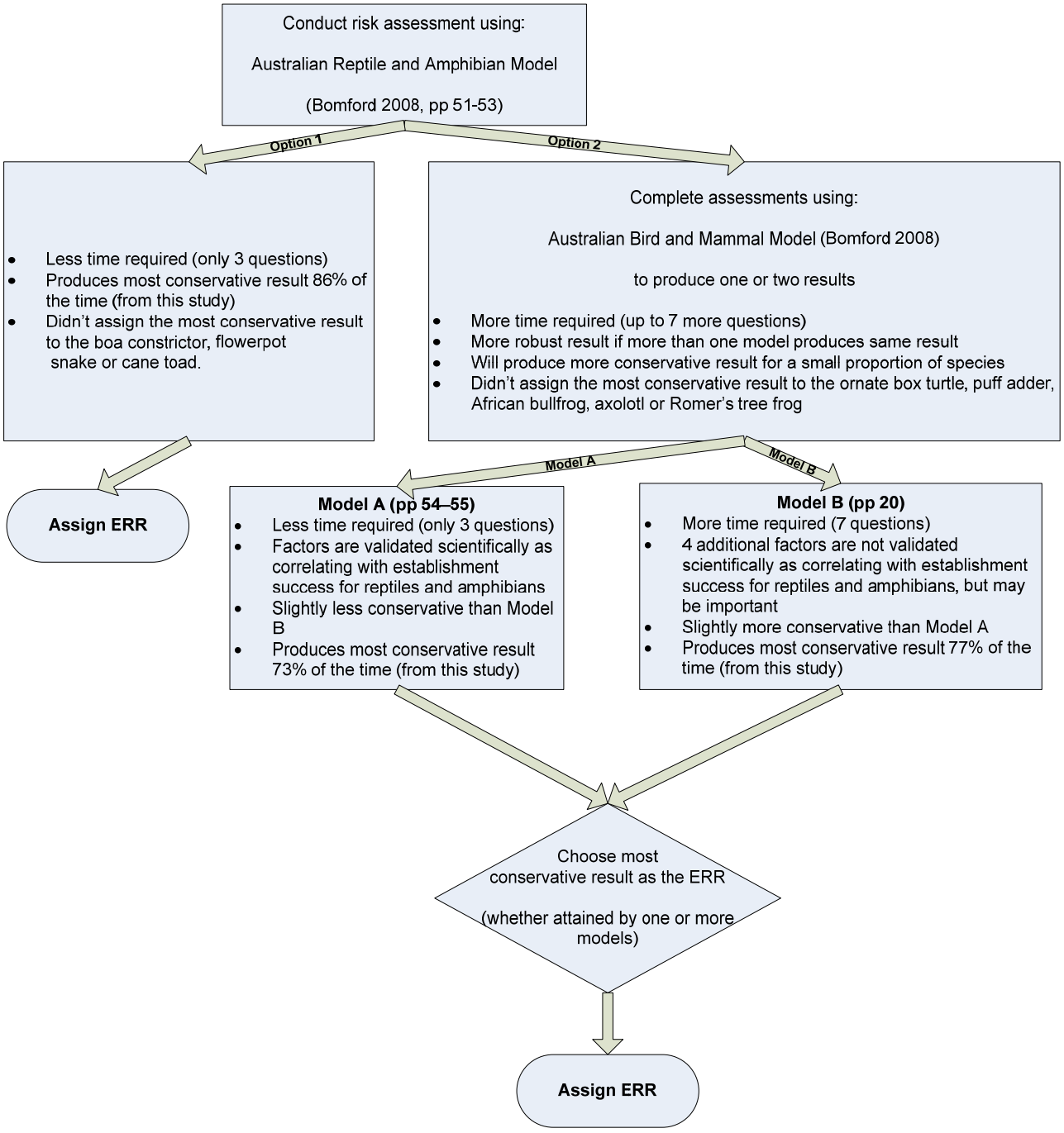
The untested underlying assumption made in developing the Australian Reptile and Amphibian Model, using introduction data for Britain, Florida and California, was that the results of these analyses would also apply to introductions of reptiles and amphibians to Australia. Therefore, predictions made by this model may be less reliable than predictions made by the models for mammals and birds, which were based on data for Australian introductions (Bomford et al 2005). We decided to indicate this lower dependency in our results by indicating the underlying assumption as a footnote.

In addition, after discussions with Dr Bomford, we agreed that if either version of the Bird and Mammal Model predicted a level of risk equivalent to that of the Reptile and Amphibian Model, then that result should be considered more robust than the result based on the Reptile and Amphibian Model alone. However, if the three models predicted different levels of risk, a precautionary approach would accept the highest level of risk.

2.5.4 Efficient assignment of ERRs

In order to efficiently assign robust and precautionary ERRs for reptiles and amphibians, we developed the process outlined in Figure 2.2. Depending on the time available to an assessor, the degree of robustness required, use of the precautionary approach and the confidence attributed to our results, Option 1 (just using the Reptile and Amphibian Model) may be acceptable.

Figure 2.2 Streamlined processes for assigning Establishment Risk Ranks (ERRs) to reptiles and amphibians, using the Australian Reptile and Amphibian Model and the Australian Bird and Mammal Model (Bomford 2008)



2.6 Other information gathered to assess pest risks posed by reptiles and amphibians

2.6.1 Checklist of factors associated with adverse impacts

While ERRs based on a quantitative model were assigned for reptiles and amphibians, assessing pest risk was more difficult. Bomford et al (2005) state that there is insufficient reliable knowledge of the factors correlated with impacts of exotic reptiles and amphibians to make the development of a quantitative model feasible for assessing the risks of impact for new species in Australia. However, Bomford et al (2005) also state that a review of factors associated with adverse impacts indicates that an increased risk is associated with introduced reptiles and amphibians that:

1. Have adverse impacts elsewhere.
2. Have close relatives with similar behavioural and ecological strategies that have had adverse impacts elsewhere* (*see below).
3. Are dietary generalists.
4. Stir up sediments to increase turbidity in aquatic habitats.*
5. Occur in high densities over their native or introduced distribution.*
6. Harbour or transmit diseases or parasites that are present in Australia.*
7. Have close relatives among Australia's endemic reptiles and amphibians.
8. Are known to have spread rapidly following their release into new environments.*
9. Are predatory.

Bomford et al (2005) suggest that this list could be used as a checklist to qualitatively assess the threat posed by the establishment of new exotic reptiles and amphibians in Australia — with the caveat that species lacking these factors cannot necessarily be taken to pose a low risk of harm. Therefore, for each reptile and amphibian species, we collected information according to this checklist and recorded the number of factors for which information was confirmed. However, this was done as a demonstration only, because the same rigour and effort was not put into the literature review for all checklist factors: asterisked (*) factors were usually addressed using standard text books only, so the data may be incomplete.

2.6.2 Predicting adverse impacts on Australian native species and primary production

We attempted to predict possible adverse impacts of reptiles and amphibians on Australian native species and primary production. This was done by comparing the geographic distribution of susceptible native species or communities, and susceptible primary production, with the Australian climate match output map for each species (ie by addressing questions C6 and C8 from stage C of the Australian Bird and Mammal Model [Bomford 2008, pp 22–25], and by using the same scoring system).

These comparisons for reptiles and amphibians were done to the same standard as for bird and mammal assessments (ie based on thorough literature reviews).

2.6.3 Predicting risks to public safety posed by captive or released individuals

We also attempted to predict the risks to public safety posed by captive or released reptile and amphibian individuals. This was done by addressing the public safety questions in stage A of the Australian Bird and Mammal Model (Bomford 2008, pp 17), using the same scoring system to assign a species to one of three ranks: Not Dangerous, Moderately Dangerous or Highly Dangerous. These comparisons for reptiles and amphibians were also done to the same standard as for adverse impact predictions above.

2.7 Indicating information-related uncertainty in risk assessments

We attempted to indicate the degree of uncertainty associated with the risk assessments by comparing the number of references collected for each assessment and for the four taxonomic classes of animals.

The references used for each assessment were compiled for the following criteria:

- risks to public safety posed by captive or released individuals (stage A of the Australian Bird and Mammal Model)
- establishment risk (stage B of the Australian Bird and Mammal Model, and the Reptile and Amphibian Model)
- overseas environmental and agricultural adverse impacts (questions C5 and C7 of the Australian Bird and Mammal Model).

Because literature reviews for this study were conducted in a standardised, consistent manner (described below) to obtain references relating to public safety and establishment risk, and environmental and agricultural adverse impacts, it was possible to validly compare the numbers of these references.

We compared the numbers of references per species for each taxonomic class by analysis of variance (with square root transformation). While the reptile and amphibian species had been partly chosen for this study to ensure a range of risk results, the same was not true for the mammals, since a larger number of well-known pests had been assessed (for which very large numbers of references were found). Hence, a group of 11 mammals was selected for some analyses on the basis that it was similar to the groups of reptiles and amphibians (ie containing species with a range of risk rankings). Two sets of analyses of variance were then performed with data for mammals comprising these 11 or all 17 species.

References that were not included in these counts were those for Australian-specific information and personal communications. In instances where the same reference was used more than once in the same group, the reference was only counted once.

2.8 Assigning DAFWA Threat Categories and Alternative Threat Categories to reptiles and amphibians

The VPC Guidelines refer only to the assignment of VPC Threat Categories based on the original Australian Bird and Mammal Model (Bomford 2003). In order to provide the option of an equivalent threat category for reptiles and amphibians, we investigated the development of a method consistent with these guidelines to assign reptiles and amphibians to 'DAFWA Threat Categories', comprising indications of public safety, establishment and pest risk.

As outlined above, the process in place to assign an ERR is well established. We decided that, for the purposes of this study, the process to assign a PSRR would be as per the original Australian Bird and Mammal Model and the existing VPC Guidelines. That is, there would be two questions, which would result in the assignment of a Not Dangerous, Moderately Dangerous or Highly Dangerous PSRR.

We also decided that, for the purposes of this study, the information available on adverse impacts would be divided into two sections: a checklist of factors associated with adverse impacts, and predicted adverse impacts on Australian native species and primary production.

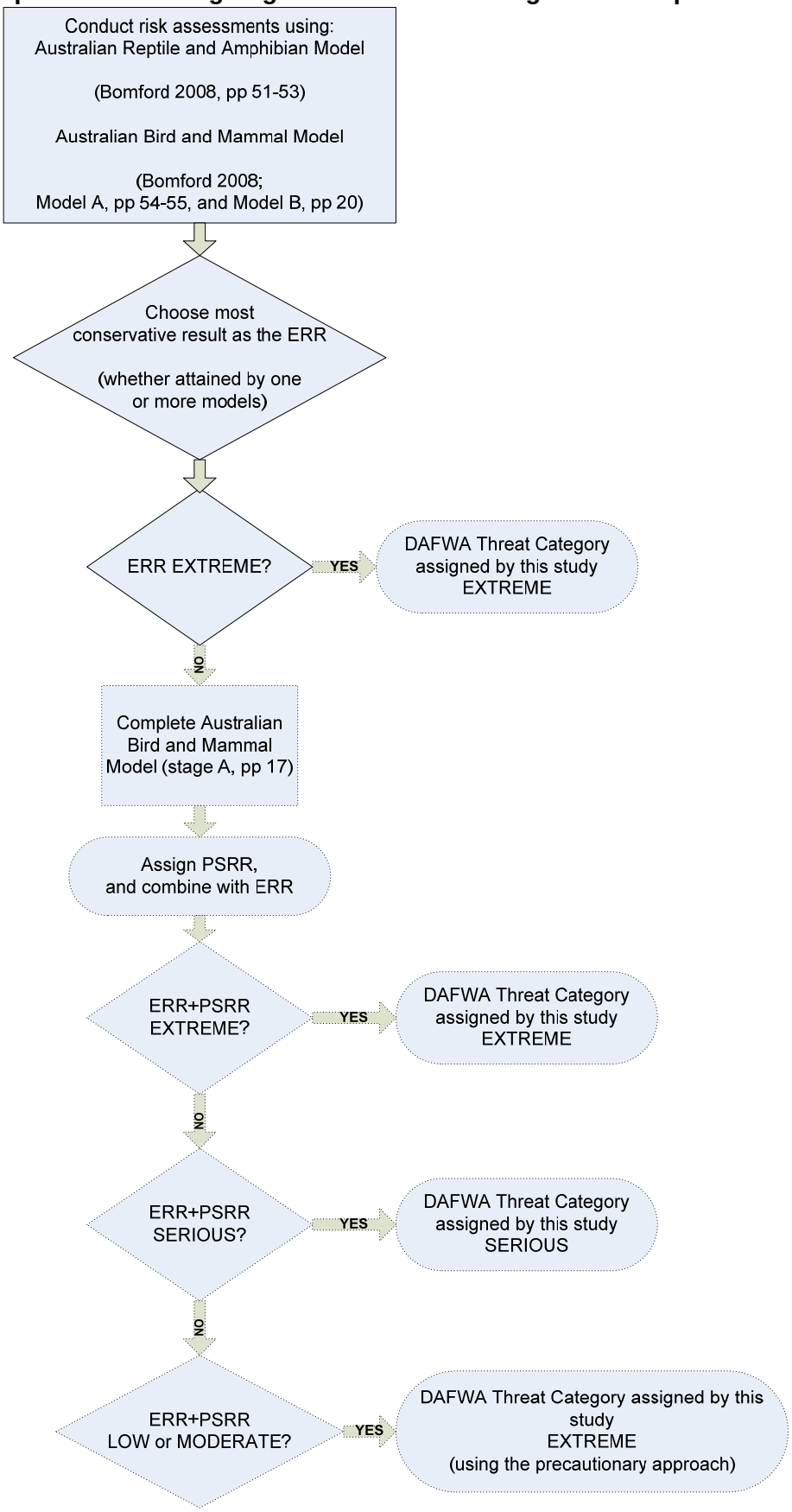
Using the conventions in the VPC Guidelines and combining ERRs and PSRRs, with use of the precautionary approach where required, we developed a process to assign DAFWA Threat Categories to reptiles and amphibians (Figure 2.3). First, we simply combined the ERR and PSRR, and then referred to the VPC Threat Category Table (Appendix B) to assign a threat category. For example, following the guidelines, where the assigned ERR is Extreme, the assigned threat category is also Extreme, and where the ERR is Low and the PSRR is Highly Dangerous, the assigned threat category is Serious.

However, where the assigned threat category was Low or Moderate, we used the precautionary approach to elevate species to the Extreme DAFWA Threat Category, because adverse impacts have not been assessed in this process. The VPC Guidelines indicate that 'any exotic vertebrate species either proposed for import or detected in the country, that has not been assessed previously will be considered to be in the Extreme Threat Category and will be treated accordingly, until a risk assessment is conducted' (VPC Guidelines, (NRMSC 2004). This approach is further supported by suggestions made during the risk assessment workshop that emphasised the need to be transparent about knowledge gaps, and to establish a clear process to manage uncertainty, including use of the precautionary approach (Henderson 2009).

While DAFWA Threat Categories provide rankings for reptiles and amphibians equivalent to the VPC Threat Category for birds and mammals, the lack of consideration of adverse impacts almost certainly results in imprecise categorisation of some species. In an attempt to increase precision, we developed a process where the ERR+PSRR combination was arbitrarily increased by one rank, based on the (qualitative) presence of the most important adverse impact factors (factor 1 or 5), or maximum scoring for potential effects on Australian species or primary production (Figure 2.4). We have called this the 'Alternative Threat Category'. These categories may be more realistic than the DAFWA Threat Categories, because they consider this extra information.

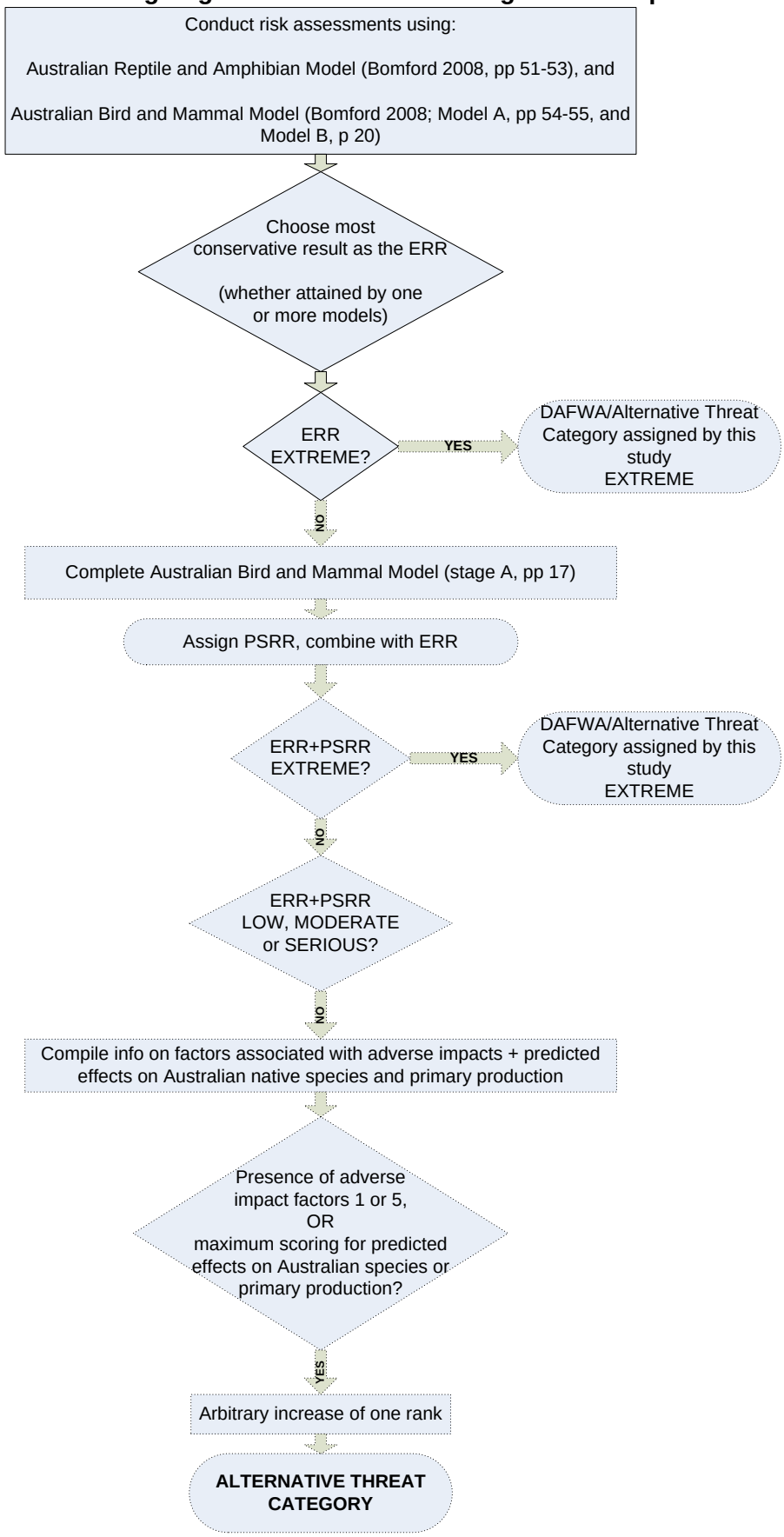
NB: The DAFWA and Alternative Threat Categories we assigned to reptiles and amphibians have not been endorsed by the VPC. These are purposely distinguished from VPC Threat Categories, which have been endorsed by the VPC.

Figure 2.3 Proposed process for assigning DAFWA Threat Categories* to reptiles and amphibians



* Ranking assigned to a reptile or amphibian by this study only.
For reptiles and amphibians, these threat categories have not been endorsed by the VPC.
Dashed lines indicate parts of the process that have not been endorsed by the VPC.

Figure 2.4 Process for assigning Alternative Threat Categories* to reptiles and amphibians



* Category assigned to a reptile or amphibian by this study only.
For reptiles and amphibians, these categories have not been endorsed by the VPC.
Dashed lines indicate parts of the process that have not been endorsed by the VPC.

2.9 Prioritisation of species

To further prioritise the assessed species, information was compiled on invasion pathways by which these animals might be introduced into the wild in Australia (Appendix A). Kraus (2003) indicated the following pathways are responsible for the most global introductions of exotic vertebrates:

- mammals introduced deliberately for aesthetic purposes (ie to establish wild populations, but not necessarily connected to the pet trade) and for game
- birds introduced deliberately for game and pets
- reptiles and amphibians introduced via cargo and the pet trade, as well as for biocontrol, food, aesthetics and the nursery trade.

Information specific to Australia was also compiled (Appendix A) for each species regarding:

- presence in the wild or in countries neighbouring Australia
- if detected entering Australia
- presence on the DEWHA Live Import List (DEWHA 2009b)
- presence in accredited zoo collections
- presence in legal non-accredited keeping facilities
- recorded seizures or surrenders of illegally held animals or known illegal keeping.

For each species, the information was put into a risk matrix (Burgman et al 2009) along with either the VPC Threat Category (for birds and mammals) or Alternative Threat Category (for reptiles and amphibians).

2.10 Assessment processes

The general process outlined below was followed for all assessments (although as indicated above in Section 2.6, some of the checklist factors were not subject to this process). Each assessment took an average of 4.5 days to complete over a period of 16 to 24 weeks and was comprised of the steps listed below.

