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Bureau of Rural Sciences

Risk assessment for the establishment of exotic vertebrates in Australia: recalibration and refinement of models

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A report produced for the Department of the Environment and Heritage

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Foreword

Exotic vertebrates can establish wild pest populations that cause environmental and economic harm. These introduced species have the potential to reduce the profitability of agricultural industries and cause extinctions of native species or reduce their range and abundance.

There is a risk that new vertebrate species could establish as wild pests in Australia. If such species escaped or were illegally released into a favourable environment, they could start to breed in the wild and spread to new locations. Once they are widespread, eradication becomes virtually impossible.

Not all exotic vertebrate species pose the same level of threat for establishing a wild pest population. The Bureau of Rural Sciences has produced models to assess the risks that exotic species proposed for import into Australia could establish wild pest populations. This report further refines these models. A key component of the models is climate matching between a species' overseas geographic range and Australia. A recently published Bureau of Rural Sciences report has updated the climate matching model CLIMATE for use in a PC Windows environment. This report adapts and calibrates the risk assessment models to use this updated version of CLIMATE.

The Bureau of Rural Sciences produced this report for The Department of the Environment and Heritage. The report provides information to assist the Australian and State and Territory Governments assess the risks posed by the import and keeping of exotic vertebrates.

C. Samson

Dr Cliff Samson
Executive Director
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Summary

Risk assessment models for mammals, birds and freshwater finfish were developed from analyses of successful and failed species introduced to Australia.

The Bureau of Rural Sciences has developed models for assessing the risk that exotic vertebrates could establish in Australia for mammals, birds, freshwater finfish, reptiles and amphibians. An integral part of these models is climate matching between each species' overseas geographic range and Australia. The risk assessment models for mammals, birds and freshwater finfish were developed from analyses of successful and failed introductions of exotic mammals, birds and finfish to Australia. The attributes of the species that established exotic populations were compared to the attributes of species that were released in Australia but which failed to establish. Overall, successfully introduced species had high climate match scores and failed species had low scores and this difference was highly statistically significant. It was assumed that potential future introductions of exotic species in these taxa which have high climate match scores will have a high probability of successfully establishing whereas species with low climate match scores will have a low probability of establishing.

The risk assessment models were recalibrated for use with the PC version of CLIMATE.

Climate matching discriminates well between successful and failed species.

The risk assessment models use the software package CLIMATE to conduct this climate matching. The Bureau of Rural Sciences has recently produced a new version of CLIMATE that runs in a PC Windows environment. This report presents updated versions of the risk assessment models recalibrated for use with the new version of CLIMATE. Analyses of exotic vertebrates introduced to Australia are presented using both the old and the new models. The purpose of this comparison was to see if the PC version of CLIMATE gives as good discrimination between climate match scores for successful versus failed exotic mammals and birds introduced to Australia as the old version, and to select the best PC CLIMATE analysis type to use in the risk assessment models. While successfully introduced species have higher climate matches than failed introduced species in all the analyses conducted, there is always considerable overlap between the two groups. However, all three types of analysis performed gave high levels of statistical significance, indicating that climate matching gives good statistical discrimination between successful and failed introductions of exotic birds, mammals and freshwater fish.

Too few exotic reptiles and amphibians were introduced to Australia for climate match comparisons.

It was not possible to compare the climate match scores of successful and failed introductions of exotic reptiles and amphibians introduced to Australia because too few exotic species in these taxa have been introduced – only five successful species and two failed species known for mainland Australia. Instead, climate match scores were calculated for exotic reptiles and amphibians introduced to Britain, Florida and California – where reasonably large numbers of exotic reptiles and amphibians have been introduced. A model was then developed based on the assumption that the results of these analyses of overseas introductions of exotic reptiles and amphibians would also apply to introductions of species in these taxa to Australia. It was assumed that the large sample sizes and variable conditions in the

Instead, climate matches for reptiles and amphibians were compared for Britain, Florida and California and used to develop a model.

three jurisdictions used would give some robustness and generality to the model. Because this assumption is untested, and because assumptions made in calibrating the model for Australian conditions are also untested, predictions made by this model may be less reliable than predictions made by the models for mammals, birds and freshwater finfish which were based on data for Australian introductions. Therefore this report adapts the mammal and bird risk assessment model for use with reptiles and amphibians. Exotic reptiles and amphibians proposed for introduction to Australia can be assessed using both models. If both models predict an equivalent level of risk, then that result may be more robust than the result taken from the original reptile and amphibian model alone. If the two models predict different levels of risk, a precautionary approach would accept the higher level of risk.

If there are few meteorological stations in a species' range, CLIMATE may underestimate the climate match. A correction factor was inserted in the models to correct this bias.

The CLIMATE software contains data for approximately 8000 meteorological stations outside Australia but some areas of the world are not well represented. Where there are few meteorological stations in a species' overseas range, CLIMATE may underestimate the climate match to Australia for that species. Tests were conducted to assess the degree to which this occurs. The results were variable because data from different input meteorological stations have differing levels of influence on the climate match output. But generally the level of climate match showed little decline if the number of input stations was 50 or more, but dropped at an increasing rate below 50, and then dropped steeply when the number of input stations was 12 or fewer. Therefore if the overseas range of a species has 12 or fewer meteorological stations in the CLIMATE database, then CLIMATE is likely to considerably underestimate the climate match to Australia. Correction factors were inserted into the models to correct this bias.

The original risk assessment model for mammals and birds contained six variables to assess the risk an exotic species would establish in the wild in Australia:
1. Degree of climate match between species overseas range and Australia
2. Record of establishing exotic populations overseas
3. Taxonomic class
4. Migratory behaviour
5. Diet
6. Ability to lives in disturbed habitat.

The new model for mammals and birds adds a seventh risk variable: overseas geographic range size.

The new model for mammals and birds presented in this report adds a seventh risk variable: overseas geographic range size. Analyses presented in this report show that scores for diet, habitat and migration differ little between successful and failed species introduced to Australia. However, migratory species have been shown to have a significantly lower establishment success than non-migratory species for mammals introduced to Australia and for birds introduced to New Zealand and elsewhere. Published expert opinion in the ecological literature strongly suggests that being a dietary and/or habitat generalist is likely to enhance establishment success.

habitat and migration differ little between successful and failed species introduced to Australia.

However, historical introductions of exotic vertebrates to Australia were not a random set of species – nearly all were dietary and habitat generalists. Therefore a statistically significant difference for these two factors for successful and failed mammals and birds introduced to Australia could be unlikely even if these factors do influence establishment success. Tests based on the Australian dataset would have little discriminatory power for these two factors because of the small sample sizes of dietary and habitat specialists. Therefore, it may still be worthwhile to include all three factors in the model despite their lack of a statistical effect in the Australian data. This report presents two alternative risk assessment models, both with and without these three controversial risk factors.

Establishment Risk Ranks are recalibrated to four levels to meet the Vertebrate Pests Committee's requirements.

The Vertebrate Pests Committee (VPC) is a committee representing the Australian, New Zealand and all Australian State and Territory Governments whose role is to provide coordinated policy and planning solutions to pest animal issues. The VPC's Guidelines for the Import, Movement and Keeping of Exotic Vertebrates in Australia assess risk posed by exotic species based on four levels of Establishment Risk Rank: extreme, serious, moderate or low. The previously published Bureau of Rural Sciences risk assessment models rank risk of establishment at six levels. This report recalibrates establishment risk ranks in all the models to four levels of risk to maintain consistency with the VPC's risk rankings. Further, the cutoff score thresholds have been adjusted so that each Establishment Risk Rank (extreme, serious, moderate or low) corresponds to a roughly equivalent level of establishment risk in all the models. For example, at the 'moderate' establishment risk level, the ratio of established **:** failed introduced exotic species is approximately 1**:**2 in all three models.

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1. Introduction

Models for assessing the risk that exotic vertebrates could establish in Australia have been developed for mammals and birds (Bomford 2003), freshwater finfish (Bomford and Glover 2004) and reptiles and amphibians (Bomford et al. 2005). An integral part of these models is climate matching between a species' overseas geographic range and Australia. The risk assessment models use the software package CLIMATE to conduct this climate matching. Bomford (2003) and Bomford and Glover (2004) used a version of CLIMATE that runs on Apple Macintosh computers (Pheloung 1996). The Bureau of Rural Sciences has recently produced a new windows PC version of Climate (Bureau of Rural Sciences 2004). This report recalibrates Bomford's (2003) model for mammals and birds and Bomford and Glover's (2004) model for freshwater finfish for use with the updated PC version of Climate (Bureau of Rural Sciences 2004).

The underlying framework for Bomford's (2003) model for mammals and birds and Bomford and Glover's (2004) model for freshwater finfish was developed from analyses of successful and failed introductions of exotic mammals, birds and finfish to Australia. The attributes of the species that established exotic populations were compared to the attributes of species that were released in Australia but which failed to establish. Overall, successfully introduced species had high climate match scores and failed species had low scores and this difference was highly statistically significant. It is assumed that potential future introductions of exotic species in these taxa which have high climate match scores will have a high probability of successfully establishing whereas species with low climate match scores will have a low probability of establishing.

The approach taken with mammals, birds and fish was not possible for exotic reptiles and amphibians because too few exotic species in these taxa have been introduced to Australia. The alternative approach taken for these taxa by Bomford et al. (2005) was to analyse the attributes of exotic reptiles and amphibians introduced to Britain, Florida and California. A model was then developed based on the assumption that the results of these analyses of overseas introductions of exotic reptiles and amphibians are would also apply to future introductions of species in these taxa to Australia. Because this assumption is untested, and because assumptions made in calibrating the model for Australian conditions are also untested, predictions made by Bomford et al.'s (2005) model may be less reliable than predictions made by Bomford's (2003) model for mammals and birds or Bomford and Glover's (2004) model for freshwater finfish. Therefore this report adapts Bomford's (2003) mammal and bird model for use with reptiles and amphibians. It is proposed that exotic reptiles and amphibians proposed for introduction to Australia be assessed using both models. If both models predict an equivalent level of risk, then that results may be more robust than the result taken from Bomford et al.'s (2005) model alone. If the two models predict different levels of risk, a precautionary approach would accept the higher level of risk.

2. CLIMATE software

CLIMATE software contains data for 16 climate variables (Table 1) for approximately 8000 meteorological stations outside Australia. Climate data from meteorological stations that fall within the overseas range of a species (outside of Australia) are used as input data for that species. Australia is divided into 2795 grid cells using a spatial resolution of 0.5^{o} (latitude × longitude), and the value of each of the 16 climate variables was estimated at each grid cell using long-term data from meteorological stations in Australia (Nix 1986). For each species, the number of grid cells allocated to each climate matching class is a measure of Australia's land area in that climate matching class. The PC version of CLIMATE produces different outputs from the Mac version of CLIMATE. There are two types of analysis available in the PC version of Climate: 'Euclidian' or 'Closest Standard Match'. The PC Closest Standard Match uses the same algorithm as the Mac version of Climate, but the climate match outputs from the two programs differs because the Australian grid surface has been adjusted in the PC version to more accurately reflect Australian climate conditions.

No climate land grid surface is available in CLIMATE for locations outside Australia. For climate matching to global locations outside Australia, the 16 climate variables are used, but they match to individual meteorological station locations in the selected countries. For each species, the number of meteorological stations allocated to each climate matching class in the selected country gives a measure of the species' overall climate match to that country.

Table 1. Climate variables used in CLIMATE.

16 climate variables used in CLIMATE
Average annual rainfall
Mean annual temperature
Coefficient of variation of monthly rainfall
Minimum temperature of coolest month
Mean temperature of coolest quarter
Rainfall of driest month
Rainfall of driest quarter
Rainfall of coolest quarter
Rainfall of warmest quarter
Average temperature range
Mean temperature of driest quarter
Mean temperature of wettest quarter
Maximum temperature of warmest month
Mean temperature of warmest quarter
Rainfall of wettest month
Rainfall of wettest quarter

3. Recalibrated climate matches for bird and mammal establishment scores

3.1 Climate matching data: comparisons and selection

Bomford (2003) used the Mac version of CLIMATE to conduct climate matches for exotic mammals and birds introduced to Australia. In this section the results of three types of CLIMATE analyses are compared (all conducted with all 16 climate variables from Table 1 included):

1. Euclidian analyses using the PC version of CLIMATE
2. Closest Standard Match analyses using the PC version of CLIMATE
3. Closest Standard Match analyses using the Mac version of CLIMATE

The purpose of this comparison is to see if the PC version of CLIMATE gives as good discrimination between climate match scores for successful versus failed exotic mammals and birds introduced to Australia and to select the best PC CLIMATE analysis type to use in the mammal and bird risk assessment model.

3.2 Analyses

Student's t-tests are used to determine whether the difference between two data sets is statistically significant. T-values ≤ 0.05 are statistically significant, values ≤ 0.01 are highly significant and values ≤ 0.001 are very highly significant. An assumption required for the t-test is that the data are normally distributed. While this assumption is not always strictly met by all the data in this report, the statistical significance levels of all the test results used in the risk assessment models are so high that transforming the data into normal distributions would have been most unlikely to have changed any of the conclusions.

Bomford (2003) presented data on 24 successful and 18 failed introductions of exotic mammal species to Australia. Long (2003) listed an additional five species of exotic mammal that are thought to have been released in Australia and failed to establish:

- House shrew *Suncus murinus*
- Grey mongoose *Herpestes edwardsi*
- Golden hamster *Mesocricetus auratus*
- Stoat (ermine) *Mustela erminea*
- Weasel *Mustela nivalis*.

These five extra mammal species are included in the analysis results presented in Tables 2, 3, 5 and 6 and Figures 1–5 of this report. Long (2003) further listed the small Indian mongoose *Herpestes auropunctatus* as having failed to establish in Australia, but this species was included by Bomford (2003) as the Indian grey mongoose *H. javanicus*, and so it is not included as an additional species in this report.

3.3 Results

In Appendix A, Tables A1–A6 present the climate match results for exotic mammals introduced to Australia, using the three alternative types of CLIMATE analyses. In Appendix B, Tables B1–B6 present the climate match results for exotic birds introduced to Australia. In Appendix C, Tables C1–C6 present the climate match results for exotic mammals and birds (combined) introduced to Australia.

3.3.1 Successful versus failed exotic mammals

Table 2 presents the results of t-tests comparing the climate match scores for successful and failed exotic mammals introduced to Australia for the three alternative types of CLIMATE analyses. All three types of analysis give high levels of statistical significance, indicating that climate matching gives good statistical discrimination between successful and failed introductions of exotic mammals.

Table 2. T-test results (P = probability scores[1]) comparing climate match scores for successful and failed exotic mammals introduced to Australia.
All P values ≤ 0.05 are statistically significant. For PC Euclidian all levels between Σ8 and Σ3 are statistically significant.

For PC Closest Standard Match all levels between Σ9 and Σ3 are statistically significant.
For Mac all levels between 10 and Σ3 are statistically significant. For all three types of analysis the best discrimination between successful and failed mammals occurs around the middle range (Σ6– Σ7) for the cumulative climate match scores (which is equivalent to Σ40–Σ50% in the classification used in the Mac version of CLIMATE).

CLIMATE analysis type	**Cumulative climate match level[2]**								
	10	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**
PC Euclidian	0.082	0.123	0.003	8E-04	0.002	0.007	0.012	0.027	0.062
PC Closest Standard Match	0.367	0.004	0.002	9E-04	8E-04	0.002	0.01	0.037	0.071
Mac	0.004	0.004	0.001	6E-04	7E-04	0.003	0.028	0.021	0.172

[1]Where a *P* value is presented in the form XE-0Y, Y is the number of zeros following the decimal point, for example 7.09E-05 = 0.00000709.
[2] See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Inclusion of the five additional failed mammal species listed by Long (2003) gave t-test results which are more highly significant than the equivalent analyses excluding these five species. Appendix E Table E1 presents t-test results comparing climate match scores for successful and failed exotic mammals introduced to Australia excluding these five species for comparison with Table 2 above which includes the five extra species. For example, for the PC Closest Standard Match at the Σ6 level, the t-test result with the five failed mammals included is $P<0.0008$ (very highly significant) in Table 2, compared to a t-test result of $P<0.002$ (highly significant). This increase in statistical significance with the inclusion of these extra five species provides stronger scientific validation for the use of Climate matching in the updated Bomford model (Section 6).

3.3.2 Successful versus failed exotic birds

Table 3 presents the results of t-tests comparing the climate match scores for successful and failed exotic birds introduced to Australia for the three alternative types of CLIMATE analyses.

All three types of analysis give high levels of statistical significance, indicating that climate matching gives good statistical discrimination between successful and failed exotic birds.

Table 3. T-test results (*P* = probability scores) comparing climate match scores for successful and failed exotic birds introduced to Australia. Scores for each climate match level are summed to give cumulative totals. All *P* values ≤ 0.05 are statistically significant. For PC Euclidian all levels between Σ9 and Σ2 are statistically significant. For PC Closest Standard Match all levels between Σ9 and Σ2 are statistically significant. For Mac all levels between 10 and Σ3 are statistically significant (which is equivalent to Σ10%–Σ80% in the classification used in the Mac version of CLIMATE – see Appendix D, Table D1). For all three types of analysis high levels of discrimination between successful and failed birds occurs around the Σ4–Σ7 range for the cumulative climate match scores.

CLIMATE analysis type	**Cumulative climate match level***								
	10	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**
PC Euclidian	n/a	0.009	0.014	0.007	0.007	0.005	0.004	0.007	0.02
PC Closest Standard Match	0.489	0.01	0.008	0.005	0.005	0.003	0.001	0.002	0.04
Mac	0.009	0.004	0.002	0.002	0.002	0.002	0.002	0.017	0.089

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

3.3.3 Comparison of mammals and birds

The next step was to test if the climate match scores for mammals and birds were significantly different from each other. If not, it is statistically valid to combine the two data sets, which increases the sample size, which in turn gives more power to the statistical analyses.

Tables 4 and 5 present the results of t-tests comparing the climate match scores for exotic species introduced to Australia for the three alternative types of CLIMATE analyses: successful mammals compared to successful birds, and failed mammals compared to failed birds. All three types of analysis give non-significant levels of statistical significance at all levels of climate matching (54 tests) except for two isolated scores at the 10 and Σ9 levels for Mac analyses for failed introductions. These results indicate that there is no justification for running separate analyses for birds and mammals and that the mammal and bird climate match results can be combined into a single data set.

Table 4. T-test results (*P* = probability scores) comparing climate match scores for successful exotic mammals introduced to Australia to successful exotic birds introduced to Australia, and comparing the climate match scores for failed exotic mammals introduced to Australia to failed exotic birds introduced to Australia for the three alternative types of CLIMATE analyses. All *P* values ≤ 0.05 are statistically significant. For all three types of analysis all levels between 10 and Σ2 (ie all levels of matching) are statistically not significant.

CLIMATE analysis type	**Cumulative climate match level***								
	10	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**
PC Euclidian	0.097	0.171	0.264	0.498	0.335	0.270	0.258	0.212	0.168
PC Closest Standard Match	0.442	0.268	0.326	0.466	0.447	0.317	0.128	0.118	0.074
Mac	0.417	0.33	0.342	0.401	0.309	0.188	0.131	0.358	0.125

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Table 5. T-test results (P = probability scores) comparing the climate match scores for failed exotic mammals introduced to Australia to failed exotic birds introduced to Australia for the three alternative types of CLIMATE analyses.
All P values ≤ 0.05 are statistically significant. For all PC analyses all levels are statistically not significant. For Mac analyses only the 10 and Σ9 levels are statistically significant.

CLIMATE analysis type	Cumulative climate match level*								
	10	Σ9	Σ8	Σ7	Σ6	Σ5	Σ4	Σ3	Σ2
PC Euclidian	n/a	0.229	0.097	0.096	0.135	0.307	0.480	0.405	0.365
PC Closest Standard Match	0.431	0.129	0.101	0.104	0.126	0.198	0.329	0.393	0.430
Mac	0.048	0.023	0.059	0.129	0.145	0.243	0.398	0.291	0.129

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

In Appendix C, Tables C1–C6 present the climate match results for combined data sets for exotic mammals and birds introduced to Australia, using the three alternative types of CLIMATE analyses

3.3.4 Successful versus failed exotic birds and mammals combined

Table 6 presents the results of t-tests on climate match scores for combined data on mammals and birds introduced to Australia. Climate match scores are compared for successful versus failed introductions for the three alternative types of CLIMATE analyses**:**

- For PC Euclidian analyses, all levels between Σ8–Σ2 are statistically significant. Level Σ7 has the highest discrimination between successful and failed species.
- For PC Closest Standard Match analyses, all levels between Σ9–Σ2 are statistically significant. PC Closest Standard Match Σ7–Σ5 levels all show similar very highly significant differences between successful and failed species. All three levels for PC Closest Standard Match are more statistically significant than any levels using PC Euclidian analyses. Level Σ6 was selected to use in the bird and mammal risk assessment model.
- For Mac analyses, all levels between 10–Σ3 are statistically significant. Σ8–Σ5 levels all show very highly significant differences between successful and failed species — similar to the very high levels of significance found for the PC Closest Standard Match analyses.

While all three types of analysis give high levels of statistical significance in Table 6, indicating that climate matching gives good statistical discrimination between successful versus failed introductions of exotic birds and mammals (combined), PC Closest Standard Match analyses gave higher levels of significance than PC Euclidian analyses. PC Closest Standard Match analyses at the Σ6 level were selected to use in the bird and mammal risk assessment model.

3.4 Cut-off thresholds

For each of the three types of CLIMATE analysis, the results for both the Σ6 and Σ7 levels were categorised into six levels, ranging from Extreme for the highest level of climate match down to Very Low. The cut-off thresholds for these categories were selected to give the best possible discrimination between successful and failed introduced species. The number of species in each of the categories is presented for the Σ6 and Σ7 levels for each of the three types of climate match analyses (Figures 1–3). These graphs show clearly that while successfully introduced species have higher climate matches than failed introduced species in all the analyses conducted, there is always considerable overlap between the two groups. The PC Closest Standard Match analyses give the best discrimination between the successful and failed mammals and birds introduced to Australia (Figure 2) and this type of analysis at the Σ6 level (Figure 2a) was selected to use in the risk assessment model for mammals and birds.

Table 6. Results of t-tests (*P* = probability scores[1]) on climate match scores for combined data on mammals and birds introduced to Australia.
Climate match scores are compared for successful versus failed introductions for the three alternative types of CLIMATE analyses. All *P* values ≤ 0.05 are statistically significant.
For PC Euclidian all levels between Σ8 and Σ2 are statistically significant.
For PC Closest Standard Match all levels between Σ9 and Σ2 are statistically significant.
For Mac all levels between 10 and Σ3 are statistically significant.

CLIMATE analysis type	Cumulative climate match level[2]								
	10	Σ9	Σ8	Σ7	Σ6	Σ5	Σ4	Σ3	Σ2
PC Euclidian	0.0614	0.0811	0.0003	9.37E-05	0.0002	0.0002	0.0002	0.0007	0.0040
PC Closest Standard Match	0.4723	0.0003	0.0001	5.32E-05	6.26E-05	6.54E-05	0.0002	0.0004	0.0074
Mac	0.0005	0.0003	4.61E-05	2.03E-05	2.91E-05	7.09E-05	0.0002	0.0012	0.4283

[1]Where a *P* value is presented in the form XE-0Y, Y is the number of zeros following the decimal point, for example 7.09E-05 = 0.00000709.
[2]See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

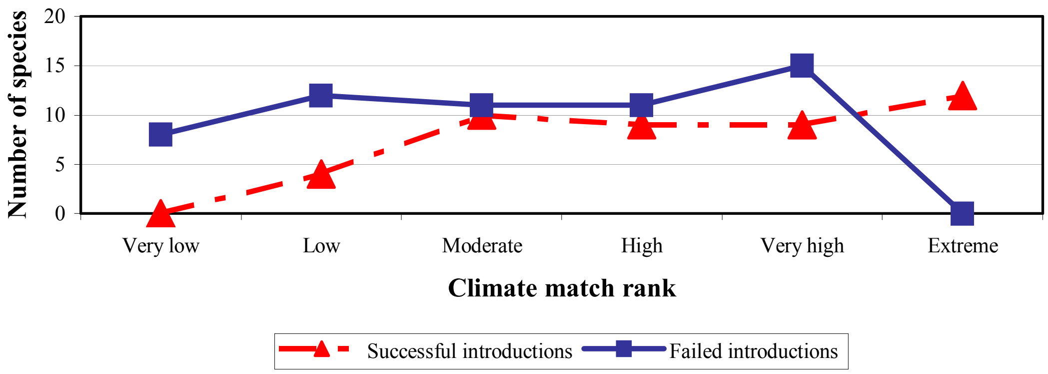

Figure 1a. PC Euclidian analyses (Σ6 level): number of species in each climate match rank, compared for successful and failed exotic mammals and birds (combined) introduced to Australia. (Data in Appendix C, Tables C1 and C2). Cut-off thresholds for Climate Match Scores for each level are:

Climate Match Score	Climate Match Rank	Climate match PC Euclidian (Σ6 level)
6	Extreme	≥ 2750
5	Very High	2000–2749
4	High	1200–1999
3	Moderate	800–1199
2	Low	200–799
1	Very Low	< 200.

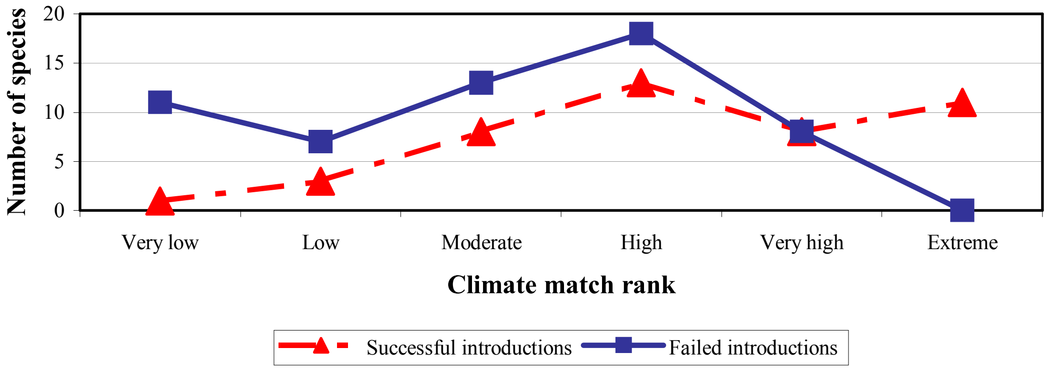

Figure 1b. PC Euclidian analyses (Σ7 level): number of species in each climate match rank, compared for successful and failed exotic mammals and birds (combined) introduced to Australia (Data in Appendix C, Tables C1 and C2). Cut-off thresholds for Climate Match Scores for each level are:

Climate Match Score	Climate Match Rank	Climate match PC Euclidian (Σ7 level)
6	Extreme	≥ 2600
5	Very High	≥ 1500
4	High	≥ 700
3	Moderate	≥ 400
2	Low	≥ 100
1	Very Low	< 100.

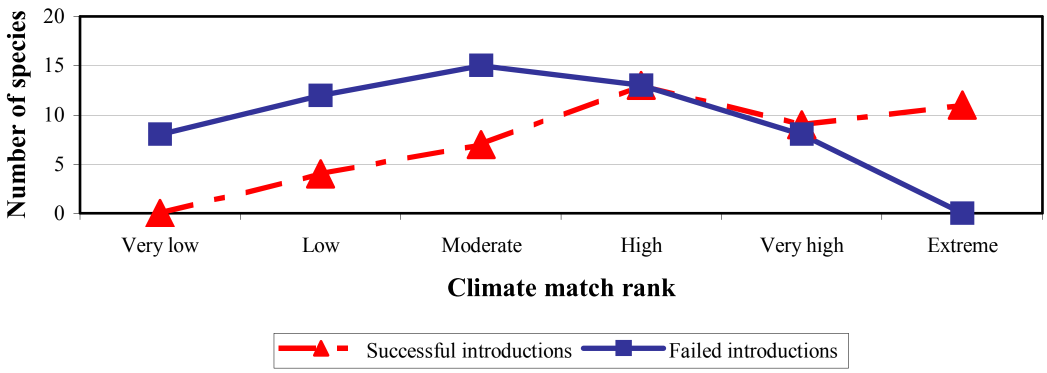

Figure 2a. PC Closest Standard Match analyses (Σ6 level): number of species in each climate match rank, compared for successful and failed exotic mammals and birds (combined) introduced to Australia (Data in Appendix C, Tables C3 and C4).
Cut-off thresholds for Climate Match Scores for each level are:

Climate Match Score	Climate Match Rank	Climate match PC Closest Standard Match (Σ6 level)
6	Extreme	≥ 2700
5	Very High	≥ 1700
4	High	≥ 900
3	Moderate	≥ 600
2	Low	≥ 100
1	Very Low	< 100.

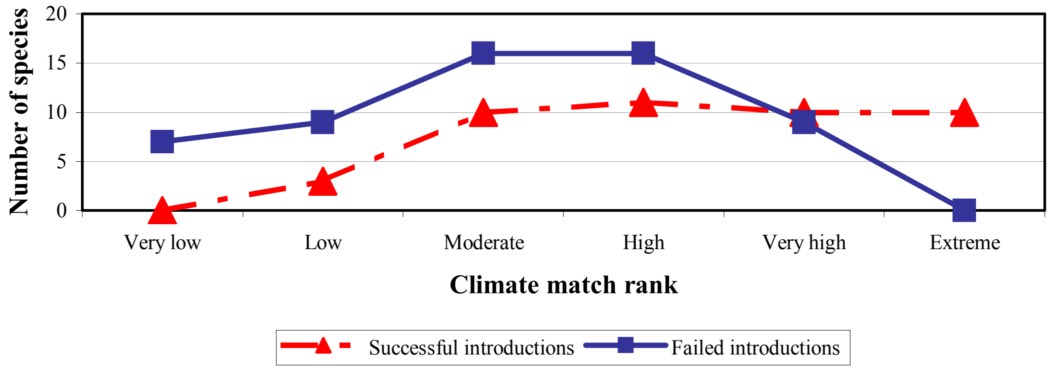

Figure 2b. PC Closest Standard Match analyses (Σ7 level): number of species in each climate match rank, compared for successful and failed exotic mammals and birds (combined) introduced to Australia (Data in Appendix C, Tables C3 and C4). Cut-off thresholds for Climate Match Scores for each level are:

Climate Match Score	Climate Match Rank	Climate match PC Closest Standard Match (Σ7 level)
6	Extreme	≥ 2200
5	Very High	900–2199
4	High	550–899
3	Moderate	200–549
2	Low	10–199
1	Very Low	< 10.

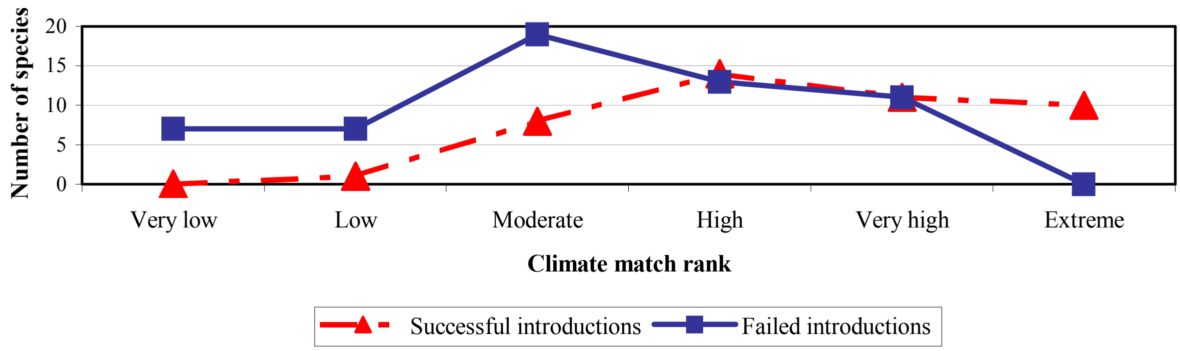

Figure 3a. Mac analyses (Σ6 level): number of species in each climate match rank, compared for successful and failed exotic mammals and birds (combined) introduced to Australia (Data in Appendix C, Tables C5 and C6).
Cut-off thresholds for Climate Match Scores for each level are:

Climate Match Score	Climate Match Rank	Climate match Mac Closest Standard Match (Σ6 level)
6	Extreme	≥ 2780
5	Very High	≥ 2000
4	High	≥ 1000
3	Moderate	≥ 600
2	Low	≥ 200
1	Very Low	< 200.

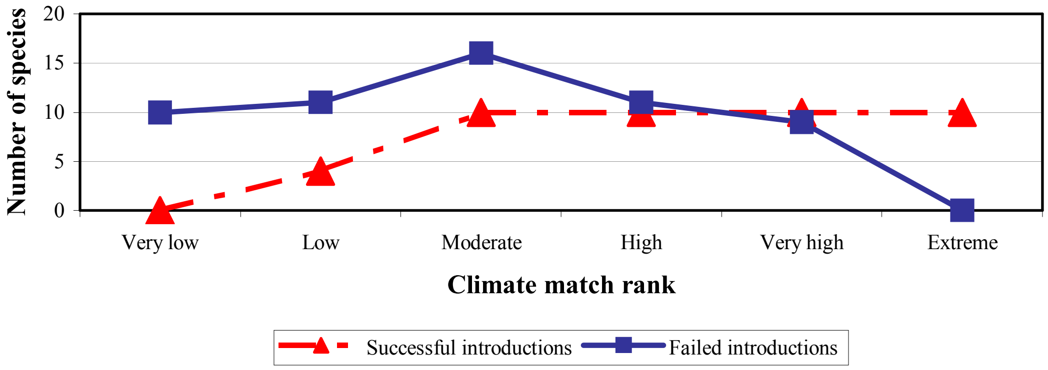

Figure 3b. Mac analyses: number of species in each climate match rank (Σ7 level), compared for successful and failed exotic mammals and birds introduced to Australia. Cut-off thresholds for Climate Match Scores for each level are:

Climate Match Score	Climate Match Rank	Climate match Mac Closest Standard Match (Σ7level)
6	Extreme	≥ 2700
5	Very High	1400–2699
4	High	900–1399
3	Moderate	500–899
2	Low	100–499
1	Very Low	< 100.

3.5 Inputs from places with few meteorological stations in the CLIMATE database

CLIMATE software contains data for approximately 8000 meteorological stations outside Australia but some areas of the world are not well represented. Where there are few meteorological stations in the overseas range of a species, CLIMATE may underestimate the climate match to Australia for that species. Tests were conducted to assess the degree to which this occurs (Appendix F, Table F1). Five overseas locations were selected, and climatically matched to Australia. For each location, meteorological stations were randomly removed from the input data file and then the culled input file was re-matched to Australia. This was repeated for each location, successively removing more and more input meteorological stations for each analysis.

The results were variable because data from different input meteorological stations have differing levels of influence on the climate match output. But generally the level of climate match showed little decline if the number of points was 50 or more, but dropped at an increasing rate below 50, and then dropped steeply when the number of input points was 12 or fewer. The variable results make it difficult to draw any generalised rule about how to correct for underestimated levels of climate match for species which have few meteorological stations in their overseas range (Appendix F, Table F1). If, however, the input area has 12 or fewer meteorological stations, then CLIMATE is likely to considerably underestimate the climate match to Australia. In this case, it is advisable to increase the climate match score by one increment in Step 3 of the directions for use of the newly calibrated model for establishment risk assessment for mammals and birds (Section 6). For example, if a mammal's overseas range had only five meteorological stations, and the sum of the values for the five highest match classes to Australia equalled 504 (ie Σ6 = 504), then this would give a Climate Match Score = 2 + 1 = 3.

