APAMP Final Report

Invasive Species Science, Department of Agriculture and Food, Western Australia

1. **01/09/2012**

2. **Name of project**

   Prioritising Vertebrate Pests on the Brink of Introduction and Establishment Using Bayesian Networks

3. Project aims and objectives

Prioritisation of pests on the brink of establishing wild populations for risk management is important due to increasingly limited resources. This could be achieved by developing Bayesian Belief Networks (BBNs), incorporating a range of data and expert opinion, to objectively produce establishment likelihood predictions. The resulting list of species prioritised on the basis of their establishment likelihood and Bomford assessment results would be provided to the Vertebrate Pest Committee. Risk management strategies could then be applied for the prioritised species as detailed in the Australia Pest Animal Strategy.

- Development of Bayesian Belief Networks to predict the likelihood of establishment in the wild of selected species groups.
- Prioritisation of species for risk management strategies, by combining establishment likelihood with Bomford assessment results (i.e. establishment risk, pest risk and public safety risk ranks) to produce a threat rating.
- Extension of species lists to the VPC and affiliated agencies.
- Production of education and publicity material (e.g. National Pest Alerts) for an agreed group of high-priority species.

4. Project location

Perth, Western Australia.

5. Methodology

Conduct an initial small-scale pilot project in Western Australia, which following review, could be fine-tuned and expanded to further jurisdictions:

Project stages -

1. Selection of suitable species, risk assessment of some species and endorsement by VPC.
2. Development of a general BBN framework for the establishment of pest species, potentially applicable to multiple species.
3. Development of specific BBN models for bird, mammal, reptile and amphibian species.
4. Collection of empirical data if required.
5. Adaption of the models to other similar species and production of likelihood ratings.
6. Prioritisation of species for risk management strategies by combining establishment likelihood with pest risk and public safety risk ranks to produce a threat rating.

7. Building on the models to include more jurisdictions, additional data, likelihood ratings and prioritisation of species for risk management.
8. Consideration of the list of modelled species by the VPC and affiliated agencies, with possible addition of species to the National Surveillance and Alert Lists.
9. Preparation of project report and journal article.

6. Results

1. Selection of suitable species, risk assessment of some species and endorsement by VPC.

Species for which BBNs could be developed were selected using data from around Australia on species being kept, reported in the wild, established in the wild, surrendered or seized, etc (see (Massam *et al* 2009), Appendix C, for some of this information). The list included a maximum of five species for the WA pilot and 15 other species covering other jurisdictions, including birds, mammals, reptiles and amphibians. This will allow these models to have wider applicability than just to WA. The selected species were reviewed by the project collaborators and other peers.

A list of species (Appendix 4) were preselected for the workshop to use as examples to identify priority species for a pest alert publication. Two species, the red-eared slider turtle and the Indian ringneck parakeet, were selected from this list as subjects for the development of a general network.

2. Development of a general BBN framework for the establishment of pest species, potentially applicable to multiple species.

An initial Bayesian belief network (Appendix 1 – BBN) was constructed using information from (Bomford 2003, Bomford 2006, Bomford 2008), (Bomford *et al* 2005, Bomford *et al* 2009a, Bomford *et al* 2009b), and a literature search using the search string; *introduced mammals/birds/reptiles/amphibians establishment factors'*. This pre-workshop BBN was discussed with various collaborators in preparation for further development during a workshop.

A general BBN framework for the establishment of pest species was developed using available empirical data and expert opinion (factors) for input as the nodes of the network. This network could indicate the likelihood of a species establishing self-sustaining wild populations and possibly include an establishment risk rank generated by the relevant Bomford model.

Factors used as Nodes for the framework included;

- Use of animals as game or pet species or as aesthetically pleasing,
- Use of animals for food, medicine, skins,
- Likelihood of introduction into the wild in cargo, horticulture trade,
- Presence of species in facilities having various levels of security,
- Seizures or surrenders of captive animals,
- Monetary value,
- Numbers and distribution of captive animals,
- Community/keeper attitudes to captive and established exotic species,
- Presence of new species detected in the wild,
- Reports of releases or escapes.
- Establishment Risk Rank results from the Bomford models,

- Risk management strategies:
    - keeping regulation
    - incursion management
    - border controls.

One-day Workshop

A one-day workshop was held in Melbourne on 24th March 2011, attended by representatives from; IACRC, Department of Sustainability and Environment Victoria, Department of Employment, Economic Development and Innovations Queensland, Australian Bureaus of Agriculture and Resource Economics and Sciences, Department of Primary Industries Victoria, University of Melbourne School of Botany, Biosecurity South Australia, and Department of Agriculture and Food Western Australia. The workshop was facilitated by Ann Nicholson, Bayesian Intelligence PL.

The objective of the workshop was to predict which species might be next to establish self-sustaining wild populations in Australia, and to develop a BBN network.