1. A literature review was conducted (see section below), with additional reference material obtained online or ordered through libraries.
2. All assessment questions that did not require information from climate analyses were attempted. This was done using available information, while awaiting the arrival of ordered reference material.
3. Once all relevant references arrived, attempted questions were reviewed. This sometimes resulted in the ordering of further reference material.

4. When all relevant reference material had been incorporated, the climate analysis was conducted (to ensure that all information on the naturally occurring and introduced distribution of the species was available) and the output used to complete the remaining questions.

5. The assessment was then subject to four levels of review (see below).

6. A final version of the assessment was produced.

2.10.1 Consistency of model use

Consistency of application of the models across assessments was addressed during each assessment, in part by re-reading each question before allocating a score. Having a database of over 200 already completed assessments also allowed for review of the scores allocated for other species. This sometimes resulted in moderation of scores to ensure consistency across assessments.

2.10.2 Literature reviews

As far as possible, literature reviews were conducted in a standardised, consistent manner, using reputable sources, in order to amass directly comparable numbers of references for each assessment. This was deemed important because both the number and content of references were considered when allocating scores for some questions, in order to judge the amount of knowledge available for checklist factors, or the degree of uncertainty of assessments overall.

The literature reviews involved sourcing English language information from scientific journals, standard text books (Appendix C), published and unpublished reports, bibliographies available on disc, reports collected from email discussion groups, news items, and web-based publications and information systems such as Google, BIOSIS and the Catalogue of Life (Appendix D), and other electronic databases. Only reputable information that was relevant, current and accurate was selected and used.

The references ultimately used in the assessments were stored electronically in EndNote®, which is a commercial reference management software package, used to manage bibliographies and references when writing articles. This allowed a reference list to be generated efficiently and automatically for each assessment.

2.10.3 Literature review key words

In general, reviews were conducted using the scientific name and common name(s) of the species (using ‘or’ to source papers with any of the scientific or common names; exact phrase; sort by relevance). Useful key words (when large numbers of references needed to be reviewed) included: damage, crop, compet*, fruit, vegetable, (nest) hollow, feral, exotic, establish, pest, new, aggres*, naturalised, disease, spoilage, manag*, control techniques, problem bird, alien, invas*.

2.10.4 Assessment review

Completed assessments were subject to four levels of review using the process below.

1. First draft reviewed by another assessor.
2. Comments, corrections and adjustments incorporated into a second draft.
3. Second draft reviewed by the project leader.
4. Comments, corrections and adjustments incorporated into a third draft.
5. Third draft reviewed externally by a suitably qualified wildlife expert with either an ecology background or specific knowledge of the species being assessed.
6. Comments, corrections and adjustments incorporated into a fourth draft.
7. Fourth draft reviewed again by the original assessor.
8. This draft distributed to the VPC for review, comment and eventual endorsement of the VPC Threat Category or ERR for the species.
9. Any final adjustments incorporated into a final version.

2.11 Assessor credentials, selection and training

The two personnel who completed the assessments for this study and the project leader hold tertiary qualifications in biological sciences, and are employed as technical or professional officers by the Invasive Species Program of the Western Australian Department of Agriculture and Food (DAFWA). Two staff spend time managing the keeping of exotic animals and dealing with incursions of animals in Western Australia. All are women within the following age groups: 24–34, 35–44 and 55–64. The senior assessor and the project leader have conducted risk assessments using versions of the Bomford models since 2001. These factors reduced the ‘uncertainty due to assessors’ in the assessment process (see the Discussion for further explanation).

The junior assessor engaged specifically for this study has a degree in biology (including some understanding of animal ecology), a demonstrated ability to conduct literature searches and experience with reviewing qualitative and quantitative information.

Bomford (2008) states that ‘the calibre of a risk assessment is related to the quality of data available, so ensuring that a thorough and comprehensive literature review is undertaken for each species assessed can reduce one source of uncertainty’. Bomford (2008) also states that ‘risk assessments contain literature search results that are a combination of scientifically defensible data and other information that may be anecdotal or experience based’. Consequently, the junior assessor received three months of risk assessment training, focussing on selecting and scrutinising appropriate literature. Training was also provided in the accurate use of CLIMATE software, after our in-house testing indicated that failure to include the relevant meteorological stations for a particular species, using both distribution and altitude information, could result in inaccurate climate match output maps. This could then have a negative flow-on effect on the risk assessment. The training included practising the various methods by which locations can be selected using CLIMATE, including large areas of the world or specific named or altitude-based locations.

3 Results

The results for full risk assessments of the bird and mammals are summarised in Table 3.1. The listed VPC Threat Categories have been endorsed by the VPC. Full details of bird and mammal scores and ranks are in Appendix E and F. The results for reptiles and amphibians are summarised in Table 3.3, although it should be noted that ten Establishment Risk Ranks (ERRs) have not yet been endorsed by the VPC. Full details of scores from the models are in Appendix G and H. The criteria used to select species for this study, including invasion pathways, related Australian-specific information, predicted VPC Threat Categories and ERRs are in Appendix A. Risk assessments are available at www.feral.org.au under 'Policy'.

Results with respect to the models' assignments, robustness and inconsistencies are discussed separately below for the bird and mammals, and for the reptiles and amphibians.

3.1 Currency of risk assessments

No time limit on currency has previously been applied to this style of risk assessment, but we consider that the assessments could remain reasonably current for approximately two years. Fewer resources will be required in the future to bring the completed assessments up to date.

3.2 Bird and mammal assessments

3.2.1 Summary of results for the bird and mammals

Seventeen mammal species and one bird were assessed (Table 3.1, Appendix E and F). The 11 mammalian families represented include Bovidae, Callitrichidae, Canidae, Cervidae, Felidae, Leporidae, Mustelidae and Ursidae, from which some species have already been assessed for the VPC (Massam et al in prep). We also assessed species from Herpestidae, Hylobatidae, Marcropodidae (mammals) and Struthionidae (bird), from which no species have previously been evaluated for the VPC. Twelve mammals were assigned to the Extreme VPC Threat Category, one mammal and the bird to the Serious category, and four mammals to the Moderate category. No species were assigned to the Low category.

The model assigned similar VPC categories for species grouped according to the selection criteria in Appendix A. For instance, all species recognised internationally as invasive were assigned by the model to the Extreme VPC Threat Category. These include chital and red deer, sheep, European rabbit, red fox and stoat. Similarly, all assessed species with introduced populations overseas, including New Zealand (chital, fallow and red deer, sheep, European hare and rabbit, fishing cat, red fox and stoat), were assessed as being in the Extreme VPC Threat Category. All mammals with introduced populations in Australia (chital, fallow and red deer, sheep, European hare and rabbit and red fox), were also assessed as being in the Extreme VPC Threat Category. The ostrich, for which there are recent sightings in the wild in Australia (Birds Australia 2009), was assigned to the Serious category.

Table 3.1. Summarised risk ranks and VPC Threat Categories for the bird and mammals using the Australian Bird and Mammal Model (Bomford 2008)

Scientific name	Common name	Public Safety Risk Rank	Establishment Risk Rank (Model 1, 4 factors)	Establishment Risk Rank (Model 2, 7 factors)	Pest Risk Rank	VPC Threat Category
Aonyx cinereus	oriental small-clawed otter	Moderately dangerous	Low	Moderate	Serious	Serious
Axis axis	chital deer ++	Moderately dangerous	Extreme	Extreme	Extreme	Extreme
Cervus elaphus	red deer ++	Moderately dangerous	Extreme	Extreme	Extreme	Extreme
Dama dama	fallow deer ++	Moderately dangerous	Extreme	Extreme	Extreme	Extreme
Dorcopsis luctuosa	grey dorcopsis	Not dangerous	Low	Low	Moderate	Moderate
Helarctos malayanus	Malayan sun bear	Highly dangerous	Low	Moderate	Extreme	Extreme
Leontopithecus rosalia	golden lion tamarin	Moderately dangerous	Low	Low	Moderate	Moderate
Lepus europaeus	European hare++	Not dangerous	Extreme	Extreme	Extreme	Extreme
Lynx lynx	Eurasian lynx	Moderately dangerous	Low	Moderate	Extreme	Extreme
Mustela erminea	stoat	Not dangerous	Serious	Serious	Extreme	Extreme
Oryctolagus cuniculus	European rabbit ++	Not dangerous	Serious	Serious	Extreme	Extreme
Ovis aries	domestic sheep – no breeds distinguished ++	Moderately dangerous	Moderate	Moderate	Extreme	Extreme
Ovis orientalis	domestic sheep's ancestor – mouflon	NA	Low	Low	NA	NA
Ovis aries	merino sheep breed ++	NA	Moderate	Moderate	NA	NA
Ovis aries	damara sheep breed	NA	Low	Low	NA	NA
Ovis aries	dorper sheep breed	NA	Moderate	Moderate	NA	NA
Prionailurus viverrinus	fishing cat	Moderately dangerous	Serious	Serious	Extreme	Extreme
Struthio camelus	ostrich ++(?)	Moderately dangerous	Moderate	Moderate	Serious	Serious
Suricata suricatta	meerkat	Moderately dangerous	Moderate	Moderate	Moderate	Moderate
Symphalangus syndactylus	siamang	Moderately dangerous	Low	Low	Low	Moderate
Ursus arctos	brown bear	Highly dangerous	Moderate	Moderate	Extreme	Extreme
Vulpes vulpes	red fox ++	Moderately dangerous	Extreme	Extreme	Extreme	Extreme

Bird and mammal VPC Threat Categories have been endorsed by the VPC.
++ = species has successfully established introduced populations in Australia. The ostrich has recently been reported in the wild.
NA = no analysis or allocation of rank due to insufficient information.

Livestock species (chital, fallow and red deer, domestic sheep and ostrich), were assessed as being in the Extreme or Serious VPC Threat Category. The risk assessments assigned the domestic sheep (no breeds distinguished), and the dorper and merino breeds to the Moderate ERR, and the damara breed and mouflon to the Low ERR. In all cases, this was because of their low climate match scores. [The domestic sheep (no breeds distinguished) was assigned to the Extreme VPC Threat Category because it was assigned to the Extreme Pest Risk Rank.] All assessed game species (chital, fallow and red deer, European hare and rabbit, red fox), were also assigned to the Extreme VPC Threat Category.

Of the assessed species present in Australasia in accredited zoo collections, many (brown bear, chital, fallow and red deer, fishing cat, Malayan sun bear, oriental small-clawed otter and red fox), were assigned to the Extreme VPC Threat Category. The ostrich was assigned to the Serious category. The golden lion tamarin, meerkat and siamang were assigned to the Moderate category.

Of the assessed species held (legally or illegally) by private keepers or known to have been seized from or surrendered by keepers, most (chital, fallow and red deer, domestic sheep, European hare and rabbit, fishing cat and red fox), were assessed as being in the Extreme VPC Threat Category. The dorcopsis was assigned to the Moderate category. Apart from the dorcopsis, all other mammals assessed are present in one or more overseas trades for pet, food, skin, medicine or similar, increasing the likelihood that they may be discovered being illegally held in Australia in the future.

3.2.2 Comparison of the models in assigning ERRs

For all species, the ERRs assigned by the different models only ever differed by one level. Three species — Eurasian lynx, Malayan sun bear and oriental small-clawed otter — were assigned to the Low ERR by Model 1 (4 factors) and to the Moderate ERR by Model 2 (7 factors), while all the others (86 per cent) were assigned to the same ERR by both models (Table 3.1). These three exceptions have moderate climate matches but do not have exotic populations overseas (both factors in Model 1); whereas most species assigned to the Moderate ERR have higher climate matches and/or do have exotic populations overseas.

3.2.3 Inconsistencies in assigning threat categories

Threat category assignments were not always at the level we predicted (see Appendix A).

Attempts were made to produce a range of threat categories within the families Callitrichidae Cervidae, Felidae, Mustelidae and Ursidae, but because of our misperceptions about the species, this was only achieved for Callitrichidae (golden lion tamarin, for comparison with the previously assessed common marmoset, *Callithrix jacchus*) and Mustelidae (oriental small-clawed otter and stoat, for comparison with the previously assessed ferret, *Mustela putorius furo*). All the species from Cervidae, Felidae and Ursidae were assessed as being in the Extreme VPC Threat Category.

Of the six species selected on our perception that they would be assigned to the Low or Moderate VPC Threat Category, three (grey dorcopsis, golden lion tamarin and siamang) were assessed as such. The other three species (Eurasian lynx, fishing cat and Malayan sun bear) were assigned to the Extreme category.

Eleven of the 12 species selected on our perception that they would be assigned to the Serious or Extreme VPC Threat Category (Appendix A) were assigned as such. These included all livestock species. The one exception was the meerkat, which was assigned to the Moderate category.

There were four mammal species assigned to the Moderate VPC Threat Category: grey dorcopsis, golden lion tamarin, meerkat and siamang. However, we used less than the median number of references (37) for all of these species (see Appendix I), increasing the level of information-related uncertainty for these assessments.

3.2.4 Comparison with Bomford 2006 study

Nine species assessed for this study were previously assessed by Bomford (2006) for Australia and assigned ERRs. A comparison of these results (Table 3.2) indicates that we assigned these species to ERRs that were the same or more conservative than those determined by Bomford (2006). All of these nine species have successfully established introduced populations in Australia, apart from the stoat, which was assigned by both studies to the Serious ERR.

Using Model 1, we assigned seven species to the same ERR as Bomford. However, we assigned fallow and red deer to a higher rank (Extreme) than Bomford did. Using Model 2, we assigned six species to the same ERR as Bomford. However, we assigned chital, fallow and red deer to a higher rank (Extreme) than Bomford did. Also, unlike Bomford, the rankings we assigned for particular species using Models 1 and 2 were either the same or more conservative using Model 2 (see Section 3.2.2). These results were almost certainly because of our access to a wider range of references collected via literature reviews conducted in the standardised, consistent manner described in the Methods section (Chapter 2). In contrast, Bomford used information from standard text books (Dr Mary Bomford, pers comm).

3.3 Reptile and amphibian assessments

3.3.1 Summary of results for reptiles and amphibians

The risk of establishment in the wild (ie the assignment of an ERR) was assessed for 11 reptile and 11 amphibian species. Results are summarised in Table 3.3 and full details of scores and ranks are in Appendix G and H. Note that ERRs for ten species have not yet been endorsed by the VPC (see below).

The 14 families represented are Ambystomatidae, Boidae, Bufonidae, Colubridae, Emydidae, Geoemydidae, Megophryidae, Microhylidae, Pipidae, Ranidae, Rhacophoridae, Salamandridae, Typhlopidae, and Viperidae. None of these species has previously been assessed for the VPC.

A range of risk ranks was achieved within the families Ambystomatidae, Boidae, Bufonidae, Emydidae, Salamandridae, and Viperidae. The biggest range was produced within Boidae with the emerald tree boa assigned to the Low rank and the boa constrictor assigned to the Extreme rank. In contrast, the two species from Geoemydidae were assigned to the Low rank, and the two from Colubridae were assigned to the Moderate rank.

Table 3.2. Comparison of results from Bomford (2006) and this study to assess the risks of mammals and birds introduced to Australia

Scientific name	Common name	Data source	Establish-ment risk score	Establishment Risk Rank (ERR) Model 1 (4 factors)	Establish-ment risk score	Establishment Risk Rank (ERR) Model 2 (7 factors)
Axis axis	chital deer ++	Bomford	11	Extreme	13	Serious
		This study	11	Extreme	14	Extreme
Cervus elaphus	red deer ++	Bomford	10	Serious	11	Moderate
		This study	11	Extreme	14	Extreme
Dama dama	fallow deer ++	Bomford	9	Serious	11	Moderate
		This study	11	Extreme	14	Extreme
Lepus europaeus	European hare ++	Bomford	12	Extreme	15	Extreme
		This study	11	Extreme	14	Extreme
Mustela erminea	stoat	Bomford	9	Serious	12	Serious
		This study	10	Serious	13	Serious
Oryctolagus cuniculus	European rabbit ++	Bomford	9	Serious	12	Serious
		This study	9	Serious	12	Serious
Ovis aries	domestic sheep ++	Bomford	8	Moderate	11	Moderate
		This study	8	Moderate	11	Moderate
Struthio camelus	ostrich ++	Bomford	6	Moderate	9	Moderate
		This study	6	Moderate	9	Moderate
Vulpes vulpes	red fox ++	Bomford	12	Extreme	15	Extreme
		This study	13	Extreme	16	Extreme

++ = species has successfully established introduced populations in Australia. The ostrich has recently been reported in the wild. The Australian Bird and Mammal Model (Bomford 2008) was used (see Chapter 2).

Five reptiles and amphibians were assigned to the Extreme ERR, seven to the Serious rank, four to the Moderate rank and six to the Low rank, giving a good range of results across the four rank levels. See Appendix G and H for more detailed information. The results for the ten species that were assigned to the Moderate or Low ERR have not yet been endorsed by the VPC and are 'on hold' while further information is considered.

The models assigned similar ERRs for species grouped according to the selection criteria in Appendix A. The three species recognised internationally as highly invasive (African clawed frog, cane toad and pond slider), were assessed as belonging to the Extreme ERR. Most species with introduced populations overseas, including New Zealand (African clawed frog, Asiatic painted frog, black-spined toad, boa constrictor, cane toad, flowerpot snake, pond slider and Romer's tree frog), were assessed as belonging to the Extreme or Serious ERR (Table 3.3, Appendix A).

Table 3.3. Summarised results for assessments of establishment risk of reptiles and amphibians

Scientific Name	Common name	Establishment Risk Rank (ERR)			
		Bird and Mammal Model A (3 questions)	Bird and Mammal Model B (7 questions)	Reptile and Amphibian Model*, #	Highest rank
Ambystoma mavortium	western tiger salamander	Serious	Serious	Serious	Serious
Ambystoma mexicanum	axolotl	Low	Low	Moderate	Moderate*
Bitis arietans	puff adder	Moderate	Moderate	Serious	Serious
Bitis nasicornis	rhinoceros viper	Low	Low	Low	Low*
Boa constrictor	boa constrictor	Extreme	Extreme	Serious	Extreme
Bufo marinus	cane toad ++	Extreme	Extreme	Serious	Extreme
Bufo melanostictus	black-spined toad	Serious	Serious	Serious	Serious
Chirixalus romeri	Romer's tree frog	Moderate	Moderate	Serious	Serious
Corallus caninus	emerald tree boa	Low	Low	Low	Low*
Cuora trifasciata	Chinese three-striped box turtle	Low	Low	Low	Low*
Elaphe guttata	corn snake	Moderate	Moderate	Moderate	Moderate*
Elaphe taeniura	beauty snake	Moderate	Moderate	Moderate	Moderate*
Heosemys spinosa	spiny turtle	Low	Low	Low	Low*
Kaloula pulchra	Asiatic painted frog	Serious	Serious	Serious	Serious
Megophrys montana	Javan horned frog	Low	Low	Low	Low*
Pyxicephalus adspersus	African bullfrog	Moderate	Moderate	Serious	Serious
Ramphotyphlops braminus	flowerpot snake ++	Extreme	Extreme	Serious	Extreme
Taricha granulosa	rough-skinned newt	Low	Low	Low	Low*
Terrapene ornata	ornate box turtle	Moderate	Moderate	Serious	Serious
Trachemys scripta	pond slider ++	Extreme	Extreme	Extreme	Extreme
Triturus vulgaris	smooth newt	Low	Moderate	Moderate	Moderate*
Xenopus laevis	African clawed frog	Extreme	Extreme	Extreme	Extreme

*Low and Moderate ERR results have not yet been endorsed by the VPC.
#The underlying assumptions made in developing the Reptile and Amphibian Model, from introduction data for Britain, Florida and California, are untested. Therefore, predictions made by this model may be less reliable than predictions made by the models for mammals and birds, which were based on data for Australian introductions (Bomford 2006).
++ = species has successfully established introduced populations in Australia.

Species established or occasionally found in the wild in Australia were assigned an Extreme ERR (boa constrictor, cane toad, flowerpot snake and pond slider) or Moderate ERR (corn snake). The two amphibians known to have been detected entering Australia (Asiatic painted frog and black-spined toad) were assessed as belonging to the Serious ERR.

Species present in Australasia in accredited zoo collections were assigned to ERRs across the full range. Zoo species assigned to the Extreme ERR are the African clawed frog, boa constrictor, cane toad and pond slider. Species held (legally or illegally) by private keepers, or known to have been seized from or surrendered by keepers, were also assigned to ERRs across the full range. As mentioned above, held species assigned to the Extreme ERR are the African clawed frog, boa constrictor, cane toad and pond slider.

Except for Romer's tree frog, all of the 22 reptile and amphibian species assessed are known to be in overseas trade for pet, food, skin, medicine or similar, increasing the likelihood that they may be discovered being illegally held in Australia in the future.

3.3.2 Comparison of the models in assigning ERRs

For all species, the ERRs assigned by the different models only ever differed by one level. For example, the puff adder was assigned to the Moderate rank by the two versions of the Bird and Mammal Model, and to the Serious rank by the Reptile and Amphibian Model (Table 3.3, Appendix G).