4. Recalibrated establishment risk assessments for birds and mammals

Bomford's (2003) risk assessment model used six variables to assess the risk an exotic species would establish in Australia (score range in brackets)

1. Degree of climate match between species overseas range and Australia (1–6)
2. Exotic population established overseas (0–4)
3. Taxonomic Class (0–1)
4. Non-migratory behaviour (0–1)
5. Diet (0–1)
6. Lives in disturbed habitat (0–1)

Bomford (2003) also acknowledged that a species' overseas geographic range size contributed to the risk that an exotic species will establish although this variable was not included in the establishment risk component of Bomford's model but only in the pest risk assessment component.

In Appendix G, Table G1 presents data for assessing establishment risk for exotic mammals and birds introduced to Australia for each of Bomford's (2003) six variables plus data for overseas range size. Climate match outputs from PC Closest Standard Match (Σ6 level) are used instead of the Mac climate match outputs used by Bomford (2003). These Closest Standard Match outputs are converted to Climate Match Scores (1–6) using the cut-off thresholds presented in Figure 2a. The data for overseas geographic range sizes are converted to Overseas Range Size Scores (0–2) based on the analyses and cut-off thresholds presented in Appendix H, Figure H2.

4.1 Comparisons of risk scores

Table 7 presents a summary of the results averaged for introduced birds, mammals, and combined mammals plus birds (data presented in Appendix G, Table G1). The averages presented in Table 7 indicate that the scores for diet, habitat and migration differ little between successful and failed species. It therefore seemed possible that deleting these three factors from the model would make it simpler without much reducing the model's ability to discriminate between successful and failed introduced species. Bomford (2003) pointed out that although many ecologists consider these factors influence establishment success, supporting data is unavailable. Two types of Establishment Risk Scores were calculated: (1) with seven factors, (2) with only four factors, excluding scores for diet, habitat and migration (Appendix G, Table G2). Figure 4 presents Establishment Risk Scores for mammals and birds (combined) introduced to Australia based on seven risk factors. Figure 5 presents Establishment Risk Scores for mammals and birds (combined) introduced to Australia based on only four risk factors. Both types of Establishment Risk Score showed very highly significant differences between successful and failed introduced species, and the inclusion of the scores for diet, habitat and migration did not increase the statistical significance (Table 7). However, expert opinion in published ecological papers, suggests that being a dietary and/or habitat generalist is likely to enhance establishment success (Bomford 2003). Migratory species have been shown to have a significantly lower establishment success than non-migratory species for mammals introduced to Australia (Forsyth et al. 2004) and for birds introduced to New Zealand (Veltman et al. 1996) and birds introduced elsewhere around the world (Bomford 2003). Further, historical introductions of exotic vertebrates to Australia were not a random set of species – nearly all were dietary and habitat generalists. Therefore a statistically significant difference for these two factors for successful and failed mammals and birds introduced to Australia might be unlikely even if these factors do influence establishment success (Bomford 2003). The tests would have had little power because of the small sample sizes of dietary and habitat specialists. Therefore, it may still be worthwhile to include these three factors in the model despite their lack of a statistical effect in the Australian data.

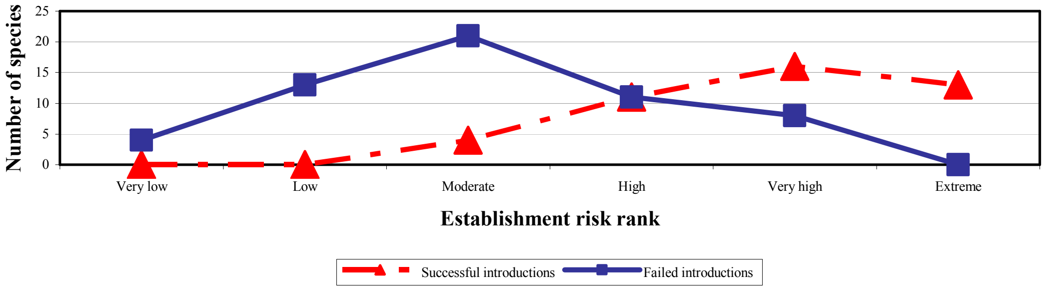

Figure 4. Number of species in each Establishment Risk Rank for mammals and birds (combined) introduced to Australia based on seven risk factors.

Climate matches from Closest Standard Match on PC (Σ6 level) are converted to a Climate Match Score using cut-off thresholds presented in Figure 2a above). The Climate Match Score plus six other risk scores presented in Appendix G, Table G1: (1. Overseas Range Size Score based on score range 0–2 (ie 3-point score in Appendix H, Table H3); 2. Taxonomic Score; 3. Exotic Population Established Overseas Score; 4. Migratory Score; 5. Diet Score; 6. Habitat Score) are summed to calculate the Establishment Risk Score. Cut-off thresholds for converting Establishment Risk Scores to Establishment Risk Ranks are presented below:

Establishment Risk Rank	Establishment Risk Score
Extreme	≥ 14
Very high	12–13
High	10–11
Moderate	7–9
Low	5–6
Very low	≤ 4

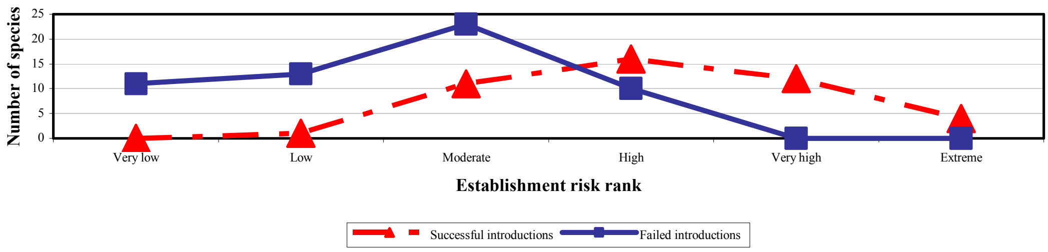

Figure 5. Number of species in each Establishment Risk Rank for mammals and birds (combined) introduced to Australia based on four risk factors.

Climate matches from Closest Standard Match on PC (Σ6 level) are converted to a Climate Match Score using cut-off thresholds presented in Figure 2a above). The Climate Match Score plus three other risk scores presented in Appendix G, Table G2: (1. Overseas Range Size Score based on score range 0–2 (ie 3-point score in Appendix H, Table H3); 2. Taxonomic Score; 3. Exotic Population Established Overseas Score) are summed to calculate the Establishment Risk Score. Cut-off thresholds for converting Establishment Risk Scores to Establishment Risk Ranks are presented below:

Establishment Risk Rank	Establishment Risk Score
Extreme	13
Very High	11–12
High	9–10
Moderate	6–8
Low	4–5
Very Low	≤ 3

Table 7. Mean scores for seven risk factors for establishment success and mean establishment risk scores for exotic birds, mammals, and combined mammals plus birds introduced to Australia, and t-test results (*P* = probability scores[1]) for comparisons between successfully established and failed species. All *P* values ≤ 0.05 are statistically significant.

Function	**Climate Match Score[2]**	**Exotic population overseas score**	**Taxon score**	**Migratory score**	**Diet score**	**Habitat score**	**Overseas range size score (3-point)**	**Establish-ment Risk Score: seven factors**	**Establish-ment Risk Score: four factors[3]**
Mean successful mammals	4.3	3.5	1	0.9	1	0.9	1.1	12.8	9.96
Mean successful birds	4.4	3.7	0	0.6	1	1	1.2	11.9	9.30
Mean successful mammals plus birds	4.4	3.6	n/a	0.8	1	1.0	1.2	12.4	9.66
Mean failed mammals	2.8	1.4	1	0.7	0.9	0.7	0.7	8.3	5.96
Mean failed birds	3.1	2.0	0	0.7	1	0.8	0.9	8.4	5.88
Mean failed mammals plus birds	3.0	1.6	n/a	0.7	1.0	0.8	0.8	8.3	5.60
T-test successful mammals vs failed mammals	0.0002	8.57E-06	n/a	0.055018	0.07	0.03	0.0135	1.26E-06	4.98E-08
T-test successful birds vs failed birds	0.0003	0.000161	n/a	0.2175	n/a	0.015	0.0010	1.17E-06	3.44E-07
T-test successful mammals plus birds vs failed mammals plus birds	2.8E-05	1.9E-08	n/a	0.27361	0.1067	0.003	0.0002	3.75E-12	1.01E-12

[1]Where a *P* value is presented in the form XE-0Y, Y is the number of zeros following the decimal point, for example 7E-04 = 0.00007.
[2]Based on Σ6 climate match Closest Standard Match values converted to Climate Match Scores using the cut-off thresholds presented in Figure 2a.
[3]Excluding scores for diet, habitat and migration.

4.2 Establishment Risk Scores based on Mac CLIMATE scores.

Appendix I, Table I1 presents climate match data for the Mac version of CLIMATE with the results incorporated into an Establishment Risk Score according to the formula published by Bomford (2003). Figure 6 presents the number of species (combined birds and mammals introduced to Australia) in each of the risk categories using Bomford's (2003) model. Figure 7 presents the same data but with the addition of a component score representing overseas range size which was excluded from Bomford's original (2003) model. A comparison of Figures 6 and 7 with Figures 4 and 5 above indicates that the model based on the PC version of CLIMATE gives as good or better discrimination between successful and failed mammals and birds introduced to Australia as the previously published model using the Mac version of CLIMATE.

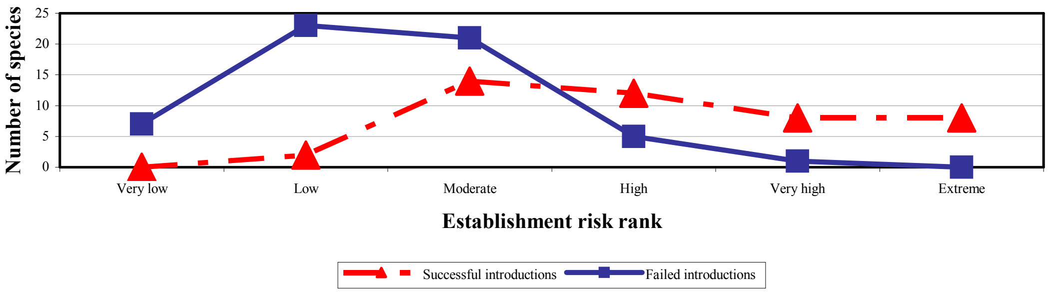

Figure 6. Number of species in each Establishment Risk Rank for mammals and birds (combined) introduced to Australia calculated using six risk factors excluding overseas range size and using six Establishment Risk Ranks. Climate matches from the Mac version of CLIMATE are converted to a Climate Match Score from the formula presented in Bomford's (2003) risk assessment model based on the weighted values for climate match outputs in the Σ10%–Σ50% range. The Climate Match Score, plus five other risk factors (excluding overseas range size) presented in Appendix I, Table I1, are summed to calculate the Establishment Risk Score. Cut-off thresholds for converting Establishment Risk Scores to Establishment Risk Ranks are presented below:

Establishment Risk Rank	Establishment Risk Score
Extreme	14
Very high	13
High	12
Moderate	9–11
Low	5–8
Very low	≤ 4

4.3 Adjusting the Establishment Risk Ranks to match VPC Guidelines

Establishment Risk Scores based on seven risk factors, including Climate Match Scores calculated from PC CLIMATE Closest Standard Match (Σ6 level) outputs, were selected as the most appropriate to use in the risk assessment model (Figure 4). However, the cut-off thresholds presented in Figure 4 create six Establishment Risk Ranks. The Vertebrate Pests Committee Guidelines (Natural Resource Management Standing Committee and Vertebrate Pests Committee 2004) assess risk based on only four levels of Establishment Risk Rank. Therefore new cut-off thresholds were selected to create four levels as presented in Figure 8. Figure 8 shows good separation of successful vs failed species at the four levels of establishment risk, and at the 'Moderate' level, the ratio of the number of species established to the number that failed to establish, is similar to that obtained for a Moderate Establishment Risk Rank in both the re-calibrated fish risk assessment model (Section 7.3, Figure 14) and the reptile and amphibian risk assessment model (Section 9.2, Figure 17).

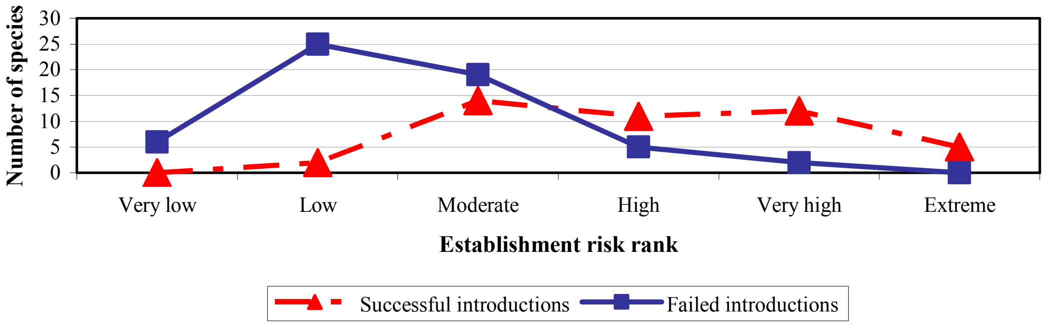

Figure 7. Number of species in each Establishment Risk Rank for mammals and birds (combined) introduced to Australia calculated using seven risk factors including overseas range size and using six Establishment Risk Ranks. Climate matches from the Mac version of CLIMATE are converted to a Climate Match Score from the formula presented in Bomford's (2003) risk assessment model based on the weighted values for Climate outputs in the Σ10%–Σ50% range. The Climate Match Score, plus six other risk factors presented in Appendix I, Table I1 (including overseas range size, 3-point score), are summed to calculate the Establishment Risk Score. Cut-off thresholds for converting Establishment Risk Scores to Establishment Risk Ranks are presented below:

Establishment Risk Rank	Establishment Risk Score
Extreme	16
Very high	14–15
High	13
Moderate	10–12
Low	5–9
Very low	≤ 4

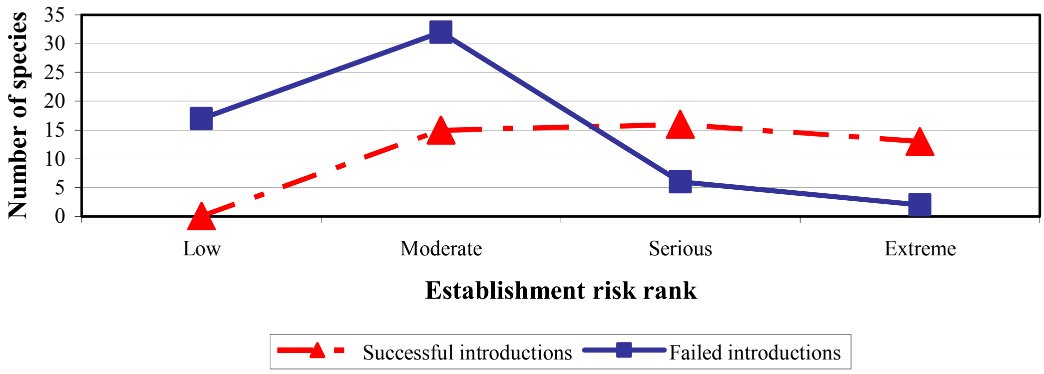

Figure 8. Number of species in each Establishment Risk Rank for mammals and birds (combined) introduced to Australia calculated using seven risk factors and four Establishment Risk Ranks. Climate matches from PC CLIMATE Closest Standard Match (Σ6 level) are converted to Climate Match Scores using the cut-off thresholds presented in Figure 2a). The Climate Match Score plus six other risk scores presented in Appendix G, Table G1: (1. Overseas Range Size Score based on score range 0–2 (ie 3-point score in Appendix H, Table H3); 2. Taxonomic Score; 3. Exotic Population Established Overseas Score; 4. Migratory Score; 5. Diet Score; 6. Habitat Score) are summed to calculate the Establishment Risk Score. Cut-off thresholds for converting Establishment Risk Scores to Establishment Risk Ranks for four levels are presented below:

Establishment Risk Rank	Establishment Risk Score
Extreme	≥ 14
Serious	12–13
Moderate	7–11
Low	≤ 6

For comparison, the Establishment Risk Ranks presented in Figure 5, also using PC CLIMATE Closest Standard Match (Σ6 level) Climate Match Scores, but only using three other risk factors, are presented in Figure 9. This Figure also shows good separation of successful vs failed species at the four levels of establishment risk, and at the 'Moderate' level, the ratio of the number of species established to the number that failed to establish, is similar to that obtained for a Moderate Establishment Risk Rank in both the re-calibrated fish risk assessment model (Section 7.3, Figure 14) and the reptile and amphibian risk assessment model (Section 9.2, Figure 17). Therefore, this alternative version of the model could be used to do quicker lower-cost assessments if required.

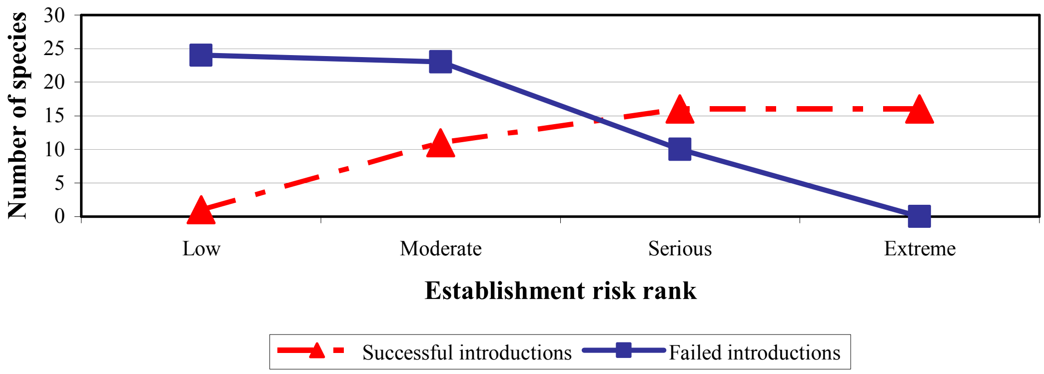

Figure 9. Number of species in each Establishment Risk Rank category for mammals and birds (combined) introduced to Australia calculated using four risk factors and four Establishment Risk Ranks. Climate matches from PC CLIMATE Closest Standard Match (Σ6 level) are converted to Climate Match Scores using cut-off thresholds presented in Figure 2a). The Climate Match Score (1–6) plus the three other risk scores presented in Appendix G, Table G2: (1. Overseas Range Size Score based on score range 0–2 (ie 3-point score in Appendix H, Table H3); 2. Taxonomic Score (0–1); 3. Exotic Population Established Overseas Score (0–4)) are summed to calculate the Establishment Risk Score (1–13). Cut-off thresholds for converting Establishment Risk Scores to Establishment Risk Ranks for levels are presented below:

Establishment Risk Rank	Establishment Risk Score
Extreme	11–13
Serious	9–10
Moderate	6–8
Low	≤ 5

5. Recalibrated climate matches for bird and mammal pest scores

Bomford (2003) used the Mac version of CLIMATE to calibrate exotic bird and mammal species' pest risk scores. This section compares climate match Closest Standard Match analyses for PC CLIMATE and Mac CLIMATE to enable the pest risk scores to be recalibrated using PC CLIMATE Closest Standard Match analyses.

Table 8 presents climate match outputs for Closest Standard Match analyses compared for the PC and Mac versions of CLIMATE, averaged for all exotic birds and mammals introduced to Australia. The PC version of CLIMATE gives lower output scores at all levels of match. The values in Table 8 were used to recalibrate Bomford's (2003) model for assessing the risk that exotic mammals and birds could become agricultural or environmental pests if they established in Australia. The nearest equivalent match level selected was one increment lower for the PC version compared to the Mac version. For example, if Bomford's (2003) model referred to 'the number of grid squares within a 20% climate match' (ie the highest two climate match classes) using the Mac version of CLIMATE, this would be considered equivalent to the 'the number of grid squares within a Σ8 level of climate match' (ie the highest three climate match classes) using the PC version of CLIMATE. The amended bird and mammal pest risk assessment model, incorporating this new PC CLIMATE match scoring, is presented in Section 6, Stage C.

Table 8. Climate match output cumulative scores compared for Closest Standard Match analyses on PC and Mac versions of CLIMATE. The scores are averages for all exotic birds and mammals (n = 101) introduced to Australia. The PC version of CLIMATE gives lower average output scores at all levels of match

PC Closest Standard Match	**10**	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**
	0.15	39.9	326	810	1209	1559	1907	2300	2641
Mac Closest Standard Match	**Σ10 %**	**Σ20 %**	**Σ30 %**	**Σ40 %**	**Σ50 %**	**Σ60 %**	**Σ70 %**	**Σ80 %**	**Σ90 %**
	21.8	232	687	1116	1488	1766	2206	2613	2791
Match level	Highest matches→ includes moderate matches→ includes low matches								

6. Updated bird and mammal risk assessment model

The model presented in this section is updated from Bomford (2003) to incorporate the changes presented in Sections 3, 4 and 5 of this report. The wording of some questions has also been modified to enhance clarity, following suggestions made by Win Kirkpatrick and Marion Massam (Department of Agriculture and Food, Western Australia) who have used Bomford's (2003) model to conduct risk assessments on over 100 species.

Stage A: Risks posed by captive or released individuals

A1. Risk to people from individual escapees (0–2)

Assess the risk that individuals of the species could harm people. (NB, this question only relates to aggressive behaviour shown by escaped or released individual animals. Question C11 addresses the risk of harm from aggressive behaviour if the species establishes a wild population).

Aggressive behaviour, size, plus the possession of organs capable of inflicting harm, such as sharp teeth, claws, spines, a sharp bill, or toxin-delivering apparatus may enable individual animals to harm people. Any known history of the species attacking, injuring or killing people should also be taken into account. Assume the individual is not protecting nest or young. Choose one:

- animal that sometimes attacks when unprovoked and is capable of causing serious injury (requiring hospitalisation) or fatality = 2
- animal that can make unprovoked attacks causing moderate injury (requiring medical attention) or severe discomfort but is highly unlikely (few if any records) to cause serious injury (requiring hospitalisation) if unprovoked OR animal that is unlikely to make an unprovoked attack but which can cause serious injury (requiring hospitalisation) or fatality if cornered or handled = 1
- all other animals posing a lower risk of harm to people (ie animals that will not make unprovoked attacks causing injury requiring medical attention, and which, even if cornered or handled, are unlikely to cause injury requiring hospitalisation) = 0.

A2. Risk to public safety from individual captive animals (0–2)

Assess the risk that irresponsible use of products obtained from captive individuals of the species (such as toxins) pose a public safety risk (excluding the safety of anyone entering the animals' cage/enclosure or otherwise coming within reach of the captive animals)

- nil or low risk (highly unlikely or not possible) = 0
- moderate risk (few records and consequences unlikely to be fatal) = 1
- high risk (feasible and consequences could be fatal) = 2.

Public Safety Risk Score

A species' Public Safety Risk Score = A = the sum of its scores for A1 and A2.

Public Safety Risk Rank

A species' Public Safety Risk Score is converted to a Public Safety Risk Rank using the following cut-off thresholds:

Public Safety Risk Rank	Risk to Public Safety Score
Not dangerous	A = 0
Moderately dangerous	A = 1
Highly dangerous	A ≥ 2

Stage B: Probability escaped or released individuals will establish a free-living population

B1. Climate Match Score (1–6)

Map the selected mammal or bird species' overseas range — including its entire native and exotic (excluding Australia) ranges over the past 1000 years. Use PC CLIMATE (Bureau of Rural Sciences 2004) and select:

- '*worlddata_all.txt*' as the world data location
- '*cntry92.shp*' as the shapefile
- all 16 climatic parameters for matching locations (see Table 1)
- Closest Standard Match for the analysis (can take over an hour to run for species with large overseas ranges).

Sum the values for the five highest match classes (ie sum the scores for match classes 10, 9, 8, 7 and 6) = 'Value X'

Convert 'Value X' to a Climate Match Score (1–6) using the following cut-off thresholds:

Climate Match Score		CLIMATE Closest Standard Match Σ6 level (Value X) (sum of highest five match classes)
1	(Very low)	< 100
2	(Low)	100–599
3	(Moderate)	600–899
4	(High)	900–1699
5	(Very high)	1700–2699
6	(Extreme)	≥ 2700

If the input range for a species has 12 or fewer meteorological stations, then it is likely to underestimate the climate match to Australia. If this is the case, it is advisable to increase the climate match score by one increment. For example, if the input range for a species included only five meteorological stations, and the sum of the values for the five highest match classes to Australia equalled 504 (ie 'Value X' = 504), then this would give a Climate Match Score = 2 + 1 = 3.

B2. Exotic Population Established Overseas Score (0–4)

- No exotic population ever established = 0
- Exotic populations only established on small islands less than 50 000 square kilometres (Tasmania is 67 800 square kilometres) = 2
- Exotic population established on an island larger than 50 000 square kilometres or anywhere on a continent (including elsewhere on the land mass where the natural distribution of the animal is if this population is due to human introduction and is geographically separate from the natural range of the species) = 4.

B3. Taxonomic Class Score (0–1)

- Bird = 0
- Mammal, reptile or amphibian = 1.

B4. Migratory Score (0–1)

- Always migratory in its native range = 0
- Non-migratory or facultative migrant in its native range or unknown = 1.

B5. Diet Score (0–1)

- Specialist dependent on a restricted range of foods = 0
- Generalist with a broad diet of many food types or diet unknown = 1.

B6. Habitat Score (0–1)

- Only lives in undisturbed (natural) habitats = 0
- Can live in human-disturbed habitats (including grazing and agricultural lands, forests that are intensively managed or planted for timber harvesting and/or urban–suburban environments) or habitat use unknown = 1.

B7. Overseas Range Size Score (0–2)

Estimate the species overseas range size including current and past 1000 years, natural and introduced range in millions of square kilometres

Overseas Range Size Score	Overseas range size (millions of square kilometres)
2	≥ 70
1	2–69
0	0–1

Establishment Risk Score

A species' Establishment Risk Score = B = the sum of its scores for B1–B7.

Establishment Risk Rank

A species' Establishment Risk Score is converted to an Establishment Risk Rank (Low, Moderate, Serious or Extreme) using the following cut-off thresholds:

Establishment Risk Rank	Establishment Risk Score
Extreme	≥ 14
Serious	12–13
Moderate	7–11
Low	≤ 6

Stage C: Probability an established exotic mammal or bird will become a pest

C1. Taxonomic group (0–4)

- Mammal in one of the orders that have been demonstrated to have detrimental effects on prey abundance and/or habitat degradation (Carnivora, Artiodactyla, Rodentia, Lagomorpha, Perissodactyla and Marsupialia) = 2

AND/OR (Score 4 if affirmative for both these points)

- Mammal in one of the families that are particularly prone to cause agricultural damage (Canidae, Mustelidae, Cervidae, Leporidae, Muridae, Bovidae) = 2
- Bird in one of the taxa that are particularly prone to cause agricultural damage (Psittaciformes, Fringillidae, Ploceidae, Sturnidae, Anatidae and Corvidae) = 2

AND/OR (Score 3 if affirmative for both these points)

- Bird in one of the families likely to hybridise with native species, Anatidae and Phasianidae, and if there are relatives in the same genus among Australian native birds = 1
- Other group = 0.

C2. Overseas range size (0–2)

Estimate the species overseas range size (including current and past 1000 years, natural and introduced range) in millions of square kilometres:

- Overseas geographic range less than 10 million square kilometres = 0
- Overseas geographic range 10–30 million square kilometres = 1
- Overseas geographic range greater than 30 million square kilometres = 2
- Overseas geographic range unknown = 2.

C3. Diet and feeding (0–3)

- Mammal that is a strict carnivore (eats only animal matter) and arboreal (climbs trees) = 3
- Mammal that is a strict carnivore but not arboreal = 2
- Mammal that is a non-strict carnivore (mixed animal–plant matter in diet) = 1
- Mammal that is a primarily a grazer or browser = 3
- Other herbivorous mammal or not a mammal = 0
- Unknown diet = 3.

C4. Competition with native fauna for tree hollows (0–2)

- Can nest or shelter in tree hollows = 2
- Does not use tree hollows = 0
- Unknown = 2.

C5. Overseas environmental pest status (0–3)

Has the species been reported to cause declines in abundance of any native species of plant or animal or cause degradation to any natural communities in any country or region of the world?

- Never reported as an environmental pest in any country or region = 0
- Minor environmental pest in any country or region = 1
- Moderate environmental pest in any country or region = 2
- Major environmental pest in any country or region = 3
- Unknown overseas environmental pest status = 3.

C6. Climate match to areas with susceptible native species or communities (0–5)

Identify any native Australian animal or plant species or communities that could be susceptible to harm by the exotic species if it were to establish a wild population here. Consider specific habitat use and animal behaviour. (For example, if the species being assessed has a score of 1 or more for C3, C4 or C5 above, or for bullets 1 and 4 in C1 above, or if it could compete with, or prey or graze on native species). Compare the geographic distribution of these susceptible plants, animals or communities with the climate match output map of Australia for the species generated by the PC CLIMATE Closest Standard Match analysis (Section 6, Stage B, Score B1).

- The species has no grid squares within the highest six climate match classes (ie in classes 10, 9, 8, 7, 6, and 5) that overlap the distribution of any susceptible native species or ecological communities = 0
- The species has no grid squares within the highest four climate match classes (ie in classes 10, 9, 8 and 7) that overlap the distribution of any susceptible native species or communities, and has 1–50 grid squares within the highest six climate match classes that overlap the distribution of any susceptible native species or ecological communities = 1

- The species has no grid squares within the highest two climate match classes (ie in classes 10 and 9) that overlap the distribution of any susceptible native species or ecological communities, and has 1–9 grid squares within the highest four climate match classes that overlap the distribution of any susceptible native species or ecological communities = 2
- The species has 1–9 grid squares within the highest two climate match classes, and/or has 10–29 grid squares within the highest four climate match classes, that overlap the distribution of any susceptible native species or ecological communities = 3
- The species has 10–20 grid squares within the highest two climate match classes, and/or has 30–100 grid squares within the highest four climate match classes, that overlap the distribution of any susceptible native species or ecological communities = 4
- The species has more than 20 grid squares within the highest two climate match classes, and/or has more than 100 grid squares within the highest four climate match classes, that overlap the distribution of any susceptible native species or ecological communities,
  OR
  One or more susceptible native species or ecological communities that are listed as vulnerable or endangered under the Australian Government *Environment Protection and Biodiversity Conservation Act 1999* has a restricted geographic range that lies within the mapped area of the highest six climate match classes (ie in classes 10, 9, 8, 7, 6, and 5) for the exotic species being assessed,
  OR
  Overseas range for the exotic species unknown and climate match to Australia unknown = 5.

List susceptible Australian native species or natural communities that could be threatened.

C7. Overseas primary production pest status (0–3)

Has the species been reported to damage crops or other primary production in any country or region of the world?

- No reports of damage to crops or other primary production in any country or region = 0
- Minor pest of primary production in any country or region = 1
- Moderate pest of primary production in any country or region = 2
- Major pest of primary production in any country or region = 3
- Unknown overseas primary production pest status = 3.

C8. Climate match to susceptible primary production (0–5)

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

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

Enter these Potential Commodity Impact Scores in Table 9, Column 3.

Calculate the Climate Match to Commodity Score (CMCS) for the species in Australia. Australian Bureau of Statistics (ABS) data for commodity production figures by Statistical Local Area should assist with these assessments. Compare the geographic distribution of susceptible agricultural commodities with the climate match output map of Australia for the species generated by the PC CLIMATE Closest Standard Match analysis (Section 6, Stage B, Score B1):

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

OR

- More than 50% of the commodity is produced in areas where the species has a climate match within the highest six climate match classes BUT less than 20% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes = 4
- More than 20% of the commodity is produced in areas where the species has a climate match within the highest three climate match classes OR overseas range unknown and climate match to Australia unknown = 5.

Enter these Climate Match to Commodity Scores in Table 9, Column 4.

Calculate the Potential Commodity Damage Scores (CDS) by multiplying the Commodity Value Indices (CVI) in Table 9, Column 2 with the Potential Commodity Impact Scores (PCIS) in Column 3 and the Climate Match to Commodity Scores (CMCS) in Column 4, and enter the CDS for each commodity in Column 5. Sum the CDSs in Column 5 to get a TCDS for the species, then convert it to a C8 score using the conversion factors given in Table 9.

The Commodity Value Index (CVI in Table 9, Column 2) is an index of the value of the annual production value of a commodity. Adjustments to the CVI for a commodity will be required when potential damage by the species is restricted to a particular component of the commodity being assessed. For example, some exotic species may contaminate and consume food at feedlots, and hence cause potential harm to feedlot production of livestock, but not to livestock in the paddock. In such cases, the CVI should be adjusted down in proportion to the value of the susceptible component of the commodity.

C9. Spread disease (1–2)

Assess the risk that the species could play a role in the spread of disease or parasites to other animals. This question only relates to the risk of the species assisting in the spread of diseases or parasites already present in Australia. The risk that individual animals of the species could carry exotic diseases or parasites in with them when they are imported into Australia is subject to a separate import risk analysis conducted by Biosecurity Australia.

- All birds and mammals (likely or unknown effect on native species and on livestock and other domestic animals) = 2
- All amphibians and reptiles (likely or unknown effect on native species, generally unlikely to affect livestock and other domestic animals) = 1.

Table 9. Calculating Total Commodity Damage Score.
The Commodity Value Index scores in this table are derived from Australian Bureau of Statistics 1999–2000 data and will need to be updated if these values change significantly. Directions for completing this Table are presented in Section 6, Stage C, Score C8).

Column 1	**Column 2**	**Column 3**	**Column 4**	**Column 5**
Industry	**Commodity Value Index**[1]	**Potential Commodity Impact Score (0–3)**	**Climate Match to Commodity Score (0–5)**	**Commodity Damage Score (columns 2 x 3 x 4)**
Sheep (includes wool and sheep meat)	10			
Cattle (includes dairy and beef)	10			
Timber (includes native and plantation forests)	10			
Cereal grain (includes wheat, barley sorghum etc)	10			
Pigs	2			
Poultry and eggs	2			
Aquaculture(includes coastal mariculture)	2			
Cotton	2			
Oilseeds (includes canola, sunflower etc)	2			
Grain legumes (includes soybeans)	2			
Sugarcane	2			
Grapes	2			
Other fruit	2			
Vegetables	2			
Nuts	1			
Other livestock (includes goats, deer, camels, rabbits)	1			
Honey and beeswax	1			
Other horticulture (includes flowers etc)	1			
Total Commodity Damage Score (TCDS)	—	—	—	

[1]The Commodity Value Index is an index of the value of the annual production value of a commodity. Adjustments to the CVI for a commodity will be required when potential damage by the species is restricted to a particular component of the commodity being assessed. For example, some exotic species may contaminate and consume food at feedlots, and hence cause potential harm to feedlot production of livestock, but not to livestock in the paddock. In such cases, the CVI should be adjusted down in proportion to the value of the susceptible component of the commodity.

TCDS = 0:	C8 = 0
TCDS = 1–19:	C8 = 1
TCDS = 20–49:	C8 = 2
TCDS = 50–99:	C8 = 3
TCDS = 100–149:	C8 = 4
TCDS $\geq$ 150	C8 = 5

C10. Harm to property (0–3)

Assess the risk that the species could inflict damage on buildings, vehicles, fences, roads, equipment or ornamental gardens by chewing or burrowing or polluting with droppings or nesting material. Estimate the total annual dollar value of such damage if the exotic species established throughout the area for which it has a climate match of in areas where the species has a climate match within the highest six climate match classes (ie classes 10, 9, 8, 7, 6 and 5, based on the climate match output map of Australia for the species generated by PC CLIMATE Closest Standard Match analysis in Section 6, Stage B, Score B1).