Topics covered in the workshop included;

- Species selection,
- Development of a general BBN framework and specific BBN models,
- Collation of sources of empirical data and other expert opinion.

Data used in the workshop were sourced over a six month period from newsprint advertisements in the For Sale and Lost and Found sections of The West Australian, Sunday Times and the Quokka.

The workshop participants were provided with an introduction to networks and a demonstration of building networks using Netica software (http://www.norsys.com/index.html).

The conceptual framework for a BBN (Appendix 5 Specifications for building the network) was developed by participants brainstorming factors that could lead to vertebrates establishing in the wild.

The factors or nodes that were identified and selected as important for establishing a framework included; biology, habitat preference, introduction pathways and human intervention. The nodes were then grouped and a conceptual or structural framework was developed that identified the factors for vertebrates establishing wild populations.

Further work identified node thresholds and quantified relationships.

The following limitations of the initial pre-workshop BB network (Appendix 1) were identified by the participants;

- Validation difficult when data are absent or limited
- Model builders being confused about direction of the node arcs
- Complex systems with few nodes will be more of an approximation
- Most techniques have few observations, but these limited data are better than no data.

The variables in the conceptual framework developed in the workshop were compared with those identified in the pre-workshop BB network and used to produce the workshop BB network or model (Appendix 2).

The workshop concluded with discussion on how to validate this model by using trial case studies and future scenario-based trial runs.

The model of the workshop BB network (Appendix 2) comprised of 56 nodes and showed the complexity of the system for identifying vertebrates likely to establish populations in the wild and hence justify a pest alert. It was agreed that 56 nodes was too great a number, and resulted in a too great a level of complexity for the study. The network was subsequently refined by reducing the number of nodes.

Each of the original 56 nodes were examined and the following criteria applied to enable deletion of some nodes:

- Nodes that are unlikely to affect the outcome of any intervention or be changed by it (i.e. Proportion of Keepers with Permits and associated nodes – doubtful that extension material would make a difference and improvement in the level of security an animal is kept under would be more important rather than keepers with or without permits).
- Nodes of lesser importance (i.e. Risk of Prosecution and Keeping Restrictions nodes are likely to be less important than the Manageability of the Animal and Monetary Value nodes).
- Nodes for which there is no data and/or which may not be represented by expert opinion (i.e. WA has collected data on pet shop sales and import numbers, but other jurisdictions are unlikely to have collected this data; it is also hard to estimate however, all jurisdictions could collect relevant data by interrogating the Buy and Sell Adverts in the print media).
- If a large amount of work is required to obtain data for nodes (apply caution that critical factors/nodes are excluded due to being placed in the too hard basket).
- The number of parent nodes to any given node should be kept to five or fewer.

The workshop BBN was subsequently simplified with input from participants at a teleconference held on 12th May 2011. The result was a third network that included only 22 nodes (Appendix 3). Notes explaining node deletions and node intentions was included in diagrammatic representation of the BBN.

The main changes to the network were to add pre-border information (i.e. number of seizures, commonly kept as pets overseas, number smuggled into Australia, and number of stowaways into Australia), and to reduce the area of the network relating to habitat (suitable habitat/habitat preferences).

The simplified version was then sent back to the workshop facilitator for the addition of simple data to the network contingency probability tables for some nodes (these tables quantify the effects between nodes).

The project was prematurely concluded in August 2011 due to reduced capacity to achieve objectives of the project and therefore only results for Points 1 and 2 of Section 5 Methodology were completed.

7. Discussion

Due to the project being concluded prior to most of the objectives being met discussion is limited.

Further work is required to obtain value from the model of a bayesian belief network for prioritising vertebrate pests on the brink of introduction and establishment. produced by this

project. However the model is a template that could be validated with risk assessment and developed further by the completion of the objectives of the original project.

8. Provide a table of actual versus anticipated performance indicators against the milestone dates outlined in your original application (i.e. Annexure A of this Contract); and estimates for any of the output measures that may be relevant to your project as appropriate (*only for the **six-month period** to which this report relates*). The following are examples of output measures but you may use other measures if these are not relevant to your project.

Objective	**Milestone date**	**Outcome**	**Performance indicator(s)** (must be specified and measurable)	**Progress**
1. Selection of suitable species (assume risk assessments already completed for 15 species, need to complete 5 risk assessments). **1a.** Risk assessments completed for 5 species	**Jun-11** **Dec-10**	Consultation with collaborators, peers and other organisations to select species. Conduct full risk assessments for 5 species, internal and external review, VPC endorsement.	Species selected 5 completed risk assessments	A list of species developed. (Appendix 4) Not completed
2. Development of a general framework for the establishment of pest species, applicable to multiple species.	**Dec-10**	Consultation with collaborators to develop general framework.	Development of general framework	General BN framework developed. Appendix 3
3. Development of specific models for bird, mammal, reptile and amphibian species.	**Feb-11**	Consultation with collaborators to develop specific models.	Development of specific models.	Not completed project concluded Aug-11
4. If necessary, collection of empirical data. (Filemaker pro)	**Feb-11**	Data sets from a wide range of sources collected and inputted into electronic system	Completion of collection and input of data.	Enquiries made with DAFWA's special resource group regarding access to mailing lists of relevant stakeholders to provide data.
5. Adaption of the models to other similar species and production of likelihood ratings.	**Apr-11**	Consultation with collaborators to adapt to other species. Production of likelihood ratings.	Adaption of the models to other similar species and production of likelihood ratings.	Not completed project concluded Aug-11
6. Prioritisation of species for risk management strategies by combining	**Jun-11**	Data combined. High quality list of	Prioritisation of species for risk management strategies.	Not completed project concluded