All three models assigned the same rank (ie highest for the species) to 59 per cent of the species, and either two or all three of the models assigned the same highest rank (for that species) to 77 per cent of the species (Table 3.4). The Reptile and Amphibian Model and either version of the Bird and Mammal Model assigned the same highest rank to 59 per cent of the species, while the two versions of the Bird and Mammal Model assigned the same highest rank to 73 per cent of the species.

The Reptile and Amphibian Model was the most conservative model, assigning the highest rank to 86 per cent of the species. The Bird and Mammal Model B assigned the highest rank to 77 per cent and Model A assigned the highest rank to 73 per cent (Table 3.4).

The Reptile and Amphibian Model assigned a higher rank than the two versions of the Bird and Mammal Model to the African bullfrog, axolotl, ornate box turtle, puff adder and Romer's tree frog (Table 3.4, Appendix G). However, this model also assigned a lower rank than the Bird and Mammal Model versions to the boa constrictor, cane toad and flowerpot snake.

For the Reptile and Amphibian Model, the combination of varying scores for climate match and taxonomic family seemed to result in the assignment of the higher rank to the African bullfrog, ornate box turtle and puff adder. For example, the puff adder had a climate match score of 79, but belongs to a Moderate risk family (score of 10), while the African bullfrog had a lower climate match of 46, but belongs to an Extreme risk family (score of 30) (Appendix G).

Romer's tree frog was assigned to the higher rank by the Reptile and Amphibian Model because of high scores for exotic populations and family risk (Appendix G). This was even though its exotic populations result only from translocation by humans.

For the Reptile and Amphibian Model, the more conservative scoring of the 'presence of exotic populations' factor, where even non-breeding groups are allocated a score (species must have bred outside of captivity to be assessed as having an exotic population by the Bird and Mammal Model), combined with a score for a high-risk family, resulted in the assignment of the higher Moderate rank to the axolotl (Appendix G). Relatively low climate match scores resulted in the assignment of the lower Serious rank to the boa constrictor, flowerpot snake and cane toad (Appendix G).

Table 3.4. Consistency of Establishment Risk Rank assigned by the three models to assess the risk of establishment of reptiles and amphibians introduced to Australia

Establishment Risk Rank*	**Number of species** total (reptiles+ amphibians)	**Percentage** of total 22 reptiles and amphibians
Same rank assigned by all three models	13 (7 + 6)	59
Same rank assigned by two or three of the models, and highest for the species	17 (9 + 8)	77
Same rank assigned and highest for the species by Australian Bird and Mammal Models A and B	16 (9 + 7)	73
Same rank assigned and highest for the species by Australian Bird and Mammal Model A *AND* Australian Reptile and Amphibian Model	13 (7 + 6)	59
Same rank assigned and highest for the species by Australian Bird and Mammal Model B *AND* Australian Reptile and Amphibian Model	13 (7 + 6)	59
Highest assigned for the species by Australian Bird and Mammal Model A	16 (9 + 7)	73
Highest assigned for the species by Australian Bird and Mammal Model B	17 (9 + 8)	77
Highest assigned for the species by Australian Reptile and Amphibian Model	19 (9 + 10)	86
Highest assigned for the species by Australian Bird and Mammal Model A, but not so assigned by Reptile and Amphibian Model	3 (2 + 1) boa constrictor, flowerpot snake, cane toad	NA
Highest assigned for the species by Australian Bird and Mammal Model B, but not so assigned by Reptile and Amphibian Model	3 (2 + 1) boa constrictor, flowerpot snake, cane toad	NA
Highest assigned for the species by Australian Reptile and Amphibian Model, but not so assigned by Bird and Mammal Model A and B	5 (2 + 3) ornate box turtle, puff adder, African bullfrog, axolotl, Romer's tree frog	NA

***** as assigned by the Australian Bird and Mammal Models A or B, or the Australian Reptile and Amphibian Model, Bomford 2008 — see Chapter 2.

3.3.3 Inconsistencies in assigning ERRs

ERR assignments were not always as we predicted (see Appendix A).

Of the 12 reptiles and amphibians selected that we anticipated would be assigned to either the Low or Moderate ERR, all but four were assigned as such. The four exceptions are Romer's tree frog and the western tiger salamander (assigned to the Serious ERR), and the flowerpot snake and ornate box turtle (assigned to the Extreme ERR).

Of the ten reptiles and amphibians selected that we anticipated would be assigned to either the Serious or Extreme ERR, all but two were also assigned as such by the various models. The two exceptions are the corn snake and the smooth newt, both assigned to the Moderate rank.

3.3.4 Comparison with Bomford 2006 study

Five species assessed for this study were previously assessed by Bomford (2006) for Australia and assigned ERRs. A comparison of these results is provided in Table 3.5. Our scores for many of these species were very close to those of Bomford (2006). Comparing results produced using the Bird and Mammal Model versions, our results were the same as Bomford's for four of the five species. Using the Reptile and Amphibian Model, two of our results were the same as Bomford's, two were more conservative and one was less conservative.

Our scores for the axolotl were higher, with more conservative scores assigned for climate match in all three model versions, and exotic populations in the Reptile and Amphibian Model. This scoring was done after extensive consultation with Dr Bomford to ensure correct interpretation of the relevant questions, given we had information that was probably not previously available for her assessments.

The scores we assigned for the flowerpot snake and pond slider were also more conservative than those of Bomford, and are likely due to our use of more complete sets of distribution data. Also, Bomford assessed the red-eared slider (*T. scripta elegans*), whereas we assessed the entire species, the pond slider (*T. scripta* – see Table 3.5). Our Climate Match Risk Score (Reptile and Amphibian Model) for the cane toad was lower than that of Bomford, but we used many references to determine an accurate distribution and believe that our score is precise.

3.4 Information on adverse impacts of reptiles and amphibians

As described in Chapter 2, we could not assign VPC Threat Categories to reptiles and amphibians only using the models to assign ERRs. In order to undertake a qualitative assessment of the threat of impacts posed by the establishment of new reptile and amphibian species in Australia, information was collected on adverse impacts of each species (Appendix H). It includes data in relation to:

- factors associated with an increased risk of adverse impacts
- predicted adverse impacts on Australian native species and primary production
- risks to public safety posed by captive or released individuals.

3.4.1 Factors associated with increased risk of adverse impacts

Bomford et al (2005) indicated that an increased risk of adverse impacts is associated with reptiles and amphibians that have nine particular attributes. These attributes/factors include whether the species have adverse impacts elsewhere (outside Australia), are generalist feeders or are predatory. Bomford et al (2005) suggested that these factors could be used as the basis for a checklist to make a qualitative assessment of the threat of impacts posed by the establishment of new reptile and amphibian species in Australia. So, we collected information on as many of these factors as possible.

The total number of factors for which information was confirmed for species varied from one to six of a possible nine, with a mean of 4.2 (standard deviation 1.3). Seven factors were recorded for the cane toad, and six for the beauty snake, black-spined toad, corn snake and pond slider. The two most important factors thought to be associated with increased risk of adverse impacts are: having adverse impacts elsewhere (Factor 1), and occurring in high densities in the native or introduced range

Table 3.5. Comparison of results from Bomford (2006) and this study for reptiles and amphibians

Scientific Name (Data source)	Common name	Climate match (1-6)	Exotic populations overseas (0-4)	Overseas range size (0-2)	Bird and Mammal Model A ERR	Taxonomic class (0-1)	Diet score (0-1)	Habitat score (0-1)	Migratory behaviour (0-1)	Bird and Mammal Model B ERR	Climate Match Risk Score (0-100)	Exotic Elsewhere Risk Score (0, 15, or 30)	Taxonomic Family Risk Score (0, 5, 10, 15, 20, or 30)	Reptile and Amphibian Model ERR
Ambystoma mexicanum	axolotl (x)													
Bomford 2006		1	0	1	Low	1	1	1	1	Low	0	0	15	Low
This study		2	0	0	Low	1	1	1	1	Low	10[a]	15[b]	15	Moderate
Bufo marinus	cane toad ++													
Bomford 2006		5	4	1	Extreme	1	1	1	1	Extreme	66	30	20	Extreme
This study		5	4	1	Extreme	1	1	1	1	Extreme	54.9	30	20	Serious
Bufo melanostictus	black-spined toad (x)													
Bomford 2006		4	4	1	Serious	1	1	1	1	Serious	35	30	20	Serious
This study		4	4	1	Serious	1	1	1	1	Serious	27.2	30	20	Serious

Scientific Name (Data source)	Common name	Climate match (1-6)	Exotic populations overseas (0-4)	Overseas range size (0-2)	Bird and Mammal Model A ERR	Taxonomic class (0-1)	Diet score (0-1)	Habitat score (0-1)	Migratory behaviour (0-1)	Bird and Mammal Model B ERR	Climate Match Risk Score (0-100)	Exotic Elsewhere Risk Score (0, 15, or 30)	Taxonomic Family Risk Score (0, 5, 10, 15, 20, or 30)	Reptile and Amphibian Model ERR
Ramphotyphlops braminus	flowerpot snake ++													
(Bomford 2006)		4	4	1	Serious	1	1	1	1	Serious	34	30	30	Serious
This study		5	4	1	Extreme	1	1	1	1	Extreme	33	30	30	Serious
Trachemys scripta	pond slider++													
Bomford 2006 for *T. s. elegans*		5	4	1	Extreme	1	1	1	1	Extreme	54	30	15	Serious
This study		6	4	1	Extreme	1	1	1	1	Extreme	92	30	15	Extreme

The Australian Bird and Mammal Model and the Australian Reptile and Amphibian Model* (Bomford 2008) were used for this study — see Chapter 2.

*The underlying assumptions made in developing the Reptile and Amphibian Model, from introduction data for Britain, Florida and California, are untested. Therefore, predictions made by this model may be less reliable than predictions made by the models for mammals and birds which were based on data for Australian introductions.

++ = species has successfully established introduced populations in Australia.

a. allocated because of small number of available meteorological stations.

b. allocated for records of non-breeding exotic populations.

x. failed introduction (Bomford 2006).

ERR = Establishment Risk Rank.

(Factor 5) (Dr Mary Bomford, pers comm). Information for both of these factors was found for the cane toad, black-spined toad and pond slider. Only information on one or the other factor was found for other species. Other species confirmed as causing adverse impacts elsewhere are the African clawed frog, beauty snake, boa constrictor, corn snake, puff adder, rhinoceros viper and western tiger salamander. Other species confirmed as occurring in high densities in their native or introduced range are the Asiatic painted frog and the rough-skinned newt.

3.4.2 Adverse impacts on Australian native species and primary production

For each species, the score assigned for overlap between the geographic distribution of susceptible native species or communities and the Australian climate match output map could range from 1 to 5. The maximum score of 5 was achieved by 20 of the 22 species. However, the axolotl was assigned a score of 1 and the Javan horned frog a score of 2.

Three factors contribute to scores for predicted adverse impacts on susceptible native species and account for the high number of assessed species being assigned the maximum score of 5:

- the area of Australia covered by the climate match map — a large area will be more likely to significantly overlap the distributions of some native species
- diet and feeding characteristics — all reptiles and amphibians assessed for this study are predatory species, and so will prey on at least some native species
- a climate match overlap with distributions of nationally listed endangered or vulnerable native species — an overlap with only one endangered or threatened native species results in the maximum score being achieved.

For each species, the score assigned for overlap between the geographic distribution of susceptible primary production and the climate match output map of Australia could be 0 to 5. The species we assessed had a mean score of 0.6 (standard deviation 1.4). The minimum score of 0 was assigned to 14 of the 22 species. However, the beauty snake, cane toad, corn snake, pond slider and western tiger salamander were assigned a score of 1 based on diet preferences. The African clawed frog, boa constrictor and puff adder scored 2 as a result of reports of adverse impacts on livestock.

3.4.3 Risks to public safety posed by captive or released individuals

The Public Safety Risk Rank (PSRR) comprises scores for two types of harm to people: the risk of direct harm from attacks or actions of a cornered animal, and harm from the irresponsible use of products (eg venom) obtained from a captive animal.

Fifteen species were assigned to the minimum PSRR of Not Dangerous. The boa constrictor, black-spined toad, emerald tree boa and rough-skinned newt were assigned to the Moderately Dangerous rank, and the cane toad, puff adder and rhinoceros viper to the Highly Dangerous rank. The puff adder and rhinoceros viper pose risks by direct injection of venom and misuse of collected venom, whereas the risk of harm from the cane toad is limited to misuse of toxic secretions from its parotid glands.

3.5 Indications of information-related uncertainty in all risk assessments

Over 1600 references were used for the bird, mammal, reptile and amphibian risk assessments in this study. Of these, references relating to public safety risk, establishment risk and overseas environmental and agricultural adverse impacts (a total of 1229) were subjected to analysis of variance (with square root transformation) (Appendix I). Just over half of all references were for mammals, which comprised the biggest group (17 species of 40) assessed.

The number of references within this subgroup used for each assessment, along with the median for the taxonomic class, was documented in each assessment document as an indicator of the level of information-related uncertainty.

3.5.1 Differences in numbers of references overall

Analysis of variance, combining the numbers of references for public safety risk, establishment risk, and overseas environmental and agricultural adverse impacts, indicated that there was a significant difference with regard to the numbers of references for mammals ($p=0.014$) and other taxa (reptiles, amphibians and birds). There was no significant difference between the numbers of references for reptiles, amphibians and birds ($p=0.623$).

The numbers of references for the 17 mammals assessed ranged from 68 for both the European hare and domestic sheep to 10 for the grey dorcopsis. The median number of references was 37. The numbers of references for the 11 reptile assessments ranged from 110 for the pond slider to 11 for the Chinese three-striped box turtle. The median number of references was 20. The numbers of references for the 11 amphibian assessments ranged from 44 for the African clawed frog to 5 for Romer's tree frog. The median number of references was 19.

These results indicate that there was less information overall available for reptiles and amphibians, increasing the degree of uncertainty associated with assessments for these species.

3.5.2 Differences in numbers of references on overseas adverse impacts

Analysis of variance also indicated that there was a significant difference with regard to the numbers of references for overseas environmental and agricultural adverse impacts, between mammals and the other taxa (reptiles, amphibians and birds). The variance was $p=0.018$ for 11 mammals chosen with a range of risk assessment results, and $p<0.001$ for all 17 mammals assessed for the project. There was no significant difference between the numbers of references for reptiles, amphibians and birds ($p=0.967$).

The numbers of references for the 17 mammals assessed ranged from 28 for the European hare to 0 for the grey dorcopsis, golden lion tamarin, meerkat and siamang. The median number of references was 11. The numbers of references for the 11 reptile assessments ranged from 26 for the pond slider to 0 for six species: Chinese three-striped box turtle, emerald tree boa, flowerpot snake, ornate box turtle, rhinoceros viper and spiny turtle. The median number of references was 0. The numbers of references for the 11 amphibian assessments ranged from 9 for the African clawed frog to 0 for seven species; African bullfrog, Asiatic painted frog, axolotl, Javan horned frog, Romer's tree frog, rough-skinned newt and smooth newt. The median number of references was 0.

These results indicate that there was less information available on overseas adverse impacts for reptiles and amphibians than mammals, increasing the degree of information-related uncertainty associated with assessments for these species.

3.5.3 Differences in numbers of references on public safety and establishment risk

There were no significant differences between mammals, reptiles, amphibians and birds in the numbers of references used to determine public safety or establishment risk.

3.6 Methods to assign threat categories to reptiles and amphibians

There is currently no procedure in place to assign VPC Threat Categories to reptiles and amphibians. Hence, we developed two processes to assign threat categories (DAFWA and Alternative Threat Categories), summarised in Figures 2.3 and 2.4. Both of these processes are conservative, but reflect the paucity of information available on these species.

3.6.1 DAFWA Threat Categories

Using the conventions in the VPC Guidelines and combining ERRs and PSRRs, with use of the precautionary approach where required (Figure 2.3), we assigned DAFWA Threat Categories to reptiles and amphibians. Simply combining ERRs and PSRRs, and then referring to the VPC Threat Category Table (Appendix B) to assign a threat category, resulted in the assignment of five species to an Extreme, eight to a Serious, six to a Moderate and three to a Low DAFWA Threat Category (Appendix H). The rhinoceros viper, with a Low ERR but Highly Dangerous PSRR was assigned to a Serious DAFWA Threat Category. The emerald tree boa and rough-skinned newt, with a Low ERR, but Moderately Dangerous PSRR were assigned to a Moderate DAFWA Threat Category. These examples indicate the benefits of considering public safety for species that would otherwise have been assigned a low (ERR) rank.

Taking this approach and then elevating to the Extreme rank species initially ranked Low or Moderate, resulted in the promotion of nine species to the Extreme DAFWA Threat Category. Of these nine, only the corn snake had more than the median number of references for both the ERR and PSRR. Four other species (axolotl, emerald tree boa, rough-skinned newt and smooth newt) had less than the median number for either the ERR or PSRR and the rest had less than the median number for both ranks, further supporting the use of precaution due to a lack of information.

This approach is supported by suggestions made by Henderson (2009) about the need to be transparent about knowledge gaps and to establish a clear process to manage uncertainty including use of the precautionary approach.

3.6.2 Alternative Threat Categories

Using the process developed to assign Alternative Threat Categories (Figure 2.4), 14 species with a Low, Moderate or Serious ERR/PSRR combination were assigned to a higher Alternative Threat Category (see Appendix H for the assignments). These species included the Asiatic painted frog, black-spined toad, corn snake, puff adder and rhinoceros viper. Assignment to a higher ranking was not possible for the axolotl and Javan horned frog, based on the presence of adverse impact factors. However, less than the median number of references was used when assessing these two species (see Appendix I). This lack of information indicates a high level of uncertainty, and provides an argument for the use of the precautionary approach and assignment of these species to a higher rank anyway.

3.7 Prioritisation of species

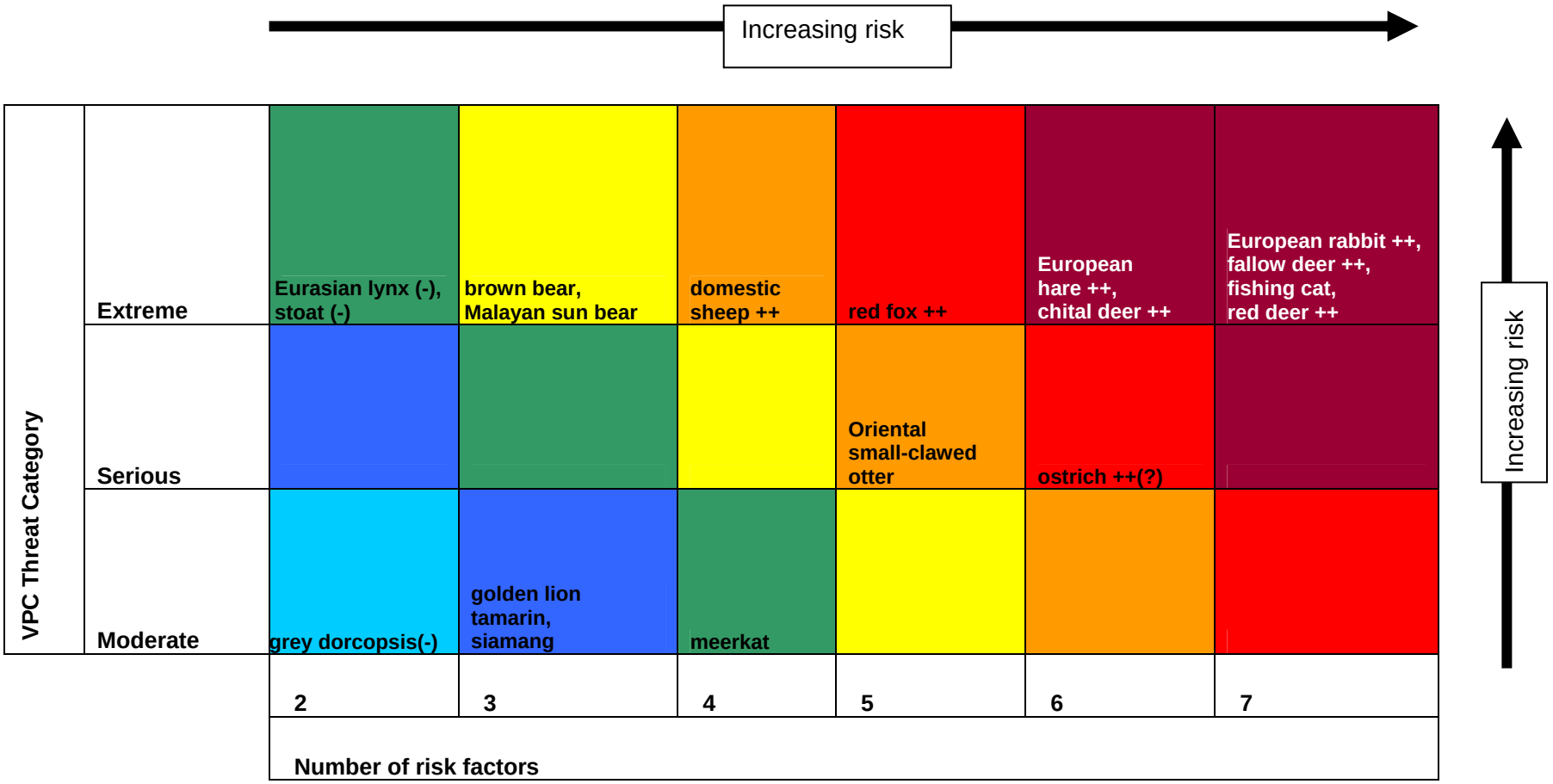
3.7.1 Birds and mammals

Species with the highest combinations of VPC Threat Category, and invasion pathway and other Australian-specific information are those species already found in the wild in Australia (Figure 3.1) — this provides increased confidence in our methodology. The species with the highest combination but that has not established introduced populations in Australia is the fishing cat, followed by the Oriental small-clawed otter, brown bear, Malayan sun bear, Eurasian lynx, stoat and meerkat. Each of these species should be considered for appropriate management action, as discussed further in Chapter 4.