Convert the property damage risk total annual dollar value to a property damage risk score:

\$0	C10 = 0
\$1.00–\$10 million	C10 = 1
\$11–\$50 million	C10 = 2
more than \$50 million	C10 = 3.

C11. Harm to people (0–5)

Assess the risk that, if a wild population established, the species could cause harm to or annoy people. Aggressive behaviour, plus the possession of organs capable of inflicting harm, such as sharp teeth, tusks, claws, spines, a sharp bill, horns, antlers or toxin-delivering organs may enable animals to harm people. Any known history of the species attacking, injuring or killing people should also be taken into account (see Stage A, Score A1). Take into account aggressive behaviour that may occur when the species is protecting nest or young. Some species are a social nuisance, especially those that live in close association with people, for example species that invade buildings, or those with communal roosts that can cause unacceptable noise. Also consider the risk that the species could become a reservoir or vector for parasites or diseases that affect people, the likelihood of transmission to people, and the level of harm caused to people should this occur.

Based on the above assessment, if the species established, score the risk of harm to people as follows:

- nil risk = 0
- very low risk = 1
- injuries, harm or annoyance likely to be minor and few people exposed: low risk = 2
- injuries or harm moderate but unlikely to be fatal and few people at risk OR annoyance moderate or severe but few people exposed OR injuries, harm or annoyance minor but many people at risk: moderate risk = 3
- injuries or harm severe or fatal but few people at risk: serious risk = 4
- injuries or harm moderate, severe or fatal and many people at risk: extreme risk = 5.

Pest Risk Score

A species' Pest Risk Score = C = the sum of its scores for C1–C11.

Pest Risk Rank

A species' Pest Risk Score is converted to a Pest Risk Rank (Low, Moderate, Serious or Extreme) using the following cut-off thresholds:

Pest Risk Rank	Pest Risk Score
Extreme	> 19
Serious	15–19
Moderate	9–14
Low	< 9

Stage D: Decision Process

To assign the species to a VPC Threat category, use the scores from Table 10 as the basis for the following decision process.

Risk to public safety posed by captive or released individuals (A= 0–4))

A = 0	not dangerous
A = 1	moderately dangerous
A ≥ 2	highly dangerous

Risk of establishing a wild population (B = 1–16)

B ≤ 6	low establishment risk
B = 7–11	moderate establishment risk
B = 12–13	serious establishment risk
B ≥ 14	extreme establishment risk

Risk of becoming a pest following establishment (C = 1–37)

C < 9	low pest risk
C = 9–14	moderate pest risk
C = 15–19	serious pest risk
C > 19	extreme pest risk

Table 10. Score sheet for risk assessment model.

Factor	Score
A1. Risk to people from individual escapees (0–2)	
A2. Risk to public safety from individual captive animals (0–2)	
Stage A. Risk to public safety from captive or released individuals: A = A1 + A2 (0–4)	
B1. Degree of climate match between species overseas range and Australia (1–6)	
B2. Exotic population established overseas (0–4)	
B3. Taxonomic Class (0–1)	
B4. Migratory behaviour (0–1)	
B5. Diet (0–1)	
B6. Habitat (0–1)	
B7. Overseas range size (0–2)	
B. Establishment Risk Score: B = B1 + B2 + B3 + B4 + B5 + B6 + B7 (1–16)	
C1. Taxonomic group (0–4)	
C2. Overseas range size (0–2)	
C3. Diet and feeding (0–3)	
C4. Competition with native fauna for tree hollows (0–2)	
C5. Overseas environmental pest status (0–3)	
C6. Climate match to areas with susceptible native species or communities (0–5)	
C7. Overseas primary production pest status (0–3)	
C8. Climate match to susceptible primary production (0–5)	
C9. Spread disease (1–2)	
C10. Harm to property (0–3)	
C11. Harm to people (0–5)	
C. Pest Risk Score: C = C1 + C2 + C3 + C4 + C5 + C6 + C7 + C8 + C9 + C10 + C11 (1–37)	

VPC Threat Category

A species' Vertebrate Pests Committee Threat Category (Natural Resource Management Standing Committee and Vertebrate Pests Committee 2004) is determined from the various combinations of its three risk scores (Table 11).

Table 11. Vertebrate Pests Committee Threat Categories, based on: risk posed by captive or released individuals (A); establishment risk (B); and pest risk (C).

Establish-ment risk[1] (B)	Pest risk[1] (C)	Risk posed by individual escapees (A)	VPC Threat Category
Extreme	Extreme	Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme
Extreme	High	Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme
Extreme	Moderate	Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme
Extreme	Low	Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme
High	Extreme	Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme
High	High	Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme
High	Moderate	Highly Dangerous, Moderately Dangerous or Not Dangerous	Serious
High	Low	Highly Dangerous, Moderately Dangerous or Not Dangerous	Serious
Moderate	Extreme	Highly Dangerous, Moderately Dangerous or Not Dangerous	Extreme
Moderate	High	Highly Dangerous, Moderately Dangerous or Not Dangerous	Serious
Moderate	Moderate	Highly Dangerous	Serious
Moderate	Moderate	Moderately Dangerous or Not Dangerous	Moderate
Moderate	Low	Highly Dangerous	Serious
Moderate	Low	Moderately Dangerous or Not Dangerous	Moderate
Low	Extreme	Highly Dangerous, Moderately Dangerous or Not Dangerous	Serious
Low	High	Highly Dangerous, Moderately Dangerous or Not Dangerous	Serious
Low	Moderate	Highly Dangerous	Serious
Low	Moderate	Moderately Dangerous or Not Dangerous	Moderate
Low	Low	Highly Dangerous	Serious
Low	Low	Moderately Dangerous	Moderate
Low	Low	Not Dangerous	Low

[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 and Vertebrate Pests Committee (2004).

7. Recalibrated climate matches for exotic freshwater finfish establishment scores

7.1 Climate matching data: comparisons and selection

Bomford and Glover (2004) used the Mac version of CLIMATE to conduct Closest Standard Match analyses for exotic freshwater finfish introduced to Australia. In this section the results of three types of CLIMATE analyses are compared (all conducted with all 16 climate variables included):

1. Euclidian analyses using the PC version of CLIMATE
2. Closest Standard Match analyses using the PC version of CLIMATE
3. Closest Standard Match analyses using the Mac version of CLIMATE

The purpose of this comparison is to select the best option for use in the recalibrated model for use with the PC version of CLIMATE.

In Appendix J, Table J1 presents the climate match results for exotic freshwater finfish introduced to Australia, using the three alternative types of CLIMATE analyses. Table 12 presents the results of t-tests comparing the climate match scores for successful and failed exotic freshwater finfish introduced to Australia for these three alternative types of CLIMATE analyses. All three types give high levels of statistical significance, indicating that climate matching gives good statistical discrimination between successfully introduced and failed exotic freshwater fish. Climate match outputs from the PC version of CLIMATE, Euclidian analysis at the Σ5 level were selected to use in the new fish risk assessment model.

Table 12. T-test results (*P* = probability scores) comparing climate match outputs for successful and failed exotic fish introduced to Australia.
All *P* values ≤ 0.05 are statistically significant.
For PC Euclidian all levels between Σ8 and Σ2 are statistically significant.
For PC Closest standard match all levels between Σ8 and Σ2 are statistically significant.
For Mac all levels between Σ9 and Σ3 are statistically significant.

CLIMATE analysis type	**Cumulative climate match level***								
	10	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**
PC Euclidian	n/a	0.112	0.037	0.035	0.023	0.009	0.005	0.012	0.008
PC Closest standard match	n/a	0.121	0.056	0.065	0.035	0.018	0.006	0.002	0.009
Mac	0.17	0.023	0.013	0.011	0.008	0.005	0.001	0.002	0.096

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Climate match outputs from the PC version of CLIMATE, Euclidian analysis at the Σ5 level are likely to underestimate the level of climate match if the input area has 12 or fewer meteorological stations (Appendix F, Table F2). If this is the case, it is advisable to increase the climate match score by one increment (Section 8.1).

7.2 Cut-off thresholds for Climate matches

Eight climate match categories (Climate Match Scores 1–8) were selected to rank levels of climate match (PC CLIMATE Euclidian Σ5 level) for the risk assessment model (Figure 10). The cut-off thresholds for these categories were chosen to give the best possible discrimination between successful and failed introduced species. Figure 10 shows clearly that while there are more successfully introduced species with higher Climate Match Scores than there are failed introduced species with these higher Climate Match Scores, and vice versa for the lower Climate Match Scores, there is considerable overlap in the Climate Match Scores of the successful and failed fish species. However, Table 13 presents the results of t-tests showing the difference in the Climate Match Scores between the two groups is statistically highly significant.

7.3 Using PC CLIMATE results in the Risk assessment Model for Exotic Finfish

The new Climate Match Scores (1–8 based on PC CLIMATE Euclidian matches at the Σ5 level using the cut-off thresholds presented in Figure 10) were then used to replace the previous Climate Match Scores (1–8 based on the Mac version of CLIMATE Closest Standard Match) in the model used in the original finfish risk assessment model (Bomford and Glover 2004). Table K1 in Appendix K presents Establishment Risk Scores for exotic finfish species introduced to Australia based on the values presented by Bomford and Glover (2004) but with Climate Match Scores (1–8) derived from the PC CLIMATE Euclidian matches (Σ5 level). Figure 11 presents the number of species in each Establishment Risk Rank using these new Climate Match Scores derived from PC CLIMATE outputs.

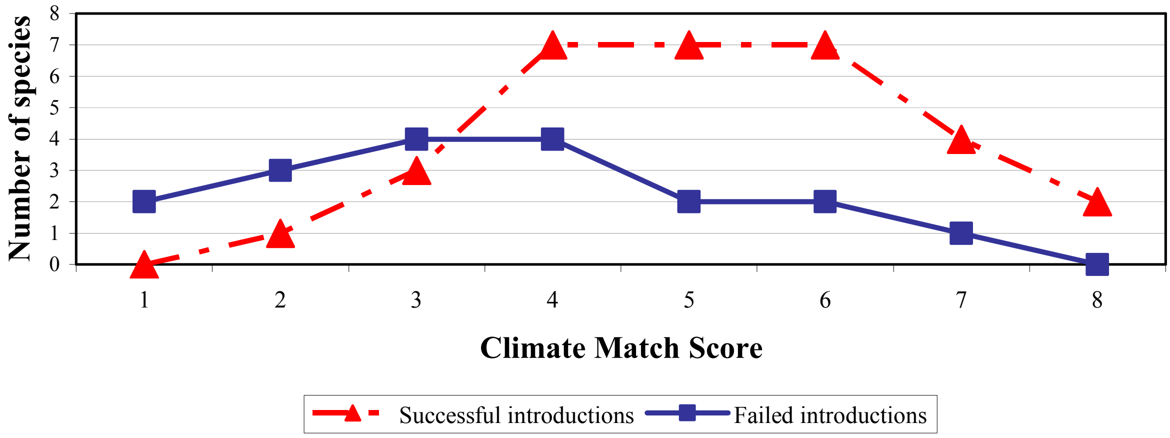

Figure 10. PC Euclidian analysis (Σ5 level): number of species in each Climate Match Score category (1–8) compared for successful and failed exotic freshwater finfish introduced to Australia.
Cut-off thresholds selected for the eight Climate Match Scores are:

	Climate Match Score	Climate match Euclidian (Σ5 level)
Very low climate match	1	0
	2	1–40
↓	3	41–150
	4	151–400
↓	5	401–1000
	6	1001–1500
	7	1501–2500
Extremely high climate match	8	> 2500

For comparison Table L1 in Appendix L presents Establishment Risk Scores for exotic finfish species introduced to Australia based on the original values presented by Bomford and Glover (2004) with Climate Match Scores (1–8) derived from the Mac version of CLIMATE. Figure 12 presents the number of species in each Establishment Risk Rank using the old (Bomford and Glover 2004) model incorporating Climate Match Scores from the Mac version of CLIMATE.

The cut-off thresholds presented in Figure 11 create six Establishment Risk Ranks equivalent to those in Bomford and Glover's (2004) model. However, the Vertebrate Pests Committee Guidelines (Natural Resource Management Standing Committee and Vertebrate Pests Committee 2004) assess risk based on only four levels of Establishment Risk Rank. Therefore new cut-off thresholds were selected to create only four levels as presented in Figure 13. Figure 13 shows good separation of successful and failed species at the four levels of establishment risk, but at the 'Moderate' level, more fish established than failed to establish, and this is a much higher ratio of established:failed species than that obtained for a Moderate Establishment Risk Rank in either the establishment risk assessment model for mammals and birds (Figure 8) or that for reptiles and amphibians (Figure 17). Therefore the lower threshold cut-off thresholds for fish were adjusted downwards (in Figure 14) to more closely match the ratio of established:failed species in the four Establishment Risk Ranks in the two establishment risk models for these other vertebrate taxa. The cut-off thresholds presented in Figure 14 were used in the recalibrated freshwater finfish risk assessment model (Section 8.1).

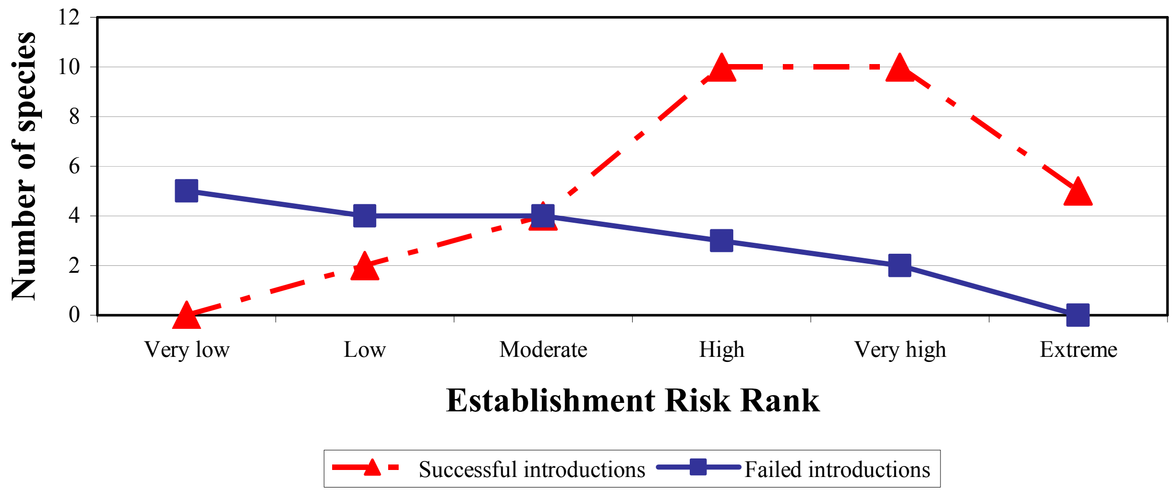

Figure 11. Number of species in each Establishment Risk Rank compared for successful and failed exotic freshwater finfish introduced to Australia.
The Establishment Risk Scores were calculated using Bomford and Glover's (2004) model, but PC CLIMATE Euclidian matches (Σ5 level) were used instead of Mac CLIMATE Closest Standard Matches.
Cut-off thresholds for the six levels of Establishment Risk Scores were:

Establishment Risk Rank	Establishment Risk Score
Extreme	≥ 22
Very high	20–21
High	15–19
Moderate	11–14
Low	10
Very low	≤ 9

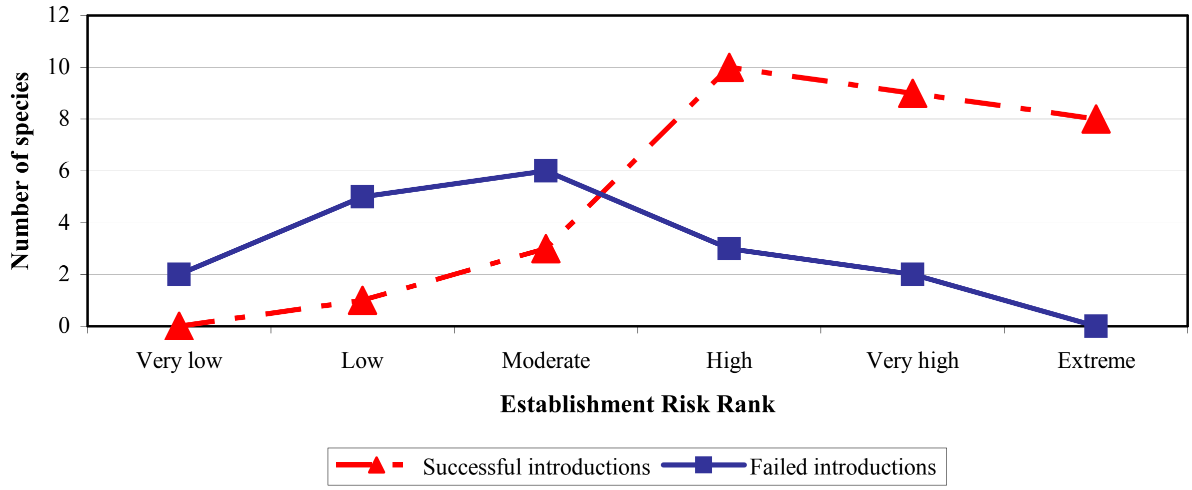

Figure 12. Number of species in each Establishment Risk Rank compared for successful and failed exotic freshwater finfish introduced to Australia.
The Mac version of CLIMATE was used with the formulas and cut-off thresholds presented by Bomford and Glover (2004).

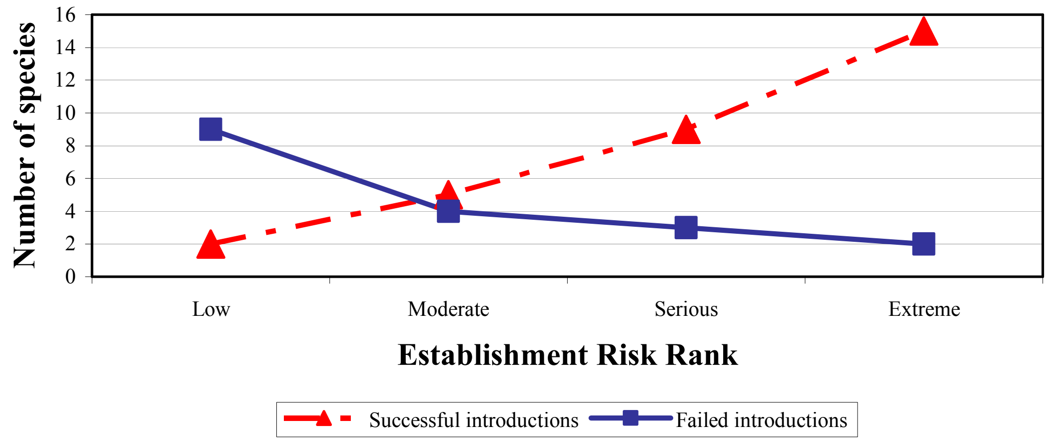

Figure 13. **Number of species in each Establishment Risk Rank compared for successful and failed exotic freshwater finfish introduced to Australia.**
PC CLIMATE Euclidian matching (Σ5 level) was used. Cut-off thresholds for the four levels of Establishment Risk Scores were:

Establishment Risk Rank	Establishment Risk Score
Extreme	≥ 20
Serious	16–19
Moderate	11–15
Low	≤ 10

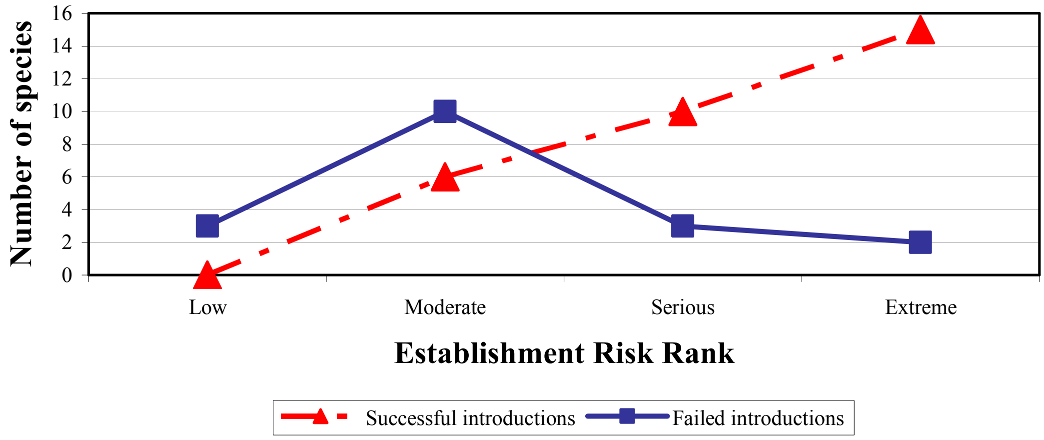

Figure 14. Number of species in each Establishment Risk Rank compared for successful and failed exotic freshwater finfish introduced to Australia with cut-off thresholds adjusted downwards.
PC CLIMATE Euclidian matching (Σ5 level) was used. Cut-off thresholds for the four Establishment Risk Ranks were adjusted downwards to more closely match the ratios of successful:failed species for each Establishment Risk Rank in the establishment risk models for other taxa (see text):

Establishment Risk Rank	Establishment Risk Score
Extreme	≥ 20
Serious	15–19
Moderate	8–14
Low	≤ 7

7.4 Comparisons of risk scores

Table 13 presents a summary of the risk score averages for exotic freshwater finfish introduced to Australia compared for successful and failed species based on the new Climate Match Scores using the PC version of CLIMATE. Table 13 also presents t-test results for comparisons of these risk scores for successful and failed fish.

Table 13. Risk score averages[1] for exotic freshwater finfish introduced to Australia compared for successful and failed species based on the new Climate Match Scores using the PC version of CLIMATE plus t-test results (*P* = probability scores[2]) for comparisons of these risk scores for successful and failed fish. All t-test results are statistically highly significant. All *P* values ≤ 0.05 are statistically significant.

Function	Climate Match Score 1–8	Overseas Range Score 0–4	Establishment Score 0–3	Introduction Success Score 0–4	Taxa Risk Score 0–5	Total Establishment Risk Score 0–24
Average for successful fish	5.0645	2.7097	2.4839	3.6129	4.3548	18.2258
Average for failed fish	3.6111	1.6111	1.6111	2.16667	3.3889	12.3889
T-test comparing successful vs failed fish	0.0015	0.0078	0.0010	1.38E-05	0.0016	9.32E-06

[1]Data presented in Appendix K, Table K1.
[2]Where a *P* value is presented in the form XE-0Y, Y is the number of zeros following the decimal point, for example 7.09E-05 = 0.00000709.

8. Updated exotic freshwater finfish risk assessment model

8.1 Establishment risk factors

A. Climate Match Score (0–8)

For the selected fish species, use PC CLIMATE (Bureau of Rural Sciences 2004) and select:

- '*worlddata_all.txt*' as the world data location
- '*cntry92.shp*' as the shapefile
- all 16 climatic parameters for matching locations (see Table 1)
- '*Euclidian match*' for the analysis.

Sum the values for the six highest match classes (ie the scores for match levels 10, 9, 8, 7, 6 and 5) = 'Value X'

Convert 'Value X' to a Climate Match Score (1–8) using the following cut-off thresholds:

	Climate Match Score	PC CLIMATE Euclidian Σ5 level (Value X) (sum of highest six match classes)
Very low climate match	1	0
	2	1–40
↓	3	41–150
	4	151–400
↓	5	401–1000
	6	1001–1500
	7	1501–2500
Extremely high climate match	8	> 2500

If the input area has 12 or fewer meteorological stations, then it is likely to underestimate the climate match to Australia. If this is the case, it is advisable to increase the climate match score by one increment. For example, if the input range for a species included only five meteorological stations, and the sum of the values for the six highest match classes to Australia equalled 104 (ie 'Value X' = 104), then this would give a Climate Match Score = 3 + 1 = 4.

B. Overseas Range Score (0–4)

Count the number of 1^{o} latitude by 1^{o} longitude grid squares in which an occurrence of the species is recorded in Fishbase excluding Australia.

Overseas range score	Number of grid squares with species present
0	≤ 4
1	5–10
2	11–20
3	21–30
4	≥ 31

C. Establishment Score (0–3)

Check Fishbase for locations where successful introductions of the species have occurred excluding Australia. A moderate risk rank score of 1 is given where there are no recorded introductions, although a precautionary approach could warrant a higher risk score.

Establishment score	Introduction outcome overseas
0	Introduced but never established
1	Never introduced
2	Only established exotic population(s) on island(s) or on one continent (from choice of five continents excluding Australia: Africa; Europe; Asia; North and Central America; or South America)
3	Established exotic populations on more than one continent (excluding Australia).

D. Introduction Success Score (0–4)

Count the number of known successful introductions of the species worldwide excluding Australia and express this as a proportion of the total number of introductions (using data from Fishbase). A moderate Introduction Success Score of 2 is given where there are no recorded introductions, although a precautionary approach could warrant a higher Introduction Success Score.

Introduction Success Score	Introduction success rate
0	Introduced but success rate = 0
1	Success rate of >0 ≤ 0.25
2	Success rate of >0.25 ≤ 0.5 OR Never introduced
3	Success rate of >0.5 ≤ 0.75
4	Success rate of >0.75 ≤ 1.0

E. Taxa Risk Score (0–5)

Success rates for worldwide introductions of the family or genus of the species being assessed. The Taxa Risk Score is either a species' Genus Risk Score, or where there are too few introduction records within the species' genus to enable a Genus Risk Score to be calculated, an alternative Family Risk Score is calculated.

Genus Risk Score

The Genus Risk Score is used as the taxa risk score when the number of introduction events of all species within the same Genus as the species being assessed ≥ 4.

The Genus Risk Score is calculated from all recorded worldwide introductions of all species within the same Genus as the species being assessed:

Genus success rate % = 100 × (Number of successful introductions of species in the Genus ÷ Total number of introductions of species in the Genus)

Genus Risk Score	Genus success rate %
0 = Very low	0%
1 = Low	>0%<10%
2 = Moderate	10%–25%
3 = High	>25%<40%
4 = Very high	40%–60%
5 = Extreme	>60%

Family Risk Score

The Family Risk Score is used as the taxa risk score to increase the sample size when number of introduction events of all species within the same genus as the species being assessed = 0–3.

The Family Risk Score is calculated from all recorded worldwide introductions of all species within the same family as the species being assessed:

Family success rate % = 100 × (Number of successful introductions of species in the Family ÷ Total number of introductions of species in the Family)

Where there are no recorded introductions, or where sample sizes are small, a moderate (or more moderate) Family Risk Score is given, although a precautionary approach could warrant a higher Family Risk Score.

Family Risk Score	Family success rate %
0 = Very low	0% (number introductions ≥ 3)
1 = Low	0% (number introductions 1–2)
2 = Moderate	1–25% (any number introductions) OR Never introduced (number introductions 0)
3 = High	>25%–60% (any number introductions)
4 = Very high	>60% (number introductions 1–2)
5 = Extreme	>60% (number introductions ≥ 3)

Establishment Risk Score

An exotic finfish species' Establishment Risk Score = the sum of its five scores for A–E.

Establishment Risk Rank

An exotic finfish species' Establishment Risk Score is converted to an Establishment Risk Rank (Low, Moderate, Serious or Extreme) using the following cut-off thresholds:

Establishment Risk Rank	Establishment Risk Score
Extreme	≥ 20
Serious	15–19
Moderate	8–14
Low	≤ 7

8.2 Factors affecting risk of becoming a pest

Bomford and Glover (2004) reviewed factors associated with adverse impacts of exotic freshwater finfish and concluded that reliable knowledge about impacts is sparse. They found insufficient reliable knowledge of the factors correlated with impacts of exotic fish to make the development of a quantitative model feasible for assessing the risks of impact for new species of exotic fish in Australia. Nonetheless, their review of factors associated with adverse impacts indicates that an increased risk is associated with exotic freshwater finfish that:

- have adverse impacts elsewhere
- have close relatives with similar behavioural and ecological strategies that cause adverse impacts elsewhere
- are generalist feeders
- are piscivorous
- destroy or modify aquatic vegetation or stir up sediments to increase turbidity

- have the potential to cause physical injury
- harbour or transmit diseases or parasites that are present in Australia
- have close relatives among Australia's endemic fish
- are known to have spread rapidly following their release into new environments
- have a good climate match to Australia because such species are more likely to establish over large areas so their impacts will be spread more widely.

This list could be used as a checklist to make a qualitative assessment of the threat of impacts posed by the establishment of new exotic fish species in Australia. However, an absence of these factors cannot be taken to indicate that there is a low risk of harm.

9. Evaluation and refinement of reptile and amphibian risk assessment model

The underlying framework for the climate matching used in Bomford's (2003) model for mammals and birds and Bomford and Glover's (2004) model for freshwater finfish was based on analyses of successful and failed introductions of exotic mammals, birds and finfish to Australia. The Climate Match Scores for species that established exotic populations were compared to the Climate Match Scores for species that were released in Australia but failed to establish. On average, successfully introduced species had high climate match scores and failed species had low scores and this difference was highly statistically significant. It was assumed that potential future introductions of exotic species in these taxa which have high Climate Match Scores will have a higher probability of successfully establishing exotic populations than species with low Climate Match Scores. This approach was not possible for exotic reptiles and amphibians because too few exotic species in these taxa have been introduced to Australia. The alternative approach taken for these taxa by Bomford et al. (2005) was to conduct climate matches for exotic reptiles and amphibians introduced to Britain, Florida and California, and then assume that the results of these analyses would be applicable to future introductions of species in these taxa to Australia.

This Section evaluates and refines Bomford et al.'s (2005) model.

9.1 Climate matching data: comparisons and selection

Bomford et al. (2005) developed a risk assessment model for exotic reptiles and amphibians that used PC Euclidian CLIMATE analyses. In Section 3 of this report, PC CLIMATE Closest Standard Match analyses were shown to give better predictions for exotic mammal and bird introduction outcomes than PC CLIMATE Euclidian Analyses. Therefore this Section compares the two types of analyses for exotic reptiles and amphibians to see which gives better predictions.

The results presented in Table 14 compare two different types of PC CLIMATE analyses: Euclidian and Closest Standard Matches for exotic reptiles and amphibians introduced to the three jurisdictions (Britain, California and Florida) that Bomford et al. (2005) used to develop their risk assessment model. Table 14 presents the results of these analyses with two levels of climate matching: the sum of the scores for the four highest climate match classes (that is Σ7 – the sum of the scores for classes 7, 8, 9 and 10; see Appendix M for details) and the sum of the scores for the five highest climate match classes (Σ6). Table 14 shows Euclidian matching at the Σ7 level gives consistently highly significant differences for successful versus failed species across all three jurisdictions. Euclidian matching at the Σ7 level is used in Bomford et al.'s (2005) reptile and amphibian risk assessment model.

Climate match outputs from the PC version of CLIMATE, Euclidian analysis at the Σ7 level are likely to underestimate the level of climate match if the input area has 12 or fewer meteorological stations (Appendix F, Table F3). If this is the case, it is advisable to increase the climate match score by ten points (Section 10.1, Score A).

9.2 Using PC CLIMATE results in the Risk assessment Model for Exotic Reptiles and Amphibians

A difficulty with the approach used by Bomford et al. (2005) was calibrating the reptile and amphibian model for Australian species introductions, particularly setting climate match output thresholds for the various levels of risk. Climate match output values are unique to a location, so it was not possible to combine the climate match output values for the three jurisdictions (Britain, California and Florida) used by Bomford et al. (2005). To overcome this problem, Bomford et al. (2005) converted Euclidian climate match outputs (Σ7 level) to Climate Match Scores by expressing them as a percentage of the maximum possible score for each jurisdiction (Appendix M, Table M2). In Figure 15, Climate Match Scores for Britain, California and Florida (combined) have been converted to Climate Match Risk Ranks for a visual comparison of the numbers of successful and failed species at each climate match level. Figure 15 shows there is good discrimination between successful and failed species in this combined dataset.

Table 14. PC CLIMATE analyses (Σ6 and Σ7 levels) for both Euclidian Matches and Closest Standard Matches: averages for exotic reptiles and amphibians (combined) introduced to Britain, California and Florida, compared for species that successfully established versus those that failed to establish (t-test results: P = probability scores).
All t-test results are statistically significant.

Country		**Euclidian Σ6**	**Closest Standard Match Σ6**	**Euclidian Σ7**	**Closest Standard Match Σ7**
Britain	Average successful	186	187	163	174
	Average failed	89	110	59	65
	T-test result	0.0010028	0.0033	0.000279	0.00012
California	Average successful	77	73	44	46
	Average failed	16	19.2	5.7	7.0
	T-test result*	7.09197E-06	5.89191E-05	6.07E-05	0.000108
Florida	Average successful	64	69	39	50
	Average failed	42	51	20	31
	T-test result	0.005781	0.01829	0.008339	0.014449

*Where a P value is presented in the form XE-0Y, Y is the number of zeros following the decimal point, for example 7.09E-05 = 0.00000709.

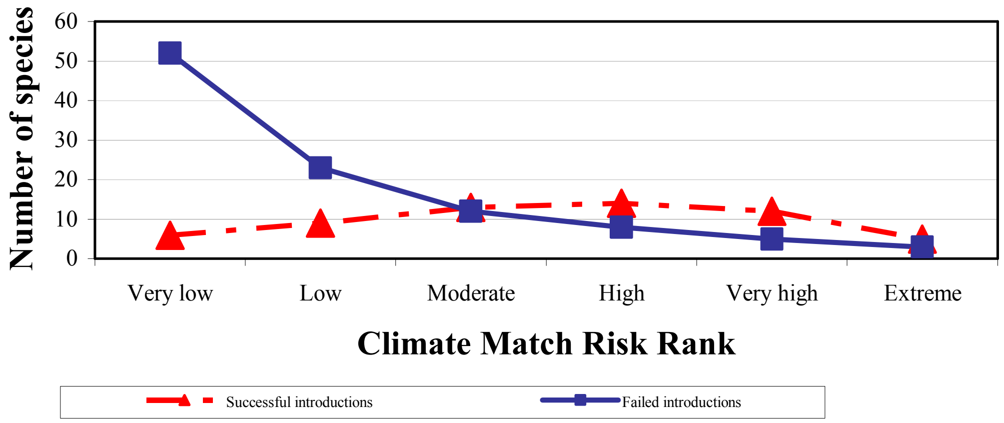

Figure 15. Number of species in each Climate Match Risk Rank for reptiles and amphibians (combined) introduced to Britain, California and Florida (combined). PC CLIMATE Euclidian matches (Σ7 level) outputs were expressed as percentages of maximum possible score for each jurisdiction to create Climate Match Scores for each species. Climate Match Scores were then converted to Climate Match Risk Ranks using the following cut-off thresholds:

<u>Climate Match Risk Rank</u>	<u>Climate Match Score %</u>
Extreme	≥ 97
Very high	70–96
High	41–69
Moderate	7–40
Low	1–6
Very low	0

Bomford et al. (2005) used the PC CLIMATE Euclidian match (Σ7 level) outputs to calculate species' Climate Match Scores (Appendix M, Table M2). The species' Climate Match Score was then added to two other risk scores (Exotic Elsewhere Risk Score and Taxonomic Family Risk Score) to calculate an Establishment Risk Score (Appendix M, Table M3). Bomford et al. (2005) converted Establishment Risk Scores to Establishment Risk Ranks (six levels: Very Low–Extreme) using the cut-off thresholds presented in Figure 16. Figure 16 shows good separation of successful and failed species: most species that failed to establish have a Very Low or Low Establishment Risk Rank, whereas most successful species have a Moderate or higher Establishment Risk Rank. The Vertebrate Pests Committee Guidelines (Natural Resource Management Standing Committee and Vertebrate Pests Committee 2004) assess risk based on only four levels of Establishment Risk Rank (Low, Moderate, Serious or Extreme) (Table 11). Therefore new cut-off thresholds were selected to create only four Establishment Risk Ranks as presented in Figure 17. Figure 17 shows good separation of successful and failed species at the four levels of establishment risk, and at the 'Moderate' level, the ratio of the number of species established to the number that failed to establish, is similar to that obtained for a Moderate Establishment Risk Rank in both the re-calibrated mammal and bird risk assessment model (Figure 8) and the re-calibrated freshwater finfish risk assessment model (Figure 14).