3.7.2 Reptiles and amphibians

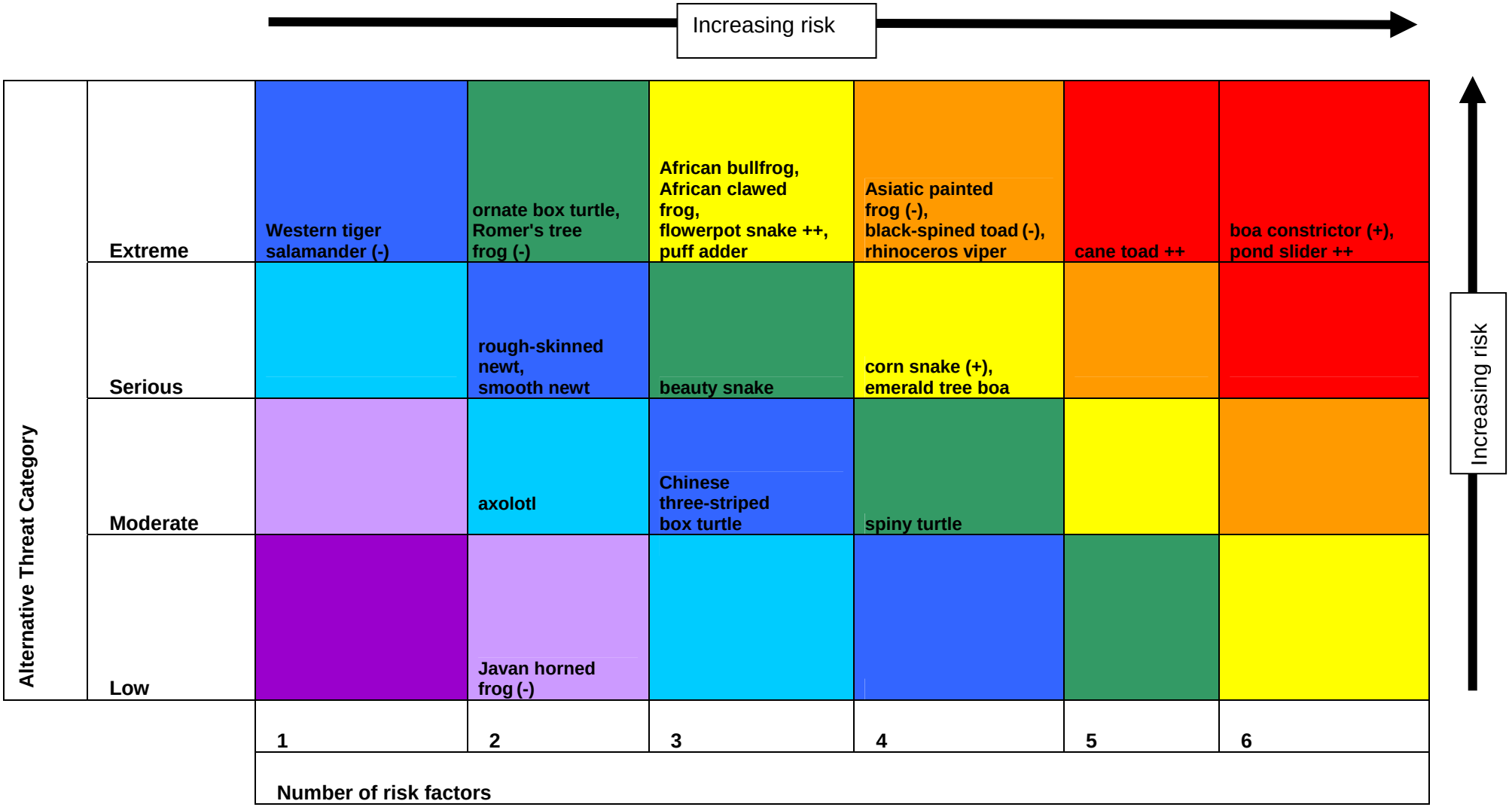
Species with high combinations of Alternative Threat Category and available information are those species already found in the wild in Australia (Figure 3.2). As with bird and mammal results, this provides increased confidence in our methodology. The species with the highest combination that has established small populations in a number of areas is the pond slider. The species with the highest combination that has not established introduced populations in Australia is the boa constrictor. However, this species has been detected in the wild here. Other species with very high combinations are the Asiatic painted frog and black-spined toad, which have both been detected entering Australia, and the rhinoceros viper. Other species with high combinations include the African bullfrog and clawed frog, puff adder, corn snake, emerald tree boa, ornate box turtle, Romer's tree frog and western tiger salamander (because it is assigned to the Extreme category). Each of these species should be considered for appropriate management action, as discussed further in Chapter 4.

Figure 3.1. Risk matrix for birds and mammals: invasion pathways and Australian-specific information versus VPC Threat Categories



Risk factors were determined from the species' occurrence in Australia and nearby countries, its game/livestock status, use in pet/fur trade etc, as shown in Appendix 1, Columns 4-7.
Colours represent comparative levels of risk, with light blue being the lowest risk level, progressing to crimson being the highest risk level.
++ species has successfully established introduced populations in Australia. The ostrich has recently been reported in the wild.
(-) species not known to be legally in Australia. All other species are able to be kept for certain purposes and by certain entities — see Appendix A).
VPC Threat Categories were produced for this study using the Australian Bird and Mammal Model (Bomford 2008) — see Chapter 2.

Figure 3.2. Risk matrix for reptiles and amphibians: invasion pathways and Australian-specific information versus Alternative Threat Category



Risk factors were determined from the species' occurrence in Australia and nearby countries, its game/livestock status, use in pet/fur trade etc, as shown in Appendix 1, Columns 4-7.
Colours represent comparative levels of risk, with purple being the lowest risk level, progressing to red being the highest risk level.
++ species has successfully established introduced populations in Australia.
(-) species not known to be legally in Australia. All other species are able to be kept for certain purposes and by certain entities — see Appendix A.
(+) species detected in the wild in Australia.
Alternative Threat Categories were produced for this study using the Australian Bird and Mammal Model and the Australian Reptile and Amphibian Model (Bomford 2008) — see Chapter 2.

4 Discussion

For this study, experienced, qualified and trained assessors using standardised processes to collect, analyse and review data followed a risk assessment methodology that was based on robust scientific knowledge and statistical analyses of past introductions. In order to assist other assessors in producing robust results, we documented in detail the processes and methodology we used.

Our results produced further evidence for the validation of the Bomford (2008) Australian Bird and Mammal Model and the Australian Reptile and Amphibian Model across a range of families and threat levels. We were able to assess and prioritise 40 species that belonged to the following groups:

1. Species not in Australia to date (eg stoat, Western tiger salamander).

2. Species that have been detected entering Australia but are not established in the wild here (eg Asiatic painted frog, black-spined toad).

3. Captive species (eg ornate box turtle, puff adder, rhinoceros viper), including some that have been detected in the wild (eg boa constrictor, corn snake).

4. 'Sleeper' or other species with isolated populations in the wild in Australia (eg pond slider, ostrich).

5. Species well established in the wild in Australia (eg cane toad, European rabbit, red fox).

This chapter summarises the management implications of our results, and includes recommendations for dealing with species in different categories. It also includes proposals for analyses of other, possibly similar, species belonging to the five groups documented above. All recommendations listed should be considered during the current review of the *VPC Guidelines for the Import, Movement and Keeping of Exotic Vertebrates in Australia*.

4.1 Management of uncertainty

There is always uncertainty in risk assessments, and these uncertainties can be divided into three types:

1. Uncertainty of the process (methodology).

2. Uncertainty of the assessor(s) (human error).

3. Uncertainty about the organism (biological and environmental unknowns).

The goal in assessing risks is to reduce the levels of uncertainty as much as possible (Bomford 2008). We used a range of techniques to achieve this, resulting in high-quality assessments produced:

- in a consistent manner, using methodology based on robust scientific knowledge and statistical analyses of past introductions

- by highly experienced or appropriately qualified and trained female assessors, with review by another professional officer, all independent of any group that may wish to import exotic animals

- with data from thorough and comprehensive literature reviews.

The processes used to produce these risk assessments also appear to be consistent with those considered best by Simons and De Poorter (2009). That is, procedures that are:

- science based
- transparent
- comparable and repeatable
- based on reliable data
- conducted using the best information available
- designed explicitly to consider uncertainties.

4.1.1 Uncertainty of the process — risk assessment models used

In order to reduce the level of uncertainty of the risk assessment process, we used a risk assessment methodology based on robust scientific knowledge and statistical analyses of past introductions; that is, the risk assessment models produced by Bomford (2003, 2006, 2008) and Bomford et al (2005).

This study also produced further evidence for the validation of the Australian Bird and Mammal Model and the Australian Reptile and Amphibian Model across a range of families and threat levels. The models enabled us to assign:

- different risk ranks to species within families
- Serious or Extreme ranks to introduced species that have already established populations in Australia
- the Extreme rank to internationally recognised invasive species.

The two models used to assess the risks posed by birds and mammals were consistent in their assignment of species to ERRs, increasing the robustness of the results:

- the ERRs assigned by the models for any species were only ever one rank apart
- 86 per cent of species were assigned to the same highest ERR by the two models, with Model 1 (4 factors) assigning a lower ERR to three species.

Model 1's four factors are strongly linked to establishment risk in the analyses by Duncan et al (2001) and Forsyth et al (2004). Model 2 includes an additional three factors that many experts suggest are linked to establishment success, but for which there is not such strong quantitative evidence (Bomford 2003 and 2006). We found that Model 2 assigned the higher ERR to slightly more species than Model 1.

The three models used to assess the risks posed by reptiles and amphibians were consistent in their assignment of species to ERRs, increasing the robustness of the results:

- the ERRs assigned by the models for any species were only ever one rank apart
- nearly 60 per cent of species were assigned to the same highest ERR by all three models, and
- nearly 80 per cent of species were assigned to the same highest ERR by two or three of the models.

The three models did predict slightly different risk ranks, with the Reptile and Amphibian Model assigning the highest rank to nearly 90 per cent of the species. However, this model assigned three species to ERRs that were one rank lower than the other models, whereas the Bird and Reptile Model versions assigned five species to ERRs one rank lower.

The Reptile and Amphibian Model is based on exhaustive analyses of reptile and amphibian establishment data from overseas (Bomford et al 2005, 2009; Bomford 2006, 2008). The reliability of predictions made by this model has been considered uncertain for Australia because the cut-off thresholds were untested (Bomford et al 2005). However, this study indicates that the model produces results consistent with others based on Australian establishment data (for birds and mammals), although the results are generally more precautionary for most species. We also note suggestions from Henderson (2009) for validation exercises and international peer review of the Bomford models.

Although the use of some of the factors in our Australian Bird and Mammal Model B (7 factors) for assessing reptiles and amphibians has not been scientifically validated as being correlated with establishment success, Bomford (2008) indicates that such factors may be potentially important. We found that Model B assigned the highest ERR to slightly more species than Model A (3 factors).

4.1.2 Further validation of the models for Australia

Only 22 reptiles and amphibians have been assessed to date by us, compared with over 100 birds and mammals, and there is a general paucity of information available for reptiles and amphibians, as evidenced by our reference analyses and the various analyses performed by Bomford. So far only 20 per cent of the VPC's list of around 700 species has been assessed using the currently available models. Many reptiles, amphibians, birds and mammals that have not been assessed are either already in Australia or there is some likelihood of their arrival here.

Recommendation to further validate models

To further validate the models for assessing risks posed by reptiles and amphibians, more species should be assessed to produce more results across a range of families and threat levels.

4.1.3 Uncertainty of the process — assessment processes followed

In order to provide for repeatability of individual risk assessments and realistic comparisons between assessments, the same overall process, including thorough literature review, was followed in a

consistent manner for all assessments, and scores were moderated across assessments. However, this process took significant resourcing.

We obtained a high level of consistency between our results and those of Bomford (2006). Differences were mainly due to the more extensive literature reviews done by this study, which unearthed extra information including more precise distribution information and, under the guidance of Dr Bomford, careful interpretation of relevant questions in the risk assessment models.

4.1.4 Uncertainty of the assessors

One of Henderson's (2009) key recommendations was for 'a nationally agreed approach for a single risk assessment system, each species assessed once, by an accredited, independent assessor paid for by the (import) applicant.' Bomford (2008) indicated that 'uncertainty of the assessor(s) is best handled by having appropriately qualified people with an objective approach conducting the assessments'. Burgman et al (2009) suggested that the age and sex of assessors can affect results, and that young women are more likely to provide accurate assessments than other groups. They also indicated that scientists have 'motivational biases' that may affect their assessment judgements.

To reduce the level of uncertainty due to the risk assessors, we (1) ensured that a highly experienced, appropriately qualified assessor conducted the assessments and (2) oversaw a more junior, specifically selected, appropriately qualified and trained assessor. The assessments were then reviewed by a third experienced, qualified assessor. The three officers involved were female, within three age ranges, and so may have produced more accurate assessments than some other demographic groups. The assessors were employed by the Invasive Species Program of the Department of Agriculture and Food, Western Australia (DAFWA), which might have caused some motivational bias that in turn might have potentially affected the risk assessment results. However, the officers involved were independent of any group that may wish to apply to import introduced species. (Our experience in reviewing import applications is that important information relating to species invasiveness is often not included.)

Recommendation to reduce assessor uncertainty

Given the amount of time needed to gain experience in risk assessments and to train new staff, and the need to ensure the independence of assessments, we agree with Henderson's (2009) suggestions, echoed by Simons and De Poorter (2009), for:

- sharing of risk assessment information via a community of expertise
- processes to ensure assessments are independent.

4.1.5 Uncertainty about the organism

The level of uncertainty about the organism being assessed can be reduced by 'ensuring that a thorough and comprehensive literature review is undertaken for each species assessed' (Bomford et al 2005). Hence, we ensured this was done for all species in this study.

Bomford (2008) states that 'risk assessments contain literature search results that are a combination of scientifically defensible data and other information that may be anecdotal or experience based'. Our experience in reviewing biological information provided by those wishing to import animals is that

sometimes the information provided appears not to have been collected in a thorough and comprehensive manner. Hence, an important part of the junior assessor's on-the-job training for this study focussed on selection of appropriate literature.

Hayes and Sliwa (2003) state that 'one problem that can lead to bias is that literature reviews are often restricted to publications in English and global coverage is often neither complete nor uniform across continents'. Bomford et al (2005) also identified that 'knowledge about exotic species introductions and their impacts is uneven on a world scale'. We used reputable information collected in a consistent manner, but only used English-language references from available sources, so cannot claim to have fully addressed this kind of bias. The cost of having non-English references translated was prohibitive to their inclusion in risk assessments for this study.

Decisions about which reptile and amphibian species are safe to import because they are perceived to pose a low risk of harm will be subject to some uncertainty, because there is insufficient reliable knowledge to develop a quantitative method for assessing the risks of adverse impacts of new species in these classes (Bomford et al 2005). Our comparisons of the numbers of references used for each class support this statement. We used significantly more references for mammals overall and for overseas environment and agricultural impacts, than for reptiles, amphibians and the one bird.

The level of uncertainty about the organism can also be reduced by 'ensuring that the risk assessment is reviewed by scientists familiar with the species being assessed' (Bomford et al 2005). We addressed this form of bias by ensuring that each assessment was reviewed by a suitably qualified wildlife expert with either an ecological background or specific biological knowledge of the species being assessed. Finally, the VPC reviewed and endorsed the risk assessments and ERRs or VPC Threat Categories arising from this study.

Recommendations to reduce uncertainty in assessments

- We recommend continued use and improvement of the Bomford risk assessment models.
- Although pre-import screening of exotic vertebrates is recognised as a primary and cost-effective tool to prevent the potential harm caused by exotic vertebrates (NRMMC 2007), we warn that risk assessments, for which the three types of uncertainty (process, assessors, organism) have been reduced to a minimum, require significant resourcing.
- In order to rationalise resourcing requirements across the country, we agree with Henderson's (2009) key recommendation for 'a nationally agreed approach for a single risk assessment system, each species assessed once, by an accredited, independent assessor.'
- The need for adequate resourcing to ensure that risk assessments have low levels of uncertainty should be considered during the current review of the VPC Guidelines and included in any future edition.
- Qualitative issues, which may be raised by reviewers or assessors in conducting assessments, are not able to be incorporated into the quantitative risk assessment models at present, but should be considered when devising risk management strategies.

For the domestic sheep assessment, the comments of one reviewer were considered significant enough to add to the actual assessment and be recirculated to the VPC. The qualitative issues raised by the reviewer, including the ability of damara and dorper sheep to shed fleece, to generalise their diet and to escape fences, and general sheep behaviour in relation to wild dogs, are not able to be incorporated into the quantitative risk assessment model at present. However, these issues should be taken into account if risk management strategies are considered for sheep.

4.1.6 Comparisons between predicted and actual results

When first selecting species for this study, we underestimated the ERRs for two reptiles (flowerpot snake and ornate box turtle) and two amphibians (western tiger salamander and Romer's tree frog) and underestimated the VPC Threat Categories for three mammals (Malayan sun bear, Eurasian lynx and fishing cat). This was because we did not fully consider public safety risks, we lacked knowledge of exotic populations overseas, and our perception was that some of these species did not cause adverse impacts. These underestimates occurred even though we are probably more conservative in our risk assessment judgements than many members of the public.

In contrast, we overestimated the ERRs for one reptile (corn snake) and one amphibian (smooth newt) and we overestimated the VPC Threat Category for the meerkat. The reptile and amphibian overestimations were probably due to our knowledge of seizures of these species from illegal keepers in Australia, their presence in overseas trade and a perception of their pest risks. The meerkat overestimation was probably due to our knowledge of the proliferation of this species in non-statutory facilities around Australia.

We believe these under- and overestimations further underline the importance of collecting relevant information and conducting as objective an assessment as possible before making decisions about the management of species. Our approach also indicated the need for further development and VPC endorsement of reptile and amphibian assessments incorporating public safety and possibly pest risks.

4.1.7 Developing methods to assign DAFWA and Alternative Threat Categories to reptiles and amphibians

For this study we developed a method to assign DAFWA Threat Categories to reptiles and amphibians based on the format of the original Australian Bird and Mammal Model and the existing VPC Guidelines; that is, by combining ERRs with Public Safety Risk Ranks, then using the conventions in the VPC Guidelines for assignment of threat categories where possible, and the precautionary approach otherwise. This process enabled recognition of the public safety risks posed by some species, and use of the precautionary approach, backed up by a demonstrated lack of information available (low numbers of references, documented in the assessments) upon which to assign species.

We also developed a rudimentary method to quantitatively consider adverse impact factors and predicted effects on Australian species and primary production, and to combine this information with ERRs and public safety risks to produce Alternative Threat Categories. This increased our understanding of the potential adverse impacts these reptile and amphibian species may have if they became established in Australia.

Recommendations for reptile and amphibian assessments

- In the short term, there is a need to seek VPC endorsement (or further development and endorsement) of the method developed by this study to assign Threat Categories to reptiles and amphibians, or an alternative method.
- In the longer term, there is a need to further develop a method that considers adverse impact factors and predicted effects of exotic reptiles and amphibians on Australian species and primary production, as part of risk assessment for reptiles and amphibians.

4.1.8 Management of mammals assigned to the Moderate VPC Threat Category

Four mammal species were assigned to the Moderate VPC Threat Category: grey dorcopsis, siamang, golden lion tamarin and meerkat.

The VPC Guidelines recommend that species in this category should be restricted to collections approved and registered by the relevant state or territory authority for the keeping of Moderate threat species. The guidelines also indicate that states and territories may continue to impose any additional restrictions on acquisition and keeping of Moderate threat species. However, assignment to this category is generally taken to mean that private keeping of the species is permissible.

Three of these species, the golden lion tamarin, the siamang and the grey dorposis, are listed as endangered by the International Union for Conservation of Nature (IUCN 2009). The tamarin and siamang are also listed in Appendix 1 of the Convention on International Trade in Endangered Species (CITES 2009). Breeding programs for such species would be unlikely to sanction their holding in what would probably be low-security facilities.

In addition, we used less than the median number of references for these species. Hence, the level of uncertainty for these assessments could be considered to be high, providing an argument for use of the precautionary approach and assignment of these species to a higher rank.

Recommendation for Low/Moderate category mammals

- Management of mammals that have been assigned to the Low or Moderate VPC Threat Category need to be further considered by the VPC, including their conservation status and the degree of assessment uncertainty.

4.2 Assessment, prioritisation and management of assessed species

We assigned 40 species that are either already in Australia, or that could potentially enter the country, to VPC Threat Categories, ERRs, novel DAFWA and Alternative Threat Categories developed by this study. We also combined VPC Threat Categories or Alternative Threat Categories with information relating to potential invasion pathways and other Australian-specific data. All these results allowed for the prioritisation of species and evaluation of priority species against relevant goals, objectives and actions from the *Australian Pest Animal Strategy* (APAS, NRMSC 2007) (Table 4.1). The following sections document how priority species could be managed in light of the goals, objectives and actions of the APAS.

Table 4.1 Evaluation of assessed high-priority species against the *Australian Pest Animal Strategy* (APAS, NRMMC 2007)

APAS Goals	1 Provide leadership for the management of pest animals	2 Prevent establishment of new pest animals			2 Prevent establishment of new pest animals 3 Manage the impacts of established pest animals	2 Prevent establishment of new pest animals			
APAS Objectives	1.3 To improve public awareness of pest animals, research coordination and its support for pest management at the national level, and adoption of best practice management methods.	2.1 To prevent the introduction of new animals with pest potential.			2.2 To ensure early detection of, and rapid response to, new incursions of exotic animals. 3.1 To identify established pest animals of national significance.	2.2 To ensure early detection of, and rapid response to, new incursions of exotic animals.	2.3 To reduce the spread of pest animals to new areas within Australia.		
APAS Actions	1.3.1 Raise awareness of pest animal impacts among landholders and the general community and their support for pest management through a communication plan to increase engagement in reducing pest animal threats.	2.1.1 Work with Australia's trading partners, countries of origin of human visitors and near neighbours to minimise the risk of introducing pest animals into Australia.	2.1.2 Maintain approaches for assessing the pest animal risk of all new animal imports.	2.1.3 Minimise the risk of escapes of legally held captive or pet exotic species.	2.2.1 Develop and maintain nationally agreed lists of high-risk animal species for surveillance and national response: NSL or NAL. 3.1.1 Identify established pest animals of national significance as subjects of nationally coordinated action: EPANS List	2.2.5 Guided by feasibility and cost–benefit assessments, conduct eradication programs for new incursions.	2.3.1 Reduce the risk posed by legally held species through containment and contingencies in case of release or escape.	2.3.2 Through education and enforcement, control the natural spread or translocation of pest animals.	2.3.3 Assess the threat of 'sleeper' or other isolated populations, and eradicate or contain these according to assessments of feasibility, costs and benefits
Asiatic painted frog, black-spined toad, Eurasian lynx, stoat, Western tiger salamander	✓	✓	*do not add to list**	✓	*consider addition to the NSL*	✓			
Romer's tree frog	✓	✓	*consider removal from list**	✓	*consider addition to the NSL*	✓	*NA*		

African bullfrog, African clawed frog, beauty snake, boa constrictor, brown bear, emerald tree boa, fishing cat, Malayan sun bear, meerkat, Oriental small-clawed otter, rhinoceros viper,	✓	✓	*consider removal from list**	✓	*consider addition to the NSL*	✓	✓	✓	
corn snake, ornate box turtle, puff adder, spiny turtle	✓	✓	*do not add to list**	✓	*consider addition to the NSL*	✓	✓	✓	
sheep, fallow deer, flowerpot snake, ostrich, pond slider, red deer	✓	✓	*consider removal from list**	✓	*consider addition to the NAL*	✓	✓*(particularly islands)*	✓*(particularly islands)*	✓
chital deer	✓	✓	*do not add to list**	✓	*consider addition to the NAL*	✓	✓*(particularly islands)*	✓*(particularly islands)*	✓
European hare, European rabbit	✓	✓	*consider removal from list**		*consider addition to the EPANS List and NAL*		✓*(particularly islands)*	✓*(particularly islands)*	
cane toad, red fox	✓	✓	*do not add to list**		*consider addition to the EPANS List and NAL.*		✓*(particularly islands)*	✓*(particularly islands)*	

* DEWHA Live Import List; EPANS List = List of Established Species of National Significance; NAL = National Alert List; NSL = National Surveillance List.

4.3 Providing leadership and coordination for the management of pest animals

4.3.1 Research to address a lack of ecological knowledge

In order for desktop research like our study to continue, there is a need for research programs to 'especially address the lack of ecological knowledge for some species' (APAS Objective 1.3 and Action 1.3.2).

Our reference analysis results agree with those of Bomford (2008) and Bomford et al (2005) that there is insufficient information on the adverse impacts of new reptile and amphibian species. Further research should focus on the nine attributes/factors identified by Bomford associated with increased risks of adverse impacts of reptiles and amphibians.

Recommendations for research

- Further research is required on the nine factors identified by Bomford associated with increased risks of adverse impacts of reptiles and amphibians, in order to improve studies like this one.
- A review of species for which such information is lacking would also assist in focussing research efforts.

4.3.2 Improving public awareness of pest animals

For many of the animals we assessed, raising awareness among a variety of stakeholders is vital for effective management in Australia (APAS Objective 1.3 and Action 1.3.1). One of Henderson's (2009) key recommendations was a review of existing education packages and a rollout of revised packages in a communication campaign as a component of the APAS. Significant messages flowing from our study that could be included in such a campaign include:

- which species are most likely to be detected arriving in Australia and why — for example, see House Crow National Pest Alert brochure (Kirkpatrick and Massam 2008d), Black-spined Toad Fact Sheet (AQIS 2008c), stoat in Prohibited Pets Fact Sheet (Biosecurity Queensland 2007b)

- what to do to prevent escapes and releases of captive animals and why — for example, Standards/conditions document for keeping fallow and red deer species in Western Australia (Department of Agriculture and Food 2007), Requirements for fencing farmed deer in South Australia: Deer Advisory Note (Department of Water Land and Biodiversity Conservation 2006)

- which species are most likely to be detected in the wild in Australia and why — for example, see Ferret (Kirkpatrick et al 2008) and Indian Ringneck National Pest Alerts (Kirkpatrick and Massam 2007), Corn Snake Warning (Biosecurity Queensland 2007a), prohibited pets (Department of Sustainability and Environment 2006, Biosecurity Queensland 2007b)

- which species are most likely to spread further in Australia and why — for example, see information on common myna (Tracey et al 2007, Kirkpatrick and Massam 2008b), red-eared slider (Biosecurity Queensland 2007c, Kirkpatrick et al 2009), and deer (Temby 2003, Department of Water Land and Biodiversity Conservation 2007)

- best practice management of widespread species (many publications from many jurisdictions are available)
- where to report animals found at large — for example, Pest and Disease Information Service, DAFWA (http://www.agric.wa.gov.au).

Recommendations for awareness raising

- Copies of this report should be made available to appropriate agencies to assist in prioritising awareness-raising actions.
- A national review should be conducted to determine all species for which awareness-raising materials should be produced and/or made widely available in any communication plan.
- From this study, species for which awareness raising is thought to be totally lacking and should be considered are, in order of priority:
    1. For mammals and birds: fishing cat, European hare, domestic sheep, oriental small-clawed otter, brown bear, Malayan sun bear, Eurasian lynx and meerkat.
    2. For reptiles and amphibians: Asiatic painted frog, rhinoceros viper, African bullfrog and clawed frog, flowerpot snake, puff adder, emerald tree boa, ornate box turtle, Romer's tree frog, beauty snake, spiny turtle and western tiger salamander.

4.4 Preventing the introduction of new animals with pest potential

Preventing the introduction of new animals with pest potential (APAS Objective 2.1) is the primary and most cost-effective way to manage invasive species (NRMMC 2007). Prevention includes pre-border, border and post-border actions designed to minimise the risks posed by invasion pathways, legal imports and introduction effort.

Strengthening the ability of our trading partners, the countries of origin of human visitors, and our near neighbours to manage invasive species and so prevent their entry to Australia is clearly important for the management of such species (APAS Action 2.1.1). It appears this is being done for black-spined toads in some countries, with a report of AQIS import clearance officers visiting the Freeport Mine in West Papua (AQIS 2006).

The black-spined toad and Asiatic painted frog have so far not established populations in Australia but we consider them high risk for establishment in the future. The Asiatic painted frog has been detected in Australia and in New Zealand at least once (Tyler and Chapman 2005), and the black-spined toad has been detected in at least the following Australian locations: Cairns (Dodd 2002, Anonymous 2006, AQIS 2008a), Sydney (AQIS 2008a), Brisbane and Perth (Tyler and Chapman 2005, Anonymous 2006, AQIS 2008a). A toad barrier has been installed around the unloading dock at Cairns Port to prevent escape of these and other introduced amphibians in the event of an unwanted incursion (AQIS 2006). In 2009, a live toad was found in New Plymouth, New Zealand, in a container used to import

chemicals from Melbourne, but the pathway for the toad's presence in the container has not yet been determined (J. Burley, Victorian Govt, pers comm).

Given their prioritisation (Figure 3.1 and 3.2) we also consider that management actions should be considered to prevent the Eurasian lynx, Romer's tree frog and wester tiger salamander from becoming established in the wild in Australia. Romer's tree frog was assigned to a high ranking based largely on the basis of it having exotic populations, even though these are due to translocation by humans because of the development of a new airport. However, management is still required to prevent this species being widely held and finding its way into the wild.

4.4.1 Update of Bomford (2006) assessments

Bomford (2006) assessed many reptiles, amphibians, birds and mammals with introduced populations in Australia, but the mammals and birds were only assigned to ERRs (indicating risk of establishment), whereas the species we assessed were further assigned VPC Threat Categories (incorporating pest potential). In general, we also assigned species to slightly more conservative categories than Bomford, due to the more extensive literature reviews of this study and slightly different interpretation of some questions in the risk assessment models.

Recommendations for new assessments

- In order to assist border actions overseen by AQIS, other species that have entered or could enter the country should be listed, reviewed and subjected to risk assessment and prioritisation (consideration of invasion pathways and other relevant information) as part of an early-warning system against establishment of new species. This could be achieved by developing Bayesian Belief Networks (Heckerman 1996), incorporating a range of data and expert opinion, to objectively produce establishment likelihood predictions. [See Runde et al (2007) for a somewhat similar idea.]

- Species that have been detected entering Australia should be reviewed. These include:
  - crested myna (*Acridotheres cristatellus*) (AQIS 2008a)
  - fire-bellied toads (*Bombina* spp) (DEWHA 2009a)
  - plantain squirrel (*Callosciurus notatus*) (AQIS 2009)
  - spotted house gecko (*Gekko monarchus*) (AQIS 2008b).

- Mammal species recognised internationally as invasive by their presence on the IUCN List of 100 of the World's Worst Invasive Alien Species (Lowe et al 2000), but that are not present in Australia should be reviewed. These include:
    - grey squirrel (*Sciurus carolinensis*)* — previous grey squirrel feral populations have occurred in Victoria (Long 2003) and South Australia (Peacock 2009).
    - Indian mongoose (*Herpestes javanicus*)* — there were several attempts to introduce Indian mongoose to Australia in the 1880s, but these were unsuccessful [(Palmer 1898) cited in Long (2003)].
    - nutria (*Myocastor coypus*) — there have been no known attempts to introduce nutria to Australia.
    - weasel (*Mustela nivalis*)* — the weasel was unsuccessfully introduced to Australia in 1885 (Hinton and Dunn 1967).
- Reptile and amphibian species considered most successful in terms of establishment by Bomford et al (2009) should be reviewed. These include:
    - common Puerto Rican anole (*Anolis cristatellus*)
    - eastern garden lizard (*Calotes versicolor*)
    - house gecko (*Hemidactylus mabouia*)
    - mangrove monitor (*Varanus indicus*)
    - marsh frog (*Rana ridibunda*)
    - Mediterranean house gecko (*Hemidactylus turcicus*)
    - moth skink (*Lipinia noctua*)
    - mudpuppy (*Necturus maculosus*)
    - ocellated gecko (*Sphaerodactylus argus*)
    - Perez's frog *(Pelophylax perezi) (*formally *Rana perezi)*
    - Rio Grande leopard frog (*Rana berlandieri*)
    - yellow-belly gecko (*Hemidactylus flaviviridis*)
    - Zanzibar day gecko (*Phelsuma dubia*).

- Reptile and amphibian species recognised internationally as invasive by their presence on the IUCN List (Lowe et al 2000) should be reviewed. These include:
    - bullfrog *(Rana catesbeiana*)
    - Caribbean tree frog *(Eleutherodactylus coqui*).
- Bird species recognised internationally as invasive by their presence on the IUCN List (Lowe et al 2000) that should be reviewed include:
    - red-vented bulbul *(Pycnonotus cafer*)*.

*Bomford (2006) assignment of ERRs needs updating to include VPC Threat Categories.

4.4.2 Maintaining approaches for assessing the risk of all new animal imports

Border actions aimed at preventing the introduction of new animals with pest potential (APAS Objective 2.1) are designed in part to minimise the risks posed by legal imports. Maintaining approaches for assessing animal pest risks has been greatly enhanced by a national risk assessment workshop (Henderson 2009). One of the workshop's key recommendations was for 'a nationally agreed approach for a single risk assessment system'. An associated issue discussed was the status of the VPC Guidelines, which covers policies for importation and keeping.

The research undertaken for this study, which has provided further evidence for the validation of the Australian Bird and Mammal Model and the Australian Reptile and Amphibian Model across a range of families and threat levels, will also assist in maintaining and developing risk assessment approaches.

4.4.3 Review of species on the DEWHA live import list

Given that risk assessment techniques are still evolving but that there is a need to minimise risks posed by legal imports, there is a need to review the DEWHA Live Import List (DEWHA 2009b).

We assessed 15 species that are in Australia already, are on the DEWHA Live Import List and which were assigned to an Extreme ERR, VPC Threat Category or Alternative Threat Category (see Appendix A for species list). Of these, five are internationally recognised as invasive species; African clawed frog, domestic sheep, European rabbit, red deer and pond slider. The VPC Guidelines (NRMSC 2004) recommend that species in the Extreme category should not be allowed to enter, or be kept in any state or territory.

Of the 15 species, the fallow and red deer and European rabbit require import permits but there are no listed conditions, while the domestic sheep does not require an import permit. The VPC Threat Categories assigned to these species, along with the qualitative comments made by the external reviewer about characteristics of the dorper and damara sheep breeds that may assist their survival in the wild, point to the need for consideration of import permits and conditions for sheep breeds and perhaps other species.

The import permit conditions for the other 11 species (see Appendix A for species list) allow for import for non-commercial purposes only, excluding household pets, and sometimes other requirements.

There are nine species, some of which are in Australia, that do not appear on the DEWHA Live Import List, which we assigned to an Extreme ERR, VPC Threat Category or Alternative Threat Category (see Appendix A for species list).

Recommendations for the live import process

- Consideration should be given to using the processes outlined in this report to assess species proposed for legal import into Australia, and the results should be considered carefully, in light of potential sources of uncertainty.
- Of the species assessed for this study that were assigned to the Extreme ERR, VPC Threat Category or Alternative Threat Category, those not on the DEWHA Live Import List should not be added to it (Asiatic painted frog, black-spined toad, cane toad, chital deer, Eurasian lynx, puff adder, red fox, stoat, and western tiger salamander) and consideration should be given to the removal of species that are on the list (African bullfrog and clawed frog, boa constrictor, brown bear, domestic sheep, European hare, European rabbit, fallow deer, fishing cat, flowerpot snake, Malayan sun bear, pond slider, red deer, rhinoceros viper and Romer's tree frog).
- A review should be conducted of high-risk species on the Live Import List for which there are no listed conditions, or for which import permits are not required. Consideration should be given to upgrading risk management requirements and appropriate import conditions should be developed.
- In order to assist post-border actions overseen by the Australian government and relevant state and territory authorities, all other species on the Live Import List should be reviewed, high-risk species should be identified and consideration should be given to their removal [see recent decision to remove sika deer, *Cervus nippon,* from the DEWHA Live Import List (Garrett 2010)].

4.4.4 Minimising the risk of escapes of captive exotic species

Post-border actions aimed at preventing the introduction of new animals with pest potential (APAS Objective 2.1) are designed in part to minimise the risks associated with introduction effort. The scientific data indicate that introduction effort or propagule pressure, defined as the number of released individuals and/or number of release events, is considered one of the significant factors affecting the likelihood of successful establishment of new terrestrial and aquatic vertebrate species in the wild (Bomford 2008).

Minimising the risk of escapes of legally (and illegally) held captive or pet exotic species (APAS Action 2.1.3), particularly those assessed as posing a significant risk, was also an issue identified by Henderson (2009).

In addition to improving public awareness (covered above), legislation and other measures are needed to decrease the risks of escapes. The management of these species should also be in line with the VPC Guidelines (NRMSC 2004), which provide a guide for the minimum level of security measures appropriate to species in each VPC Threat Category.

So far only 20 per cent of the near-700 species on the VPC's *List of Exotic Vertebrate Animals in Australia* (VPC list, VPC 2007) has been subject to the current risk assessment models. In order to better focus the management efforts of agencies, further species on the VPC List, particularly those being held legally or illegally in low-security facilities and/or those that have been surrendered or reported in the wild, need to be assessed using the currently available models. These species should also be subject to prioritisation; that is, consideration of invasion pathways and other relevant information. Using the streamlined processes we developed, assessment of animals on the VPC List could be done more quickly in future.

Of the captive mammals we assessed and prioritised that are not yet established in the wild in Australia, the fishing cat and Oriental small-clawed otter were assigned the highest priorities, with the brown bear and Malayan sun bear also rating highly (see Figure 3.1). The otter is already widely kept in non-statutory zoo collections (some accredited by the Zoo and Aquarium Association) in Australia and there are plans to increase the number of holdings of the fishing cat (currently in two non-statutory, accredited facilities) (ARAZPA 2009). Also, at least one animal previously in high-security facilities was acquired through seizure (VPC 2007). Information regarding the international development of a fishing cat X domestic cat hybrid as a pet is also of concern (DEWHA 2008).

Of the reptiles and amphibians species we assessed and prioritised that are not yet established in the wild in Australia, the African clawed frog, boa constrictor, corn snake, emerald tree boa, puff adder, Romer's tree frog and viper species (possibly including the rhinoceros viper) have been surrendered to agencies and/or reported in the wild. While, our risk assessment and prioritisation resulted in the boa constrictor being assigned the highest priority (see Figure 3.2), these other species also rated highly, as did the African bull frog.

Boa constrictors are very prolific breeders and give birth to numerous live young. Litters can be of several dozen young, with up to 63 individuals (Mole 1924), as cited by Dr Robert Reed (USGS Fort Collins Science Center, CO, 2008, pers comm), and possibly even up to 80 individuals. This means that one successful breeding event can result in the production and potential proliferation of many new animals into illegal keeping and perhaps into the wild.

4.4.5 Coming to grips with introduction effort

The Bomford risk assessment models do not include introduction effort factors, but we have tried to develop an approximation for this by collecting some of the available information for Australia (species reported in the wild, presence of species in low-security facilities, seizures, etc). There is other information that could be incorporated; for example, the likelihood that animals will escape or be released based on their monetary value.

If all this information and risk assessment results were wrapped into a Bayesian Belief Network, it may be possible to prioritise species on the brink of establishing introduced populations in Australia.

Recommendations to reduce escapes of captive/pet species

- In order to assist post-border actions overseen by the Australian government and relevant state and territory authorities, a national review should be conducted to determine which species are at risk of establishing introduced populations. Relevant information for these species and risk assessment data should then be analysed, perhaps using Bayesian networks to prioritise species on the brink of establishing introduced populations. Relevant actions as per the APAS should then be taken.

- Further species on the VPC List, particularly those being held legally or illegally in low-security facilities and/or that have been surrendered or reported in the wild, need to be assessed using the currently available models and the streamlined processes we developed. These species should then be prioritised for management.

- Awareness-raising materials are thought to be totally lacking and should be considered to highlight the risks posed by species not yet established in the wild in Australia including, in order of priority; the fishing cat, rhinoceros viper, Oriental small-clawed otter, brown bear, Malayan sun bear, African bull frog and clawed frog, puff adder and emerald tree boa.

- The captive management of these and the other species mentioned in this section should also be in line with the VPC Guidelines (NRMSC 2004).

- Some of the reptile and amphibian species that have been surrendered or seized and/or reported in the wild should be subject to risk assessment and prioritisation. These include:

    - *Cobra* species
    - green iguana (*Iguana iguana*)
    - Japanese fire-bellied newt (*Cynops pyrrhogaster*)
    - kingsnake species (*Lampropeltis* spp.)
    - rainbow boa (*Epicrates cenchria*).

- Some of the mammal species that have been surrendered or seized and/or reported in the wild and should be subject to risk assessment and prioritisation include:

    - blackbuck (Antilope cervicapra)*
    - bonnet macaque (*Macaca radiata*)
    - crab-eating macaque (*Macaca fascicularis*).

  *Bomford (2006) assignment of ERRs need updating to include VPC Threat Categories.

4.4.6 Reducing the spread of pest animals to new areas within Australia

Post-border actions aimed at reducing the spread of pest animals to new areas within Australia (APAS Objective 2.3) are designed in part to manage the risk posed by legally held species to minimise introduction effort. The captive management (containment and contingencies in case of release or escape; APAS Action 2.3.1) of these species should be in line with the VPC Guidelines (NRMSC 2004). 'Sleeper' species or other isolated populations should be assessed, and eradicated or contained according to assessments of feasibility, costs and benefits (APAS Action 2.3.3). In addition, attempts should continue to control the natural spread or translocation of pest animals through education (APAS Action 2.3.2).