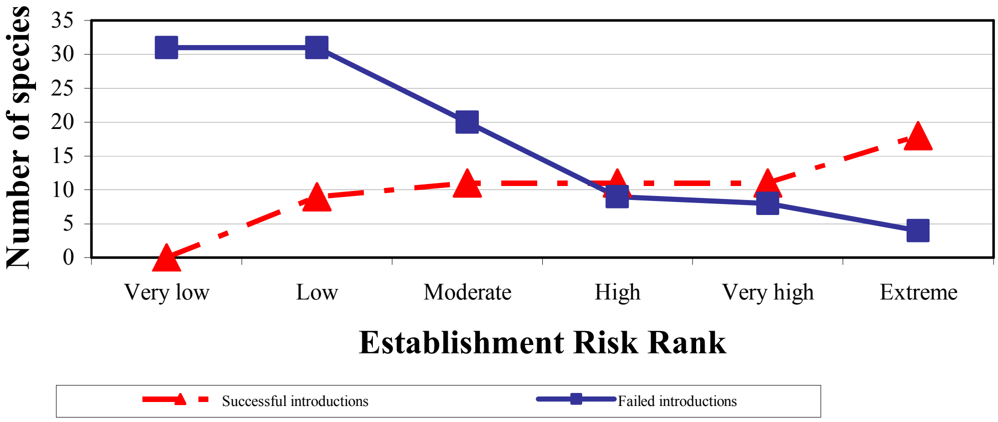

Figure 16. Number of species in each Establishment Risk Rank for reptiles and amphibians (combined) introduced to Britain, California and Florida (combined), using a six-level risk ranking (as presented by Bomford et al. 2005).

Establishment Risk Scores were calculated using the directions given in Section 10.1 of this report and then converted to six Establishment Risk Ranks using the following cut-off thresholds:

Establishment Risk Rank	Establishment Risk Score
Extreme	>115
Very high	85–115
High	61–84
Moderate	46–60
Low	20–45
Very low	<20

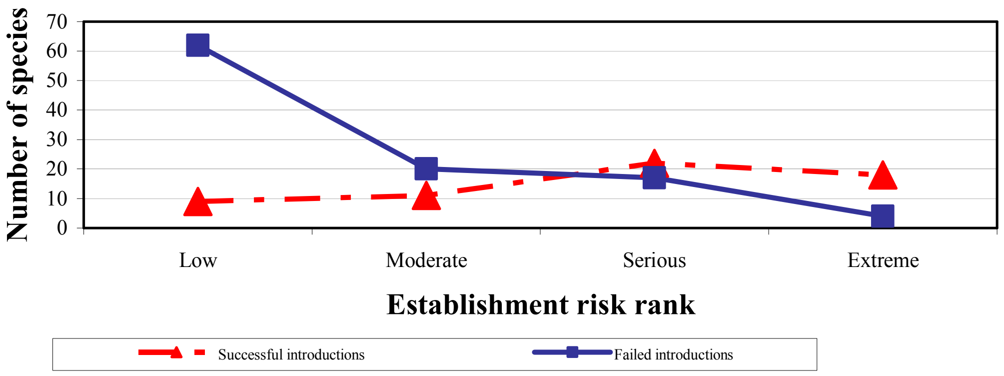

Figure 17. Number of species in each Establishment Risk Rank for reptiles and amphibians (combined) introduced to Britain, California and Florida (combined), using a four-level risk ranking. Establishment Risk Scores were calculated using the directions given in Section 10.1 of this report and then converted to four Establishment Risk Ranks using the following cut-off thresholds:

Establishment Risk Rank	Establishment Risk Score
Extreme	> 115
Serious	61–115
Moderate	46–60
Low	≤ 45

9.3 Issues of concern in regard to the reptile and amphibian risk assessment model

The cut-off thresholds for calculating Establishment Risk Ranks (Figures 16 and 17) were determined from the combined datasets for exotic reptiles and amphibians introduced to Britain, California and Florida (Table M3). There are some issues of concern regarding this approach, used to develop Bomford et al.'s (2005) model, which it would be desirable to address in the future:

- Sample sizes were small for successful species in Britain and California. To increase the sample sizes for California, translocated species from elsewhere in continental USA were included in both the successful and failed data sets.
- A few species (for example, the African clawed toad *Xenopus laevis*) occurred in more than one jurisdiction and hence were double or triple counted in the combined data set. But given the introduction outcomes and the Establishment Risk Scores for these replicated species differed between jurisdictions, replicates were retained to increase sample sizes.
- No phylogenetic corrections were performed on the data. That is, no corrections were made to account for any bias introduced by phylogenetic relationships between the species included in the data sets.
- The climate match outputs for each of the three jurisdictions (Britain, California and Florida) differ widely (Table 14). Although transforming the climate match outputs to Climate Match Scores (percentages of the highest possible score for each jurisdiction) reduced the differences between jurisdictions, the Climate Match Score averages for Britain were still far higher than the score averages for Florida, and Florida's average scores were higher than California's scores (Table 15). When these Climate Match Scores are incorporated into the Establishment Risk Scores, the differences between the jurisdictions are retained, with Britain having higher Establishment Risk Scores than Florida and California (Table 16). Therefore combining the data from the three jurisdictions into a single dataset is statistically problematic, but for lack of an alternative approach this was done so the combined dataset could be used to determine cut-off thresholds for Establishment Risk Ranks in Bomford et al.'s (2005) model.
- In developing the risk assessment model for exotic reptiles and amphibians proposed for introduction to Australia, an assumption was made that equivalent values of Establishment Risk Scores for the combined Britain, California and Florida dataset, would translate to equivalent levels of establishment risk for Australia (Bomford et al. 2005). This is an untested assumption.

Table 15. Average Climate Match Scores and t-test results comparing successful vs failed exotic reptiles and amphibians introduced to Britain, California and Florida.
T-test results comparing successful and failed species for all three jurisdictions are very highly statistically significant.

Introduction outcome	Britain	California	Florida
Successful species	82.1	25.9	37.1
Failed species	30.5	1.6	16.5
T-test result	0.000279	0.0000607	0.00834

Table 16. Average Establishment Risk Scores and t-test results comparing successful vs failed exotic reptiles and amphibians introduced to Britain, California and Florida.
T-test results comparing successful and failed species for all three jurisdictions are very highly statistically significant.

Introduction outcome	Britain	California	Florida
Successful species	129.13	77.27	80.71
Failed species	66.34	30.11	35.74
T-test result[1]	8.02E-05	2.78E-07	9.16E-07

[1]Where a *P* value is presented in the form XE-0Y, Y is the number of zeros following the decimal point, for example 7.09E-05 = 0.00000709.

How appropriate the cut-off thresholds determined from the combined datasets for exotic reptiles and amphibians introduced to Britain, California and Florida are for exotic reptiles and amphibians introduced to Australia is untested. It is hoped that the large total sample size and variable conditions in the three jurisdictions used will give some robustness to the cut-off thresholds selected in the model. However, their validity cannot be determined without testing them on exotic reptiles and amphibians introduced to Australia. Unfortunately (from a statistical viewpoint) the sample size of these is small – only five successful species and two failed species known for mainland Australia (Table 17). However, Bomford et al.'s (2005) model does give reasonable predictions for the seven exotic reptile and amphibian species known to have been introduced to Australia (Table 17). The model gave one successful species (cane toad *Bufo marinus*) an Establishment Risk Rank of Extreme, and the other four successful species Establishment Risk Ranks of Serious. For the two failed species, the model ranked the Establishment Risk Rank of one (axolotl *Ambystoma mexicanum*) as Low but the other (black-spined toad *Bufo melanostictus*) was ranked as Serious, which suggests either the model has ranked the black-spined toad too high, or alternatively, that this is a high risk species, but it has not yet been subjected to sufficient propagule pressure to enable it to realise its establishment potential in Australia.

Because the above assumptions made in calibrating Bomford et al.'s (2005) model for Australian conditions are untested, the reliability of predictions made by this model may be less than predictions made by Bomford's (2003) model for mammals and birds or Bomford and Glover's (2004) model for freshwater finfish. Therefore Section 10.2 adapts Bomford's (2003) mammal and bird model for use in assessing establishment risk for exotic reptiles and amphibians proposed for introduction to Australia. Exotic reptiles and amphibians can then be assessed using both models. If both models predict an equivalent level of risk, then that result may be more robust than the result taken from Bomford et al.'s (2005) model alone. If the two models predict different levels of risk, a precautionary approach would accept the higher level of risk.

Table 17. Establishment Risk Ranks for exotic reptiles and amphibians introduced to Australia assessed using three alternative models:

A. The original reptile and amphibian model published by Bomford et al. (2005) but recalibrated to assess risk based on only four levels of Establishment Risk Rank (Low, Moderate, Serious or Extreme) instead of the original six levels used by Bomford et al. (2005) (see Section 10.1).
B. The recalibrated full mammal and bird risk assessment model (see Section 10.2.1) adapted for assessing exotic reptiles and amphibians introduced to Australia using seven risk factors.
C. The recalibrated contracted mammal and bird risk assessment model (see Section 10.2.2) adapted for assessing exotic reptiles and amphibians introduced to Australia using three risk factors with Taxonomic Score deleted from the model presented in Figure 9 because Taxonomic Score is always one for reptiles and amphibians (Bomford 2003).

A.

Introduction outcomes Australian mainland	**Family**	**Climate match PC Euclidian Σ7**	**A: Climate Match Risk Score (0–100)**	**B: Exotic Elsewhere Risk Score (0–30)**	**C: Taxonomic Family Risk Score (0–30)**	**Establishment Risk Score (0–160) (Rank)**
Successful species						
Cane toad (*Bufo marinus*)	Bufonidae	1849	66	30	20	116 (Extreme)
Asian house gecko (*Hemidactylus frenatus*)	Gekkonidae	698	25	30	30	85 (Serious)
Mourning gecko (*Lepidodactylus lugubris*)	Gekkonidae	79	3	30	30	63 (Serious)
Red-eared slider (*Trachemys scripta*)	Emydidae	1504	54	30	15	99 (Serious)
Flowerpot snake (*Ramphotyphlops braminus*)	Typhlopidae	947	34	30	30	94 (Serious)
Failed species						
Axolotl or salamander (*Ambystoma mexicanum*)	Ambystomatidae	0	0	0	15	15 (Low)
Black-spined toad (*Bufo melanostictus*)	Bufonidae	967	35	30	20	85 (Serious)

B.

Introduction outcomes Australian mainland	**Climate match PC Closest Standard Match Σ6**	**1. Climate Match Score (0–6)**	**2. Taxonomic Score (0–1)**	**3. Exotic Population Established Overseas Score (0–4)**	**4. Migratory Score (0–1)**	**5. Diet Score (0–1)**	**6. Habitat Score (0–1)**	**Overseas range size (million km^2)**	**7. Overseas Range Size Score (0–2)**	**Establishment Risk Score (0–16) (Rank)**
Successful species										
Cane toad (*Bufo marinus*)	2125	5	1	4	1	1	1	16.2	1	14 (Extreme)
Asian house gecko (*Hemidactylus frenatus*)	952	4	1	4	1	1	1	5.1	1	13 (Serious)
Mourning gecko (*Lepidodactylus lugubris*)	167	2	1	4	1	1	1	1.3	0	10 (Moderate)
Red-eared slider (*Trachemys scripta*)	1768	5	1	4	1	1	1	4.5	1	14 (Extreme)
Flowerpot snake (*Ramphotyphlops braminus*)	1092	4	1	4	1	1	1	7.2	1	13 (Serious)
Failed species										
Axolotl or salamander (*Ambystoma mexicanum*)	12	1	1	0	1	1	1	0.0003	0	6 (Low)
Black-spined toad (*Bufo melanostictus*)	1121	4	1	4	1	1	1	6.6	1	13 (Serious)

C.

Introduction outcomes Australian mainland	**Climate match PC Closest Standard Match (Σ6 level)**	**1. Climate Match Score (0–6)**	**2. Exotic Population Established Overseas Score (0–4)**	**Overseas range size (million km²)**	**3. Overseas Range Size Score (0–2)**	**Establishment Risk Score (0–12) (Rank)**
Successful species						
Cane toad (*Bufo marinus*)	2125	5	4	16.2	1	10 (Extreme)
Asian house gecko (*Hemidactylus frenatus*)	952	4	4	5.1	1	9 (Serious)
Mourning gecko (*Lepidodactylus lugubris*)	167	2	4	1.3	0	6 (Moderate)
Red-eared slider (*Trachemys scripta*)	1768	5	4	4.5	1	10 (Extreme)
Flowerpot snake (*Ramphotyphlops braminus*)	1092	4	4	7.2	1	9 (Serious)
Failed species						
Axolotl or salamander (*Ambystoma mexicanum*)	12	1	0	0.0003	0	1 (Low)
Black-spined toad (*Bufo melanostictus*)	1121	4	4	6.6	1	9 (Serious)

10. Updated reptile and amphibian risk assessment model

10.1 Refined reptile and amphibian risk assessment model

The model presented in this Section is the original model published by Bomford et al. (2005), modified to give a four-rank risk outcome instead of the original six-rank outcome. This matches the requirements of the Vertebrate Pests Committee risk assessment process (Natural Resource Management Standing Committee and Vertebrate Pests Committee 2004).

Score A: Climate Match Risk Score

Use PC CLIMATE (Bureau of Rural Sciences 2004) and select:

- '*worlddata_all.txt*' as the world data location
- '*cntry92.shp*' as the shapefile
- all 16 climatic parameters for matching locations (see Table 1)
- '*Euclidian match*' for the analysis.

If the input area has 12 or fewer meteorological stations, then CLIMATE is likely to underestimate the climate match to Australia. If this is the case, it is advisable to increase the Climate Match Risk Score by 10 percentage points.

Score A = A species' Climate Match Risk Score = the sum of its four scores for Euclidian match classes 7–10 (that is Σ7 level) expressed as a percentage of the maximum possible score for all these classes (that is 2785 for Australia).

Example 1: the cane toad (*Bufo marinus*) gets Euclidian match scores to Australia of:
Number 7 match = 857
Number 8 match = 951
Number 9 match = 41
Number 10 match = 0
Σ 7–10 matches = 1849
Score A = Climate Match Risk Score = 100×(1849/2785) = 66

Example 2: a lizard has only eight meteorological stations in its overseas range and the sum of its four highest Euclidian match classes Σ7 = 362. Its Climate Match Risk Score (Score A) = 100×(362/2785) + 10 = 13 + 10 = 23.

Score B: Exotic Elsewhere Risk Score

Score B = A species' Exotic Elsewhere Risk Score =

- 30 for a species that has established a breeding self-sustaining exotic population in another country;
- 15 for species that have been introduced into another country and for which records exist of it in the wild, but for which it is uncertain if a breeding self-sustaining exotic population has established;
- 0 for species that have not established an exotic population, including species not known to have been introduced anywhere.

For example, the cane toad gets a Score B = 30 for Australia because it has established self-sustaining exotic populations in many overseas countries including in Asia, Africa and on many Pacific islands.

Table 18. Taxonomic Family Risk Scores for exotic reptiles and amphibians (Based on data sourced from F. Kraus, unpublished database).

Family	Successful introduction events %	Taxonomic Family Risk Score
Dendrobatidae	100	30
Proteidae	100	30
Typhlopidae	95	30
Ranidae	80	30
Leptodactylidae	79	30
Chamaeleonidae	79	30
Gekkonidae	76	30
Rhacophoridae	75	30
Agamidae	70	30
Teiidae	67	20
Trionychidae	66	20
Bufonidae	60	20
Microhylidae	60	20
Plethodontidae	58	20
Lacertidae	57	20
Iguanidae	56	20
Testudinidae	48	15
Scincidae	46	15
Pipidae	42	15
Hylidae	41	15
Myobatrachidae	40	15
Emydidae	39	15
Discoglossidae	38	15
Ambystomatidae	38	15
Varanidae	38	15
Salamandridae	36	15
Anguidae	29	10
Chelydridae	29	10
Pelomedusidae	25	10
Chelidae	22	10
Viperidae	21	10
Colubridae	20	10
Cordylidae	17	10
Alligatoridae	15	10
Elapidae	11	10
Boidae	6	5
Pelobatidae	0	0
Cryptobranchidae	0	0
Amphisbaenidae	0	0
Gymnophthalmidae	0	0
Helodermatidae	0	0
Pygopodidae	0	0
Kinosternidae	0	0
Crocodylidae	0	0
Geomydidae	0	0

Score C: Taxonomic family risk score

Score C = A species' Taxonomic Family Risk Score is taken from Table 18.

- 30 = Extreme risk
- 20 = Very high risk
- 15 = High risk
- 10 = Moderate risk
- 5 = Low risk
- 0 = Very low risk

For example, the cane toad is in Family Bufonidae and gets a Very High Taxonomic Family Risk Score = 20.

Establishment Risk Score

A species' Establishment Risk Score = Score A + Score B + Score C.
Establishment Risk Scores can be converted to Establishment Risk Ranks ranging from Very Low to Extreme using the following cut-off thresholds:

Establishment Risk Rank	Establishment Risk Score
Extreme	> 115
Serious	61–115
Moderate	46–60
Low	≤45

For example, the cane toad's Establishment Risk Score for Australia =
66 + 30 + 20 = 116 = Extreme Establishment Risk.

10.2 Use of the mammal and bird risk assessment model for reptiles and amphibians

An alternative approach to assessing the risk that exotic reptiles and amphibians could establish in Australia is to use the model developed for assessing the establishment risk for exotic mammals and birds introduced to Australia (Bomford 2003). Directions and examples for this approach are described in this section. Two versions of the mammal and bird model are used – the full model with seven risk factors including overseas range size (adapted from Section 6, Stage B of this report) and a contracted model (adapted from Section 6, Stage B of this report, but using the three risk factors presented in Figure 9 with the Taxonomic Score deleted because this always has a value of one for reptiles and amphibians (Bomford 2003).

The results of using both the recalibrated mammal and bird risk assessment models on the seven exotic reptiles and amphibians introduced to Australia are presented in Table 17 b and c. Both models give the same Establishment Risk Ranks for the seven species, and these values are fairly similar to the results from using the updated version of Bomford et al.'s (2005) reptile and amphibian model (Table 17a). However, the mammal and bird model gave both the red-eared slider (*Trachemys scripta*) and the cane toad (*Bufo marinus*) an Establishment Risk Rank of Extreme (Table 17 b and c), whereas the reptile and amphibian model only gave the latter species an Extreme rank (Table 17a). The mammal and bird model gave the mourning gecko (*Lepidodactylus lugubris*) a Moderate Establishment Risk Rank (Table 17 b and c) whereas the reptile and amphibian model gave this species a Serious rank (Table 17a). For exotic reptiles and amphibians proposed for introduction to Australia, it is probably desirable to conduct assessments using both the updated reptile and amphibian model and the modified mammal and bird model (either the full or the contracted version), and if the results from the two models differ, use the higher Establishment Risk Rank for decision making, based on a precautionary approach.

10.2.1 Directions for assessing the risk of establishment for exotic reptiles and amphibians introduced to Australia using the recalibrated mammal and bird risk assessment model (full version with seven risk factors)

Step 1. Map the selected reptile or amphibian species' overseas range — including its entire native and exotic (excluding Australia) ranges over the past 1000 years. Use PC CLIMATE (Bureau of Rural Sciences 2004) and select:

- '*worlddata_all.txt*' as the world data location
- '*cntry92.shp*' as the shapefile
- all 16 climatic parameters for matching locations (see Table 1)
- Closest Standard Match for the analysis (takes over an hour for species with large overseas ranges).

Step 2. Sum the values for the five highest match classes (ie the scores for match classes 10, 9, 8, 7 and 6) = 'Value X'

Step 3.

Climate Match Score (1–6)

Convert 'Value X' to a Climate Match Score using the following cut-off thresholds:

Climate Match Score	PC CLIMATE Closest Standard Match Σ6 level (Value X) (sum of highest five match classes)
1	<100
2	100–599
3	600–899
4	900–1699
5	1700–2699
6	≥ 2700

If the input range for a species has 12 or fewer meteorological stations, then it is likely to underestimate the climate match to Australia. If this is the case, it is advisable to increase the climate match score by one increment. For example, if the input range for a species included only five meteorological stations, and the sum of the values for the five highest match classes to Australia equalled 504 (ie 'Value X' = 504), then this would give a Climate Match Score = 2 + 1 = 3.

Step 4. Calculate the five following scores from Bomford (2003):

Exotic Population Established Overseas Score (0–4)

- No exotic population ever established = 0
- Exotic populations only established on small islands less than 50 000 square kilometres (Tasmania is 67 800 square kilometres) = 2
- Exotic population established on an island larger than 50 000 square kilometres or anywhere on a continent = 4.

Taxonomic Class Score (0–1) [will always be 1 for reptiles and amphibians]

- Bird = 0
- Mammal, reptile or amphibian = 1.

Migratory Score (0–1)

- Migratory in its native range = 0
- Non-migratory in its native range or unknown = 1.

Diet Score (0–1)

- Specialist with a restricted range of foods = 0
- Generalist with a broad diet of many food types or diet unknown = 1.

Habitat Score (0–1)

- Only lives in undisturbed (natural) habitats = 0
- Can live in human-disturbed habitats (including grazing and agricultural lands, forests that are intensively managed or planted for timber harvesting and/or urban–suburban environments) or habitat use unknown = 1.

Step 5.

Overseas Range Size Score (0–2)

Calculate Overseas Range Size Score based on an estimate of the species' overseas range size (including current and past 1000 years, natural and introduced range) in millions of square kilometres using the following cut-off thresholds:

Overseas Range Size Score	Overseas range size (millions of square kilometres)
2	≥ 70
1	2–69
0	0–1

Step 6.

Establishment Risk Score (1–16)

Calculate the Establishment Risk Score = the sum of the following seven scores:

- The Climate Match Score (1–6) obtained in Step 3 above
- The five scores obtained in Step 4 above
- The Overseas Range Size Score (0–2) obtained in Step 5 above.

Step 7.

Establishment Risk Rank (Low–Extreme)

Convert the Establishment Risk Score obtained in Step 6 above to an Establishment Risk Rank using the following cut-off thresholds:

Establishment Risk Rank	Establishment Risk Score
Extreme	≥ 14
Serious	12–13
Moderate	7–11
Low	≤ 6

10.2.2 Directions for assessing the risk of establishment for exotic reptiles and amphibians introduced to Australia using the recalibrated mammal and bird risk assessment model (contracted version)

Step 1. Map the selected reptile or amphibian species' overseas range — including its entire native and exotic (excluding Australia) ranges over the past 1000 years. Use PC CLIMATE (Bureau of Rural

Sciences 2004), to determine the climate match between this overseas range and Australia, selecting Closest Standard Match and using all 16 climate variables for the analysis.

Step 2. Sum the values for the five highest match classes (ie the scores for match classes 10, 9, 8, 7 and 6) = 'Value X'.

Step 3.

Climate Match Score (1–6)

Convert 'Value X' to a Climate Match Score (1–6) using the following cut-off thresholds:

Climate Match Score	PC CLIMATE Closest Standard Match Σ6 level (Value X) (sum of highest five match classes)
1	<100
2	100–599
3	600–899
4	900–1699
5	1700–2699
6	≥ 2700

If the input range for a species has 12 or fewer meteorological stations, then it is likely to underestimate the climate match to Australia. If this is the case, it is advisable to increase the climate match score by one increment. For example, if the input range for a species included only five meteorological stations, and the sum of the values for the five highest match classes to Australia equalled 504 (ie 'Value X' = 504), then this would give a Climate Match Score = 2 + 1 = 3.

Step 4.

Exotic Population Established Overseas Score (0–4)

Calculate the Exotic Population Established Overseas Score (0–4)

- No exotic population ever established = 0
- Exotic populations only established on small island less than 50 000 square kilometres (Tasmania is 67 800 square kilometres) = 2
- Exotic population established on an island larger than 50 000 square kilometres or anywhere on a continent = 4.

Step 5.

Overseas Range Size Score (0–2)

Calculate Overseas Range Size Score based on an estimate of the species' overseas range size (including current and past 1000 years, natural and introduced range) in millions of square kilometres using the following cut-off thresholds:

Overseas Range Size Score	Overseas range size (millions of square kilometres)
2	≥ 70
1	2–69
0	0–1

Step 6.

Establishment Risk Score (1–16)

Calculate the Establishment Risk Score = the sum of the following three scores:
- The Climate Match Score (1–6) obtained in Step 3 above
- The Exotic Population Established Overseas Score (0–4) obtained in Step 4 above
- The Overseas Range Size Score (0–2) obtained in Step 5 above.

Step 7.

Establishment Risk Rank (Low–Extreme)

Convert the Establishment Risk Score (1–12) obtained in Step 6 above to an Establishment Risk Rank (Low, Moderate, Serious or Extreme) using the following cut-off thresholds:

Establishment Risk Rank	Establishment Risk Score
Extreme	10–12
Serious	8–9
Moderate	5–7
Low	≤ 4

10.3 Factors affecting risk of becoming a pest

Bomford et al. (2005) reviewed the factors associated with adverse impacts of exotic reptiles and amphibians and concluded that reliable knowledge about these impacts is sparse. They found 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 of exotic fish in Australia. Nonetheless, their review of factors associated with adverse impacts indicates that an increased risk is associated with exotic reptiles and amphibians that:

- have adverse impacts elsewhere
- have close relatives with similar behavioural and ecological strategies that have had adverse impacts elsewhere
- are dietary generalists
- stir up sediments to increase turbidity in aquatic habitats occur in high densities in their native or introduced range
- have the potential to cause poisoning and/or physical injury
- harbour or transmit diseases or parasites that are present in Australia
- have close relatives among Australia's endemic reptiles and amphibians
- are known to have spread rapidly following their release into new environments
- have a good climate match to Australia because such species are more likely to establish over large areas so their impacts will be spread more widely.

This list could be used as a checklist for a qualitative assessment of the threat of impacts posed by the establishment of new exotic reptile and amphibian species in Australia. However, an absence of these factors does not indicate a low risk of harm.

Acknowledgements

Win Kirkpatrick and Marion Massam provided valuable comments on several questions in the Bomford (2003) risk assessment model which enabled them to be rewritten to improve their clarity in this report. Win Kirkpatrick also pointed out that CLIMATE often underestimates the climate match to Australia for species with small geographic ranges containing low numbers of meteorological stations. This enabled corrections for this bias to be included in the models presented in this report. Leanne Brown conducted many of the CLIMATE analyses presented in this report and also provided valuable comments on their interpretation.

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Appendix A
Climate match results for exotic mammals introduced to Australia, using the three alternative types of CLIMATE analyses

Appendix A Table A1. Exotic mammals successfully introduced to the Australian mainland: PC Euclidian analysis.

PC Euclidean Successful mammals Sorted Σ6 level*	**10**	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**
Bos javanicus	0	0	65	415	802	1060	1413	1866	2209
Bos taurus	0	4	236	903	1554	2159	2590	2775	2780
Bubalus bubalis	0	0	128	690	958	1264	1699	2176	2591
Camelus dromedarius	0	0	0	83	987	1996	2419	2576	2661
Canis lupus	0	82	2046	2775	2785	2785	2785	2785	2785
Capra hircus	0	3	366	2054	2677	2742	2758	2770	2772
Cervus axis	0	0	319	1614	2479	2740	2762	2771	2778
Cervus elaphus	0	5	257	850	1661	1978	2223	2507	2743
Cervus porcinus	0	0	93	458	813	1078	1437	1958	2418
Cervus timorensis	0	0	25	105	240	464	900	1400	1848
Cervus unicolor	0	1	160	789	1138	1570	2129	2618	2784
Dama dama	0	2	238	648	1068	1636	2139	2543	2638
Equus asinus	0	1	369	1546	2287	2649	2722	2762	2775
Equus caballus	0	2	195	879	1728	2466	2719	2755	2771
Felis catus	0	69	1927	2766	2783	2784	2785	2785	2785
Funambulus pennanti	0	0	4	631	1524	2156	2507	2609	2670
Lepus capensis	0	31	1122	2636	2768	2779	2782	2783	2785
Mus domesticus	0	82	2038	2775	2784	2785	2785	2785	2785
Oryctolagus cuniculus	0	4	241	658	1067	1646	2040	2422	2662
Ovis aries	0	1	49	322	746	1722	2380	2557	2646
Rattus norvegicus	0	70	1596	2760	2779	2782	2785	2785	2785
Rattus rattus	0	78	2033	2769	2783	2783	2785	2785	2785
Sus scrofa	0	2065	2758	2781	2785	2785	2785	2785	2785
Vulpes vulpes	0	3	504	2245	2770	2784	2785	2785	2785

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix A Table A2. Exotic mammals introduced to the Australian mainland that failed to establish: PC Euclidian analysis.

PC Euclidean Failed mammals Sorted Σ6 level*	**10**	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**
Alces alces	0	0	2	29	206	568	903	1299	1616
Antilope cervicapra	0	0	271	1553	2192	2652	2753	2768	2773
Canis aureus	0	1	294	1661	2603	2769	2773	2777	2784
Capreolus capreolus	0	3	244	660	1084	1692	2107	2537	2751
Cervus duvauceli	0	0	8	57	328	518	777	1010	1286
Cervus marianus	0	0	2	13	57	112	205	357	607
Cervus nippon	0	0	22	128	385	888	1604	2637	2782
Equus burchelli	0	17	539	1498	2480	2729	2771	2777	2783
Herpestes edwardsi	0	0	91	1035	1726	2335	2669	2761	2776
Herpestes javanicus	0	0	104	996	1755	2369	2667	2736	2756
Hydropotes inervuis	0	0	1	12	121	425	793	1684	2462

Lama guanicoe	0	0	14	427	1185	1909	2316	2648	2777
Lama vicugna	0	0	2	24	125	1106	2072	2521	2708
Mesocricetus auratus	0	1	34	298	549	742	1305	1765	2470
Moschus moschiferus	0	0	0	3	123	358	911	1923	2605
Mustela erminea	0	4	141	427	760	1133	1447	1729	1981
Mustela nivalis	0	3	291	778	1623	2310	2495	2676	2785
Mustela putorius	0	2	226	641	1063	1632	2013	2299	2510
Sciurus carolinensis	0	6	219	493	738	1071	1759	2369	2746
Suncus murinus	0	0	272	935	1375	2161	2640	2748	2773
Syncernus kaffir	0	16	519	1341	2184	2705	2769	2776	2783
Tragelaphus oryx	0	8	463	964	1511	2362	2758	2772	2775
Tragulus meminna	0	0	19	303	805	1223	1671	2167	2582

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix A Table A3. Exotic mammals successfully introduced to the Australian mainland: PC Closest Standard Match analysis.

PC Closest Standard Match Successful mammals Sorted Σ6 level*	**10**	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**
Cervus timorensis	0	0	16	55	119	235	429	877	2054
Camelus dromedarius	0	0	0	22	154	767	1381	2209	2662
Ovis aries	0	2	60	263	595	897	1352	2434	2753
Bos javanicus	0	0	38	233	607	1091	1538	1929	2628
Cervus porcinus	0	0	45	288	665	1107	1530	1939	2655
Oryctolagus cuniculus	0	25	226	520	696	881	1242	2017	2736
Dama dama	0	23	224	541	731	954	1398	1939	2746
Bubalus bubalis	0	1	90	582	931	1280	1595	2292	2771
Funambulus pennanti	0	0	2	178	943	1409	1814	2441	2706
Cervus unicolor	0	5	128	647	1035	1472	1905	2653	2785
Cervus elaphus	0	41	258	658	1087	1475	1815	2445	2781
Bos taurus	0	23	195	535	1088	1700	2207	2658	2782
Equus caballus	0	16	155	522	1177	2253	2520	2743	2770
Equus asinus	0	22	381	1158	1841	2404	2685	2757	2781
Cervus axis	0	13	360	1273	1989	2537	2725	2765	2781
Capra hircus	0	26	282	1287	2250	2662	2715	2752	2774
Vulpes vulpes	0	45	589	1551	2591	2770	2784	2785	2785
Lepus capensis	0	130	837	2102	2718	2767	2779	2782	2784
Sus scrofa	0	119	1033	2511	2766	2781	2783	2784	2785
Rattus norvegicus	0	212	1325	2477	2768	2781	2783	2784	2785
Felis catus	1	236	1623	2582	2772	2782	2786	2786	2786
Rattus rattus	1	271	1743	2637	2776	2783	2783	2785	2785
Mus domesticus	1	297	1768	2640	2778	2785	2785	2785	2785
Canis lupus	1	298	1778	2643	2780	2785	2785	2785	2785

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix A Table A4. Exotic mammals introduced to the Australian mainland that failed to establish: PC Closest Standard Match analysis.

PC Closest Standard Match Failed mammals Sorted Σ6 level*	**10**	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**
Cervus marianus	0	0	3	8	21	53	112	281	1009
Hydropotes inervuis	0	0	1	2	42	329	981	1836	2769
Lama vicugna	0	0	3	12	52	304	902	1630	2300

Moschus moschiferus	0	0	0	2	69	360	818	2021	2719
Alces alces	0	0	1	22	101	382	734	1497	2063
Cervus duvauceli	0	0	11	35	185	351	487	804	1294
Cervus nippon	0	1	21	91	256	629	1408	2547	2784
Mesocricetus auratus	0	2	43	226	482	649	894	1644	2710
Mustela erminea	0	19	131	336	525	745	1061	1975	2758
Sciurus carolinensis	0	21	161	362	575	735	951	1717	2744
Lama guanicoe#	0	0	13	165	611	1531	2213	2746	2783
Tragulus meminna	0	0	0	249	636	1123	1489	2243	2731
Mustela putorius	0	19	206	509	684	848	1235	1836	2699
Capreolus capreolus	0	26	243	555	759	1117	1643	2396	2782
Mustela nivalis	0	36	302	599	797	1190	1913	2575	2785
Suncus murinus	0	8	192	764	1074	1614	2273	2542	2783
Tragelaphus oryx	1	46	363	731	1140	1758	2410	2770	2778
Herpestes javanicus	0	0	58	469	1328	1726	2252	2671	2764
Herpestes edwardsi	0	1	60	655	1351	1696	2261	2730	2783
Syncernus kaffir	1	55	376	851	1523	2202	2647	2775	2783
Equus burchelli	1	60	417	947	1622	2213	2692	2775	2783
Antilope cervicapra	0	11	326	1252	1943	2394	2636	2758	2780
Canis aureus	0	22	289	1245	2054	2538	2769	2776	2785

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix A Table A5. Exotic mammals successfully introduced to the Australian mainland: Mac analysis.