4.4.7 Assessment and management of 'sleeper' or other isolated populations

The pond slider (subspecies known as the red-eared slider) was the only 'sleeper' species we assessed. This species has been surrendered to agencies or seized, and is appearing in the wild in new areas (see Appendix A). Feral populations of the pond slider have been found in urban and semi-rural areas in Queensland, the Australian Capital Territory and New South Wales. Single animals have been found in the wild in Victoria and Western Australia (Kirkpatrick et al 2009). Along with the boa constrictor, the slider was considered the highest priority of any reptile or amphibian assessed (see Figure 3.2). It poses an extreme threat and there are many and varied invasion pathways and other relevant factors that contribute to its high priority for management.

The flowerpot snake is restricted to northern areas of Australia including Darwin and Katherine, Northern Territory, and scattered settlements in Queensland (Lever 2006), and at least four settled locations in the Kimberley and Pilbara regions of Western Australia (Maryan 2001). However, there is potential for this species to be spread to further parts of the country in 'garden plant soil and watercraft soil ballast' (Ehmann 1992, cited in Lever 2006) and perhaps via other pathways. Further overseas importations are also possible, given the report of a specimen in Adelaide near an imported container (AQIS 2007). The flowerpot snake was considered a high priority (see Figure 3.2); it poses an extreme threat and should also be considered for management.

4.4.8 Control of the natural spread or translocation of pest animals

Of the species we assessed with large established populations in the wild, cane toads, chital deer, domestic sheep, European hare and rabbit, fallow deer, red deer and red foxes are being legally and illegally held in low-security facilities, have been surrendered to agencies or seized and are being reported in the wild in new locations around Australia. Risk assessment and prioritisation resulted in the cane toad; chital, fallow and red deer; European hare and rabbit being assigned the highest priorities (see Figure 3.1 and 3.2). However, the red fox also rated highly. This information points to a need to better control the natural spread or translocation of these pest animals.

4.4.9 Livestock species

Our results indicate that for assessed livestock species (chital, fallow and red deer, domestic sheep, ostrich), reconsideration of risk management strategies (including the feasibility of removing feral animals at large) is required to prevent release, escape and translocation, and to raise awareness of the risks posed by these animals.

Six deer species present in Australia have now been assigned to the Extreme VPC Threat Category: these include four species in this study, and rusa (*C. timorensis*, Massam et al in prep) and sika deer

(*C. nippon*, Braysher Consulting 2006, Takatsuki 2009 — the sika deer assessment has not yet been endorsed by the VPC). The increased emphasis placed on the distribution and management of captive and feral deer in Australia (Hamilton 1982, Moriarty 2004, Shephard 2002, Jesser 2005) is clearly supported by these assessment results.

Not all jurisdictions currently acknowledge the extreme threat posed by deer. The New South Wales parliament is currently considering a private members bill to amend the *Game and Feral Animal Control Act 2002*. The new Act would allow for the provision for game reserves to be established in New South Wales, where invasive game animals could be 'housed' and birds could be 'released' for private hunting. This would in effect allow the release of introduced species into the wild for game purposes (IA CRC 2009). This bill is at odds with two objectives of the APAS: prevention of the introduction of new animals with pest potential (Objective 2.1) and reduction of the spread of pest animals to new areas within Australia (Objective 2.3). The VPC Guidelines also state that 'release of all exotic species from effective human control should continue to be prohibited' (NRMSC 2004).

There has also been a report of the sale of blackbuck (*Antilope cervicapra*) by Dubbo Zoo to a member of the Shooters' Party who proposes to charge hunters for the right to shoot them on a private game reserve (Jensen 2009). This species is assigned to the Serious VPC Threat Category (VPC 2007), and has previously established introduced populations in Australia (Long 2003). This transaction is also at odds with the APAS.

Management of sheep should also be reconsidered in light of our assignment of the species to the Extreme VPC Threat Category. Comments made by the external reviewer about characteristics of dorper and damara sheep breeds that may assist their survival in the wild over that of the merino, suggest that management focus should probably be on these two breeds.

We also assigned the ostrich to the Serious VPC Threat Category and consider that it could establish further introduced populations in Australia.

We have previously assigned seven other livestock species to the Extreme Threat Category: alpaca (*Lama pacos*), American bison (*Bison bison*), banteng (*Bos javanicus*), feral camel (*Camelus dromedarius*), feral goat (*Capra hircus*), feral pig (*Sus scrofa*), guanaco (*L. guanicoe*) and llama (*L. glama*) (Massam et al in prep). It would appear that for the *Lama* species, although they were assigned to the Extreme category, qualitative factors not dealt with by the risk assessment model have so far prevented the establishment of introduced populations. However, for some of the other species, reconsideration of risk management strategies is warranted, given the likelihood of their establishment of introduced populations.

Recommendations for reducing the spread of pest animals to new areas

- A national review should be conducted to determine species at risk of establishing further introduced populations, in order to assist post-border actions overseen by the Australian government and relevant state and territory authorities. Relevant information for these species and risk assessment data should then be analysed, perhaps using a Bayesian network to prioritise species on the cusp of establishing introduced populations. Relevant actions as per the APAS should then be taken.

- Awareness-raising materials concerning the risks posed by the domestic sheep and European hare should be produced and made widely available. Emphasis should be placed on the potential adverse impacts of releasing individuals of these species into the wild in new locations.

- The captive management of these and the other species mentioned in this section should be in line with the VPC Guidelines (NRMSC 2004).

- The pond (or red-eared) slider was assigned the highest priority of any reptile or amphibian assessed. It should be a high priority for management to prevent further populations becoming established in the wild across the country and to eradicate existing populations.

- The flowerpot snake was also assigned a high priority and should be considered for management.

- The status of the ostrich in the wild should be further investigated and consideration given to removal of any remaining animals at large.

- The feasibility and cost effectiveness of the removal of animals like the cane toad, chital, fallow and red deer, domestic sheep, European hare and rabbit and red foxes from key (mainly environmental) assets should also be assessed.

- Risk assessment and prioritisation should be conducted for reptile species that have established isolated populations, including:

    - Asian house gecko (*Hemidactylus frenatus*)*, Christmas Island grass-skink (*Lygosoma bowringii*), mourning gecko (*Lepidodactylus lugubris*) * and wolf snake (*Lycodon capucinus*).

- Risk assessment and prioritisation should be conducted for mammal species that have established introduced populations that could spread further, including:

    - feral buffalo (*Bubalus bubalis*)*, hog deer (*Axis porcinus*)*, northern palm squirrel (*Funambulus pennantii*)*, Pacific rat (*Rattus exulans*) and sambar deer (*Cervus unicolor*)*.

*Bomford (2006) assignment of ERRs needs updating to include VPC Threat Categories.

- Risk assessment and prioritisation should be conducted for bird species that have established introduced populations that could spread further, including:

    - California quail (*Callipepla californica*), collared dove (*Streptopelia roseogrisea*), common blackbird (*Turdus* merula)*, common pheasant (*Phasianus colchicus*)*, common redpoll (*Acanthis flammea*), common greenfinch (*Chloris chloris*)*, Eurasian skylark (*Alauda arvensis*)*, European goldfinch (*Carduelis carduelis*)*, green junglefowl (*Gallus varius*), helmeted guineafowl (*Numida meleagris*)*, house sparrow (*Passer domesticus*)*, Indian peafowl (*Pavo cristatus*)*, Java sparrow (*Lonchura* oryzivora)*, laughing dove (*S. senegalensis*)*, nutmeg mannikin (*Lonchura punctulata*)*, red junglefowl (*G. gallus*)*, song thrush (*Turdus philomelos*)*, spotted dove (*S. chinensis*)*, tree sparrow (*P. montanus*)*, wild turkey (*Meleagris gallopavo*) and yellowhammer (*Emberiza citrinella*)*.

*Bomford (2006) assignment of ERRs needs updating to include VPC Threat Categories.

4.4.10 Additions to nationally agreed lists of high-risk species

To ensure early detection of, and rapid response to, new incursions of exotic animals (APAS Objective 2.2), several of the species we assessed should be considered for addition to one of the proposed lists of high-risk animal species for surveillance and national response (APAS Action 2.2.1). These lists are:

- A National Surveillance List of species, to be identified through pathway analysis of species at risk of arriving in Australia and assessment of the risk posed by their potential establishment in the wild. Species on this list will be a focus for national surveillance activities and presumably immediate eradication if feasible (APAS Action 2.2.5).

- A National Alert List, to cover species already established in Australia with the potential for further spread. These species will be the subject to assessment for eradication or containment (APAS Action 2.2.5).

Recommendations for National Surveillance and Alert Lists

- The following species should be considered for addition to a National Surveillance List: African bullfrog and clawed frog, Asiatic painted frog, beauty snake, black-spined toad, boa constrictor, brown bear, corn snake, emerald tree boa, Eurasian lynx, fishing cat, Malayan sun bear, meerkat, oriental small-clawed otter, ornate box turtle, puff adder, rhinoceros viper, Romer's tree frog, spiny turtle, stoat and western tiger salamander.

- The following species should be considered for addition to a National Alert List: chital deer, domestic sheep, fallow deer, flowerpot snake, ostrich, pond slider and red deer. Braysher (2000) suggested the addition of the fallow deer, European hare, European rabbit, pond slider, red deer and red fox.

4.5 Managing the impacts of established pest animals

4.5.1 Established pest animals of national significance

To manage the impacts of established pest animals (APAS Goal 3), it is proposed that those species of national significance will be identified as subjects for nationally coordinated action on a List of Established Species of National Significance (APAS Action 3.1.1).

> **Recommendations for List of Established Pest Animals of National Significance**
>
> - The following species should be considered for addition to a List of Established Species of National Significance: cane toad, European hare and rabbit and red fox.
> - Consideration needs to be given to the overlap between the three proposed national lists, because all of the species listed in the dot point above could also be candidates for the Alert List in some parts of Australia.

4.6 General conclusions

In this study we developed and used many techniques to reduce the three types of uncertainty (process, assessors, and organism) in risk assessments. This methodology resulted in the production of high-quality assessments of 40 species using the Bomford 2008 models and has further validated the current Australian Bird and Mammal Model and the Australian Reptile and Amphibian Model.

We developed streamlined methods to more efficiently assign VPC Threat Categories and ERRs. We also developed new methods that require further improvement and/or VPC endorsement.

The species we assessed were prioritised for awareness-raising, prevention, detection, eradication and spread reduction actions under the APAS, including suggested addition to one of the three proposed national lists. However, reviews are required to identify other species requiring management to minimise the risks of new incursions of invasive species and the spread of species already established in the wild in Australia.

There is a need for research to address the lack of ecological knowledge for some invasive species in order for desktop research like our study to continue. Such research would also assist in the development of a quantitative method for assessing the pest risk of reptiles and amphibians. Further investigation of the use of Bayesian networks to assess introduction effort could also assist in the prioritisation of species for management.

Risk assessments, for which the three types of uncertainty have been reduced to a minimum, require significant resourcing. Implementation of ‘a nationally agreed approach for a single risk assessment system, each species assessed once, by an accredited, independent assessor’ (Henderson 2009) will significantly improve the efficiency and cost effectiveness of current processes. We hope that the methodology and results from this study will add to the development of such a system, endorsed by all relevant groups.

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Appendix A. Criteria used to select species for this study

Order/ Family	Scientific name	Common name **+ *(Number of risk factors** from columns 4-7**)***	Australian-specific information **Established wild populations in Australia?**	Australian-specific information **In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]**	Invasion pathway information **Introduced populations overseas?**	Invasion pathway information **Other information- livestock, pet, food, game, conservation status, etc**	**Predicted result**	**(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC)** **(ii) DAFWA Threat Category** **(iii) Alternative Threat Category**
Caudata/ Ambystomatidae	*Ambystoma mavortium*	western tiger salamander *(1)*	x	x Not on DEWHA Live Import List.	x	In overseas pet trade (Exotic-Pets.co.uk 2009).	Low	Serious ERR Serious Extreme
Caudata/ Ambystomatidae	*Ambystoma mexicanum*	axolotl *(2)*	x	Privately kept in Australia and NZ. Not on DEWHA Live Import List.	x But reports of the species in the wild overseas (Lever 2006).	In overseas pet trade (Exotic-Pets.co.uk 2009). Was once a food item in its native range (Griffiths and Thomas 1988).	Low	Moderate ERR* Extreme Moderate
Carnivora/ Mustelidae	*Aonyx cinereus*	oriental small-clawed otter *(5)*	x	Widely held in the region in accredited zoo collections. On DEWHA Live Import List - import for non-commercial purposes only, excluding household pets, import permit required.	x	In overseas pet trade (International Otter Survival Fund 2009). Trained by traditional fishermen in Asia to assist with fishing (Mason and Macdonald 1986). Present in Indonesia, including Java, Sumatra and Borneo (Nowak	Serious	Serious VPC

Order/ Family	Scientific name	Common name	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
		+ (Number of risk factors** from columns 4-7**)	**Established wild populations in Australia?**	**In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]**	**Introduced populations overseas?**	**Other information- livestock, pet, food, game, conservation status, etc**		
						1999a). Skins very valuable and other body parts said to have therapeutic properties (Foster-Turley et al 1990). Aquatic species (Nowak 1999a). Vulnerable (IUCN 2009).		
Artiodactyla/ Cervidae	*Axis axis*	chital deer *(6)*	✓	In Australia in accredited zoo collections; privately kept in some jurisdictions. Not on DEWHA Live Import List.	✓	Livestock (Moriarty 2004). Game animal (Moriarty 2004). Listed on the Global Invasive Species Database (Invasive Species Specialist Group 2008). Skins and antlers seized from wildlife smugglers in India (TRAFFIC 2008). Venison production (Moriarty 2004).	Serious	Extreme VPC

Order/ Family	Scientific name	Common name	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
		+ *(Number of risk factors from columns 4-7**)***	**Established wild populations in Australia?**	**In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]**	**Introduced populations overseas?**	**Other information- livestock, pet, food, game, conservation status, etc**		
Squamata/ Viperidae	*Bitis arietans*	puff adder *(3)*	x	DEWHA has permitted species to be held in secure facilities in South Australia (M. Williams, South Australian Govt. pers comm); seized from illegal private keepers (K. Larner, Victorian Govt pers comm). Not on DEWHA Live Import List.	x	In overseas pet trade (Bey et al 1997). Africa's most dangerous snake (Spawls and Branch 1995). Bears many live young (Spawls and Branch 1995).	Extreme	Serious ERR Serious Extreme
Squamata/ Viperidae	*Bitis nasicornis*	rhinoceros viper *(4)*	x	In Australia in accredited zoo collections, more acquisitions from outside Australia possibly planned; 'vipers' seized from illegal private keepers (K. Larner, Victorian Govt pers comm). On DEWHA Live Import List - commercial venom production and eligible non-commercial purpose only, excluding household pets and travelling exhibitions.	x	In overseas pet trade (Malina and Krecsak 2008). Smaller distribution than *Bitis arietans* (Spawls and Branch 1995).	Moderate	Low ERR* Serious Extreme

Order/ Family	Scientific name	Common name	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
		+ (Number of risk factors from columns 4-7)	**Established wild populations in Australia?**	**In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]**	**Introduced populations overseas?**	**Other information- livestock, pet, food, game, conservation status, etc**		
				High security facilities only, import permit required.				
Squamata Boidae	*Boa constrictor*	boa constrictor *(6)*	x but individuals detected in the wild (J. Burley, Victorian Govt pers comm).	In Australia, in accredited zoo collections; seized from illegal private keepers (K. Larner, Victorian Govt pers comm). On DEWHA Live Import List - import for non-commercial purposes only, excluding household pets, import permit required.	✓	In overseas pet trade - frequently smuggled (TRAFFIC 2008). Bears many live young (Smith 1999). Skin used to make leather goods (Smith 1999).	Extreme	Extreme ERR Extreme Extreme
Anura/ Bufonidae	*Bufo marinus*	cane toad *(5)*	✓	In Australia, accredited zoo collections; seized from the public in areas where the species is not found in the wild (K. Larner, Victorian Govt pers comm). Not on DEWHA Live Import List.	✓	In overseas pet trade (Exotic-Pets.co.uk 2009). Present in countries neighbouring Australia including Papua New Guinea (Lever 2001). Listed by the IUCN as one of 100 of the world's worst invasive alien species (Invasive Species Specialist Group 2008).	Extreme	Extreme ERR Extreme Extreme

Order/ Family	Scientific name	Common name	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
		+ *(Number of risk factors from columns 4-7)*	Established wild populations in Australia?	In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]	Introduced populations overseas?	Other information- livestock, pet, food, game, conservation status, etc		
						One of 11 major introduced vertebrate pests of Australian agricultural industries and the environment (McLeod 2004). Leather products produced in Australia (Toad Leather 2005).		
Anura/ Bufonidae	*Bufo melanostictus*	black-spined toad *(4)*	× but has been detected entering Australia (e.g. AQIS 2008).	× Not on DEWHA Live Import List.	✓ including detection in NZ (VPC pers comm 2009).	In overseas pet trade (Exotic-Pets.co.uk 2009). Present in countries just north of Australia, including East Timor (The Reptile Database 2007). Food and medicine source in some Asian countries (van Dijk et al 2004).	Extreme	Serious ERR Serious Extreme
Artiodactyla/ Cervidae	*Cervus elaphus*	red deer *(7)*	✓	In the region, accredited zoo collections and privately kept in some jurisdictions; illegal private keeping in WA. Widely kept in Australia .	✓	Livestock (Moriarty 2004). Game animal (Moriarty 2004). Present in countries	Extreme	Extreme VPC

Order/ Family	Scientific name	Common name	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
		+ (Number of risk factors** from columns 4-7**)	**Established wild populations in Australia?**	**In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]**	**Introduced populations overseas?**	**Other information- livestock, pet, food, game, conservation status, etc**		
				On DEWHA Live Import List – no listed conditions, import permit required.		neighbouring Australia including NZ (King 2005). Possibly pest of emerging significance (Invasive Animals CRC 2007). Listed by the IUCN as one of 100 of the world's worst invasive alien species (Invasive Species Specialist Group 2008). Skins supplied from Spain (Iberstruz SL 2005) and the US (Chichester Inc. 2009). Venison and velvet production (Tuckwell 2002).		
Anura/ Rhacophoridae	*Chirixalus romeri*	Romer's tree frog *(2)*	×	× Has been in Australia - at least one animal previously in high-security facilities acquired through seizure (VPC 2007);	✓	-	Low	Serious ERR Serious Extreme

Order/ Family	Scientific name	Common name	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
		+ (Number of risk factors** from columns 4-7**)	**Established wild populations in Australia?**	**In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]**	**Introduced populations overseas?**	**Other information- livestock, pet, food, game, conservation status, etc**		
				also captive breeding program in high-security facilities (Banks 2004). On DEWHA Live Import List - import for non-commercial purposes only, excluding household pets, high security facilities only, import permit required.				
Squamata/ Boidae	*Corallus caninus*	emerald tree boa *(4)*	x	In Australia, in accredited zoo collections; at least one animal in high-security facilities acquired through seizure (VPC 2007); seized from illegal private keepers (K. Larner, Victorian Govt pers comm). On DEWHA Live Import List - import for non-commercial purposes only, excluding household pets, import permit required.	x	In overseas pet trade - smuggling in Guyana (TRAFFIC 2008). South American distribution (The Reptile Database 2007).	Low	Low ERR* Extreme Serious

Order/ Family	Scientific name	Common name *+ **(Number of risk factors** from columns 4-7**)***	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
			Established wild populations in Australia?	In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]	Introduced populations overseas?	Other information- livestock, pet, food, game, conservation status, etc		
Testudines/ Geomydidae	*Cuora trifasciata*	Chinese three-striped box turtle *(3)*	×	Australia, accredited zoo collections, more acquisitions planned. Not on DEWHA Live Import List.	×	In overseas pet trade (The Turtle Puddle 2009). In high demand for sale in traditional medicine markets in China, high value species for collectors, since critically endangered (IUCN 2009).	Low	Low ERR* Extreme Moderate
Artiodactyla/ Cervidae	*Dama dama*	fallow deer *(7)*	✓	The region, accredited zoo collections and privately kept in some jurisdictions; illegal private keeping in WA (G. Gray, Western Australian Govt. pers comm). Widely kept in Australia . On DEWHA Live Import List – no listed conditions, import permit required.	✓	Livestock (Moriarty 2004). Game animal (Moriarty 2004). Present in countries neighbouring Australia including NZ (King 2005). Possibly pest of emerging significance (Invasive Animals CRC 2007). Skins sold in the US (Chichester Inc. 2009). Venison production (Tuckwell 2002).	Extreme	Extreme VPC