Mac analysis Successful mammals Sorted Σ6 level*	**10**	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**
Cervus timorensis	3	13	50	123	289	466	991	2561	2798
Ovis aries	0	42	236	504	655	797	1538	2774	2798
Camelus dromedarius	0	1	25	139	717	1317	2237	2690	2795
Oryctolagus cuniculus	20	156	394	603	734	905	1499	2667	2798
Dama dama	10	148	447	611	761	923	1395	2617	2798
Funambulus pennanti	0	0	4	398	1060	1565	2364	2716	2797
Cervus elaphus	16	151	431	773	1115	1386	2010	2791	2798
Bos javanicus	0	25	313	737	1337	1599	2184	2716	2798
Cervus porcinus	0	37	352	787	1354	1595	2213	2726	2798
Bubalus bubalis	0	53	506	1046	1411	1737	2366	2790	2798
Cervus unicolor	4	78	573	1160	1587	1975	2661	2798	2798
Bos taurus	7	54	294	987	1664	2182	2722	2795	2798
Equus caballus	3	27	217	903	1727	2413	2761	2792	2798
Equus asinus	0	123	824	1666	2417	2669	2776	2795	2798
Cervus axis	2	125	883	1837	2585	2752	2790	2794	2798
Capra hircus	11	101	618	1999	2645	2740	2788	2797	2798
Vulpes vulpes	24	322	1067	2104	2761	2795	2797	2798	2798
Lepus capensis	89	658	1692	2655	2769	2793	2795	2796	2798
Rattus norvegicus	95	772	2200	2771	2792	2796	2797	2798	2798
Sus scrofa	68	603	1833	2744	2792	2796	2797	2798	2798
Felis catus	96	993	2343	2789	2795	2797	2797	2798	2798
Rattus rattus	111	1149	2532	2792	2795	2796	2798	2798	2798
Mus domesticus	123	1163	2530	2785	2796	2797	2798	2798	2798
Canis lupus	125	1174	2550	2794	2796	2797	2798	2798	2798

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix A Table A6. Exotic mammals introduced to the Australian mainland that failed to establish: Mac analysis.

Mac analysis Failed mammals Sorted Σ6 level*	**10**	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	Σ2
Cervus marianus	0	3	11	34	82	159	359	1161	2798
Hydropotes inervuis	0	0	1	15	105	374	1189	2720	2798
Lama vicugna	0	0	9	39	117	320	1431	2471	2798
Alces alces	0	0	3	22	130	379	933	1769	2798
Moschus moschiferus	0	0	0	32	202	512	1692	2758	2798
Cervus duvauceli	0	0	24	127	358	561	1019	1399	2797
Cervus nippon	0	7	47	163	456	927	2720	2798	2798
Mesocricetus auratus	0	36	207	436	578	686	1047	2084	2098
Mustela erminea	13	98	252	418	633	874	1607	2436	2798
Sciurus carolinensis	25	145	377	560	754	950	1478	2790	2798
Capreolus capreolus	10	175	462	634	823	1136	1822	2762	2798
Lama guanicoe	0	1	45	301	835	1454	2327	2797	2798
Mustela nivalis	28	252	524	697	932	1377	2354	2798	2798
Mustela putorius	28	248	522	691	988	1390	2314	2793	2798
Tragulus meminna	0	2	270	763	1231	1641	2315	2783	2798
Herpestes javanicus	0	52	367	1008	1557	2028	2675	2783	2798
Herpestes edwardsi	0	23	438	1125	1567	2046	2743	2796	2798
Tragelaphus oryx	0	100	434	1027	1584	2170	2728	2789	2798
Suncus murinus	7	123	617	1215	1584	2122	2666	2838	2838
Syncernus kaffir	14	138	561	1278	1990	2588	2794	2796	2798
Equus burchelli	18	158	549	1301	2119	2574	2794	2795	2798
Antilope cervicapra	1	95	798	1765	2293	2508	2782	2790	2798
Canis aureus	13	240	1151	1939	2622	2790	2797	2797	2798

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix B
Climate match results for exotic birds introduced to Australia, using the three alternative types of CLIMATE analyses

Appendix B Table B1. Exotic birds successfully introduced to the Australian mainland: PC Euclidian analysis.

PC Euclidean Successful birds Sorted Σ6 level*	10	Σ9	Σ8	Σ7	Σ6	Σ5	Σ4	Σ3	Σ2
Cygnus olor	0	0	52	374	619	842	1366	2131	2660
Turdus philomelos	0	2	147	473	798	1160	1469	1789	2096
Lonchura puntulata	0	0	138	731	1068	1449	1864	2355	2743
Streptopelia chinensis	0	0	134	718	1175	1878	2554	2765	2777
Pavo cristatus	0	0	88	738	1175	1650	2168	2627	2779
Pycnonotus jocosus	0	0	102	681	1223	1840	2365	2753	2766
Acridotheres tristis	0	1	181	956	1532	2600	2783	2784	2784
Carduelis chloris	0	5	270	765	1600	2111	2367	2544	2674
Alauda arvensis	0	4	267	764	1620	2113	2367	2520	2678
Passer montanus	0	3	296	1125	1974	2648	2783	2783	2784
Anas platyrhynchos	0	6	421	1380	2207	2429	2545	2635	2725
Carduelis carduelis	0	5	283	1244	2366	2641	2721	2758	2779
Streptopelia decaocto	0	2	337	1643	2451	2780	2781	2782	2784
Struthio camelus	0	0	318	1823	2457	2699	2770	2777	2783
Turdus merula	0	5	308	1608	2710	2782	2784	2785	2785
Sturnus vulgaris	0	51	1326	2594	2734	2758	2771	2780	2782
Streptopelia senegalensis	0	24	1300	2666	2755	2771	2775	2779	2784
Ardeola ibis	0	62	1690	2705	2767	2776	2780	2784	2784
Columba livia	0	46	1428	2757	2780	2782	2785	2785	2785
Passer domesticus	0	82	1992	2764	2781	2784	2785	2785	2785

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix B Table B2. Exotic birds introduced to the Australian mainland that failed to establish: PC Euclidian analysis.

PC Euclidean Failed birds Sorted Σ6 level*	10	Σ9	Σ8	Σ7	Σ6	Σ5	Σ4	Σ3	Σ2
Lophura ignita	0	0	0	0	0	0	2	16	61
Fringilla montifringilla	0	0	0	8	45	88	136	231	423
Serinus canarius	0	0	0	0	83	478	932	1940	2696
Aix galericulata	0	0	6	36	147	324	573	874	1569
Padda oryzivora	0	0	14	91	217	399	647	960	1315
Branta canadensis	0	1	38	153	382	674	1057	1794	2263
Lophura nycthemera	0	0	51	269	473	696	1071	1483	2205
Carduelis spinus	0	0	35	328	653	891	1332	1966	2363
Pyrrhula pyrrhula	0	2	115	354	656	913	1337	1966	2363
Emberiza citrinella	0	2	183	467	716	1023	1546	1962	2259
Perdix perdix	0	2	170	580	856	1361	1784	2072	2433
Gallus gallus	0	0	103	463	894	1534	2145	2718	2766
Erithacus rubecula	0	3	243	616	990	1636	2033	2341	2619
Alectoris rufa	0	1	204	628	1057	1630	2013	2299	2510
Emberiza hortulana	0	2	224	649	1067	1639	2033	2512	2673
Lophophorus impejanus	0	0	8	432	1124	1764	2085	2350	2629

Lonchura malacca	0	0	105	714	1150	1424	1796	2224	2614
Pycnonotus cafer	0	0	76	802	1210	1791	2110	2353	2644
Corvus splendens	0	0	132	801	1228	1597	2102	2729	2776
Alectoris barbara	0	0	98	407	1229	1903	2209	2388	2546
Luscinia megarhynchos	0	3	254	751	1570	1985	2251	2465	2634
Acanthis cannabina	0	3	263	760	1577	1991	2384	2554	2655
Fringilla coelebs	0	3	261	758	1577	1961	2206	2524	2673
Callipepla californicus	0	2	85	830	2071	2470	2612	2685	2752
Agapornis roseicollis	0	0	258	1279	2108	2421	2567	2661	2718
Alectoris Chukar	0	1	226	1264	2114	2547	2620	2680	2728
Pterocles exustus	0	0	105	1161	2160	2707	2768	2775	2783
Streptopelia turtur	0	3	271	1192	2364	2607	2679	2725	2744
Phasianus colchicus	0	3	614	2113	2525	2727	2782	2785	2785
Euplectes albonotatus	0	17	573	1515	2539	2747	2771	2777	2783
Numida meleagris	0	17	766	2263	2700	2755	2774	2778	2783
Euplectes orix	0	23	1162	2533	2715	2753	2774	2777	2783
Plectropterus gambensis	0	23	1164	2537	2725	2756	2774	2778	2783
Oena capensis	0	23	1199	2567	2729	2759	2776	2779	2783

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix B Table B3. Exotic birds successfully introduced to the Australian mainland: PC Closest Standard Match analysis.

PC Closest Standard Match Successful birds Sorted Σ6 level*	10	Σ9	Σ8	Σ7	Σ6	Σ5	Σ4	Σ3	Σ2
Cygnus olor	0	2	61	233	479	708	1011	1616	2726
Turdus philomelos	0	14	152	400	644	922	1380	1861	2725
Carduelis chloris	0	42	281	582	765	1152	1881	2534	2764
Alauda arvensis	0	27	257	573	787	1178	1899	2614	2785
Pavo cristatus	0	2	68	557	962	1390	1776	2491	2783
Lonchura puntulata	0	1	102	622	991	1358	1692	2378	2785
Pycnonotus jocosus	0	1	73	476	996	1546	2134	2732	2776
Streptopelia chinensis	0	1	98	618	1059	1805	2591	2770	2785
Acridotheres tristis	0	6	139	740	1224	1843	2583	2782	2785
Carduelis carduelis	0	42	284	710	1433	2236	2622	2734	2783
Passer montanus	0	18	259	803	1434	2190	2771	2783	2785
Anas platyrhynchos	0	55	398	996	1902	2382	2520	2679	2785
Struthio camelus	0	8	234	1191	1945	2468	2741	2772	2782
Turdus merula	0	43	302	927	1977	2612	2782	2784	2785
Streptopelia decaocto	0	19	285	1200	2036	2477	2774	2782	2785
Sturnus vulgaris	0	137	1033	2158	2639	2724	2752	2774	2783
Streptopelia senegalensis	1	109	961	2314	2717	2764	2773	2778	2784
Ardeola ibis	1	181	1429	2522	2746	2772	2777	2781	2784
Columba livia	0	152	1230	2553	2769	2781	2783	2784	2785
Passer domesticus	1	290	1726	2608	2772	2782	2784	2785	2785

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix B Table B4. Exotic birds introduced to the Australian mainland that failed to establish: PC Closest Standard Match analysis.

PC Closest Standard Match Failed birds Sorted Σ6 level*	10	Σ9	Σ8	Σ7	Σ6	Σ5	Σ4	Σ3	Σ2
Lophura ignita	0	0	0	0	0	0	1	25	159

Fringilla montifringilla	0	0	0	7	26	62	117	220	662
Serinus canarius	0	0	0	0	48	251	543	1186	2408
Aix galericulata	0	0	3	8	75	229	460	1365	2760
Padda oryzivora	0	0	8	32	105	232	416	740	1854
Branta canadensis	0	4	39	98	185	505	1139	1737	2439
Lophura nycthemera	0	0	8	93	298	557	813	1625	2591
Alectoris barbara	0	15	88	236	435	692	1731	2371	2630
Carduelis spinus	0	1	39	211	542	851	1350	1851	2725
Emberiza citrinella	0	14	171	380	591	842	1098	1592	2378
Pyrrhula pyrrhula	0	14	109	313	614	915	1364	1861	2725
Lophophorus impejanus	0	0	11	140	648	1030	1572	2113	2671
Alectoris rufa	0	14	178	478	668	834	1224	1830	2680
Perdix perdix	0	19	168	499	689	925	1349	1802	2502
Erithacus rubecula	0	26	246	554	714	947	1384	2020	2761
Gallus gallus	0	1	64	301	719	1353	2055	2661	2777
Emberiza hortulana	0	21	225	535	722	974	1393	1940	2748
Luscinia megarhynchos	0	35	258	572	753	1140	1773	2341	2763
Acanthis cannabina	0	36	270	577	762	1147	1778	2495	2764
Fringilla coelebs	0	36	271	580	762	1145	1774	2335	2758
Pycnonotus cafer	0	1	56	553	948	1339	1816	2310	2777
Lonchura malacca	0	0	80	490	978	1326	1656	2338	2783
Corvus splendens	0	1	92	623	1028	1403	1715	2630	2783
Callipepla californicus	0	7	96	351	1029	2134	2455	2624	2745
Streptopelia turtur	0	35	268	693	1451	2187	2557	2682	2766
Agapornis roseicollis	0	8	182	780	1506	2079	2395	2645	2724
Alectoris chukar	0	12	187	776	1592	2155	2521	2690	2772
Pterocles exustus	0	0	64	703	1615	2222	2737	2772	2783
Euplectes albonotatus	1	63	457	1072	2037	2668	2757	2775	2783
Phasianus colchicus	0	40	635	1717	2380	2556	2684	2781	2785
Numida meleagris	1	67	541	1496	2415	2723	2769	2776	2783
Euplectes orix	1	91	800	2067	2601	2722	2768	2777	2783
Plectropterus gambensis	1	91	800	2061	2601	2728	2771	2778	2783
Oena capensis	1	95	832	2108	2631	2738	2774	2779	2783

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix B Table B5. Exotic birds successfully introduced to the Australian mainland: Mac analysis.

Mac analysis Successful birds Sorted Σ6 level*	**10**	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**
Passer domesticus	155	1174	2416	2779	2796	2797	2797	2798	2798
Ardeola ibis	130	1170	2492	2757	2789	2794	2797	2798	2798
Streptopelia senegalensis	82	934	2193	2746	2785	2791	2796	2797	2798
Columba livia	82	928	2476	2781	2795	2796	2797	2798	2798
Sturnus vulgaris	65	617	1997	2631	2752	2778	2792	2797	2798
Struthio camelus	14	436	1376	2022	2459	2737	2795	2796	2798
Turdus merula	28	246	769	1645	2360	2759	2797	2798	2798
Passer montanus	21	300	873	1501	2258	2622	2798	2798	2798
Anas platyrhynchos	25	204	590	1384	2169	2403	2762	2797	2798
Carduelis carduelis	27	218	494	876	1812	2510	2689	2794	2798
Streptopelia decaocto	9	289	1045	1850	2398	2700	2796	2797	2798
Carduelis chloris	27	212	491	667	954	1377	2289	2790	2798
Alauda arvensis	25	184	464	668	986	1405	2412	2794	2798

Acridotheres tristis	9	165	681	1307	1927	2456	2797	2798	2798
Streptopelia chinensis	7	156	627	1224	1920	2495	2795	2798	2798
Lonchura punctulata	8	156	631	1159	1584	1902	2686	2798	2798
Pycnonotus jocosus	5	129	564	1090	1803	2195	2775	2798	2798
Pavo cristatus	3	61	568	1119	1526	1946	2580	2792	2798
Turdus philomelos	8	101	301	538	738	892	1292	2199	2798
Cygnus olor	0	26	164	400	628	766	1315	2371	2798

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix B Table B6. Exotic birds introduced to the Australian mainland that failed to establish: Mac analysis.

Mac analysis Failed birds Sorted Σ6 level*	**10**	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**
Oena capensis	81	740	1814	2610	2767	2788	2797	2797	2798
Euplectes orix	67	693	1761	2607	2766	2787	2796	2797	2798
Plectropterus gambensis	66	702	1783	2569	2765	2787	2796	2797	2798
Numida meleagris	53	479	1221	2039	2664	2782	2797	2797	2798
Luscinia megarhynchos	23	198	481	656	950	1356	2019	2789	2798
Euplectes albonotatus	33	279	815	1707	2453	2735	2795	2796	2798
Phasianus colchicus	9	235	1254	2151	2710	2793	2797	2798	2798
Streptopelia turtur	23	208	493	818	2000	2578	2745	2793	2798
Agapornis roseicollis	8	233	652	1097	1819	2350	2687	2747	2797
Acanthis cannabina	23	206	485	664	949	1367	2074	2789	2798
Fringilla coelebs	23	204	486	664	940	1358	2011	2789	2798
Pterocles exustus	1	146	688	1629	2309	2641	2796	2797	2798
Gallus gallus	8	141	455	883	1736	2123	2633	2798	2798
Alectoris Chukar	4	126	505	990	1836	2350	2702	2789	2798
Lonchura malacca	7	151	599	1079	1490	1820	2504	2791	2798
Corvus splendens	5	125	597	1144	1527	2017	2696	2796	2798
Erithacus rubecula	15	175	451	606	735	947	1430	2631	2798
Callipepla californicus	5	25	162	874	1935	2531	2749	2798	2798
Emberiza citrinella	15	130	309	448	690	879	1203	1706	2798
Emberiza hortulana	5	157	452	614	777	944	1407	2627	2798
Pycnonotus cafer	1	71	549	1049	1397	1714	2338	2789	2798
Alectoris barbara	12	78	186	386	682	1191	2369	2704	2797
Perdix perdix	5	124	389	569	709	853	1262	1921	2798
Alectoris rufa	6	105	358	579	738	902	1394	2575	2798
Pyrrhula pyrrhula	6	78	281	505	653	833	1279	2199	2798
Lophura nycthemera	1	27	155	387	674	1006	2363	2782	2798
Carduelis spinus	0	15	145	448	606	775	1250	2197	2798
Lophophorus impejanus	0	2	37	176	602	941	1231	1765	2797
Padda oryzivora	0	14	69	201	356	495	931	2306	2798
Branta canadensis	1	12	40	84	234	487	1034	1705	2798
Serinus canarius	0	0	2	59	335	564	1039	2161	2798
Aix galericulata	0	2	7	39	182	455	1469	2636	2798
Lophura ignita	0	0	0	1	40	136	494	1643	2798
Fringilla montifringilla	0	0	0	0	11	39	112	355	2798

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix C

Climate match results for combined data sets for exotic mammals and birds (combined) introduced to Australia, using the three alternative types of CLIMATE analyses

Appendix C Table C1. Exotic mammals and birds (combined) successfully introduced to the Australian mainland: PC Euclidian analysis.

PC Euclidian analysis Successful mammals and birds Sorted Σ7 level*	**10**	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**
Camelus dromedarius	0	0	0	83	987	1996	2419	2576	2661
Cervus timorensis	0	0	25	105	240	464	900	1400	1848
Ovis aries	0	1	49	322	746	1722	2380	2557	2646
Cygnus olor	0	0	52	374	619	842	1366	2131	2660
Bos javanicus	0	0	65	415	802	1060	1413	1866	2209
Cervus porcinus	0	0	93	458	813	1078	1437	1958	2418
Turdus philomelos	0	2	147	473	798	1160	1469	1789	2096
Funambulus pennanti	0	0	4	631	1524	2156	2507	2609	2670
Dama dama	0	2	238	648	1068	1636	2139	2543	2638
Oryctolagus cuniculus	0	4	241	658	1067	1646	2040	2422	2662
Pycnonotus jocosus	0	0	102	681	1223	1840	2365	2753	2766
Bubalus bubalis	0	0	128	690	958	1264	1699	2176	2591
Streptopelia chinensis	0	0	134	718	1175	1878	2554	2765	2777
Lonchura punctulata	0	0	138	731	1068	1449	1864	2355	2743
Pavo cristatus	0	0	88	738	1175	1650	2168	2627	2779
Alauda arvensis	0	4	267	764	1620	2113	2367	2520	2678
Carduelis chloris	0	5	270	765	1600	2111	2367	2544	2674
Cervus unicolor	0	1	160	789	1138	1570	2129	2618	2784
Cervus elaphus	0	5	257	850	1661	1978	2223	2507	2743
Equus caballus	0	2	195	879	1728	2466	2719	2755	2771
Bos taurus	0	4	236	903	1554	2159	2590	2775	2780
Acridotheres tristis	0	1	181	956	1532	2600	2783	2784	2784
Passer montanus	0	3	296	1125	1974	2648	2783	2783	2784
Carduelis carduelis	0	5	283	1244	2366	2641	2721	2758	2779
Anas platyrhynchos	0	6	421	1380	2207	2429	2545	2635	2725
Equus asinus	0	1	369	1546	2287	2649	2722	2762	2775
Turdus merula	0	5	308	1608	2710	2782	2784	2785	2785
Cervus axis	0	0	319	1614	2479	2740	2762	2771	2778
Streptopelia decaocto	0	2	337	1643	2451	2780	2781	2782	2784
Struthio camelus	0	0	318	1823	2457	2699	2770	2777	2783
Capra hircus	0	3	366	2054	2677	2742	2758	2770	2772
Vulpes vulpes	0	3	504	2245	2770	2784	2785	2785	2785
Sturnus vulgaris	0	51	1326	2594	2734	2758	2771	2780	2782
Lepus capensis	0	31	1122	2636	2768	2779	2782	2783	2785
Streptopelia senegalensis	0	24	1300	2666	2755	2771	2775	2779	2784
Ardeola ibis	0	62	1690	2705	2767	2776	2780	2784	2784
Columba livia	0	46	1428	2757	2780	2782	2785	2785	2785
Rattus norvegicus	0	70	1596	2760	2779	2782	2785	2785	2785
Passer domesticus	0	82	1992	2764	2781	2784	2785	2785	2785
Felis catus	0	69	1927	2766	2783	2784	2785	2785	2785

Rattus rattus	0	78	2033	2769	2783	2783	2785	2785	2785
Mus domesticus	0	82	2038	2775	2784	2785	2785	2785	2785
Canis lupus	0	82	2046	2775	2785	2785	2785	2785	2785
Sus scrofa	0	2065	2758	2781	2785	2785	2785	2785	2785

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix C Table C2. Exotic mammals and birds (combined) introduced to the Australian mainland that failed to establish: PC Euclidian analysis.

PC Euclidian analysis Failed mammals and birds Sorted Σ7 level*	**10**	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**
Lophura ignita	0	0	0	0	0	0	2	16	61
Serinus canarius	0	0	0	0	83	478	932	1940	2696
Moschus moschiferus	0	0	0	3	123	358	911	1923	2605
Fringilla montifringilla	0	0	0	8	45	88	136	231	423
Hydropotes inervuis	0	0	1	12	121	425	793	1684	2462
Cervus marianus	0	0	2	13	57	112	205	357	607
Lama vicugna	0	0	2	24	125	1106	2072	2521	2708
Alces alces	0	0	2	29	206	568	903	1299	1616
Aix galericulata	0	0	6	36	147	324	573	874	1569
Cervus duvauceli	0	0	8	57	328	518	777	1010	1286
Padda oryzivora	0	0	14	91	217	399	647	960	1315
Cervus nippon	0	0	22	128	385	888	1604	2637	2782
Branta canadensis	0	1	38	153	382	674	1057	1794	2263
Lophura nycthemera	0	0	51	269	473	696	1071	1483	2205
Mesocricetus auratus	0	1	34	298	549	742	1305	1765	2470
Tragulus meminna	0	0	19	303	805	1223	1671	2167	2582
Carduelis spinus	0	0	35	328	653	891	1332	1966	2363
Pyrrhula pyrrhula	0	2	115	354	656	913	1337	1966	2363
Alectoris barbara	0	0	98	407	1229	1903	2209	2388	2546
Mustela erminea	0	4	141	427	760	1133	1447	1729	1981
Lama guanicoe	0	0	14	427	1185	1909	2316	2648	2777
Lophophorus impejanus	0	0	8	432	1124	1764	2085	2350	2629
Gallus gallus	0	0	103	463	894	1534	2145	2718	2766
Emberiza citrinella	0	2	183	467	716	1023	1546	1962	2259
Sciurus carolinensis	0	6	219	493	738	1071	1759	2369	2746
Perdix perdix	0	2	170	580	856	1361	1784	2072	2433
Erithacus rubecula	0	3	243	616	990	1636	2033	2341	2619
Alectoris rufa	0	1	204	628	1057	1630	2013	2299	2510
Mustela putorius	0	2	226	641	1063	1632	2013	2299	2510
Emberiza hortulana	0	2	224	649	1067	1639	2033	2512	2673
Capreolus capreolus	0	3	244	660	1084	1692	2107	2537	2751
Lonchura malacca	0	0	105	714	1150	1424	1796	2224	2614
Luscinia megarhynchos	0	3	254	751	1570	1985	2251	2465	2634
Fringilla coelebs	0	3	261	758	1577	1961	2206	2524	2673
Acanthis cannabina	0	3	263	760	1577	1991	2384	2554	2655
Mustela nivalis	0	3	291	778	1623	2310	2495	2676	2785
Corvus splendens	0	0	132	801	1228	1597	2102	2729	2776
Pycnonotus cafer	0	0	76	802	1210	1791	2110	2353	2644
Callipepla californicus	0	2	85	830	2071	2470	2612	2685	2752
Suncus murinus	0	0	272	935	1375	2161	2640	2748	2773
Tragelaphus oryx	0	8	463	964	1511	2362	2758	2772	2775

Herpestes javanicus	0	0	104	996	1755	2369	2667	2736	2756
Herpestes edwardsi	0	0	91	1035	1726	2335	2669	2761	2776
Pterocles exustus	0	0	105	1161	2160	2707	2768	2775	2783
Streptopelia turtur	0	3	271	1192	2364	2607	2679	2725	2744
Alectoris Chukar	0	1	226	1264	2114	2547	2620	2680	2728
Agapornis roseicollis	0	0	258	1279	2108	2421	2567	2661	2718
Syncernus kaffir	0	16	519	1341	2184	2705	2769	2776	2783
Equus burchelli	0	17	539	1498	2480	2729	2771	2777	2783
Euplectes albonotatus	0	17	573	1515	2539	2747	2771	2777	2783
Antilope cervicapra	0	0	271	1553	2192	2652	2753	2768	2773
Canis aureus	0	1	294	1661	2603	2769	2773	2777	2784
Phasianus colchicus	0	3	614	2113	2525	2727	2782	2785	2785
Numida meleagris	0	17	766	2263	2700	2755	2774	2778	2783
Euplectes orix	0	23	1162	2533	2715	2753	2774	2777	2783
Plectropterus gambensis	0	23	1164	2537	2725	2756	2774	2778	2783
Oena capensis	0	23	1199	2567	2729	2759	2776	2779	2783

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix C Table C3. Exotic mammals and birds (combined) successfully introduced to the Australian mainland: PC Closest Standard Match analysis.

PC Closest Standard Match Successful mammals and birds Sorted Σ6 level %*	10	Σ9	Σ8	Σ7	Σ6	Σ5	Σ4	Σ3	Σ2
Cervus timorensis	0	0	16	55	119	235	429	877	2054
Camelus dromedarius	0	0	0	22	154	767	1381	2209	2662
Cygnus olor	0	2	61	233	479	708	1011	1616	2726
Ovis aries	0	2	60	263	595	897	1352	2434	2753
Bos javanicus	0	0	38	233	607	1091	1538	1929	2628
Turdus philomelos	0	14	152	400	644	922	1380	1861	2725
Cervus porcinus	0	0	45	288	665	1107	1530	1939	2655
Oryctolagus cuniculus	0	25	226	520	696	881	1242	2017	2736
Dama dama	0	23	224	541	731	954	1398	1939	2746
Carduelis chloris	0	42	281	582	765	1152	1881	2534	2764
Alauda arvensis	0	27	257	573	787	1178	1899	2614	2785
Bubalus bubalis	0	1	90	582	931	1280	1595	2292	2771
Funambulus pennanti	0	0	2	178	943	1409	1814	2441	2706
Pavo cristatus	0	2	68	557	962	1390	1776	2491	2783
Lonchura puntulata	0	1	102	622	991	1358	1692	2378	2785
Pycnonotus jocosus	0	1	73	476	996	1546	2134	2732	2776
Cervus unicolor	0	5	128	647	1035	1472	1905	2653	2785
Streptopelia chinensis	0	1	98	618	1059	1805	2591	2770	2785
Cervus elaphus	0	41	258	658	1087	1475	1815	2445	2781
Bos taurus	0	23	195	535	1088	1700	2207	2658	2782
Equus caballus	0	16	155	522	1177	2253	2520	2743	2770
Acridotheres tristis	0	6	139	740	1224	1843	2583	2782	2785
Carduelis carduelis	0	42	284	710	1433	2236	2622	2734	2783
Passer montanus	0	18	259	803	1434	2190	2771	2783	2785
Equus asinus	0	22	381	1158	1841	2404	2685	2757	2781
Anas platyrhynchos	0	55	398	996	1902	2382	2520	2679	2785
Struthio camelus	0	8	234	1191	1945	2468	2741	2772	2782
Turdus merula	0	43	302	927	1977	2612	2782	2784	2785
Cervus axis	0	13	360	1273	1989	2537	2725	2765	2781

Streptopelia decaocto	0	19	285	1200	2036	2477	2774	2782	2785
Capra hircus	0	26	282	1287	2250	2662	2715	2752	2774
Vulpes vulpes	0	45	589	1551	2591	2770	2784	2785	2785
Sturnus vulgaris	0	137	1033	2158	2639	2724	2752	2774	2783
Streptopelia senegalensis	1	109	961	2314	2717	2764	2773	2778	2784
Lepus capensis	0	130	837	2102	2718	2767	2779	2782	2784
Ardeola ibis	1	181	1429	2522	2746	2772	2777	2781	2784
Sus scrofa	0	119	1033	2511	2766	2781	2783	2784	2785
Rattus norvegicus	0	212	1325	2477	2768	2781	2783	2784	2785
Columba livia	0	152	1230	2553	2769	2781	2783	2784	2785
Felis catus	1	236	1623	2582	2772	2782	2786	2786	2786
Passer domesticus	1	290	1726	2608	2772	2782	2784	2785	2785
Rattus rattus	1	271	1743	2637	2776	2783	2783	2785	2785
Mus domesticus	1	297	1768	2640	2778	2785	2785	2785	2785
Canis lupus	1	298	1778	2643	2780	2785	2785	2785	2785

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix C Table C4. Exotic mammals and birds (combined) introduced to the Australian mainland that failed to establish: PC Closest Standard Match analysis.

PC Closest Standard Match Failed mammals and birds Sorted Σ6 level*	**10**	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**
Lophura ignita	0	0	0	0	0	0	1	25	159
Cervus marianus	0	0	3	8	21	53	112	281	1009
Fringilla montifringilla	0	0	0	7	26	62	117	220	662
Hydropotes inervuis	0	0	1	2	42	329	981	1836	2769
Serinus canarius	0	0	0	0	48	251	543	1186	2408
Lama vicugna	0	0	3	12	52	304	902	1630	2300
Moschus moschiferus	0	0	0	2	69	360	818	2021	2719
Aix galericulata	0	0	3	8	75	229	460	1365	2760
Alces alces	0	0	1	22	101	382	734	1497	2063
Padda oryzivora	0	0	8	32	105	232	416	740	1854
Cervus duvauceli	0	0	11	35	185	351	487	804	1294
Branta canadensis	0	4	39	98	185	505	1139	1737	2439
Cervus nippon	0	1	21	91	256	629	1408	2547	2784
Lophura nycthemera	0	0	8	93	298	557	813	1625	2591
Alectoris barbara	0	15	88	236	435	692	1731	2371	2630
Mesocricetus auratus	0	2	43	226	482	649	894	1644	2710
Mustela erminea	0	19	131	336	525	745	1061	1975	2758
Carduelis spinus	0	1	39	211	542	851	1350	1851	2725
Sciurus carolinensis	0	21	161	362	575	735	951	1717	2744
Emberiza citrinella	0	14	171	380	591	842	1098	1592	2378
Lama guanicoe	0	0	13	165	611	1531	2213	2746	2783
Pyrrhula pyrrhula	0	14	109	313	614	915	1364	1861	2725
Tragulus meminna	0	0	0	249	636	1123	1489	2243	2731
Lophophorus impejanus	0	0	11	140	648	1030	1572	2113	2671
Alectoris rufa	0	14	178	478	668	834	1224	1830	2680
Mustela putorius	0	19	206	509	684	848	1235	1836	2699
Perdix perdix	0	19	168	499	689	925	1349	1802	2502
Erithacus rubecula	0	26	246	554	714	947	1384	2020	2761
Gallus gallus	0	1	64	301	719	1353	2055	2661	2777
Emberiza hortulana	0	21	225	535	722	974	1393	1940	2748

Luscinia megarhynchos	0	35	258	572	753	1140	1773	2341	2763
Capreolus capreolus	0	26	243	555	759	1117	1643	2396	2782
Acanthis cannabina	0	36	270	577	762	1147	1778	2495	2764
Fringilla coelebs	0	36	271	580	762	1145	1774	2335	2758
Mustela nivalis	0	36	302	599	797	1190	1913	2575	2785
Pycnonotus cafer	0	1	56	553	948	1339	1816	2310	2777
Lonchura malacca	0	0	80	490	978	1326	1656	2338	2783
Corvus splendens	0	1	92	623	1028	1403	1715	2630	2783
Callipepla californicus	0	7	96	351	1029	2134	2455	2624	2745
Suncus murinus	0	8	192	764	1074	1614	2273	2542	2783
Tragelaphus oryx	1	46	363	731	1140	1758	2410	2770	2778
Herpestes javanicus	0	0	58	469	1328	1726	2252	2671	2764
Herpestes edwardsi	0	1	60	655	1351	1696	2261	2730	2783
Streptopelia turtur	0	35	268	693	1451	2187	2557	2682	2766
Agapornis roseicollis	0	8	182	780	1506	2079	2395	2645	2724
Syncernus kaffir	1	55	376	851	1523	2202	2647	2775	2783
Alectoris Chukar	0	12	187	776	1592	2155	2521	2690	2772
Pterocles exustus	0	0	64	703	1615	2222	2737	2772	2783
Equus burchelli	1	60	417	947	1622	2213	2692	2775	2783
Antilope cervicapra	0	11	326	1252	1943	2394	2636	2758	2780
Euplectes albonotatus	1	63	457	1072	2037	2668	2757	2775	2783
Canis aureus	0	22	289	1245	2054	2538	2769	2776	2785
Phasianus colchicus	0	40	635	1717	2380	2556	2684	2781	2785
Numida meleagris	1	67	541	1496	2415	2723	2769	2776	2783
Euplectes orix	1	91	800	2067	2601	2722	2768	2777	2783
Plectropterus gambensis	1	91	800	2061	2601	2728	2771	2778	2783
Oena capensis	1	95	832	2108	2631	2738	2774	2779	2783

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix C Table C5. Exotic mammals and birds (combined) successfully introduced to the Australian mainland: Mac analysis.

Mac analysis Successful mammals and birds Sorted Σ6 level*	**10**	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**
Cervus timorensis	3	13	50	123	289	466	991	2561	2798
Cygnus olor	0	26	164	400	628	766	1315	2371	2798
Ovis aries	0	42	236	504	655	797	1538	2774	2798
Camelus dromedarius	0	1	25	139	717	1317	2237	2690	2795
Oryctolagus cuniculus	20	156	394	603	734	905	1499	2667	2798
Turdus philomelos	8	101	301	538	738	892	1292	2199	2798
Dama dama	10	148	447	611	761	923	1395	2617	2798
Carduelis chloris	27	212	491	667	954	1377	2289	2790	2798
Alauda arvensis	25	184	464	668	986	1405	2412	2794	2798
Funambulus pennanti	0	0	4	398	1060	1565	2364	2716	2797
Cervus elaphus	16	151	431	773	1115	1386	2010	2791	2798
Bos javanicus	0	25	313	737	1337	1599	2184	2716	2798
Cervus porcinus	0	37	352	787	1354	1595	2213	2726	2798
Bubalus bubalis	0	53	506	1046	1411	1737	2366	2790	2798
Pavo cristatus	3	61	568	1119	1526	1946	2580	2792	2798
Lonchura puntulata	8	156	631	1159	1584	1902	2686	2798	2798
Cervus unicolor	4	78	573	1160	1587	1975	2661	2798	2798
Bos taurus	7	54	294	987	1664	2182	2722	2795	2798

Equus caballus	3	27	217	903	1727	2413	2761	2792	2798
Pycnonotus jocosus	5	129	564	1090	1803	2195	2775	2798	2798
Carduelis carduelis	27	218	494	876	1812	2510	2689	2794	2798
Streptopelia chinensis	7	156	627	1224	1920	2495	2795	2798	2798
Acridotheres tristis	9	165	681	1307	1927	2456	2797	2798	2798
Anas platyrhynchos	25	204	590	1384	2169	2403	2762	2797	2798
Passer montanus	21	300	873	1501	2258	2622	2798	2798	2798
Turdus merula	28	246	769	1645	2360	2759	2797	2798	2798
Streptopelia decaocto	9	289	1045	1850	2398	2700	2796	2797	2798
Equus asinus	0	123	824	1666	2417	2669	2776	2795	2798
Struthio camelus	14	436	1376	2022	2459	2737	2795	2796	2798
Cervus axis	2	125	883	1837	2585	2752	2790	2794	2798
Capra hircus	11	101	618	1999	2645	2740	2788	2797	2798
Sturnus vulgaris	65	617	1997	2631	2752	2778	2792	2797	2798
Vulpes vulpes	24	322	1067	2104	2761	2795	2797	2798	2798
Lepus capensis	89	658	1692	2655	2769	2793	2795	2796	2798
Streptopelia senegalensis	82	934	2193	2746	2785	2791	2796	2797	2798
Ardeola ibis	130	1170	2492	2757	2789	2794	2797	2798	2798
Rattus norvegicus	95	772	2200	2771	2792	2796	2797	2798	2798
Sus scrofa	68	603	1833	2744	2792	2796	2797	2798	2798
Felis catus	96	993	2343	2789	2795	2797	2797	2798	2798
Rattus rattus	111	1149	2532	2792	2795	2796	2798	2798	2798
Columba livia	82	928	2476	2781	2795	2796	2797	2798	2798
Mus domesticus	123	1163	2530	2785	2796	2797	2798	2798	2798
Canis lupus	125	1174	2550	2794	2796	2797	2798	2798	2798
Passer domesticus	155	1174	2416	2779	2796	2797	2797	2798	2798

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix C Table C6. Exotic mammals and birds (combined) introduced to the Australian mainland that failed to establish: Mac analysis.

Mac analysis Failed mammals and birds Sorted Σ6*	**10**	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**
Fringilla montifringilla	0	0	0	0	11	39	112	355	2798
Lophura ignita	0	0	0	1	40	136	494	1643	2798
Cervus marianus	0	3	11	34	82	159	359	1161	2798
Hydropotes inervuis	0	0	1	15	105	374	1189	2720	2798
Lama vicugna	0	0	9	39	117	320	1431	2471	2798
Alces alces	0	0	3	22	130	379	933	1769	2798
Aix galericulata	0	2	7	39	182	455	1469	2636	2798
Moschus moschiferus	0	0	0	32	202	512	1692	2758	2798
Branta canadensis	1	12	40	84	234	487	1034	1705	2798
Serinus canarius	0	0	2	59	335	564	1039	2161	2798
Padda oryzivora	0	14	69	201	356	495	931	2306	2798
Cervus duvauceli	0	0	24	127	358	561	1019	1399	2797
Cervus nippon	0	7	47	163	456	927	2720	2798	2798
Mesocricetus auratus	0	36	207	436	578	686	1047	2084	2098
Lophophorus impejanus	0	2	37	176	602	941	1231	1765	2797
Carduelis spinus	0	15	145	448	606	775	1250	2197	2798
Mustela erminea	13	98	252	418	633	874	1607	2436	2798
Pyrrhula pyrrhula	6	78	281	505	653	833	1279	2199	2798
Lophura nycthemera	1	27	155	387	674	1006	2363	2782	2798

Alectoris barbara	12	78	186	386	682	1191	2369	2704	2797
Emberiza citrinella	15	130	309	448	690	879	1203	1706	2798
Perdix perdix	5	124	389	569	709	853	1262	1921	2798
Erithacus rubecula	15	175	451	606	735	947	1430	2631	2798
Alectoris rufa	6	105	358	579	738	902	1394	2575	2798
Sciurus carolinensis	25	145	377	560	754	950	1478	2790	2798
Emberiza hortulana	5	157	452	614	777	944	1407	2627	2798
Capreolus capreolus	10	175	462	634	823	1136	1822	2762	2798
Lama guanicoe	0	1	45	301	835	1454	2327	2797	2798
Mustela nivalis	28	252	524	697	932	1377	2354	2798	2798
Fringilla coelebs	23	204	486	664	940	1358	2011	2789	2798
Acanthis cannabina	23	206	485	664	949	1367	2074	2789	2798
Luscinia megarhynchos	23	198	481	656	950	1356	2019	2789	2798
Mustela putorius	28	248	522	691	988	1390	2314	2793	2798
Tragulus meminna	0	2	270	763	1231	1641	2315	2783	2798
Pycnonotus cafer	1	71	549	1049	1397	1714	2338	2789	2798
Lonchura malacca	7	151	599	1079	1490	1820	2504	2791	2798
Corvus splendens	5	125	597	1144	1527	2017	2696	2796	2798
Herpestes javanicus	0	52	367	1008	1557	2028	2675	2783	2798
Herpestes edwardsi	0	23	438	1125	1567	2046	2743	2796	2798
Tragelaphus oryx	0	100	434	1027	1584	2170	2728	2789	2798
Suncus murinus	7	123	617	1215	1584	2122	2666	2838	2838
Gallus gallus	8	141	455	883	1736	2123	2633	2798	2798
Agapornis roseicollis	8	233	652	1097	1819	2350	2687	2747	2797
Alectoris Chukar	4	126	505	990	1836	2350	2702	2789	2798
Callipepla californicus	5	25	162	874	1935	2531	2749	2798	2798
Syncernus kaffir	14	138	561	1278	1990	2588	2794	2796	2798
Streptopelia turtur	23	208	493	818	2000	2578	2745	2793	2798
Equus burchelli	18	158	549	1301	2119	2574	2794	2795	2798
Antilope cervicapra	1	95	798	1765	2293	2508	2782	2790	2798
Pterocles exustus	1	146	688	1629	2309	2641	2796	2797	2798
Euplectes albonotatus	33	279	815	1707	2453	2735	2795	2796	2798
Canis aureus	13	240	1151	1939	2622	2790	2797	2797	2798
Numida meleagris	53	479	1221	2039	2664	2782	2797	2797	2798
Phasianus colchicus	9	235	1254	2151	2710	2793	2797	2798	2798
Plectropterus gambensis	66	702	1783	2569	2765	2787	2796	2797	2798
Euplectes orix	67	693	1761	2607	2766	2787	2796	2797	2798
Oena capensis	81	740	1814	2610	2767	2788	2797	2797	2798

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix D

Guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE

Appendix D Table D1. Guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE

Guide to class/percentiles	**Best match**	------>	------>	------>	------>	------>	------>	------>	**Worst match**		
Mac: Closest Standard Match	10%	20%	30%	40%	50%	60%	70%	80%	90%		
PC: Closest Standard Match	10 matches	9 matches	8 matches	7 matches	6 matches	5 matches	4 matches	3 matches	2 matches	1 match	0 matches
PC: Euclidean match	10 matches	9 matches	8 matches	7 matches	6 matches	5 matches	4 matches	3 matches	2 matches	1 match	0 matches
Cumulative score (Mac)	Σ0% = 10%	Σ20% = Σ10% +20%	Σ30% = Σ20% +30%	Σ40% = Σ30% +40%	Σ50% = Σ40% +50%	Σ60% = Σ50% +60%	Σ70% = Σ60% +70%	Σ80% = Σ70% +80%	Σ90% = Σ80% +90%		
Cumulative score (PC)	10 (number of matches at level 10)	Σ9 (number of matches at levels 9 and 10)	Σ8 (number of matches at level 8 + Σ9)	Σ7 (number of matches at level 7 + Σ8)	Σ6 (number of matches at level 6 + Σ7	Σ5 (number of matches at level 5 + Σ6	Σ4 (number of matches at level 4 + Σ5	Σ3 (number of matches at level 3 + Σ4	Σ2 (number of matches at level 2 + Σ3	Σ1 (number of matches at level 1 + Σ2	

Appendix E

T-test results comparing cumulative climate match scores for successful and failed exotic mammals introduced to Australia without the inclusion of the five additional mammals

Appendix E Table E1. T-test results (*P* = probability scores) comparing cumulative climate match scores for successful and failed exotic mammals introduced to Australia excluding the five species of exotic mammals (*Suncus murinus*, *Herpestes edwardsi*, *Mesocricetus auratus*, *Mustela erminea* and *Mustela nivalis*) unsuccessfully introduced to Australia according to Long (2003) but absent from the climate match analyses conducted by Bomford (2003).
All *P* values ≤ 0.05 are statistically significant. For PC Euclidian all levels between Σ8 and Σ3 are statistically significant. For PC Closest Standard Score all levels between Σ9 and Σ2 are statistically significant. For Mac all levels between 10 and Σ3 are statistically significant. For all three types of analysis the best discrimination between successful and failed mammals occurs around the middle range (Σ6– Σ7) of the cumulative climate match scores (which is equivalent to Σ40–Σ50% in the classification used in the Mac version of CLIMATE).

CLIMATE analysis type	**Cumulative climate match level***								
	10	Σ9	Σ8	Σ7	Σ6	Σ5	Σ4	Σ3	Σ2
PC Euclidian	0.11	0.154	0.006	0.002	0.003	0.007	0.01	0.027	0.059
PC Closest Standard Score	0.5	0.01	0.005	0.002	0.002	0.004	0.013	0.033	0.039
Mac	0.008	0.007	0.003	0.001	0.002	0.005	0.031	0.025	0.243

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D, Table D1.

Appendix F

Climate matching for places with few meteorological stations in the CLIMATE database

CLIMATE software contains data for approximately 8000 meteorological stations outside Australia but some areas of the world are not well represented. Where there are few meteorological stations in the overseas range of a species, CLIMATE may underestimate the climate match to Australia for that species. Tests were conducted to assess the degree to which this occurs.

Methods: Five overseas locations were selected, and climatically matched to Australia. For each location, meteorological stations were then randomly removed from the input data file and then the culled input file was re-matched to Australia. This was repeated for each location, successively removing more and more input meteorological stations for each analysis.

Results: Table F1 presents results for PC CLIMATE Closest Standard Match analyses (Σ6 level) which are the analyses used in the mammal and bird risk assessment model (Section 6). Table F2 presents results for Euclidian analyses at the Σ5 which is the type of analysis used in the freshwater finfish model (Section 8). Table F3 presents results for Euclidian analyses at the Σ7 which is the type of analysis used in the reptile and amphibian model (Section 10).

All locations and types of analysis show a declining level of climate match as the number of input meteorological stations in the source region is reduced. The decline generally becomes steeper when the number of meteorological stations drops below ten. But the extent of the decline, and where it becomes steep, varies considerably between locations. Outputs even vary considerably when the process is repeated twice for the same location, because different input data points will have differing levels of influence on the output.

These variable results make it difficult to draw any generalised rule about how to correct for underestimated levels of climate match for species which have few meteorological stations in their overseas range. If, however, the input area has 12 or fewer meteorological stations, then CLIMATE is likely to considerably underestimate the climate match to Australia. In this case, it is advisable to adjust the climate match score as follows:

In the newly calibrated model for establishment risk assessment for mammals and birds (see the directions for use in Section 6, Stage B, Score B1), increase the Climate Match Score by one increment in Step 3 if the input area has 12 or fewer meteorological stations. For example, if a mammal's overseas range had only five meteorological stations, and the sum of the values for the five highest match classes to Australia equalled 504 (ie Σ6 = 504), then this would give a Climate Match Score = 2 + 1 = 3.

In the newly calibrated model for establishment risk assessment for freshwater finfish (see the directions for use in Section 8.1, Score A), increase the Climate Match Score by one increment in Step 3 if the input area has 12 or fewer meteorological stations.

In the model for establishment risk assessment for reptiles and amphibians (see the directions for use in Section 10.1, Score A), increase the Climate Match Risk Score by 10 percentage points if the input area has 12 or fewer meteorological stations.

These corrections are based on the assumption that the climate matches for a species being assessed follow the same general pattern as the examples presented in Tables F1–F3. This assumption may not be valid for all species matches. A better option will always be to investigate whether additional meteorological station data are available within the overseas range of the species, and if so, incorporating these data into the CLIMATE database prior to conducting the species' climate match.

Fortunately, relatively few of the species assessed for developing the risk assessment models had overseas range sizes containing 12 or fewer meteorological stations. The dataset for reptiles and amphibians introduced to Florida had the most species in this category: four successful species (*Anolis chlorocyanus, A. ferreus, A. garmani* and *Leiocephalus schreibersi*) and five failed species (*Anolis conspersus, Atelopus zetiki, Bufo blombergi, Podocnemis lewyana* and *P. sextuberculata*). Climate Match Risk Scores for these exotic reptiles and amphibians introduced to Florida were recalculated with scores adjusted by adding the ten percentage points to correct for this source of bias. The results are presented in Table F4. Applying the corrections made little difference to the average Climate Match Scores or Establishment Risk Scores for this dataset. However, it is likely that it improved the accuracy of these scores for the individual species that had a low number of input stations.

Appendix F Table F1. Climate match outputs (PC CLIMATE Closest Standard Match Σ6) between five overseas locations and Australia, calculated with meteorological stations randomly removed in successive steps from the input data file for each location.
For India the exercise is repeated twice, with different random meteorological stations being removed. PC CLIMATE Closest Standard Match Σ6 outputs are used in the mammal and bird risk assessment model (Section 6, Stage B, Score B1).

Location (full number of meteorological stations)	**Number of meteorological stations used in analysis**								
	Full set	**100**	**50**	**25**	**12**	**10**	**8**	**6**	**4**
India A (201)	888	767	750	728	658	606	585	405	549
India B (201)	888	750	717	544	504	452	452	148	413
Britain (194)	90	84	66	63	54	54	39	39	19
California (172)	665	643	635	569	59	55	49	43	43
New Zealand (70)	118	-	112	104	94	94	94	86	79
Tropical west Africa (70)	181	-	180	136	104	104	19	19	19
Average drop %	0%	-	12%	33%	44%	46%	47%	59%	64%

Appendix F Table F2. Climate match outputs (PC CLIMATE Euclidian Σ5) between five overseas locations and Australia, calculated with meteorological stations randomly removed in successive steps from the input data file for each location.
For India the exercise is repeated twice, with different random meteorological stations being removed. PC CLIMATE Euclidian Σ5 outputs are used in the freshwater finfish risk assessment model (Section 8.1, Score A).

Location (full number of meteorological stations)	Number of meteorological stations used in analysis								
	Full set	100	50	25	12	10	8	6	4
India A (201)	1406	1399	1271	1220	1121	1117	902	597	581
India B (201)	1406	1372	1222	1115	1107	1106	1091	1049	1049
Britain (194)	195	184	164	150	139	139	125	125	115
California (172)	1656	1590	1590	1525	240	230	230	209	206
New Zealand (70)	280	-	278	270	198	198	196	188	181
Tropical west Africa (70)	3452	-	2975	2500	2019	1547	1076	946	816
Average drop %	0%	-	10%	16%	38%	40%	47%	52%	54%

Appendix F Table F3. Climate match outputs (PC CLIMATE Euclidian Σ7) between five overseas locations and Australia, calculated with meteorological stations randomly removed in successive steps from the input data file for each location.
For India the exercise is repeated twice, with different random meteorological stations being removed. PC CLIMATE Euclidian Σ7 are used in the reptile and amphibian model (Section 10.1, Score A).

Location (full number of meteorological stations)	Number of meteorological stations used in analysis								
	Full set	100	50	25	12	10	8	6	4
India A (201)	734	623	580	531	469	469	168	78	64
India B (201)	734	596	410	395	311	311	231	214	213
Britain (194)	72	71	56	49	40	40	22	22	13
California (172)	460	419	419	387	34	27	23	19	19
New Zealand (70)	95	-	94	85	69	69	69	69	65
Tropical west Africa (70)	166	-	166	110	78	78	4	4	4
Average drop %	0%	-	16%	28%	52%	52%	72%	75%	78%

Appendix F Table F4. Average Climate Match Scores and Establishment Risk Scores for successful and failed reptiles and amphibians (combined) introduced to Florida, with and without corrections for 12 or fewer input meteorological stations (See Section 10.3, Stage A).

		Average Climate Match Score	Average Establishment Risk Score
Data not corrected for few input stations	Successful	37.2	80.7
	Failed	18.7	35.7
	T-test (not corrected) [1]	0.00834	9.16E-07
Data corrected for few input stations	Successful	38.2	81.7
	Failed	20.6	37.6
	T-test (corrected)[1]	0.00974	1.05E-06

[1]Where a *P* value is presented in the form XE-0Y, Y is the number of zeros following the decimal point, for example 7.09E-05 = 0.00000709.

Appendix G

Data for assessing establishment risk for exotic mammals and birds introduced to Australia

Appendix G Table G1. Data for assessing establishment risk for exotic mammals and birds (combined) introduced to Australia based on the sum of Bomford's (2003) six variables plus an additional score for overseas range size. A. Successful mammals. B. Failed mammals. C. Successful birds. D. Failed Birds. CLIMATE match outputs are PC Closest Standard Match (Σ6 level) instead of the Mac CLIMATE outputs used by Bomford (2003). These Closest Standard Match outputs are converted to Climate Match Scores (1–6) using the cut-off thresholds presented in Figure 2a. The data for overseas geographic range sizes are converted to Overseas Range Size Scores (0–2) based on the analyses and cut-off thresholds presented in Appendix H.

A. Successful mammals	**Climate Match PC Closest Standard Match Σ6 level**	**Overseas range size (million km^2)[1]**	**1. Climate Match Score[2] (1–6)**	**2. Exotic Population Overseas Score (0–4)**	**3. Taxon Score (0–1)**	**4. Migration Score (0–1)**	**5. Diet Score (0–1)**	**6. Habitat Score (0–1)**	**7. Overseas range size Score[3] (0–2)**	**Establishment Risk Score (0–16)[4]**
Camelus dromedarius	154	3	2	0	1	1	1	1	1	7
Bos javanicus	607	1	3	2	1	1	1	1	0	9
Funambulus pennanti	943	2	4	0	1	1	1	1	1	9
Cervus porcinus	665	3	3	2	1	1	1	1	1	10
Cervus timorensis	119	1	2	4	1	1	1	1	0	10
Dama dama	731	11	3	4	1	0	1	1	1	11
Cervus elaphus	1087	36	4	4	1	0	1	0	1	11
Ovis aries	595	6	2	4	1	1	1	1	1	11
Oryctolagus cuniculus	696	8	3	4	1	1	1	1	1	12
Equus caballus	1177	9	4	4	1	1	1	1	1	13
Bubalus bubalis	931	4	4	4	1	1	1	1	1	13
Cervus unicolor	1035	5	4	4	1	1	1	1	1	13
Bos taurus	1088	2	4	4	1	1	1	1	1	13
Cervus axis	1989	2	5	4	1	1	1	0	1	13
Equus asinus	1841	8	5	4	1	1	1	1	1	14
Capra hircus	2250	10	5	4	1	1	1	1	1	14

Lepus capensis	2718	7	6	4	1	1	1	1	1	15
Vulpes vulpes	2591	175	5	4	1	1	1	1	2	15
Felis catus	2772	15	6	4	1	1	1	1	1	15
Rattus rattus	2776	58	6	4	1	1	1	1	1	15
Sus scrofa	2766	76	6	4	1	1	1	1	2	16
Canis lupus	2780	197	6	4	1	1	1	1	2	16
Mus domesticus	2778	162	6	4	1	1	1	1	2	16
Rattus norvegicus	2768	100	6	4	1	1	1	1	2	16

B. Failed mammals	Climate Match PC Closest Standard Match Σ6 level	Overseas range size (million km^2)[1]	1. Climate Match Score[2] (1–6)	2. Exotic Population Overseas Score (0–4)	3. Taxon Score (0–1)	4. Migration Score (0–1)	5. Diet Score (0–1)	6. Habitat Score (0–1)	7. Overseas range size Score[3] (0–2)	Establishment Risk Score (0–16)[4]
Cervus duvauceli	185	1	2	0	1	0	0	0	0	3
Cervus marianus	21	1	1	0	1	0	0	1	0	3
Lama vicugna	52	1	1	0	1	1	1	1	0	5
Moschus moschiferus	69	22	1	0	1	1	1	0	1	5
Alces alces	101	69	2	0	1	0	1	0	1	5
Mesocricetus auratus	482	1	2	0	1	1	1	0	0	5
Tragulus meminna	636	1	3	0	1	1	1	0	0	6
Equus burchelli	1622	6	4	0	1	0	1	0	1	7
Tragelaphus oryx	1140	5	4	0	1	0	1	0	1	7
Lama guanicoe	611	1	3	0	1	1	1	1	0	7
Capreolus capreolus	759	48	3	0	1	1	1	1	1	8
Sciurus carolinensis	575	6	2	2	1	1	1	1	1	9
Hydropotes inermis	42	1	1	4	1	1	1	1	0	9
Syncernus kaffir	1523	8	4	0	1	1	1	1	1	9
Cervus nippon	256	6	2	4	1	0	1	1	1	10
Mustela putorius	684	15	3	2	1	1	1	1	1	10
Canis aureus	2054	20	5	0	1	1	1	1	1	10
Antilope cervicapra	1943	1	5	2	1	1	1	1	0	11
Herpestes javanicus	1328	6	4	2	1	1	1	1	1	11
Mustela erminea	525	145	2	4	1	1	1	1	2	11
Suncus murinus	1074	14	4	4	1	1	1	1	1	13
Herpestes edwardsi	1351	4	4	4	1	1	1	1	1	13
Mustela nivalis	797	139	3	4	1	1	1	1	2	13

C. Successful birds	Climate Match PC Closest Standard Match Σ6 level	Overseas range size (million km^2)[1]	1. Climate Match Score[2] (1–6)	2. Exotic Population Overseas Score (0–4)	3. Taxon Score (0–1)	4. Migration Score (0–1)	5. Diet Score (0–1)	6. Habitat Score (0–1)	7. Overseas range size Score[3] (0–2)	Establishment Risk Score (0–16)[4]
Struthio camelus	1945	8	5	0	0	1	1	1	1	9
Cygnus olor	479	11	2	4	0	1	1	1	1	10
Alauda arvensis	787	57	3	4	0	0	1	1	1	10
Lonchura punctulata	991	9	4	2	0	1	1	1	1	10
Carduelis chloris	765	21	3	4	0	0	1	1	1	10
Turdus philomelos	644	31	3	4	0	0	1	1	1	10
Carduelis carduelis	1433	33	4	4	0	0	1	1	1	11
Pavo cristatus	962	4	4	4	0	1	1	1	1	12
Streptopelia chinensis	1059	11	4	4	0	1	1	1	1	12
Pycnonotus jocosus	996	6	4	4	0	1	1	1	1	12
Turdus merula	1977	31	5	4	0	0	1	1	1	12
Acridotheres tristis	1224	11	4	4	0	1	1	1	1	12
Sturnus vulgaris	2639	58	5	4	0	0	1	1	1	12
Anas platyrhynchos	1902	95	5	4	0	0	1	1	2	13
Ardeola ibis	2746	54	6	4	0	0	1	1	1	13
Streptopelia decaocto	2036	23	5	4	0	1	1	1	1	13
Passer montanus	1434	70	4	4	0	1	1	1	2	13
Streptopelia senegalensis	2717	44	6	4	0	1	1	1	1	14
Columba livia	2769	80	6	4	0	1	1	1	2	15
Passer domesticus	2772	110	6	4	0	1	1	1	2	15

D. Failed birds	Climate Match PC Closest Standard Match Σ6 level	Overseas range size (million km^2)[1]	1. Climate Match Score[2] (1–6)	2. Exotic Population Overseas Score (0–4)	3. Taxon Score (0–1)	4. Migration Score (0–1)	5. Diet Score (0–1)	6. Habitat Score (0–1)	7. Overseas range size Score[3] (0–2)	Establishment Risk Score (0–16)[4]
Lophura ignita	0	1	1	0	0	1	1	0	0	3
Fringilla montifringilla	26	31	1	0	0	0	1	1	1	4
Lophura nycthemera	298	2	2	0	0	1	1	0	1	5
Lophophorus impejanus	648	1	3	0	0	1	1	0	0	5
Carduelis spinus	542	22	2	0	0	0	1	1	1	5
Erithacus rubecula	714	25	3	0	0	0	1	1	1	6
Luscinia megarhynchos	753	16	3	0	0	0	1	1	1	6
Serinus canarius	48	0	1	2	0	1	1	1	0	6
Acanthis cannabina	762	25	3	0	0	0	1	1	1	6
Emberiza hortulana	722	30	3	0	0	0	1	1	1	6
Agapornis roseicollis	1506	2	4	0	0	1	1	0	1	7
Pyrrhula pyrrhula	614	41	3	0	0	1	1	1	1	7
Euplectes orix	2601	13	5	0	0	1	1	0	1	8
Euplectes albonotatus	2037	6	5	0	0	1	1	0	1	8
Alectoris barbara	435	3	2	2	0	1	1	1	1	8
Pterocles exustus	1615	15	4	0	0	1	1	1	1	8
Aix galericulata	75	3	1	4	0	0	1	1	1	8
Streptopelia turtur	1451	34	4	0	0	1	1	1	1	8

Plectropterus gambensis	2601	16	5	0	0	1	1	1	1	9
Branta canadensis	185	38	2	4	0	0	1	1	1	9
Oena capensis	2631	20	5	0	0	1	1	1	1	9
Padda oryzivora	105	1	2	4	0	1	1	1	0	9
Emberiza citrinella	591	47	2	4	0	0	1	1	1	9
Alectoris rufa	668	1	3	4	0	1	1	1	0	10
Fringilla coelebs	762	27	3	4	0	0	1	1	1	10
Gallus gallus	719	6	3	4	0	1	1	1	1	11
Alectoris Chukar	1592	23	4	4	0	1	1	0	1	11
Perdix perdix	689	32	3	4	0	1	1	1	1	11
Corvus splendens	1028	5	3	4	0	1	1	1	1	11
Lonchura malacca	978	7	4	4	0	1	1	1	1	12
Pycnonotus cafer	948	6	4	4	0	1	1	1	1	12
Callipepla californicus	1029	3	4	4	0	1	1	1	1	12
Numida meleagris	2415	20	5	4	0	1	1	1	1	13
Phasianus colchicus	2380	34	5	4	0	1	1	1	1	13

[1]Overseas range size: t-test comparing successful mammals plus birds vs failed mammals plus birds $P = 0.0077$ (highly significant).
[2]PC Climate 'Closest Standard Match' Σ 50% with following cut-off thresholds:
6 = Extreme ≥ 2700
5 = Very High ≥ 1700
4 = High ≥ 900
3 = Moderate ≥ 600
2 = Low ≥ 100
1 = Very Low < 100.
[3]Overseas range size scores – 3 point score system:
Cut-off thresholds:
0 = Low = 0–1
1 = Moderate = 2–69
2 = High ≥ 70

[4]Cut-off thresholds for converting Establishment Risk Scores to Establishment Risk Ranks are presented below.

<u>Six-rank system:</u>

Extreme	≥ 14
Very high	12–13
High	10–11
Moderate	7–9
Low	5–6
Very low	≤ 4.

<u>Four-rank system required by VPC:</u>

Extreme	≥ 14
Serious	12–13
Moderate	7–11
Low	≤ 6

Appendix G Table G2. Data for assessing establishment risk for exotic mammals and birds (combined) introduced to Australia based on the sum of four variables extracted from Table G1 (excluding diet, habitat and migration scores).

Exotic mammals and birds introduced successfully to Australia	Climate Match Score[1] (1–6)	Overseas Range Size Score[2] (0–2)	Taxon Score (0–1)	Exotic Population Overseas Score (0–4)	Establishment Risk Score (0–13) [3]
Camelus dromedarius	2	1	1	0	4
Bos javanicus	3	0	1	2	6
Funambulus pennanti	4	1	1	0	6
Struthio camelus	5	1	0	0	6
Cervus porcinus	3	1	1	2	7
Cervus timorensis	2	0	1	4	7
Cygnus olor	2	1	0	4	7
Lonchura punctulata	4	1	0	2	7
Alauda arvensis	3	1	0	4	8
Carduelis chloris	3	1	0	4	8
Turdus philomelos	3	1	0	4	8
Ovis aries	2	1	1	4	8
Dama dama	3	1	1	4	9
Carduelis carduelis	4	1	0	4	9
Oryctolagus cuniculus	3	1	1	4	9
Pavo cristatus	4	1	0	4	9
Streptopelia chinensis	4	1	0	4	9
Pycnonotus jocosus	4	1	0	4	9
Acridotheres tristis	4	1	0	4	9
Cervus elaphus	4	1	1	4	10
Turdus merula	5	1	0	4	10
Sturnus vulgaris	5	1	0	4	10
Equus caballus	4	1	1	4	10
Bubalus bubalis	4	1	1	4	10
Cervus unicolor	4	1	1	4	10
Bos taurus	4	1	1	4	10
Streptopelia decaocto	5	1	0	4	10
Passer montanus	4	2	0	4	10
Cervus axis	5	1	1	4	11
Anas platyrhynchos	5	2	0	4	11
Ardeola ibis	6	1	0	4	11
Equus asinus	5	1	1	4	11
Capra hircus	5	1	1	4	11
Streptopelia senegalensis	6	1	0	4	11
Lepus capensis	6	1	1	4	12
Vulpes vulpes	5	2	1	4	12
Felis catus	6	1	1	4	12
Rattus rattus	6	1	1	4	12
Columba livia	6	2	0	4	12
Passer domesticus	6	2	0	4	12
Sus scrofa	6	2	1	4	13
Canis lupus	6	2	1	4	13
Mus domesticus	6	2	1	4	13
Rattus norvegicus	6	2	1	4	13

Exotic mammals and birds introduced to the Australian mainland that failed to establish					
Lophura ignita	1	0	0	0	1
Cervus marianus	1	0	1	0	2
Fringilla montifringilla	1	1	0	0	2
Lama vicugna	1	0	1	0	2
Cervus duvauceli	2	0	1	0	3
Moschus moschiferus	1	1	1	0	3
Lophura nycthemera	2	1	0	0	3
Lophophorus impejanus	3	0	0	0	3
Carduelis spinus	2	1	0	0	3
Serinus canarius	1	0	0	2	3
Mesocricetus auratus	2	0	1	0	3
Alces alces	2	1	1	0	4
Tragulus meminna	3	0	1	0	4
Erithacus rubecula	3	1	0	0	4
Luscinia megarhynchos	3	1	0	0	4
Acanthis cannabina	3	1	0	0	4
Emberiza hortulana	3	1	0	0	4
Lama guanicoe	3	0	1	0	4
Pyrrhula pyrrhula	3	1	0	0	4
Agapornis roseicollis	4	1	0	0	5
Capreolus capreolus	3	1	1	0	5
Alectoris barbara	2	1	0	2	5
Pterocles exustus	4	1	0	0	5
Streptopelia turtur	4	1	0	0	5
Equus burchelli	4	1	1	0	6
Tragelaphus oryx	4	1	1	0	6
Euplectes orix	5	1	0	0	6
Euplectes albonotatus	5	1	0	0	6
Aix galericulata	1	1	0	4	6
Sciurus carolinensis	2	1	1	2	6
Hydropotes inermis	1	0	1	4	6
Syncernus kaffir	4	1	1	0	6
Plectropterus gambensis	5	1	0	0	6
Oena capensis	5	1	0	0	6
Padda oryzivora	2	0	0	4	6
Branta canadensis	2	1	0	4	7
Emberiza citrinella	2	1	0	4	7
Mustela putorius	3	1	1	2	7
Canis aureus#	5	1	1	0	7
Alectoris rufa	3	0	0	4	7
Cervus nippon	2	1	1	4	8
Fringilla coelebs	3	1	0	4	8
Antilope cervicapra	5	0	1	2	8
Herpestes javanicus	4	1	1	2	8
Gallus gallus	3	1	0	4	8
Perdix perdix	3	1	0	4	8
Corvus splendens	3	1	0	4	8
Alectoris Chukar	4	1	0	4	9

Lonchura malacca	4	1	0	4	9
Pycnonotus cafer	4	1	0	4	9
Callipepla californicus	4	1	0	4	9
Mustela erminea	2	2	1	4	9
Numida meleagris	5	1	0	4	10
Phasianus colchicus	5	1	0	4	10
Suncus murinus	4	1	1	4	10
Herpestes edwardsi	4	1	1	4	10
Mustela nivalis	3	2	1	4	10

[1]PC Climate 'Closest Standard Match' Σ6 level with following cut-off thresholds:
6 = Extreme ≥2700
5 = Very High ≥ 1700
4 = High ≥ 900
3 = Moderate ≥ 600
2 = Low ≥ 100
1 = Very Low < 100.
[2]Overseas range size scores – 3 point score system:
Cut-off thresholds: 0 = Low = 0–1; 1 = Moderate = 2–69; 2 = High ≥ 70
[3]Cut-off thresholds for converting Establishment Risk Scores to Establishment Risk Ranks are presented below:

Six-rank system:

Establishment Risk Rank	Establishment Risk Score
Extreme	13
Very High	11–12
High	9–10
Moderate	6–8
Low	4–5
Very Low	≤ 3

Four-rank system required by VPC:

Establishment Risk Rank	Establishment Risk Score
Extreme	11–13
Serious	9–10
Moderate	6–8
Low	≤ 5

Appendix H

Scoring overseas range sizes for assessing establishment risk for exotic mammals and birds introduced to Australia

Overseas range sizes for exotic mammals and birds introduced to Australia are presented in Table H1. Table H1 presents t-test results comparing overseas range sizes for successful exotic mammals introduced to Australia to successful exotic birds introduced to Australia, and comparing the overseas range sizes for failed exotic mammals introduced to Australia to failed exotic birds introduced to Australia. Neither result is statistically significant. These results indicate that no justification for running separate analyses for birds and mammals and therefore the mammal and bird overseas range data sets were combined into a single data set.

Appendix H Table H1. T-test results comparing overseas range sizes for successful exotic mammals introduced to Australia to successful exotic birds introduced to Australia, and comparing the overseas range sizes for failed exotic mammals introduced to Australia to failed exotic birds introduced to Australia.
Neither result is statistically significant.

T-test	**Result (*P* = probability value)**
Successful mammals vs successful birds	0.4785
Failed mammals vs failed birds	0.2052

Table H2 presents t-test results comparing overseas range sizes for successful exotic mammals and birds introduced to Australia to failed exotic mammals and birds introduced to Australia. The results are highly statistically significant indicating that overseas range size is strongly correlated with introduction outcomes.

Appendix H Table H2. T-test results comparing overseas range sizes for successful exotic mammals and birds introduced to Australia to failed exotic mammals and birds introduced to Australia.
The results are statistically significant for successful birds and combined mammals and birds. Although Bomford (2003) found overseas range size was statistically significantly correlated with establishment success for exotic mammals introduced to Australia, the inclusion of the five additional mammal species published by Long (2003) but not included in Bomford's (2003) original analysis, has raised the P value in the t-test to a level that is not statistically significant. However, given overseas range size is highly statistically significant for the combined data sets for mammals and birds, this factor is retained in the model.

T-test	Result (*P* = probability value)
Successful mammals vs failed mammals	0.1645
Successful birds vs failed birds	0.0004
Successful mammals+birds vs failed mammals+birds	0.0077

The overseas range sizes results were then categorised into six levels (1–6), ranging from Extreme for the largest ranges down to Very Low (Table H3). The cut-off thresholds for these categories were selected to give the best possible discrimination between successful and failed introduced species. The number of species in each of the categories is presented in Figure H1. Figure H1 shows that while there is good discrimination between successful and failed introduced species for the largest (Category 6 = Extreme) and smallest (Category 1 = Very Small) overseas ranges sizes, the middle sizes categories showed little difference between the two groups. Therefore new categories were made based on a 3-level system (0–2) as presented in Table H3 and Figure H2. This 3-level category system was selected to use in the risk assessment model for mammals and birds.