Order/ Family	Scientific name	Common name *+ **(Number of risk factors** from columns 4-7**)***	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
			Established wild populations in Australia?	**In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]**	**Introduced populations overseas?**	**Other information- livestock, pet, food, game, conservation status, etc**		
Diprotodontia Macropodidae	*Dorcopsis luctuosa*	grey dorcopsis *(2)*	×	× Has been in Australia - at least one animal previously in high-security facilities acquired through seizure (VPC 2007) Not on DEWHA Live Import List.	× (unknown when species selected).	First of this family to be assessed. Occurs in Papua New Guinea (Nowak 1999a).	Low	Moderate VPC
Squamata/ Colubridae	*Elaphe guttata*	corn snake *(4)*	× but individuals detected in the wild (K. Larner, Victorian Govt pers comm).	In Australia, accredited zoo collections; seized from illegal private keepers (K. Larner, Victorian Govt pers comm) Not on DEWHA Live Import List.	✓	In overseas pet trade – rare subspecies seized (TRAFFIC 2008).	Serious	Moderate ERR* Extreme Serious
Squamata/ Colubridae	*Elaphe taeniurus*	beauty snake *(3)*	×	In Australia, accredited zoo collections. On DEWHA Live Import List - import for non-commercial purposes only, excluding household pets, import permit required.	✓	In overseas pet trade (ReptileChannel.Com 2009). Occurs on Sumatra and Borneo, Indonesia (The Reptile Database 2007).	Moderate	Moderate ERR* Extreme Serious

Order/ Family	Scientific name	Common name	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
		+ *(Number of risk factors from columns 4-7**)***	**Established wild populations in Australia?**	**In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]**	**Introduced populations overseas?**	**Other information- livestock, pet, food, game, conservation status, etc**		
Carnivora/ Ursidae	*Helarctos malayanus*	Malayan sun bear *(3)*	×	In Australia and NZ, accredited zoo collections, more acquisitions from outside Australia possibly planned. On DEWHA Live Import List - import for non-commercial purposes only, excluding household pets, import permit required.	×	Live animals and body parts seized in several Asian countries (TRAFFIC 2008).	Moderate	Extreme VPC
Testudines/ Geomydidae	*Heosemys spinosa*	spiny turtle *(4)*	×	In Australia, accredited zoo collections, more acquisitions planned. Not on DEWHA Live Import List.	×	In overseas pet trade (The Turtle Puddle 2009). Food item in some Asian countries (IUCN 2009). Occurs across the Sunda Archipelago, just north of Australia (The Reptile Database 2007). Endangered (IUCN 2009).	Moderate	Low ERR* Extreme Moderate
Anura/ Microhylidae	*Kaloula pulchra*	Asiatic painted frog	×	×	✓	In overseas pet trade (Exotic-Pets.co.uk	Serious	Serious ERR Serious

Order/ Family	Scientific name	Common name	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
		+ *(Number of risk factors from columns 4-7**)***	**Established wild populations in Australia?**	**In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]**	**Introduced populations overseas?**	**Other information- livestock, pet, food, game, conservation status, etc**		
		(4)	but has been detected entering Australia (Tyler and Chapman 2005).	Not on DEWHA Live Import List.	Detected in NZ (Gill et al 2001)	2009). Collected for consumption in many places (IUCN 2009). Occurs on Sumatra, Borneo and Sulawesi (The Reptile Database 2007).		Extreme
Primate/ Callitrichidae	*Leontopithecus rosalia*	golden lion tamarin *(3)*	×	In Australia and NZ, accredited zoo collections, more acquisitions from outside Australia possibly planned. Several family members in Australia (ARAZPA 2009). On DEWHA Live Import List - import for non-commercial purposes only, excluding household pets, import permit required.	×	In overseas pet trade (Primate Info Net 2009). Endangered (IUCN 2009).	Moderate	Moderate VPC
Lagomorpha/ Leporidae	*Lepus europaeus*	European hare *(6)*	✓	Privately kept in some jurisdictions, seizures where species prohibited in private	✓ Overseas including NZ.	In overseas pet trade (You Pet 2009). In pet trade in Australia.	Extreme	Extreme VPC

Order/ Family	Scientific name	Common name	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC)
		+ *(Number of risk factors from columns 4-7)*	Established wild populations in Australia?	In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]	Introduced populations overseas?	Other information- livestock, pet, food, game, conservation status, etc		(ii) DAFWA Threat Category (iii) Alternative Threat Category
				keeping (F. Keenan, Queensland Govt. pers comm). On DEWHA Live Import List - import for non-commercial purposes only, excluding household pets, import permit required.		Game animal (Mitchell-Jones et al 1999). Skin to produce clothing (Nowak 1999b).		
Carnivora/ Felidae	*Lynx lynx*	Eurasian lynx *(2)*	×	× Not on DEWHA Live Import List.	×	In overseas pet trade (CentralPets.com 2009). First European felid assessed. Illegal trade in lynx skins (IUCN 2009).	Moderate	Extreme VPC
Anura/ Megophryidae	*Megophrys montana*	Javan horned frog *(2)*	×	× Proposed for import in 2004. Not on DEWHA Live Import List.	×	In overseas pet trade (Exotic-Pets.co.uk 2009). Occurs on Java (The Reptile Database 2007).	Low	LOW ERR* Extreme Low
Carnivora/ Mustelidae	*Mustela erminea*	stoat *(2)*	×	× Not on DEWHA Live Import List.	✓ Overseas including NZ.	Listed by the IUCN as one of 100 of the world's worst invasive alien species (Invasive Species Specialist Group 2008).	Extreme	Extreme VPC

Order/ Family	Scientific name	Common name	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
		+ *(Number of risk factors from columns 4-7**)***	**Established wild populations in Australia?**	**In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]**	**Introduced populations overseas?**	**Other information- livestock, pet, food, game, conservation status, etc**		
						Furs exported from many countries (Business Link 2009).		
Lagomorpha/ Leporidae	*Oryctolagus cuniculus*	European rabbit *(7)*	✓	Privately kept in some jurisdictions, seizures where species prohibited in private keeping (F. Keenan, Queensland Govt. pers comm). On DEWHA Live Import List – no listed conditions, but import permit required.	✓ Overseas including NZ.	In overseas pet trade (Nowak 1999b). In pet trade in Australia. Game animal (Mitchell-Jones et al 1999). Listed by the IUCN as one of 100 of the world's worst invasive alien species (Invasive Species Specialist Group 2008). One of 11 major introduced vertebrate pests of Australian agricultural industries and the environment (McLeod 2004). Fur used for hat-making (Akubra 2009). Important food animal (Nowak 1999b).	Extreme	Extreme VPC

Order/ Family	Scientific name	Common name	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
		+ *(Number of risk factors from columns 4-7)*	Established wild populations in Australia?	In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]	Introduced populations overseas?	Other information-livestock, pet, food, game, conservation status, etc		
Artiodactyla/ Bovidae	*Ovis aries*	domestic sheep *(4)*	✓	Widespread in private keeping. On DEWHA Live Import List – no import permit required.	✓ Overseas including NZ.	Livestock (Nowak 1999b). Listed on the Global Invasive Species Database (Invasive Species Specialist Group 2008). Skin widely used (Iberstruz SL 2005, Chichester Inc. 2009).	Extreme	Extreme VPC
Carnivora/ Felidae	*Prionailurus viverrinus*	fishing cat *(7)*	x	In Australia, accredited zoo collections, more acquisitions from outside Australia possibly planned, and for NZ; at least one animal previously in high security facilities acquired through seizure (VPC 2007) On DEWHA Live Import List - import for eligible non-commercial purposes only, excluding household pets, import permit required.	✓	In overseas pet trade (CentralPets.com 2009). Fishing cat x domestic cat hybrids are known as Viverrals, Machbagrals, or Jambi Cats. It appears that the breed is only in the early stages of development (DEWHA 2008). Small populations occur on Java (Nowak 1999a). Hunted, as considered	Low	Extreme VPC

Order/ Family	Scientific name	Common name + *(Number of risk factors from columns 4-7)*	Australian-specific information Established wild populations in Australia?	 In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]	Invasion pathway information Introduced populations overseas?	 Other information- livestock, pet, food, game, conservation status, etc	Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
						edible and skin is still valued by the fur trade (Animal Info 2006). Endangered (IUCN 2009).		
Anura/ Ranidae	*Pyxicephalus adspersus*	African bullfrog *(3)*	×	In Australia, accredited zoo collections and research facilities. On DEWHA Live Import List – import for eligible non-commercial purpose only, excluding household pets. Certified males over 14 cm snout-vent length only. High-security facilities only, import permit required.	×	In overseas pet trade (Exotic-Pets.co.uk 2009).	Serious	Serious ERR Serious Extreme
Squamata/ Typhlopidae	*Ramphotyphlops braminus*	flowerpot snake *(3)*	✓	On DEWHA Live Import List – import for eligible non-commercial purpose only, excluding household pets, import permit required.	✓	Reproduces parthenogenetically (Ernst and Ernst 2003). Transported in nursery trade (Ernst and Ernst 2003).	Low	Extreme ERR Extreme Extreme
Struthionidae/ Struthionidae	*Struthio camelus*	ostrich *(6)*	✓ Sightings in	In Australia and NZ, accredited zoo	×	In overseas pet trade (Shukla and Tyagi	Extreme	Serious VPC

Order/ Family	Scientific name	Common name	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
		+ (Number of risk factors** from columns 4-7**)	**Established wild populations in Australia?**	**In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]**	**Introduced populations overseas?**	**Other information- livestock, pet, food, game, conservation status, etc**		
			three areas in South Australia over the last 11 years (Birds Australia 2009).	collections, privately kept. On DEWHA Live Import List – specimens from certain areas excluded from import, no other conditions, import permit required.		2001). Livestock (Tuckwell 1997). Skins supplied from Spain (Iberstruz SL 2005).		
Carnivora/ Herpestidae	*Suricata suricatta*	meerkat *(4)*	x	Widely kept in Australasia, accredited zoo collections.[1] On DEWHA Live Import List - import for non-commercial purposes only, excluding household pets, import permit required.	x	In overseas pet trade(Meerkat Magic Conservation Project 2003). Stuffed meerkats seized in Belgium (TRAFFIC 2008).	Serious	Moderate VPC
Primate/ Hylobatidae	*Symphalangus syndactylus*	siamang *(3)*	x	In Australia and NZ, accredited zoo collections, more acquisitions from outside Australia possibly planned. On DEWHA Live Import List - import for non-commercial purposes only, excluding household pets, import	x	In overseas pet trade - smuggling in Japan (TRAFFIC 2008). Several family members in Australia, but none previously assessed.	Low	Moderate VPC

Order/ Family	Scientific name	Common name	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
		+ *(Number of risk factors from columns 4-7**)***	**Established wild populations in Australia?**	**In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]**	**Introduced populations overseas?**	**Other information- livestock, pet, food, game, conservation status, etc**		
				permit required.				
Caudata/ Salamandridae	*Taricha granulosa*	rough-skinned newt *(2)*	×	? On DEWHA Live Import List - import for eligible non-commercial purpose only, excluding household pets. High security facilities only, import permit required.	✓	In overseas pet trade (Edmonds 2009). Large North American distribution (The Reptile Database 2007). Toxic to humans if ingested or handled (Miller 2004).	Moderate	Low ERR* Extreme Serious
Testudines/ Emydidae	*Terrapene ornata*	ornate box turtle *(2)*	×	In Australia, accredited zoo collections.[1] Not on DEWHA Live Import List.	×	In overseas pet trade (Edmonds 2009). Large North American distribution (The Reptile Database 2007).	Moderate	Serious ERR Serious Extreme
Testudines/ Emydidae	*Trachemys scripta*	pond slider *(6)*	✓ Populations in QLD, ACT, NSW (Biosecurity Queensland 2007c, Kirkpatrick et al 2009).	In Australia, accredited zoo collections.[1] Seized from illegal private keepers (K. Larner, Victorian Govt pers comm).[2] On DEWHA Live Import List - import for non-commercial purposes only, excluding	✓ Overseas including NZ	In overseas pet trade - smuggling in Colombia and Germany (TRAFFIC 2008). Listed by the IUCN as one of 100 of the world's worst invasive alien species (Invasive Species Specialist Group 2008).	Extreme	Extreme ERR Extreme Extreme

Order/ Family	Scientific name	Common name	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
		+ (Number of risk factors from columns 4-7)	Established wild populations in Australia?	In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]	Introduced populations overseas?	Other information- livestock, pet, food, game, conservation status, etc		
				household pets, import permit required.		Species present on Bali and probably other islands in Indonesia (Asian Turtle Conservation Network 2004).		
Caudata/ Salamandridae	*Triturus vulgaris*	smooth newt *(2)*	x	? At least one animal previously in high security facilities acquired through seizure (VPC 2007). Not on DEWHA Live Import List.	x	In overseas pet trade (Edmonds 2009). European distribution (The Reptile Database 2007). Larger distribution than *Taricha granulosa* (The Reptile Database 2007). Toxic to humans if ingested or handled (Miller 2004).	Serious	Moderate ERR* Extreme Serious
Carnivora/ Ursidae	*Ursus arctos*	brown bear *(3)*	x	In Australia, accredited zoo collections.[1] On DEWHA Live Import List - import for non-commercial purposes only, excluding household pets, import permit required.	x	Dangerous to humans (Nowak 1999a). Paws seized in Russia (TRAFFIC 2008). Pelts taken in Alaska (US Fish and Wildlife Service 1980).	Extreme	Extreme VPC

Order/ Family	Scientific name	Common name	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
		+ *(Number of risk factors from columns 4-7**)***	**Established wild populations in Australia?**	**In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]**	**Introduced populations overseas?**	**Other information- livestock, pet, food, game, conservation status, etc**		
Carnivora/ Canidae	*Vulpes vulpes*	red fox *(5)*	✓	In Australia, accredited zoo collections. Privately kept in some jurisdictions, surrendered in one jurisdiction where species prohibited in private keeping (K. Larner, Victorian Govt pers comm).[1] Not on DEWHA Live Import List.	✓	Game animal (Mitchell-Jones et al 1999). Listed by the IUCN as one of 100 of the world's worst invasive alien species (Invasive Species Specialist Group 2008). One of 11 major introduced vertebrate pests of Australian agricultural industries and the environment (McLeod 2004). Skins seized in Russia (TRAFFIC 2008).	Extreme	Extreme VPC
Anura/ Pipidae	*Xenopus laevis*	African clawed frog *(3)*	x	In the region in accredited zoo collections, outside Australia[1]; has been in research facilities in Australia (M. Massam, Western Australian Govt. pers comm); at least one animal previously in high security facilities	✓	In overseas pet trade (Exotic-Pets.co.uk 2009). Listed on the Global Invasive Species Database (Invasive Species Specialist Group 2008).	Serious	Extreme ERR Extreme Extreme

Order/ Family	Scientific name	Common name	Australian-specific information		Invasion pathway information		Predicted result	(i) Establishment Risk Rank[3](ERR) or VPC Threat Category (VPC) (ii) DAFWA Threat Category (iii) Alternative Threat Category
		+ (Number of risk factors** from columns 4-7**)	**Established wild populations in Australia?**	**In accredited zoo collections in Australasia[1], proposed for import, known to have been seized, on DEWHA Live Import List[2]**	**Introduced populations overseas?**	**Other information- livestock, pet, food, game, conservation status, etc**		
				acquired through seizure (VPC 2007). On DEWHA Live Import List - import for non-commercial purposes only, excluding household pets, high security facilities only, import permit required.				

1. ARAZPA 2009.
2. DEWHA 2009b.
3. Results of assigned ERRs are on hold, not endorsed by VPC.

Appendix B. Vertebrate Pests Committee Threat Category Table

A. Public Safety Risk Rank	B. Establishment Risk Rank[1]	C. Pest Risk Rank[1]	VPC Threat Category
Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme	Extreme	Extreme
Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme	Serious	Extreme
Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme	Moderate	Extreme
Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme	Low	Extreme
Highly Dangerous, Moderately Dangerous or Not Dangerous	Serious	Extreme	Extreme
Highly Dangerous, Moderately Dangerous or Not Dangerous	Serious	Serious	Extreme
Highly Dangerous, Moderately Dangerous or Not Dangerous	Serious	Moderate	Serious
Highly Dangerous, Moderately Dangerous or Not Dangerous	Serious	Low	Serious
Highly Dangerous, Moderately Dangerous or Not Dangerous	Moderate	Extreme	Extreme
Highly Dangerous, Moderately Dangerous or Not Dangerous	Moderate	Serious	Serious
Highly Dangerous	Moderate	Moderate	Serious
Moderately Dangerous or Not Dangerous	Moderate	Moderate	Moderate
Highly Dangerous	Moderate	Low	Serious
Moderately Dangerous or Not Dangerous	Moderate	Low	Moderate

A. Public Safety Risk Rank	B. Establishment Risk Rank[1]	C. Pest Risk Rank[1]	VPC Threat Category
Highly Dangerous, Moderately Dangerous or Not Dangerous	Low	Extreme	Serious
Highly Dangerous, Moderately Dangerous or Not Dangerous	Low	Serious	Serious
Highly Dangerous	Low	Moderate	Serious
Moderately Dangerous or Not Dangerous	Low	Moderate	Moderate
Highly Dangerous	Low	Low	Serious
Moderately Dangerous	Low	Low	Moderate
Not Dangerous	Low	Low	Low

A species' VPC Threat Category (NRMSC 2004) is determined from the various combinations of its three risk ranks; (A) Public safety risk rank, (B) Establishment risk rank, and (C) Pest risk rank.
1. 'Establishment Risk' is referred to as the 'Establishment Likelihood' and 'Pest Risk' is referred to as the 'Establishment Consequences' by the Natural Resource Management Standing Committee (2004).

Appendix C. Text books useful for risk assessments

Barrett G, Silcocks A, Barry S, Cunningham R and Poulter R (2003). *The New Atlas of Australian Birds.* Royal Australasian Ornithologists Union/Birds Australia.

Christidis L and Boles WE (2008). *Systematics and Taxonomy of Australian Birds.* CSIRO Publishing: Collingwood.

Cogger HG (2000). *Reptiles and Amphibians of Australia*. Reed New Holland: Sydney.

del Hoyo J, Elliott A and Sargatal J (1992-2008). *Handbook of the Birds of the World* Vol 1-13. Lynx Edicions: Barcelona.

Lever C (1985). *Naturalised Mammals of the World*. Longman: London.

Lever C (2005). *Naturalised Birds of the World*. T & A D Poyser: London.

Lever C (2006). *Naturalized Reptiles and Amphibians of the World*. Oxford University Press.

Long JL (1981). *Introduced Birds of the World*. 1st Edition. Reed Pty Ltd: Sydney.

Long JL (2003). *Introduced Mammals of the World: Their History, Distribution and Influence.* CSIRO Publishing: Collingwood, Australia.

Nowak RM (1999). *Walker's Mammals of the World* 6th Edition. Vol 1-2. The Johns Hopkins University Press: Baltimore.

Obst FJ, Klaus R and Jacob U (1988). *The Completely Illustrated Atlas of Reptiles and Amphibians for the Terranium.* T.F.H. Publications Inc.: USA.

Strahan R (1995). *The Mammals of Australia*. 2nd Edition. Reed New Holland: Sydney, Auckland, London, Cape Town.

Wilson DE and Reeder DM (1993). *Mammal Species of the World. A Taxonomic and Geographic Reference.* Smithsonian Institution Press: Washington.

Appendix D. Useful web-based publications and other information systems

BiologyBrowser — a free web site offering resources for the life sciences information community (http://www.biologybrowser.org/).

Either BIOSIS (http://www.biosisresearch.com.au/), or Biological Abstracts (via subscription) — provide information in virtually every life sciences discipline, including biology, biochemistry, biotechnology, botany, pre-clinical and experimental medicine, pharmacology, zoology, agriculture, and veterinary science.

Catalogue of Life: Annual Checklist (http://www.usa.species2000.org).

CITES, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (http://www.cites.org).

Global Invasive Species Database (http://www.issg.org/database/species/search.asp?st=100ss).

GOOGLE search engines (http://scholar.google.com.au/; http://www.google.com.au/).

HAGR, Human Ageing Genomic Resources (http://genomics.senescence.info/).

ITIS, Integrated Taxonomic Information System (http://www.itis.gov).

IUCN Red List, International Union for Conservation of Nature (http://www.iucnredlist.org).

MEDLINE® — compiled by the U.S. National Library of Medicine and published on the web by the Community of Science, a comprehensive source of life sciences and biomedical bibliographic information (http://medline.cos.com/).

Scirus — a comprehensive science-specific search engine that searches over 485 million science-specific web pages (http://www.scirus.com/).

Species 2000 & ITIS Catalogue of Life (http://www.catalogueoflife.org/annual-checklist/search.php)

The Reptile Database (http://www.tigr.org/reptiles/search.php).

Zoological Record — the world's oldest continuing database of animal biology, considered the world's leading taxonomic reference (via subscription).