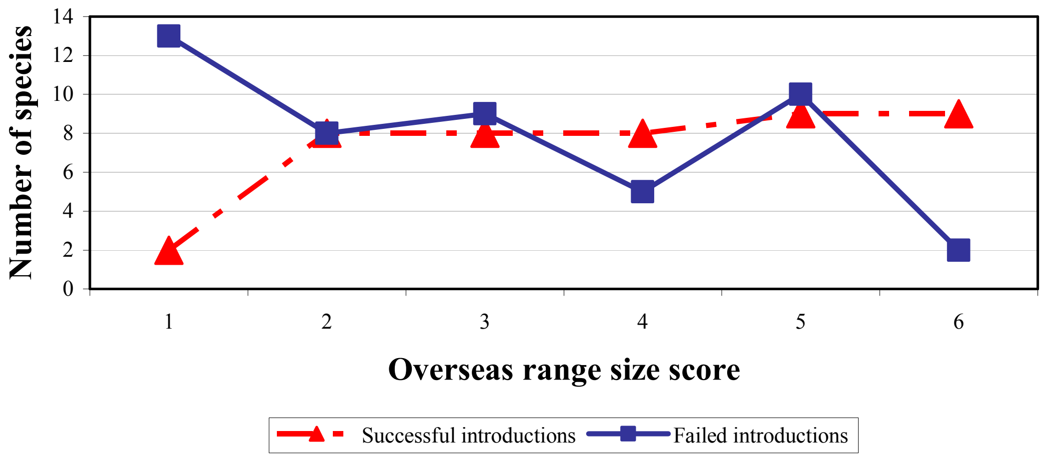
Appendix H Table H3. Overseas range sizes, categorised into six levels (1–6), ranging from Very Small (1) up to Extreme (6) or categorised into three levels (0–2), ranging from Small (0), through Moderate (1), to Large (2). Cut-off thresholds are presented as footnotes[1,2].

Exotic mammals and birds introduced to Australia	Overseas range size	Overseas range size score (1–6 score)[1]	Overseas range size score (0–2 score)[2]
Successful mammals			
Cervus timorensis	1	1	0
Bos javanicus	1	1	0
Oryctolagus cuniculus	8	3	1
Lepus capensis	7	3	1
Equus caballus	9	3	1
Equus asinus	8	3	1
Bubalus bubalis	4	2	1
Capra hircus	10	4	1
Dama dama	11	4	1
Cervus unicolor	5	2	1
Cervus elaphus	36	5	1
Camelus dromedarius	3	2	1
Felis catus	15	4	1
Bos taurus	2	2	1
Ovis aries	6	3	1
Rattus rattus	58	5	1
Cervus porcinus	3	2	1
Cervus axis	2	2	1
Funambulus pennanti	2	2	1
Sus scrofa	76	6	2
Vulpes vulpes	175	6	2
Canis lupus	197	6	2
Mus domesticus	162	6	2
Rattus norvegicus	100	6	2
Failed mammals			
Antilope cervicapra	1	1	0
Cervus duvauceli	1	1	0
Lama guanicoe	1	1	0
Lama vicugna	1	1	0
Tragulus meminna	1	1	0
Hydropotes inermis	1	1	0
Cervus marianus	1	1	0
Mesocricetus auratus	1	1	0
Sciurus carolinensis	6	3	1
Mustela putorius	15	4	1
Herpestes javanicus	6	3	1
Equus burchelli	6	3	1
Cervus nippon	6	3	1
Tragelaphus oryx	5	2	1
Moschus moschiferus	22	4	1

Syncernus kaffir	8	3	1
Capreolus capreolus	48	5	1
Canis aureus	20	4	1
Alces alces	69	5	1
Suncus murinus	14	4	1
Herpestes edwardsi	4	2	1
Mustela erminea	145	6	2
Mustela nivalis	139	6	2
Successful birds			
Struthio camelus	8	3	1
Pavo cristatus	4	2	1
Cygnus olor	11	4	1
Ardeola ibis	54	5	1
Streptopelia chinensis	11	4	1
Streptopelia senegalensis	44	5	1
Streptopelia decaocto	23	4	1
Alauda arvensis	57	5	1
Lonchura punctulata	9	3	1
Carduelis chloris	21	4	1
Carduelis carduelis	33	5	1
Pycnonotus jocosus	6	3	1
Turdus merula	31	5	1
Turdus philomelos	31	5	1
Acridotheres tristis	11	4	1
Sturnus vulgaris	58	5	1
Anas platyrhynchos	95	6	2
Columba livia	80	6	2
Passer domesticus	110	6	2
Passer montanus	70	6	2
Failed birds			
Alectoris rufa	1	1	0
Lophophorus impejanus	1	1	0
Lophura ignita	1	1	0
Padda oryzivora	1	1	0
Serinus canarius	0	1	0
Lophura nycthemera	2	2	1
Euplectes orix	13	4	1
Euplectes albonotatus	6	3	1
Lonchura malacca	7	3	1
Pycnonotus cafer	6	3	1
Numida meleagris	20	4	1
Gallus gallus	6	3	1
Callipepla californicus	3	2	1
Phasianus colchicus	34	5	1
Alectoris Chukar	23	4	1
Alectoris barbara	3	2	1
Perdix perdix	32	5	1
Pterocles exustus	15	4	1
Plectropterus gambensis	16	4	1
Branta canadensis	38	5	1
Aix galericulata	3	2	1
Streptopelia turtur	34	5	1

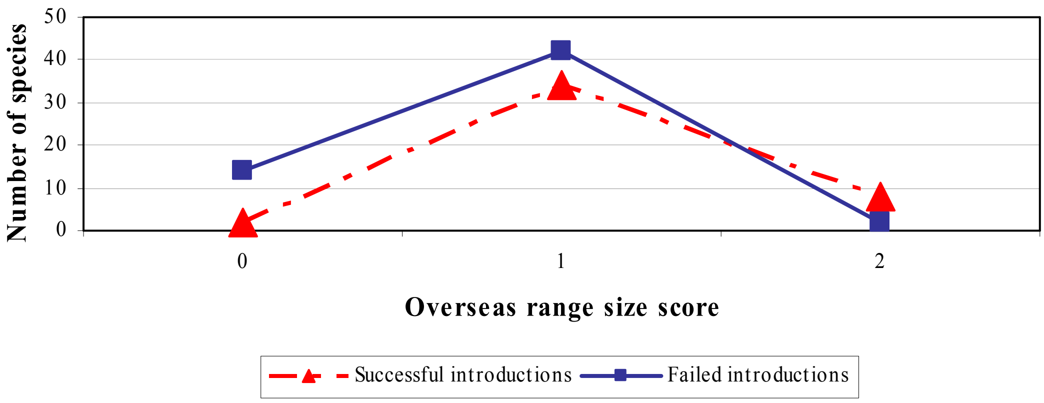
Oena capensis	20	4	1
Agapornis roseicollis	2	2	1
Erithacus rubecula	25	4	1
Luscinia megarhynchos	16	4	1
Fringilla coelebs	27	4	1
Fringilla montifringilla	31	5	1
Carduelis spinus	22	4	1
Acanthis cannabina	25	4	1
Pyrrhula pyrrhula	41	5	1
Emberiza citrinella	47	5	1
Emberiza hortulana	30	5	1
Corvus splendens	5	2	1

[1]Overseas range size scores – 6 point system (1–6).
Cut-off thresholds presented in Figure H1.
[2]Overseas range size scores – 3 point system (0–2).
Cut-off thresholds presented in Figure H2.



Appendix H Figure H1. Numbers of successful and failed introduced exotic mammal and bird species introduced to Australia in six overseas range size categories based on the following cut-off thresholds:

Overseas Range Size Score	Overseas range size (millions of square kilometres)
6	≥ 70
5	≥ 30
4	≥ 10
3	6–9
2	2–5
1	0–1



Appendix H Figure H2. Numbers of successful and failed introduced exotic mammal and bird species introduced to Australia in three overseas range size categories based on the following cut-off thresholds:

Overseas Range Size Score	Overseas range size (millions of square kilometres)
2	$\geq$ 70
1	2–69
0	0–1

Appendix I
Risk assessment scores for mammals and birds introduced to Australia based on previous model using Mac Climate scores

Appendix I Table I1. Establishment Risk Scores calculated using Mac Climate scores based on the formulas presented in Bomford (2003) with the optional addition of including an additional score for overseas range size (Appendix H, Table H3).
Cut-off thresholds for converting Establishment Risk Scores to Establishment Risk Ranks are presented in Figure 6 (without score for overseas range size) and Figure 7 (with score for overseas range size).
A. Successful mammals and birds.
B. Failed mammals and birds.

A. Successful mammals and birds	**Climate match index (Mac)** [1]	**1. Climate Match Score**[1]	**2. Exotic Population Overseas Score**	**3. Taxon Score**	**4. Migration Score**	**5. Diet Score**	**6. Habitat Score**	**7. Overseas Range Size Score (3-point)**	**Establishment Risk Score including overseas range**	**Establishment Risk Score without overseas range**[2]
Camelus dromedarius	864	3	0	1	1	1	1	1	8	7
Funambulus pennanti	1066	3	0	1	1	1	1	1	8	7
Cygnus olor	758	2	4	0	1	1	1	1	10	9
Struthio camelus	5395	6	0	0	1	1	1	1	10	9
Turdus philomelos	1675	3	4	0	0	1	1	1	10	9
Bos javanicus	2019	4	2	1	1	1	1	0	10	10
Cervus timorensis	778	2	4	1	1	1	1	0	10	10
Cervus porcinus	2167	4	2	1	1	1	1	1	11	10
Lonchura punctulata	2796	5	2	0	1	1	1	1	11	10
Pavo cristatus	1993	3	4	0	1	1	1	1	11	10
Alauda arvensis	3256	5	4	0	0	1	1	1	12	11
Carduelis carduelis	4360	5	4	0	0	1	1	1	12	11
Carduelis chloris	3472	5	4	0	0	1	1	1	12	11
Cervus elaphus	2821	5	4	1	0	1	0	1	12	11
Dama dama	2055	4	4	1	0	1	1	1	12	11

Ovis aries	877	3	4	1	1	1	1	1	12	11
Acridotheres tristis	3238	5	4	0	1	1	1	1	13	12
Ardeola ibis	15659	6	4	0	0	1	1	1	13	12
Bos taurus	2353	4	4	1	1	1	1	1	13	12
Bubalus bubalis	2348	4	4	1	1	1	1	1	13	12
Cervus axis	3736	5	4	1	1	1	0	1	13	12
Equus caballus	2041	4	4	1	1	1	1	1	13	12
Pycnonotus jocosus	2718	5	4	0	1	1	1	1	13	12
Streptopelia chinensis	3078	5	4	0	1	1	1	1	13	12
Streptopelia decaocto	4329	5	4	0	1	1	1	1	13	12
Sturnus vulgaris	9347	6	4	0	0	1	1	1	13	12
Turdus merula	5102	6	4	0	0	1	1	1	13	12
Anas platyrhynchos	4539	6	4	0	0	1	1	2	14	12
Capra hircus	3919	5	4	1	1	1	1	1	14	13
Cervus unicolor	2918	5	4	1	1	1	1	1	14	13
Equus asinus	3209	5	4	1	1	1	1	1	14	13
Oryctolagus cuniculus	2630	5	4	1	1	1	1	1	14	13
Streptopelia senegalensis	11883	6	4	0	1	1	1	1	14	13
Columba livia	11863	6	4	0	1	1	1	2	15	13
Passer domesticus	17036	6	4	0	1	1	1	2	15	13
Passer montanus	4892	6	4	0	1	1	1	2	15	13
Felis catus	6399	6	4	1	1	1	1	1	15	14
Lepus capensis	12203	6	4	1	1	1	1	1	15	14
Rattus rattus	13675	6	4	1	1	1	1	1	15	14
Canis lupus	19635	6	4	1	1	1	1	2	16	14
Mus domesticus	15411	6	4	1	1	1	1	2	16	14
Rattus norvegicus	14453	6	4	1	1	1	1	2	16	14
Sus scrofa	10841	6	4	1	1	1	1	2	16	14
Vulpes vulpes	5721	6	4	1	1	1	1	2	16	14

B. Failed mammals and birds	Climate match index[1]	Climate match score[1]	Exotic population overseas score	Taxon score	Migra-tory score	Diet score	Habitat score	Overseas range size score (3-point)	Establish-ment risk score including overseas range[2]	Establish-ment risk score without overseas range[3]
Cervus duvauceli	370	2	0	1	0	0	0	0	3	3
Lophura ignita	40	1	0	0	1	1	0	0	3	3
Alces alces	81	1	0	1	0	1	0	1	4	3
Fringilla montifringilla	11	1	0	0	0	1	1	1	4	3
Cervus marianus	182	2	0	1	0	0	1	0	4	4
Lophophorus impejanus	612	2	0	0	1	1	0	0	4	4
Carduelis spinus	681	2	0	0	0	1	1	1	5	4
Vicuna vicugna	114	1	0	1	1	1	1	0	5	5
Emberiza hortulana	1832	3	0	0	0	1	1	1	6	5
Lophura nycthemera	863	3	0	0	1	1	0	1	6	5
Moschus moschiferus	265	2	0	1	1	1	0	1	6	5
Tragulus meminna	1486	3	0	1	1	1	0	0	6	6
Mesocricetus auratus	938	3	0	1	1	1	0	0	6	6
Erithacus rubecula	2420	4	0	0	0	1	1	1	7	6
Pyrrhula pyrrhula	1367	3	0	0	1	1	1	1	7	6
Serinus canarius	335	2	2	0	1	1	1	0	7	7
Acanthis cannabina	3221	5	0	0	0	1	1	1	8	7
Agapornis roseicollis	3416	5	0	0	1	1	0	1	8	7
Equus burchelli	3936	5	0	1	0	1	0	1	8	7
Tragelaphus oryx	3531	5	0	1	0	1	0	1	8	7
Lama guanicoe[1]	2303	4	0	1	1	1	1	0	8	8
Aix galericulata	192	2	4	0	0	1	1	1	9	8
Alectoris barbara	1720	3	2	0	1	1	1	1	9	8
Branta canadensis	348	2	4	0	0	1	1	1	9	8
Capreolus capreolus	2300	4	0	1	1	1	1	1	9	8

Euplectes albonotatus	5630	6	0	0	1	1	0	1	9	8
Euplectes orix	9849	6	0	0	1	1	0	1	9	8
Luscinia megarhynchos	7592	6	0	0	0	1	1	1	9	8
Pterocles exustus	3093	5	0	0	1	1	1	1	9	8
Streptopelia turtur	4282	5	0	0	1	1	1	1	9	8
Padda oryzivora	426	2	4	0	1	1	1	0	9	9
Cervus nippon	682	2	4	1	0	1	1	1	10	9
Canis aureus	4298	5	0	1	1	1	1	1	10	9
Oena capensis	10841	6	0	0	1	1	1	1	10	9
Plectropterus gambensis	9839	6	0	0	1	1	1	1	10	9
Alectoris rufa	1587	3	4	0	1	1	1	0	10	10
Hydropotes inervuis	167	2	4	1	1	1	1	0	10	10
Emberiza citrinella	2150	4	4	0	0	1	1	1	11	10
Herpestes javanicus	2431	4	2	1	1	1	1	1	11	10
Perdix perdix	1599	3	4	0	1	1	1	1	11	10
Pycnonotus cafer	1806	3	4	0	1	1	1	1	11	10
Syncernus kaffir	4828	6	0	1	1	1	1	1	11	10
Antilope cervicapra	3122	5	2	1	1	1	1	0	11	11
Alectoris Chukar	2682	5	4	0	1	1	0	1	12	11
Callipepla californicus	2330	4	4	0	1	1	1	1	12	11
Corvus splendens	2422	4	4	0	1	1	1	1	12	11
Fringilla coelebs	3203	5	4	0	0	1	1	1	12	11
Mustela putorias	2628	5	2	1	1	1	1	1	12	11
Sciurus carolinensis	2842	5	2	1	1	1	1	1	12	11
Herpestes edwardsi	1682	3	4	1	1	1	1	1	12	11
Gallus gallus	2873	5	4	0	1	1	1	1	13	12
Lonchura malacca	2623	5	4	0	1	1	1	1	13	12
Phasianus colchicus	4371	5	4	0	1	1	1	1	13	12
Suncus murinus	2224	4	4	1	1	1	1	1	13	12
Mustela erminea	1188	3	4	1	1	1	1	2	13	11

Numida meleagris	7921	6	4	0	1	1	1	1	14	13
Mustela nivalis	2332	4	4	1	1	1	1	2	14	12

[1] Climate Match Index (CMI) and Climate Match Score (CMS) are calculated from the data presented in Tables C5 and C6 using the formula presented in Question B1of Bomford's (2003) Risk Assessment Model based on the weighted values for Climate outputs in the Σ10– Σ 50% range (see Appendix D, Table D1 for guide to cumulative scores).
[2]Scores calculated according to the formula in the original model published Bomford (2003) with the addition of an extra component score for a species' overseas range size (see Appendix H).
[3]Scores calculated according to the formula in the original model published Bomford (2003).

Appendix J

Climate match data for successful and failed fish introductions to Australia for three types of CLIMATE analyses

Appendix J Table J1. Climate match data for successful and failed fish introductions to Australia using
A. PC CLIMATE Euclidian match;
B. PC CLIMATE Closest Standard Match (equivalent to the algorithm in Mac version of CLIMATE);
C. Mac CLIMATE Closest Standard Match (used in original fish model prepared for DEH (Bomford and Glover 2004)).

(A) PC new Euclidean Sorted on Σ60%	**Cumulative climate match level***								
Successful fish	**Σ 10%**	**Σ 20%**	**Σ 30%**	**Σ 40%**	**Σ 50%**	**Σ 60%**	**Σ 70%**	**Σ 80%**	**Σ 90%**
Tilapia mariae	0	0	0	0	4	17	34	83	281
Tanichthys albonubes	0	0	1	7	24	42	81	286	516
Acentrogobius pflaumii	0	0	0	1	8	76	207	362	692
Amphilophus citrinellus	0	0	0	8	32	103	186	290	409
Misgurnus anguillicaudatus	0	0	0	1	69	189	332	587	831
Salvelinus fontinalis	0	0	0	11	76	216	563	926	1236
Phalloceros caudimaculatus	0	0	1	15	74	225	399	659	1003
Cichlasoma nigrofasciatus	0	0	19	107	180	280	399	530	784
Aequidens pulcher	0	0	0	1	42	332	728	1452	2461
Acanthogobius flavimanus	0	0	2	34	131	339	582	819	1716
Haplochromis burtoni	0	0	0	0	62	359	795	1359	2410
Astronotus ocellatus	0	0	0	22	160	411	706	1171	1854
Cichlasoma trimaculatum	0	0	22	136	248	458	826	1303	2294
Tridentiger trigonochephalus	0	0	2	48	160	463	790	1433	2538
Trichogaster trichopterus	0	0	29	186	358	537	850	1299	1946
Perca fluviatilis	0	0	6	110	305	542	741	1054	1484
Rutilus rutilus	0	0	15	135	435	796	1239	1586	1939
Cichlasoma octofasciatum	0	0	32	275	534	950	1656	2492	2719
Tinca tinca	0	6	237	466	671	1014	1653	2141	2571
Tilapia zillii	0	0	1	52	509	1044	1906	2696	2770
Salmo trutta trutta	0	0	24	236	586	1087	1743	2311	2710
Xiphophorus maculatus	0	0	9	140	452	1174	2302	2739	2763
Poecelia latipinna	0	0	26	209	428	1201	2113	2520	2669
Poecelia reticulata	0	0	5	287	753	1327	1994	2744	2775
Gambusia holbrooki	0	0	13	345	916	1379	1992	2570	2767
Hemichromis bimaculatus	0	0	48	385	1154	1724	2078	2278	2496
Xiphophorus helleri	0	9	89	321	1375	2230	2648	2731	2759
Onchorhynchus mykiss	0	0	188	1406	2010	2260	2387	2516	2675
Carassius auratus auratus	0	0	65	312	1017	2268	2752	2772	2776
Oreochromis mossambicus	0	7	329	1426	2473	2707	2744	2759	2767
Cyprinus carpio	0	0	154	1077	2136	2736	2772	2775	2777

(A) PC new Euclidean Sorted on Σ 60%	Cumulative climate match level*								
Failed fish	**Σ 10%**	**Σ 20%**	**Σ 30%**	**Σ 40%**	**Σ 50%**	**Σ 60%**	**Σ 70%**	**Σ 80%**	**Σ 90%**
Puntius tetrazona	0	0	0	0	0	0	0	0	0
Sparidentex hasta	0	0	0	0	0	0	0	0	11
Gambusia dominicensis	0	0	0	0	2	12	57	324	648
Jordanella floridae	0	0	0	2	13	33	64	190	481
Hypoplectrodes huntii	0	0	0	2	10	36	82	138	201
Cichlasoma synspila	0	0	0	2	13	67	223	484	898
Geophagus brasiliensis	0	0	1	8	29	97	297	577	918
Aequidens rivulatus	0	0	0	2	15	119	372	808	2004
Lateolbrax japonicus	0	0	0	4	35	138	276	576	1018
Forsterygion lapillum	0	1	25	64	125	233	403	511	656
Cichlasoma severus	0	0	0	14	127	293	494	919	1506
Porichthys notatus	0	0	2	67	217	347	670	2096	2483
Oncorhynchus tshawytscha	0	0	2	40	158	399	760	2303	2536
Salmo salar	0	0	59	269	430	574	835	1213	1555
Cichlasoma meeki	0	0	21	239	451	691	995	1431	2103
Puntius conchonius	0	0	23	410	774	1059	1376	1804	2144
Oreochromis aureus	0	0	0	37	498	1253	2159	2440	2611
Oreochromis urolepis hornorum	0	0	10	258	1116	1843	2265	2552	2663

(B) PC Closest standard match Sorted on Σ 60%	Cumulative climate match level*								
Successful fish	**Σ 10%**	**Σ 20%**	**Σ 30%**	**Σ 40%**	**Σ 50%**	**Σ 60%**	**Σ 70%**	**Σ 80%**	**Σ 90%**
Tilapia mariae	0	0	0	0	4	15	32	136	952
Tanichthys albonubes	0	0	1	4	11	30	59	227	972
Amphilophus citrinellus	0	0	0	0	18	43	98	234	655
Aequidens pulcher	0	0	0	0	12	46	216	957	2655
Misgurnus anguillicaudatus	0	0	0	0	11	58	138	355	1438
Acentrogobius pflaumii	0	0	0	0	9	72	193	698	2333
Acanthogobius flavimanus	0	0	4	10	40	114	263	654	1915
Salvelinus fontinalis	0	0	0	10	54	128	316	1112	1938
Phalloceros caudimaculatus	0	0	1	11	40	143	313	743	1953
Cichlasoma nigrofasciatus	0	0	14	45	104	185	291	563	1526
Tridentiger trigonochephalus	0	0	4	14	57	185	378	1112	2558
Haplochromis burtoni	0	0	0	0	22	193	634	1791	2725
Astronotus ocellatus	0	0	0	11	64	216	464	1365	2767
Cichlasoma trimaculatum	0	0	17	56	130	256	406	1191	2227
Perca fluviatilis	0	0	7	62	158	332	582	1060	1846
Xiphophorus maculatus	0	0	4	57	158	385	871	2438	2766
Trichogaster trichopterus	0	0	8	66	218	471	771	1565	2439
Tilapia zillii	0	0	0	14	185	531	1266	2326	2771
Rutilus rutilus	0	0	14	92	223	570	919	1407	2163
Tinca tinca	0	17	130	325	474	627	793	1099	1860
Cichlasoma octofasciatum	0	0	25	98	272	638	1053	1737	2711
Salmo trutta trutta	0	0	17	114	427	743	1151	1958	2633
Hemichromis bimaculatus	0	0	18	139	494	855	1095	1911	2649
Poecelia latipinna	0	0	17	118	287	1047	1516	1881	2558

Gambusia holbrooki	0	0	4	89	521	1112	1730	2350	2761
Poecelia reticulata	0	0	1	73	454	1157	1856	2560	2775
Carassius auratus auratus	0	0	57	234	481	1406	2010	2724	2773
Xiphophorus helleri	0	18	77	197	681	1515	2119	2704	2765
Onchorhynchus mykiss	0	0	188	1406	2010	2260	2387	2516	2675
Cyprinus carpio	0	0	64	526	1316	2261	2694	2772	2780
Oreochromis mossambicus	0	33	232	795	1562	2313	2675	2760	2774

(B) PC Closest standard match Sorted on Σ 60%	**Cumulative climate match level***								
Failed fish	**Σ 10%**	**Σ 20%**	**Σ 30%**	**Σ 40%**	**Σ 50%**	**Σ 60%**	**Σ 70%**	**Σ 80%**	**Σ 90%**
Puntius tetrazona	0	0	0	0	0	0	0	0	16
Sparidentex hasta	0	0	0	0	0	0	0	0	5
Gambusia dominicensis	0	0	0	0	3	11	29	131	1669
Hypoplectrodes huntii	0	0	0	0	6	14	51	128	296
Jordanella floridae	0	0	0	1	5	21	35	96	572
Cichlasoma synspila	0	0	0	0	4	22	77	401	2121
Geophagus brasiliensis	0	0	0	5	17	46	111	534	1924
Aequidens rivulatus	0	0	0	1	9	54	150	453	1850
Lateolbrax japonicus	0	0	0	2	22	98	244	630	2679
Cichlasoma severus	0	0	0	1	10	117	335	1068	2592
Forsterygion lapillum	0	3	21	46	71	129	236	391	601
Porichthys notatus	0	0	5	28	76	138	195	892	2500
Oncorhynchus tshawytscha	0	0	4	11	41	139	332	1620	2591
Salmo salar	0	0	61	208	339	421	489	728	1496
Cichlasoma meeki	0	0	18	72	243	560	889	1424	2285
Puntius conchonius	0	0	15	240	578	919	1120	1408	2331
Oreochromis urolepis hornorum	0	0	5	80	380	937	1396	2029	2697
Oreochromis aureus	0	0	0	29	356	1094	1547	2270	2626

(C) Mac Sorted on Σ 60%	**Cumulative climate match level***								
Successful fish	**Σ 10%**	**Σ 20%**	**Σ 30%**	**Σ 40%**	**Σ 50%**	**Σ 60%**	**Σ 70%**	**Σ 80%**	**Σ 90%**
Tilapia mariae	0	0	0	7	20	42	153	1318	2798
Tanichthys albonubes	0	1	7	22	38	81	430	1457	2798
Acentrogobius pflaumii	0	0	2	6	34	89	507	1734	2798
Amphilophus citrinellus	0	0	6	23	58	124	319	1033	2798
Acanthogobius flavimanus	0	0	2	21	60	143	486	1257	2798
Salvelinus fontinalis	0	0	0	4	58	154	518	1517	2798
Misgurnus anguillicaudatus	0	0	1	17	98	266	590	1870	2798
Aequidens pulcher	0	0	0	10	61	268	1017	2441	2798
Haplochromis burtoni	0	0	0	14	92	298	1616	2683	2798
Phalloceros caudimaculatus	0	3	10	35	139	342	854	2573	2798
Cichlasoma nigrofasciatus	0	5	54	143	237	362	613	1994	2797
Astronotus ocellatus	0	2	7	34	153	374	1304	2768	2798
Tridentiger trigonochephalus	0	0	8	64	198	383	1483	2636	2798
Perca fluviatilis	0	16	59	132	233	390	683	1268	2798
Cichlasoma trimaculatum	0	7	65	168	292	448	944	2227	2798
Rutilus rutilus	0	19	72	205	427	696	1084	1533	2798

Xiphophorus maculatus	0	3	21	129	337	732	1722	2794	2798
Tinca tinca	20	123	336	471	585	738	1133	1789	2798
Cichlasoma octofasciatum	0	12	76	212	394	746	1823	2797	2798
Salmo trutta trutta	1	23	86	241	575	936	1529	2612	2798
Trichogaster trichopterus	0	14	119	302	599	941	2098	2525	2798
Tilapia zillii	0	0	13	87	476	1138	2089	2723	2798
Hemichromis bimaculatus	0	15	158	430	765	1158	2014	2728	2798
Carassius auratus auratus	3	41	196	409	873	1449	2615	2789	2798
Poecelia latipinna	0	16	149	339	965	1476	2058	2636	2798
Xiphophorus helleri	12	66	170	442	1009	1680	2710	2788	2798
Gambusia holbrooki	3	11	159	690	1402	1802	2314	2789	2798
Poecelia reticulata	0	0	108	595	1382	1907	2602	2790	2798
Onchorhynchus mykiss	0	53	352	1191	1972	2204	2484	2770	2798
Oreochromis mossambicus	3	105	467	1078	1891	2523	2778	2787	2798
Cyprinus carpio	0	56	319	827	1828	2571	2788	2790	2798

(C) Mac Sorted on Σ60%	**Cumulative climate match level***								
Failed fish	**Σ 10%**	**Σ 20%**	**Σ 30%**	**Σ 40%**	**Σ 50%**	**Σ 60%**	**Σ 70%**	**Σ 80%**	**Σ 90%**
Puntius tetrazona	0	0	0	0	0	0	1	19	2798
Sparidentex hasta	0	0	0	0	0	0	0	18	2797
Gambusia dominicensis	0	0	0	2	9	27	127	1458	2798
Jordanella floridae	0	0	0	3	18	31	61	190	893
Hypoplectrodes huntii	0	0	2	8	20	37	96	220	2798
Cichlasoma synspila	0	0	0	0	4	41	398	2089	2798
Aequidens rivulatus	0	0	0	7	49	124	307	1098	2798
Geophagus brasiliensis	0	2	7	15	62	156	438	2018	2798
Oncorhynchus tshawytscha	0	0	2	21	73	156	789	2551	2798
Forsterygion lapillum	4	14	35	50	103	164	307	486	2798
Lateolbrax japonicus	0	1	4	24	83	183	743	2624	2798
Porichthys notatus	0	0	8	37	136	195	635	2367	2798
Cichlasoma severus	0	0	1	20	109	421	1221	2620	2798
Salmo salar	3	36	175	298	393	469	562	917	2798
Cichlasoma meeki	0	5	60	176	312	628	1578	2359	2798
Oreochromis urolepis hornorum	0	4	21	129	422	1151	2154	2760	2798
Puntius conchonius	0	2	158	530	992	1164	1457	1923	2797
Oreochromis aureus	0	0	5	111	583	1165	2072	2647	2798

* See guide to class/percentiles and cumulative scores for Mac and PC versions of CLIMATE, Appendix D Table D1.

Appendix K

Establishment risk scores for exotic freshwater finfish species introduced to Australia using PC CLIMATE outputs for climate match scores

Appendix K Table K1. Establishment risk scores for exotic finfish species introduced to Australia with new climate match scores based on PC CLIMATE.
A. Successful introductions.
B. Failed introductions (recorded but not known to be established).
The Climate Match Scores in Column A are based on PC CLIMATE Euclidian match (Σ60% level) converted to Climate Match Scores using the cut-off thresholds presented in Figure 10. The values in Columns B–E are taken directly from Bomford and Glover (2004). The Total Establishment Risk Score (column F) is the sum of the scores in columns A–E. The Total Establishment Risk Score (column F) is sorted in ascending order to enable new cut-off thresholds to be determined for calculating Establishment Risk Ranks for exotic finfish species introduced to Australia. These cut-off thresholds are presented in Figure 14.

A. Successfully introduced species1	**A**	**B**	**C**	**D**	**E**	**F**	**G**
	Climate Match Score 1–8	**Overseas Range Score 0–4**	**Establishment Score 0–3**	**Introduction Success Score 0–4**	**Taxa Risk Score 0–5**	**Total Establish-ment Risk Score 0–24**	**Establish-ment Risk Rank**
Three-spot cichlid *Cichlasoma trimaculatum*	4	2	0	0	4	10	Moderate
Victoria Burton's haplochromine *Haplochromis burtoni*	4	0	1	2	3	10	Moderate
Goby *Acentrogobius pflaumii*	3	0	1	2	5	11	Moderate
Blue acara *Aequidens pulcher*	4	2	2	2	3	13	Moderate
Red devil/Midas cichlid *Amphilophus citrinellus*	3	2	2	4	3	14	Moderate
Convict cichlid *iatus Archocentrus nigrofasciatus*	4	0	2	4	4	14	Moderate
Niger cichlid *Tilapia mariae*	2	3	2	4	4	15	Serious
White-cloud mountain minnow *Tanichthys albonubes*	3	4	2	4	3	16	Serious
Yellowfin goby *Acanthogobius flavimanus*	4	1	2	4	5	16	Serious
Chameleon goby *Tridentiger trigonocephalus*	5	1	2	4	5	17	Serious
One-spot live bearer *Phalloceros caudimaculatus*	4	3	2	4	5	18	Serious
Jack Dempsey *Cichlasoma octofasciatum*	5	2	3	4	4	18	Serious

A. Successfully introduced species1	A	B	C	D	E	F	G
	Climate Match Score 1–8	Overseas Range Score 0–4	Establishment Score 0–3	Introduction Success Score 0–4	Taxa Risk Score 0–5	Total Establish-ment Risk Score 0–24	Establish-ment Risk Rank
Weather loach *Misgurnus anguillicaudatus*	4	2	3	4	5	18	Serious
Brook trout *Salvelinus fontinalis*	4	4	3	3	4	18	Serious
Roach *Rutilus rutilus*	5	4	3	4	3	19	Serious
Jewel cichlid *Hemichromis bimaculatus*	5	3	2	4	5	19	Serious
Sailfin molly *Poecilia latipinna*	6	2	3	4	5	20	Extreme
Platy *Xiphophorus maculatus*	6	2	3	4	5	20	Extreme
Green swordtail *Xiphophorus hellerii*	7	1	3	4	5	20	Extreme
Redbelly tilapia *Tilapia zillii*	6	4	3	3	4	20	Extreme
Redfin perch *Perca fluviatilis*	5	3	3	4	5	20	Extreme
Tench *Tinca tinca*	6	3	3	4	5	21	Extreme
Oscar *Astronotus ocellatus*	5	4	3	4	5	21	Extreme
Rainbow trout *Oncorhynchus mykiss*	7	4	3	4	3	21	Extreme
Brown trout *Salmo trutta*	6	4	3	4	4	21	Extreme
Three-spot gourami *Trichogaster trichopterus*	5	4	3	4	5	21	Extreme
Mosquitofish *Gambusia holbrooki + affinis*	6	4	3	4	5	22	Extreme
Guppy *Poecilia reticulata*	6	4	3	4	5	22	Extreme
Goldfish *Carassius auratus*	7	4	3	4	5	23	Extreme
Mozambique tilapia *Oreochromis mossambicus*	8	4	3	4	4	23	Extreme
European carp *Cyprinus carpio*	8	4	3	4	5	24	Extreme

B. Unsuccessfully introduced species (recorded but not known to be established)	**A** Climate match score 1–8	**B** Overseas range score 0–4	**C** Establish-ment score 0–3	**D** Introduction success score 0–4	**E** Taxa risk score 0–5	**F** Total Establish-ment Risk Score 0–24	**G** Establish-ment Risk Rank
Sobaity seabream *Sparidentex hasta*	1	0	1	2	2	6	Low
Pearl cichlid *Geophagus brasiliensis*	3	1	0	0	3	7	Low
Redbanded perch *Hypoplectrodes huntii*	2	0	1	2	2	7	Low
Japanese seabass *Lateolabrax japonicus*	3	2	1	2	0	8	Moderate
Common triplefin *Forsterygion lapillum*	4	0	1	2	2	9	Moderate
Dominican gambusia *Gambusia dominicensis*	2	0	1	2	5	10	Moderate
Green terror *Aequidens rivulatus*	3	1	1	2	3	10	Moderate
Banded cichlid *Heros severus*	4	2	0	0	4	10	Moderate
American flagfish *Jordanella floridae*	2	0	1	2	5	10	Moderate
Sumatra barb *Puntius tetrazona*	1	0	3	3	5	12	Moderate
Plainfin frogfish *Porichthys notatus*	4	4	1	2	2	13	Moderate
Redhead *Vieja synspila*	3	4	1	2	4	14	Moderate
Chinook salmon *Oncorhynchus tshawytscha*	4	4	2	1	3	14	Moderate
Firemouth cichlid *Thorichtys meeki*	5	0	3	4	4	16	Serious
Atlantic salmon *Salmo salar*	5	4	3	1	4	17	Serious
Wami tilapia *Oreochromis urolepis*	7	1	3	4	4	19	Serious
Blue tilapia *Oreochromis aureus*	6	3	3	4	4	20	Extreme
Rosy barb *Puntius conchonius*	6	3	3	4	5	21	Extreme

Appendix L

Establishment risk scores for exotic freshwater finfish species introduced to Australia using Mac CLIMATE outputs for climate match scores

Appendix L Table L1. Establishment Risk Scores for exotic finfish species introduced to Australia based on the original values presented by Bomford and Glover (2004) with Climate Match Scores (1–8) in column A derived from the Mac version of Climate using the formula presented by Bomford and Glover (2004).

A. Successfully introductions.

B. Failed introductions (recorded but not known to be established).

The Total Establishment Risk Score (column F) is the sum of the scores in columns A–E. The Total Establishment Risk Score (column F) is converted to an Establishment Risk Rank (Column G) using the formula presented by Bomford and Glover (2004).

A. Successfully introduced species1	**A**	**B**	**C**	**D**	**E**	**F**	**G**
	Climate Match Score 0–8	**Overseas Range Score 0–4**	**Establish-ment Score 0–3**	**Introduction Success Score 0–4**	**Taxa Risk Score 0–5**	**Total Establish-ment Risk Score 0–24**	**Establishment Risk Rank**
Victoria Burton's haplochromine *Haplochromis burtoni*	2	0	1	2	3	8	Low
Goby *Acentrogobius pflaumii*	1	0	1	2	5	9	Moderate
Three-spot cichlid *Cichlasoma trimaculatum*	5	2	0	0	4	11	Moderate
Red devil/Midas cichlid *Amphilophus citrinellus*	1	2	2	4	3	12	High
Blue acara *Aequidens pulcher*	4	2	2	2	3	13	High
Yellowfin goby *Acanthogobius flavimanus*	1	1	2	4	5	13	High
White-cloud mountain minnow *Tanichthys albonubes*[2]	1	4	2	4	3	14	High
Niger cichlid *Tilapia mariae*	1	3	2	4	4	14	High
Convict cichlid *Archocentrus nigrofasciatus*	4	0	2	4	4	14	High
Brook trout *Salvelinus fontinalis*	1	4	3	3	4	15	High
Chameleon goby *Tridentiger trigonocephalus*	3	1	2	4	5	15	High

A. Successfully introduced species1	**A**	**B**	**C**	**D**	**E**	**F**	**G**
	Climate Match Score 0–8	**Overseas Range Score 0–4**	**Establish-ment Score 0–3**	**Introduction Success Score 0–4**	**Taxa Risk Score 0–5**	**Total Establish-ment Risk Score 0–24**	**Establishment Risk Rank**
Weather loach *Misgurnus anguillicaudatus*	2	2	3	4	5	16	High
One-spot live bearer *Phalloceros caudimaculatus*	3	3	2	4	5	17	High
Jack Dempsey *Cichlasoma octofasciatum*	4	2	3	4	4	17	High
Roach *Rutilus rutilus*	4	4	3	4	3	18	Very high
Platy *Xiphophorus maculatus*	4	2	3	4	5	18	Very high
Green swordtail *Xiphophorus hellerii*	5	1	3	4	5	18	Very high
Redbelly tilapia *Tilapia zillii*	4	4	3	3	4	18	Very high
Sailfin molly *Poecilia latipinna*	5	2	3	4	5	19	Very high
Oscar *Astronotus ocellatus*	3	4	3	4	5	19	Very high
Redfin perch *Perca fluviatilis*	4	3	3	4	5	19	Very high
Brown trout *Salmo trutta*	5	4	3	4	4	20	Very high
Tench *Tinca tinca*	6	3	3	4	5	21	Extreme
Goldfish *Carassius auratus*	5	4	3	4	5	21	Extreme
Guppy *Poecilia reticulata*	5	4	3	4	5	21	Extreme
Jewel cichlid *Hemichromis bimaculatus*	7	3	2	4	5	21	Extreme
Three-spot gourami *Trichogaster trichopterus*	5	4	3	4	5	21	Extreme
Rainbow trout *Oncorhynchus mykiss*	8	4	3	4	3	22	Extreme
European carp *Cyprinus carpio*	7	4	3	4	5	23	Extreme
Mozambique tilapia *Oreochromis mossambicus*	8	4	3	4	4	23	Extreme
Mosquitofish *Gambusia holbrooki + affinis*	8	4	3	4	5	24	Extreme

B. Failed species1 (recorded but not known to be established)	A Climate match score 0–8	B Overseas range score 0–4	C Establish-ment score 0–3	D Introduction success score 0–4	E Taxa risk score 0–5	F Total score 0–24	G Establishment Risk Rank
Sobaity seabream *Sparidentex hasta*	0	0	1	2	2	5	Very low
Pearl cichlid *Geophagus brasiliensis*	2	1	0	0	3	6	Very low
Japanese seabass *Lateolabrax japonicus*	2	2	1	2	0	7	Low
Green terror *Aequidens rivulatus*	1	1	1	2	3	8	Low
Banded cichlid *Heros severus*	2	2	0	0	4	8	Low
Common triplefin *Forsterygion lapillum*	3	0	1	2	2	8	Low
Redbanded perch *Hypoplectrodes huntii*	3	0	1	2	2	8	Low
Dominican gambusia *Gambusia dominicensis*	1	0	1	2	5	9	Moderate
American flagfish *Jordanella floridae*	1	0	1	2	5	9	Moderate
Sumatra barb *Puntius tetrazona*	0	0	3	3	5	11	Moderate
Redhead *Vieja synspila*	0	4	1	2	4	11	Moderate
Chinook salmon *Oncorhynchus tshawytscha*	1	4	2	1	3	11	Moderate
Plainfin frogfish *Porichthys notatus*	2	4	1	2	2	11	Moderate
Firemouth cichlid *Thorichtys meeki*	4	0	3	4	4	15	High
Wami tilapia *Oreochromis urolepis*	4	1	3	4	4	16	High
Atlantic salmon *Salmo salar*	5	4	3	1	4	17	High
Blue tilapia *Oreochromis aureus*	4	3	3	4	4	18	Very high
Rosy barb *Puntius conchonius*	5	3	3	4	5	20	Very high

Appendix M

Climate Match Scores for exotic reptiles and amphibians introduced to Britain, California and Florida

Bomford et al. (2005) used the Euclidian CLIMATE match outputs at the Σ7 level to calculate Climate Match Scores for exotic reptiles and amphibians introduced to Britain, California and Florida. In the CLIMATE database each jurisdiction has a different number of meteorological stations and the total maximum possible score a species being climatically matched to a jurisdiction being assessed is a function of the number of meteorological stations in the CLIMATE database for that jurisdiction. To calculate a Climate Match Score for a species at the Σ7 level, the sum of the scores for the Euclidian matches for the four highest match classes is divided by the maximum possible score for the jurisdiction where the species was introduced, and then multiplied by 100 to give a percentage score. For example, for *Xenopus laevis*, the climate scores summed for these four highest levels (Σ7) is 61 + 11 + 0 + 0 = 72 (Table M1). The maximum possible score for California (Σ7 level) is 172 (Table M2), so the Climate Match Score for *Xenopus laevis* in California = 100×72 ÷ 172 = 41.9.

Appendix M Table M1. PC CLIMATE Euclidian matches to California for the African clawed toad *Xenopus laevis*.
The number of matches at the Number 8 level is 11. This means that 11 meteorological stations inside California have this high level of match to the meteorological stations in the toad's range outside California. See text above for instructions on calculating the Climate Match Score for *Xenopus laevis* in California.

	Lowest match					**→**			**Highest match**		
Climate match level for Euclidian Match	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Number of matches for *Xenopus laevis*	0	0	3	1	23	39	34	61	11	0	0

Table M2 presents the Climate Match Scores for exotic reptiles and amphibians introduced to Britain, California and Florida (from Bomford et al. 2005).

Appendix M Table M2. PC CLIMATE Euclidian (Σ7 level) cumulative matches and Climate Match Scores for exotic reptiles and amphibians (combined)[1] introduced to Britain, California and Florida.
A = Successful species
B = Failed species.

A. Successful species

PC Euclidian analysis Sorted Σ7 level*	**10**	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**	**Climate Match Score**
Britain successful species										Maximum possible score for Britain = 194
Xenopus laevis	0	0	35	94	169	192	193	193	194	48

Triturus carnifex	0	0	36	101	162	189	194	194	194	52
Elaphe longissima	0	7	82	161	193	193	194	194	194	83
Rana ribibunda	0	37	158	189	193	194	194	194	194	97
Alytes obstetricians	0	41	170	190	193	194	194	194	194	98
Podarcis muralis	0	33	163	190	193	194	194	194	194	98
Trituris alpestris	0	40	165	190	193	194	194	194	194	98
Rana lessonae	0	37	162	192	193	194	194	194	194	99
California successful species										Maximum possible score for California = 172
Chamaeleo jacksonii	0	0	0	0	0	42	89	127	149	0
Nerodia fasciata	0	0	0	0	0	0	4	23	90	0
Chelydra serpentina	0	0	0	1	59	123	153	170	171	1
Rana berlandieri	4	6	10	10	13	48	87	109	141	6
Hemidactylus turcicus	0	20	94	138	163	172	172	172	172	8
Apalone spinifera	7	10	15	19	65	101	134	156	162	11
Trachemys scripta	1	1	7	22	80	144	166	171	171	13
Ambystoma tigrinum	1	4	14	24	71	108	141	159	171	14
Xenopus laevis	0	0	11	72	106	145	168	169	172	42
Tarentola mauritanica	0	0	15	87	128	150	165	168	172	51
Rana catesbeiana	7	15	51	116	167	171	172	172	172	67
Florida successful species										Maximum possible score for Florida = 106
Chamaeleo calyptratus	0	0	0	0	0	0	7	29	69	0
Ctenosaura pectinata	0	0	0	0	0	2	12	50	76	0
Tarentola mauritanica	0	0	0	0	0	3	50	84	105	0
Aspidoscelis motaguae	0	0	0	0	0	2	23	64	89	0
Eleutherodactylus coqui	0	0	0	1	12	42	91	105	106	1
Agama agama	0	0	0	11	70	94	106	106	106	1
Anolis ferreus	0	0	0	3	12	45	88	103	106	3
Pachydactylus bibronii	0	0	0	4	55	99	105	106	106	4
Tarentola annularis	0	0	0	4	54	83	101	106	106	4
Aspidoscelis lemniscatus	0	0	0	4	15	43	79	104	106	4
Leiocephalus schreibersi	0	0	0	5	39	67	82	97	104	5
Ctenosaurus similis	0	0	0	7	50	75	95	104	106	7
Anolis cristatellus	0	0	3	7	36	72	101	106	106	7
Phelsuma madagascariensis	0	0	0	7	32	91	106	106	106	7
Anolis chlorocyanus	0	0	3	8	43	70	84	100	106	8
Anolis cybotes	0	0	3	8	43	70	84	100	106	8
Caiman crocodilus	0	0	0	8	45	77	106	106	106	8
Basiliscus vittatus	0	0	0	20	62	80	95	104	106	19
Anolis distichus	0	0	4	29	61	82	93	102	106	27
Hemidactylus mabouia	0	0	4	37	101	106	106	106	106	35

Anolis equestris	0	0	4	38	66	83	93	104	106	36
Osteopilus septentrionalis	0	0	7	45	67	83	103	106	106	42
Anolis porcatus	0	0	7	45	67	83	98	105	106	42
Sphaerodactylus elegans	0	0	7	45	67	83	98	105	106	42
Gonatodes albogularis	0	0	7	46	67	83	103	106	106	43
Anolis garmani	0	0	16	51	80	95	105	106	106	48
Ameiva ameiva	0	0	10	54	103	104	106	106	106	51
Leiocephalus carinatus	0	0	20	57	82	95	105	106	106	54
Python molurus	0	0	21	68	85	98	106	106	106	64
Calotes versicolor	0	0	23	70	85	99	106	106	106	66
Eleutherodactylus planirostris	0	0	26	76	103	106	106	106	106	72
Hemidactylus frenatus	0	0	38	76	103	106	106	106	106	72
Gekko gecko	0	0	37	77	103	106	106	106	106	73
Cosymbotus platyurus	0	0	37	78	103	106	106	106	106	74
Hemidactylus turcicus	0	0	26	78	105	106	106	106	106	74
Iguana iguana	0	0	23	80	104	106	106	106	106	75
Ramphotyphlops braminus	0	0	47	89	103	106	106	106	106	84
Hemidactylus garnotii	0	0	59	89	103	106	106	106	106	84
Mabuya multifasciata	0	0	47	89	103	106	106	106	106	84
Boa constrictor	0	0	37	100	105	106	106	106	106	94
Anolis sagrei	0	7	68	104	106	106	106	106	106	98

B. Failed species

PC Euclidian analysis Sorted Σ7 level*	**10**	**Σ9**	**Σ8**	**Σ7**	**Σ6**	**Σ5**	**Σ4**	**Σ3**	**Σ2**	**Climate Match Score**
Britain failed species										Maximum possible score for Britain = 194
Hydromantes genei	0	0	0	0	0	0	0	0	64	0
Eleutherodactylus johnstonei	0	0	0	0	0	0	0	0	19	0
Rana pipiens	0	0	0	0	6	58	166	194	194	0
Scinax rubra	0	0	0	0	27	161	191	193	193	0
Chelydra serpentia	0	0	0	0	39	163	194	194	194	0
Chrysemys picta	0	0	0	0	2	45	161	194	194	0
Pelodiscus sinensis	0	0	0	0	0	0	10	157	193	0
Terrapene carolina	0	0	0	0	6	58	161	194	194	0
Pseudocordylus microlepidotus	0	0	0	0	1	60	146	178	190	0
Tarentola delalandii	0	0	0	0	0	8	26	92	164	0
Tarentola mauritanica	0	0	0	0	42	160	190	194	194	0
Podarcis dugesii	0	0	0	0	0	8	26	101	170	0
Podarcis sicula	0	0	0	0	40	148	190	194	194	0
Thamophis sirtalis	0	0	0	0	2	46	164	194	194	0

Testudo graeca	0	0	0	3	40	161	192	194	194	2
Coluber jugularis	0	0	0	3	40	161	192	194	194	02
Chalcides	0	0	0	5	64	191	193	194	194	3
Lampropeltis triangulum	0	0	0	8	79	193	193	194	194	04
Pseudacris regilla	0	0	3	45	136	192	194	194	194	23
Hyla meridionalis	0	0	6	64	147	187	194	194	194	33
Discoglossus pictus	0	0	49	76	151	190	193	193	193	39
Natrix tessellata	0	4	39	91	161	193	194	194	194	47
Lacerta lepida	0	1	25	108	186	193	194	194	194	56
Bombina bombina	0	4	47	121	172	194	194	194	194	62
Natrix maura	0	0	28	129	186	193	194	194	194	66
Bufo viridus	0	4	51	134	177	194	194	194	194	69
Emys orbicularis	0	16	129	172	191	194	194	194	194	89
Lacerta bilineata	0	21	139	180	193	194	194	194	194	93
Litoria ewingii	0	24	149	185	194	194	194	194	194	95
Pelobates fuscus	0	31	144	188	193	194	194	194	194	97
Salamandra salamandra	0	41	166	190	193	194	194	194	194	98
Hyla aborea	2	51	168	192	193	194	194	194	194	99
California failed species										Maximum possible score for California = 172
Andrias japonicus	0	0	0	0	0	0	0	0	0	0
Hemidactylus garnotii	0	0	0	0	0	14	61	124	146	0
Hemidactylus typus	0	0	0	0	0	14	61	115	130	0
Gehyra mutilata	0	0	0	0	0	14	61	115	130	0
Heloderma horridum	0	0	0	0	13	75	106	140	155	0
Cordylus giganteus	0	0	0	0	0	0	38	114	138	0
Stenosaura hemilopha	0	0	0	0	0	2	9	20	57	0
Iguana iguana	0	0	0	0	44	65	106	146	160	0
Palea steindachneri	0	0	0	0	0	14	61	115	130	0
Geochelone carbonaria	0	0	0	0	0	0	17	61	106	0
Varanus salvator	0	0	0	0	0	0	0	9	33	0
Leptodiera annulata	0	0	0	0	18	57	89	122	152	0
Corallus hortulanus	0	0	0	0	0	2	17	67	125	0
Python reticulatus	0	0	0	0	0	0	0	9	33	0
Python molurus	0	0	0	0	2	8	17	52	118	0
Caiman crocodilus	0	0	0	0	0	10	73	122	150	0
Notophthalmus viridescens	0	0	0	0	5	49	92	139	152	0
Sceloporus serrifer	0	0	0	0	4	16	53	106	147	0
Pseudemys floridana	0	0	0	0	0	0	0	7	34	0
Pseudemys concinna	0	0	0	0	8	59	95	136	150	0
Graptemys pseudogeographica	0	0	0	0	0	0	0	21	87	0
Macrochelys temminckii	0	0	0	0	0	0	4	26	87	0
Malaclemys terrapin	0	0	0	0	0	3	8	47	96	0
Terrapene carolina	0	0	0	0	0	41	86	133	152	0

Drymarchon corais	0	0	0	0	6	26	69	125	145	0
Nerodia sipedon	0	0	0	0	0	41	77	122	147	0
Opheodrys aestivus	0	0	0	0	4	46	86	136	150	0
Thamnophis sauritus	0	0	0	0	0	41	77	121	142	0
Alligator mississipiensis	0	0	0	0	0	0	7	40	95	0
Bufo marinus	0	0	0	1	58	97	142	162	167	1
Anolis carolinensis	0	0	0	1	14	78	124	159	160	1
Eumeces obsoletus	0	0	0	1	9	58	122	147	161	1
Sceloporus poinsettii	0	0	0	1	20	83	125	152	158	1
Sceloporus jarrovii	0	0	0	1	20	83	124	146	153	1
Phrynosoma cornutum	0	0	0	1	20	83	125	150	156	1
Elaphe guttata	0	0	0	1	20	105	133	159	162	1
Boa constrictor	0	0	0	4	63	92	141	156	166	2
Lampropeltis triangulum	0	0	0	4	13	78	144	170	171	2
Lamprophis fuliginosus	0	0	17	51	111	151	169	170	172	3
Hyla wrightorum	0	0	0	5	10	15	86	116	150	3
Chinemys reevesii	0	0	8	8	10	10	15	41	136	5
Naja haje	0	0	42	103	138	165	169	170	171	6
Terrapene ornata	0	0	8	10	13	47	94	123	153	6
Lepidodactylus lugubris	0	0	12	60	94	116	142	146	153	35
Florida failed species										Maximum possible score for Florida = 106
Cynops pyrrhogaster	0	0	0	0	22	57	88	103	106	0
Atelopus zetiki	0	0	0	0	0	0	0	0	0	0
Bufo blombergi	0	0	0	0	0	0	0	10	39	0
Pachymedusa dancicolor	0	0	0	0	0	2	12	50	76	0
Python regius	0	0	0	0	4	34	77	103	106	0
Cordylus cordylus	0	0	0	0	9	39	87	106	106	0
Basiliscus basiliscus	0	0	0	0	3	27	76	106	106	0
Podocnemis lewyana	0	0	0	0	0	9	82	104	106	0
Podocnemis sextuberculata	0	0	0	0	5	37	53	80	96	0
Trachemys dorbigni	0	0	0	1	25	56	95	105	106	1
Hymenochirus boettgeri	0	0	0	3	18	70	106	106	106	3
Sphaerodactylus macrolepis	0	0	0	3	13	49	92	105	106	3
Varanus exanthematicus	0	0	0	5	70	94	106	106	106	5
Anolis conspersus	0	0	0	6	26	60	83	101	106	6
Hemidactylus brookii	0	0	21	74	83	99	106	106	106	7
Trachemys stejnegeri	0	0	3	7	35	71	100	106	106	7
Python reticulatus	0	0	1	9	41	75	91	106	106	8
Cyclura cornuta	0	0	3	8	43	74	101	106	106	8
Chelus fimbriatus	0	0	0	16	53	80	95	106	106	15

Kinosternon scorpioides	0	0	0	25	66	81	103	106	106	24
Xenopus laevis	0	0	0	26	83	105	106	106	106	25
Podocnemis unifilis	0	0	3	29	75	98	106	106	106	27
Typhlops lumbricalis	0	0	8	45	67	83	98	105	106	42
Varanus salvator	0	0	16	44	75	87	103	106	106	42
Tupanambis nigropunctatus	0	0	8	58	102	106	106	106	106	55
Bufo arenarum	0	0	22	80	98	105	106	106	106	75
Bufo paracnemis [Analysed *Bufo schneideri*]	0	0	34	97	105	106	106	106	106	92

[1] Sources: Fred Kraus database of published records; Kevin M. Enge (Florida Fish and Wildlife Conservation Commission, pers. comm. 15 March 2005) list of exotic species established in Florida for at least ten years; Meshaka et al. (2004).

Table M3 presents Taxonomic scores, Climate Match Scores, Success Elsewhere Scores and Establishment Risk Scores for exotic reptiles and amphibians introduced to Britain, California and Florida.

Appendix M Table M3. Taxonomic scores, Climate Match Scores[1], Success Elsewhere Scores and Establishment Risk Scores for exotic reptiles and amphibians (combined)[2] introduced to
A. Britain
B. California
C. Florida.

A. Britain introduction outcome	**Family**	**Climate matches Σ7–10**	**A. Climate Match Risk Score (0–100)** (% of 194)	**B. Exotic Elsewhere Risk Score (0–30)**	**C. Taxonomic Family Risk Score (0–30)**	**Establishment Risk Score (0–160)**
Britain successful species						
Xenopus laevis (African clawed toad)	Pipidae	94	48	30	15	93
Elaphe longissima (Aesculapian snake)	Elapidae	161	83	0	10	93
Triturus carnifex (Italian crested newt)	Salamandridae	101	52	30	15	97
Alytes obstetricians (mid-wife toad)	Discoglossidae	190	98	30	15	143
Trituris alpestris (alpine newt)	Salamandridae	190	98	30	15	143
Podarcis muralis (common wall lizard)	Lacertidae	190	98	30	20	148
Rana ridibunda (marsh frog)	Ranidae	189	97	30	30	157
Rana lessonae (pool frog)	Ranidae	192	99	30	30	159
Average for Britain successful species		**163**	**84.2**	**26.3**	**18.8**	**129**
Britain failed species						
Pseudocordylus microlepidotus	Cordylidae	0	0	0	10	10
Thamnophis sirtalis	Colubridae	0	0	0	10	10
Coluber jugularis	Colubridae	3	02	0	10	12
Lampropeltis triangulum	Colubridae	8	04	0	10	14
Hydromantes genei	Plethodontidae	0	0	0	20	20
Chrysemys picta	Emydidae	0	0	15	15	30

Tarentola delalandii	Gekkonidae	0	0	0	30	30
Chelydra serpentia	Chelydridae	0	0	30	10	40
Scinax rubra	Hylidae	0	0	30	15	45
Terrapene carolina	Emydidae	0	0	30	15	45
Testudo graeca	Testudinidae	3	2	30	15	47
Chalcides ocellatus	Scincidae	5	3	30	15	48
Pelodiscus sinensis	Trionychidae	0	0	30	20	50
Podarcis dugesii	Lacertidae	0	0	30	20	50
Podarcis sicula	Lacertidae	0	0	30	20	50
Natrix tessellata	Colubridae	91	47	0	10	57
Eleutherodactylus johnstonei	Leptodactylidae	0	0	30	30	60
Rana pipiens	Ranidae	0	0	30	30	60
Tarentola mauritanica	Gekkonidae	0	0	30	30	60
Pseudacris regilla	Hylidae	45	23	30	15	68
Lacerta lepida	Lacertidae	108	56	0	20	76
Bombina bombina	Discoglossidae	121	62	0	15	77
Discoglossus pictus	Discoglossidae	76	39	30	15	84
Pelobates fuscus	Pelobatidae	188	97	0	0	97
Natrix maura	Colubridae	129	66	30	10	106
Salamandra salamandra	Salamandridae	190	98	0	15	113
Hyla aborea	Hylidae	192	99	0	15	114
Hyla meridionalis	Hylidae	64	33	30	15	114
Bufo viridus	Bufonidae	134	69	30	20	119
Emys orbicularis	Emydidae	172	89	30	15	134
Litoria ewingii	Hylidae	185	95	30	15	140

Lacerta bilineata	Lacertidae	180	93	30	20	143
Average Britain failed species		**59**	**30.5**	**18.3**	**16.4**	**66**

Table M3B.

B. Introduction outcome for California	**Family**	**Climate matches Σ7–10**	**A. Climate Match Risk Score (0–100)** (% of 172)	**B. Exotic Elsewhere Risk Score (0–30)**	**C. Taxonomic Family Risk Score (0–30)**	**Establishment Risk Score (0–160)**
California successful species						
Nerodia fasciata	Colubridae	0	0	30	10	40
Chelydra serpentina	Chelydridae	1	1	30	10	41
Trachemys scripta	Emydidae	22	13	30	15	58
Ambystoma tigrinum	Ambystomatidae	24	14	30	15	59
Chamaeleo jacksonii	Chamaeleonidae	0	0	30	30	60
Apalone spinifera	Trionychidae	19	11	30	20	61
Rana berlandieri	Ranidae	10	6	30	30	66
Xenopus laevis	Pipidae	72	42	30	15	87
Tarentola mauritanica	Gekkonidae	87	51	30	30	111
Rana catesbeiana	Ranidae	116	67	30	30	127
Hemidactylus turcicus	Gekkonidae	138	80	30	30	140
Average California successful species		**44.45**	**26**	**30**	**21.4**	**77.3**
California failed species						
Andrias japonicus	Cryptobranchidae	0	0	0	0	0
Heloderma horridum	Helodermatidae	0	0	0	0	0

Chinemys reevesii	Geoemydidae	8	5	0	0	5
Corallus hortulanus	Boidae	0	0	0	5	5
Python reticulatus	Boidae	0	0	0	5	5
Cordylus giganteus	Cordylidae	0	0	0	10	10
Leptodeira annulata	Colubridae	0	0	0	10	10
Macrochelys temminckii	Chelydridae	0	0	0	10	10
Drymarchon corais	Colubridae	0	0	0	10	10
Nerodia sipedon	Colubridae	0	0	0	10	10
Opheodrys aestivus	Colubridae	0	0	0	10	10
Lampropeltis triangulum	Colubridae	4	2	0	10	12
Geochelone carbonaria	Testudinidae	0	0	0	15	15
Varanus salvator	Varanidae	0	0	0	15	15
Notophthalmus viridescens	Salamandridae	0	0	0	15	15
Pseudemys floridana	Emydidae	0	0	0	15	15
Eumeces obsoletus	Scincidae	1	1	0	15	16
Hyla wrightorum	Hylidae	5	3	0	15	18
Sceloporus serrifer	Lacertidae	0	0	0	20	20
Sceloporus poinsettii	Lacertidae	1	1	0	20	21
Sceloporus jarrovii	Lacertidae	1	1	0	20	21
Terrapene ornata	Emydidae	10	6	0	15	21
Thamnophis sauritus	Colubridae	0	0	15	10	25
Alligator mississipiensis	Alligatoridae	0	0	15	10	25
Malaclemys terrapin	Emydidae	0	0	15	15	30
Python molurus	Boidae	0	0	30	5	35
Boa constrictor	Boidae	4	2	30	5	37

Lamprophis fuliginosus	Colubridae	51	3	0	10	40
Elaphe guttata	Elapidae	1	1	30	10	41
Caiman crocodilus	Alligatoridae	0	0	30	15	45
Pseudemys concinna	Emydidae	0	0	30	15	45
Graptemys pseudogeographica	Emydidae	0	0	30	15	45
Terrapene carolina	Emydidae	0	0	30	15	45
Ctenosaura hemilopha	Iguanidae	0	0	30	20	50
Iguana iguana	Iguanidae	0	0	30	20	50
Palea steindachneri	Trionychidae	0	0	30	20	50
Bufo marinus	Bufonidae	1	1	30	20	51
Anolis carolinensis	Iguanidae	1	1	30	20	51
Phrynosoma cornutum	Lacertidae	1	1	30	20	51
Hemidactylus garnotii	Gekkonidae	0	0	30	30	60
Hemiphyllodactylus typus	Gekkonidae	0	0	30	30	60
Gehyra mutilata	Gekkonidae	0	0	30	30	60
Naja haje	Elapidae	103	6	0	10	70
Lepidodactylus lugubris	Gekkonidae	60	35	30	30	95
Average California failed species		**5.73**	**2**	**12.6**	**14.1**	**30.1**

Table M3C.

C. Introduction outcome for Florida	**Family**	**Climate matches $\Sigma 7$–10**	**Climate Match Risk Score (0–100)** (% of 106)	**B. Exotic Elsewhere Risk Score (0–30)**	**C. Taxonomic Family Risk Score (0–30)**	**Establishment Risk Score (0–160)**
Florida successful species						
Aspidoscelis motaguae	Teiidae	0	0	0	20	20
Anolis ferreus	Iguanidae	3	3	0	20	23
Leiocephalus schreibersi	Iguanidae	5	5	0	20	25
Ctenosaura similis	Iguanidae	7	7	0	20	27
Pachydactylus bibronii	Gekkonidae	4	4	0	30	34
Tarentola annularis	Gekkonidae	4	4	0	30	34
Basiliscus vittatus	Iguanidae	20	19	0	20	39
Caiman crocodilus	Alligatoridae	8	8	30	10	48
Ctenosaura pectinata	Iguanidae	0	0	30	20	50
Cnemidophorus lemniscatus	Teiidae	4	4	30	20	54
Anolis cristatellus	Iguanidae	7	7	30	20	57
Anolis chlorocyanus	Iguanidae	8	8	30	20	58
Anolis cybotes	Iguanidae	8	8	30	20	58
Chamaeleo calyptratus	Chamaeleonidae	0	0	30	30	60
Tarentola mauritanica	Gekkonidae	0	0	30	30	60
Eleutherodactylus coqui	Leptodactylidae	1	1	30	30	61
Agama agama	Agamidae	11	1	30	30	61
Phelsuma madagascariensis	Gekkonidae	7	7	30	30	67
Python molurus	Boidae	68	64	0	5	69
Ameiva ameiva	Teiidae	54	51	0	20	71
Sphaerodactylus elegans	Gekkonidae	45	42	0	30	72
Leiocephalus carinatus	Iguanidae	57	54	0	20	74
Anolis distichus	Iguanidae	29	27	30	20	77
Anolis garmani	Iguanidae	51	48	15	20	83

Osteopilus septentrionalis	Hylidae	45	42	30	15	86
Anolis equestris	Iguanidae	38	36	30	20	86
Anolis porcatus	Iguanidae	45	42	30	20	92
Hemidactylus mabouia	Gekkonidae	37	35	30	30	95
Gonatodes albogularis	Gekkonidae	46	43	30	30	103
Cosymbotus platyurus	Gekkonidae	78	74	0	30	104
Gekko gecko	Gekkonidae	77	73	15	30	118
Iguana iguana	Iguanidae	80	75	30	20	125
Calotes versicolor	Agamidae	70	66	30	30	126
Boa constrictor	Boidae	100	94	30	5	129
Mabuya multifasciata	Scincidae	89	84	30	15	129
Eleutherodactylus planirostris	Leptodactylidae	76	72	30	30	132
Hemidactylus frenatus	Gekkonidae	76	72	30	30	132
Hemidactylus turcicus	Gekkonidae	78	74	30	30	134
Ramphotyphlops braminus	Typhloidae	89	84	30	30	144
Hemidactylus garnotii	Gekkonidae	89	84	30	30	144
Anolis sagrei	Iguanidae	104	98	30	20	148
Average for Florida successful species		**39.46**	**37**	**20.5**	**23.2**	**80.71**
Florida failed species						
Python regius	Boidae	0	0	0	5	5
Cordylus cordylus	Cordylidae	0	0	0	10	10
Podocnemis lewyana	Pelomedusidae	0	0	0	10	10
Podocnemis sextuberculata	Pelomedusidae	0	0	0	10	10
Python reticulatus	Boidae	9	8	0	5	13
Cynops pyrrhogaster	Salamandridae	0	0	0	15	15
Pachymedusa dacnicolor	Hylidae	0	0	0	15	15
Trachemys dorbigni	Emydidae	1	1	0	15	16
Hymenochirus boettgeri	Pipidae	3	3	0	15	18
Atelopus zeteki	Bufonidae	0	0	0	20	20
Bufo blombergi	Bufonidae	0	0	0	20	20
Basiliscus basiliscus	Iguanidae	0	0	0	20	20

Varanus exanthematicus	Varanidae	5	5	0	15	20
Kinosternon scorpioides	Kinosternidae	25	24	0	0	24
Chelus fimbriatus	Chelidae	16	15	0	10	25
Anolis conspersus	Iguanidae	6	6	0	20	26
Cyclura cornuta	Iguanidae	8	8	0	20	28
Sphaerodactylus macrolepis	Gekkonidae	3	3	0	30	33
Podocnemis unifilis	Pelomedusidae	29	27	0	10	37
Trachemys stejnegeri	Emydidae	7	7	30	15	52
Varanus salvator	Varanidae	44	42	0	15	57
Hemidactylus brookii	Gekkonidae	74	7	30	30	67
Xenopus laevis	Pipidae	26	25	30	15	70
Typhlops lumbricalis	Typhlopidae	45	42	0	30	72
Tupinambis nigropunctatus	Teiidae	58	55	0	20	75
Bufo arenarum	Bufonidae	80	75	0	20	95
Bufo paracnemis [Analysed *B. schneideri*]	Bufonidae	97	92	0	20	112
Average for Florida failed species		**19.85**	**19**	**3.3**	**15.9**	**35.74**

[1]The Climate Match Scores have not been corrected for small numbers of input meteorological stations where this is applicable (See Apendix F, Table F3 and Section 10.1, Score A). For Florida the successful species that had 12 or fewer meteorological stations in their overseas geographic range were: *Anolis chlorocyanus, A.. ferreus, A.. garmani* and *Leiocephalus schreibersi* and the failed species were: *Anolis conspersus, Atelopus zetiki, Bufo blombergi, Podocnemis lewyana* and *P. sextuberculata.* To correct for bias introduced due to few input meteorological stations, all these nine species should have ten points added to both their Climate Match Scores and their Establishment Risk Scores.
[2] Sources: Fred Kraus database of published records; Kevin M. Enge (Florida Fish and Wildlife Conservation Commission, pers. comm. 15 March 2005) list of exotic species established in Florida for at least ten years; Meshaka et al. (2004). Reproduced from Bomford et al. (2005).