Appendix E. Detailed results for Public Safety Risk Ranks and Establishment Risk Ranks of birds and mammals

Scientific name	Common name	A1. Risk to people by captive or released individuals (0-2)	A2. Risk to public safety from individual captive animals (0-2)	Public Safety Risk Rank	B1. Climate match (0-6)	B2. Exotic popu-lations overseas (0-4)	B3. Over-seas range size (0-2)	B4. Taxo-nomic class (0-1)	Model 1 (4 factors) Establishment Risk Rank	B5. Diet score (0-1)	B6. Habitat score (0-1)	B7. Migratory behaviour (0-1)	Model 2 (7 factors) Establishment Risk Rank
Aonyx cinereus	oriental small-clawed otter	1	0	Moderately dangerous	3	0	1	1	Low	1	1	1	Moderate
Axis axis	chital deer ++	1	0	Moderately dangerous	5	4	1	1	Extreme	1	1	1	Extreme
Cervus elaphus	red deer ++	1	0	Moderately dangerous	5	4	1	1	Extreme	1	1	1	Extreme
Dama dama	fallow deer ++	1	0	Moderately dangerous	5	4	1	1	Extreme	1	1	1	Extreme
Dorcopsis luctuosa	grey dorcopsis	0	0	Not dangerous	2	0	0	1	Low	1	1	1	Low
Helarctos malayanus	Malayan sun bear	2	0	Highly dangerous	3	0	1	1	Low	1	1	1	Moderate
Leontopithecus rosalia	golden lion tamarin	1	0	Moderately dangerous	2	0	0	1	Low	1	1	1	Low
Lepus europaeus	European hare ++	0	0	Not dangerous	5	4	1	1	Extreme	1	1	1	Extreme
Lynx lynx	Eurasian lynx	1	0	Moderately dangerous	3	0	1	1	Low	1	1	1	Moderate
Mustela erminea	stoat	0	0	Not dangerous	3	4	2	1	Serious	1	1	1	Serious
Oryctolagus cuniculus	European rabbit ++	0	0	Not dangerous	3	4	1	1	Serious	1	1	1	Serious
Ovis aries	domestic sheep (no breeds distinguished) ++	1	0	Moderately dangerous	2	4	1	1	Moderate	1	1	1	Moderate
Ovis orientalis	domestic sheep's ancestor – mouflon	-	-	NA	2	0	1	1	Low	1	1	0	Low

Scientific name	Common name	A1. Risk to people by captive or released individuals (0-2)	A2. Risk to public safety from individual captive animals (0-2)	Public Safety Risk Rank	B1. Climate match (0-6)	B2. Exotic popu-lations overseas (0-4)	B3. Over-seas range size (0-2)	B4. Taxo-nomic class (0-1)	Model 1 (4 factors) Establishment Risk Rank	B5. Diet score (0-1)	B6. Habitat score (0-1)	B7. Migratory behaviour (0-1)	Model 2 (7 factors) Establishment Risk Rank
Ovis aries	merino sheep breed ++	-	-	NA	2	4	1	1	Moderate	1	1	1	Moderate
Ovis aries	damara sheep breed	-	-	NA	2	0	0	1	Low	1	1	1	Low
Ovis aries	dorper sheep breed	-	-	NA	4	0	1	1	Moderate	1	1	1	Moderate
Prionailurus viverrinus	fishing cat	1	0	Moderately dangerous	4	4	1	1	Serious	1	1	1	Serious
Struthio camelus	ostrich ++(?)	1	0	Moderately dangerous	5	0	1	0	Moderate	1	1	1	Moderate
Suricata suricatta	meerkat	1	0	Moderately dangerous	5	0	0	1	Moderate	1	1	1	Moderate
Symphalangus syndactylus	siamang	1	0	Moderately dangerous	1	0	0	1	Low	1	1	1	Low
Ursus arctos	brown bear	2	0	Highly dangerous	5	0	2	1	Moderate	1	1	1	Moderate
Vulpes vulpes	red fox ++	1	0	Moderately dangerous	6	4	2	1	Extreme	1	1	1	Extreme

The Australian Bird and Mammal Model (Bomford 2008) was used (see Chapter 2).
++ = species has successfully established introduced populations in Australia. The ostrich has recently been reported in the wild.
NA = no analysis or allocation of rank due to insufficient information.

Appendix F. Detailed results for Pest Risk Ranks and VPC Threat Categories of birds and mammals

Scientific name	Common name	C1. Taxo-nomic group (0-4)	C2. Over-seas range size (0-2)	C3. Diet and feeding (0-3)	C4. Competi-tion with native fauna for tree hollows (0-2)	C5. Over-seas environ-mental pest status (0-3)	C6. Climate match to areas with suscep-tible native species or commun-ities (0-5)	C7. Over-seas primary produc-tion pest status (0-3)	C8. Climate match to areas with suscep-tible primary production (0-5)	C9. Spread disease (1-2)	C10. Harm to property (0-5)	C11. Harm to people (0-5)	Pest Risk Rank	VPC Threat Category
Aonyx cinereus	oriental small-clawed otter	4	0	2	0	0	4	1	1	2	0	1	Serious	Serious
Axis axis	chital deer ++	4	0	3	0	2	5	2	5	2	1	3	Extreme	Extreme
Cervus elaphus	red deer ++	4	2	3	0	3	5	2	5	2	1	3	Extreme	Extreme
Dama dama	fallow deer ++	4	1	3	0	3	5	2	5	2	1	3	Extreme	Extreme
Dorcopsis luctuosa	grey dorcopsis	2	0	3	0	0	5	0	1	2	0	0	Moderate	Moderate
Helarctos malayanus	Malayan sun bear	2	0	1	2	0	5	2	4	2	1	4	Extreme	Extreme
Leontopithecus rosalia	golden lion tamarin	0	0	1	2	0	3	0	1	2	0	1	Moderate	Moderate
Lepus europaeus	European hare ++	4	2	3	0	2	5	2	5	2	1	3	Extreme	Extreme
Lynx lynx	Eurasian lynx	2	2	3	2	0	5	2	5	2	0	3	Extreme	Extreme
Mustela erminea	stoat	4	2	1	2	2	5	1	1	2	0	0	Extreme	Extreme
Oryctolagus cuniculus	European rabbit ++	4	0	3	0	3	5	3	5	2	1	1	Extreme	Extreme
Ovis aries	domestic sheep (no breeds distinguished) ++	4	0	3	0	2	5	1	5	2	1	3	Extreme	Extreme

Scientific name	Common name	C1. Taxo-nomic group (0-4)	C2. Over-seas range size (0-2)	C3. Diet and feeding (0-3)	C4. Competi-tion with native fauna for tree hollows (0-2)	C5. Over-seas environ-mental pest status (0-3)	C6. Climate match to areas with suscep-tible native species or commun-ities (0-5)	C7. Over-seas primary produc-tion pest status (0-3)	C8. Climate match to areas with suscep-tible primary production (0-5)	C9. Spread disease (1-2)	C10. Harm to property (0-5)	C11. Harm to people (0-5)	Pest Risk Rank	VPC Threat Category
Prionailurus viverrinus	fishing cat	2	0	2	2	0	5	1	4	2	0	4	Extreme	Extreme
Struthio camelus	ostrich ++(?)	0	1	0	0	0	5	0	3	2	1	4	Serious	Serious
Suricata suricatta	meerkat	2	0	2	0	0	5	0	0	2	0	1	Moderate	Moderate
Symphalangus syndactylus	siamang	0	0	0	0	0	0	0	1	2	0	2	Low	Moderate
Ursus arctos	brown bear	2	2	1	0	0	5	2	5	2	1	4	Extreme	Extreme
Vulpes vulpes	red fox ++	4	2	1	0	2	5	2	5	2	1	3	Extreme	Extreme

The Australian Bird and Mammal Model (Bomford 2008) was used (see Chapter 2). All assigned VPC Threat categories have been endorsed by VPC.
++ = species has successfully established introduced populations in Australia. The ostrich has recently been reported in the wild.

Appendix G. Detailed results for Establishment Risk Ranks of reptiles and amphibians

Scientific name	Common name	B1. Climate match (1-6)	B2. Exotic populations overseas (0-4)	B3. Overseas range size (0-2)	Bird and Mammal Model A (3 factors) Establishment Risk Rank	B4. Taxonomic class (0-1)	B5. Diet score (0-1)	B6. Habitat score (0-1)	B7. Migratory behaviour (0-1)	Bird and Mammal Model B (7 factors) Establishment Risk Rank	A. Climate Match Risk Score (0-100)	B. Exotic Elsewhere Risk Score (0, 15, 30)	C. Taxonomic Family Risk Score (0, 5, 10, 15, 20, 30)	Reptile and Amphibian Model* Establishment Risk Rank	Establishment Risk Rank (highest of results)
Ambystoma mavortium	western tiger salamander	4	4	1	Serious	1	1	1	0	Serious	45	30	15	Serious	Serious
Ambystoma mexicanum	axolotl	2	0	0	Low	1	1	1	1	Low	10	15	15	Moderate	Moderate*
Bitis arietans	puff adder	5	0	1	Moderate	1	1	1	1	Moderate	79	0	10	Serious	Serious
Bitis nasicornis	rhinoceros viper	1	0	1	Low	1	1	1	1	Low	0.2	0	10	Low	Low*
Boa constrictor	boa constrictor	5	4	1	Extreme	1	1	1	1	Extreme	47	30	5	Serious	Extreme
Bufo marinus	cane toad ++	5	4	1	Extreme	1	1	1	1	Extreme	54.9	30	20	Serious	Extreme
Bufo melanostictus	black-spined toad	4	4	1	Serious	1	1	1	1	Serious	27.2	30	20	Serious	Serious
Chirixalus romeri	Romer's tree frog	2	4	0	Moderate	1	1	1	1	Moderate	10.2	30	30	Serious	Serious
Corallus caninus	emerald tree boa	2	0	1	Low	1	1	0	1	Low	2	0	5	Low	Low*
Cuora trifasciata	Chinese three-striped box turtle	1	0	0	Low	1	1	0	1	Low	0.5	0	0	Low	Low*
Elaphe guttata	corn snake	2	2	1	Moderate	1	1	1	1	Moderate	4	30	10	Moderate	Moderate*
Elaphe taeniura	beauty snake	4	2	1	Moderate	1	1	1	1	Moderate	19	30	10	Moderate	Moderate*
Heosemys spinosa	spiny turtle	1	0	0	Low	1	1	0	1	Low	0.7	0	0	Low	Low*

Scientific name	Common name	B1. Climate match (1-6)	B2. Exotic populations overseas (0-4)	B3. Overseas range size (0-2)	Bird and Mammal Model A (3 factors) Establishment Risk Rank	B4. Taxonomic class (0-1)	B5. Diet score (0-1)	B6. Habitat score (0-1)	B7. Migratory behaviour (0-1)	Bird and Mammal Model B (7 factors) Establishment Risk Rank	A. Climate Match Risk Score (0-100)	B. Exotic Elsewhere Risk Score (0, 15, 30)	C. Taxonomic Family Risk Score (0, 5, 10, 15, 20, 30)	Reptile and Amphibian Model* Establishment Risk Rank	Establishment Risk Rank (highest of results)
Kaloula pulchra	Asiatic painted frog	4	4	1	Serious	1	1	1	1	Serious	19	30	20	Serious	Serious
Megophrys montana	Javan horned frog	1	0	0	Low	1	1	1	1	Low	0.1	0	0	Low	Low*
Pyxicephalus adspersus	African bullfrog	5	0	1	Moderate	1	1	1	1	Moderate	46	0	30	Serious	Serious
Ramphotyphlops braminus	flowerpot snake ++	5	4	1	Extreme	1	1	1	1	Extreme	33	30	30	Serious	Extreme
Taricha granulosa	rough-skinned newt	2	0	1	Low	1	1	1	0	Low	2	0	15	Low	Low*
Terrapene ornata	ornate box turtle	5	0	1	Moderate	1	1	1	1	Moderate	52	0	15	Serious	Serious
Trachemys scripta	pond slider ++	6	4	1	Extreme	1	1	1	1	Extreme	92	30	15	Extreme	Extreme
Triturus vulgaris	smooth newt	3	0	1	Low	1	1	1	0	Moderate	18	0	15	Moderate	Moderate*
Xenopus laevis	African clawed frog	5	4	1	Extreme	1	1	1	1	Extreme	78	30	15	Extreme	Extreme

The Australian Bird and Mammal Models A and B and the Australian Reptile and Amphibian Model (Bomford 2008) were used in these assessments (see Chapter 2).
The underlying assumptions made in developing the Reptile and Amphibian Model, from introduction data for Britain, Florida and California, are untested. Therefore, predictions made by this model may be less reliable than predictions made by the models for mammals and birds, which were based on data for Australian introductions (Bomford 2006).
++ = species has successfully established introduced populations in Australia
*Low and Moderate results are on hold and not endorsed by VPC.

Appendix H. Detailed results for reptiles and amphibians: Establishment Risk Ranks, Public Safety Risk Ranks and threat categories*

Scientific name	Common name	Establishment Risk Rank[1] (ERR)	A1. Risk to people by captive or released individuals (0-2)	A2. Risk to public safety from individual captive animals (0-2)	Public Safety Risk Rank (PSRR)	DAFWA Threat Category[2] assigned for this study	Checklist of factors associated with adverse impacts[3]	Australian species potentially at risk (0-5)	Australian primary production commodities potentially risk (0-5)	Alternative Threat Category[4]
Ambystoma mavortium	western tiger salamander	Serious	0	0	Not dangerous	Serious	1,3,6,9	5	1	Extreme
Ambystoma mexicanum	axolotl	Moderate*	0	0	Not dangerous	Extreme	3,6,9	1	0	Moderate
Bitis arietans	puff adder	Serious	2	1	Highly dangerous	Serious	1,3,6,9	5	2	Extreme
Bitis nasicornis	rhinoceros viper	Low*	2	1	Highly dangerous	Serious	1,3,6,9	5	0	Extreme
Boa constrictor	boa constrictor	Extreme	1	0	Moderately dangerous	Extreme	1,3,6,8,9	5	2	Extreme
Bufo marinus	cane toad ++	Extreme	0	2	Highly dangerous	Extreme	1,2,3,5,6,8,9	5	1	Extreme
Bufo melanostictus	black-spined toad	Serious	0	1	Moderately dangerous	Serious	1,2,3,5,6,9	5	0	Extreme
Chirixalus romeri	Romer's tree frog	Serious	0	0	Not dangerous	Serious	3,6,9	5	0	Extreme
Corallus caninus	emerald tree boa	Low*	1	0	Moderately dangerous	Extreme	3,6,9	5	0	Serious
Cuora trifasciata	Chinese three-striped box turtle	Low*	0	0	Not dangerous	Extreme	3,6,9	5	0	Moderate
Elaphe guttata	corn snake	Moderate*	0	0	Not dangerous	Extreme	1,2,3,6,7,9	5	1	Serious
Elaphe taeniura	beauty snake	Moderate*	0	0	Not dangerous	Extreme	1,2,3,6,7,9	5	1	Serious
Heosemys spinosa	spiny turtle	Low*	0	0	Not dangerous	Extreme	3,6,9	5	0	Moderate

Scientific name	Common name	Establishment Risk Rank[1] (ERR)	A1. Risk to people by captive or released individuals (0-2)	A2. Risk to public safety from individual captive animals (0-2)	Public Safety Risk Rank (PSRR)	DAFWA Threat Category[2] assigned for this study	Checklist of factors associated with adverse impacts[3]	Australian species potentially at risk (0-5)	Australian primary production commodities potentially risk (0-5)	Alternative Threat Category[4]
Kaloula pulchra	Asiatic painted frog	Serious	0	0	Not dangerous	Serious	3,5,6,7,9	5	0	Extreme
Megophrys montana	Javan horned frog	Low*	0	0	Not dangerous	Extreme	6,9	2	0	Low
Pyxicephalus adspersus	African bullfrog	Serious	0	0	Not dangerous	Serious	3,6,7,9	5	0	Extreme
Ramphotyphlops braminus	flowerpot snake ++	Extreme	0	0	Not dangerous	Extreme	3,6,7,9	5	0	Extreme
Taricha granulosa	rough-skinned newt	Low*	0	1	Moderately dangerous	Extreme	3,5,6,9	5	0	Serious
Terrapene ornata	ornate box turtle	Serious	0	0	Not dangerous	Serious	3,6,9	5	0	Extreme
Trachemys scripta	pond slider ++	Extreme	0	0	Not dangerous	Extreme	1,3,5,6,8,9	5	1	Extreme
Triturus vulgaris	smooth newt	Moderate*	0	0	Not dangerous	Extreme	3,6,9	5	0	Serious
Xenopus laevis	African clawed frog	Extreme	0	0	Not dangerous	Extreme	1,3,6,9	5	2	Extreme

The Australian Bird and Mammal Models A and B and the Australian Reptile and Amphibian Model (Bomford 2008) were used to obtain these results (see Chapter 2).
*These assignments to threat categories have not been endorsed by the VPC.
++ = species has successfully established introduced populations in Australia.
1. Highest of results.
2. DAFWA Threat Category assigned by combining ERR and PSRR (see Chapter 2).plus use of precautionary approach (see Chapter 2).
3. See Chapter 2 for details of these factors. Factor 1 = having adverse impacts elsewhere. Factor 5 = occurring in high densities in native or introduced range.
4. Alternative Threat Category assigned by combining ERR and PSRR plus arbitrary increase of one rank, based on presence of adverse impact factors 1 or 5, or maximum scoring for predicted effects on Australian species or primary production (see Chapter 2).

Appendix I. Numbers of references collected for risk assessments of reptiles, amphibians, mammals and birds

Scientific name	Common name	Public Safety Risk references (3 questions)	Establishment Risk references (7 questions)	Environmental and agricultural adverse impacts references (2 questions)	Total references (12 questions)
Aonyx cinereous	oriental small-clawed otter	0	22	7	29
Axis axis	chital deer ++	2	21	10	33
Cervus elaphus	red deer ++	3	16	20	39
Dama dama	fallow deer ++	3	24	20	47
Dorcopsis luctuosa	grey dorcopsis	0	10	0	10
Helarctos malayanus	Malayan sun bear	6	13	5	24
Leontopithecus rosalia	golden lion tamarin	1	20	0	21
Lepus europaeus	European hare ++	0	40	28	68
Lynx lynx	Eurasian lynx	3	23	11	37
Mustela erminea	stoat	3	26	25	54
Oryctolagus cuniculus	European rabbit ++	1	32	23	56
Ovis aries	domestic sheep ++	3	42	23	68
Prionailurus viverrinus	fishing cat	5	19	4	28
Suricata suricatta	meerkat	0	14	0	14
Symphalangus syndactylus	siamang	4	18	0	22
Ursus arctos	brown bear	19	22	12	53
Vulpes vulpes	red fox ++	1	34	22	57
Mammals (n=17)	Total (%) Median	54 (44.3) 3	396 (47.0) 22	210 (79.6) 11	660 (53.7) 37
Bitis arietans	puff adder	10	13	2	25
Bitis nasicornis	rhinoceros viper	7	9	0	16
Boa constrictor	boa constrictor	7	29	2	38
Corallus caninus	emerald tree boa	6	14	0	20
Cuora trifasciata	Chinese three-striped box turtle	0	11	0	11
Elaphe guttata	corn snake	5	25	1	31

Scientific name	Common name	Public Safety Risk references (3 questions)	Establishment Risk references (7 questions)	Environmental and agricultural adverse impacts references (2 questions)	Total references (12 questions)
Elaphe taeniurus	beauty snake	1	15	2	18
Heosemys spinosa	spiny turtle	0	12	0	12
Ramphotyphlops braminus	flowerpot snake ++	0	22	0	22
Terrapene ornata	ornate box turtle	0	15	0	15
Trachemys scripta	pond slider ++	2	82	26	110
Reptiles (n=11)	Total (%)	38 (31.2)	247 (29.3)	33 (12.5)	318 (25.9)
	Median	2	15	0	20
Ambystoma mavortium	western tiger salamander	2	13	5	20
Ambystoma mexicanum	axolotl	0	17	0	17
Bufo marinus	cane toad ++	11	26	5	42
Bufo melanosticus	black-spined toad	2	12	1	15
Chirixalus romeri	Romer's tree frog	0	5	0	5
Kaloula pulchra	Asiatic painted frog	1	24	0	25
Megophrys montana	Javan horned frog	0	6	0	6
Pyxicephalus adspersus	African bullfrog	3	9	0	12
Taricha granulosa	rough-skinned newt	4	15	0	19
Triturus vulgaris	smooth newt	0	22	0	22
Xenopus laevis	African clawed frog	0	35	9	44
Amphibians (n=11)	Total (%)	23 (18.9)	184 (21.8)	20 (7.6)	227 (18.5)
	Median	1	15	0	19
Struthio camelus	ostrich ++(?)	7	16	1	24
Birds (n=1)	Total (%)	7 (5.7)	16 (1.9)	1 (0.4)	24 (2.0)
	TOTALS	122	843	264	1229

++ = species has successfully established introduced populations in Australia. The ostrich has recently been reported in the wild.

Appendix J. Risk assessments for selected species introduced to Australia

The following full risk assessments (based on the DAFWA methodology described in Chapter 2) are available to download from the Policy section of www.feral.org.au.

Mammals:

1. Domestic sheep *Ovis aries*

2. Fishing cat *Prionailurus viverrinus*

3. Stoat *Mustela erminea*

Reptiles:

4. Boa constrictor *Boa constrictor*

5. Corn snake *Elaphe guttata*

6. Rhinoceros viper *Bitis nasicornis*

Amphibians:

7. Asiatic painted frog *Kaloula pulchra*

8. Black-spined toad *Bufo melanosticus*

9. Cane toad *Bufo marinus*

10. Pond slider *Trachemys scripta*

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