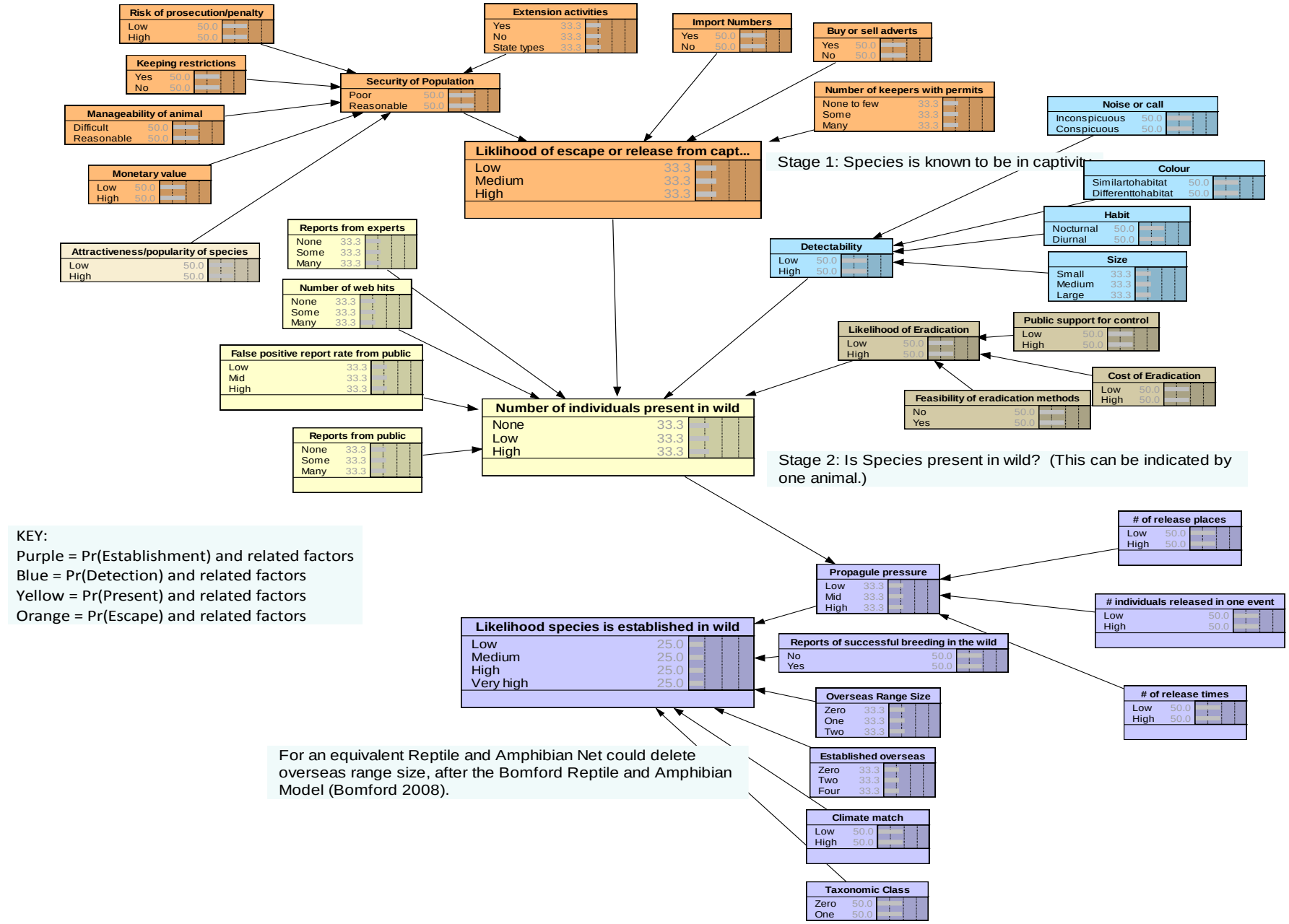
establishment likelihood with pest risk and public safety risk ranks to produce a threat rating.		species produced.		
7. Up-scaling of models to include more jurisdictions, incorporation of additional data, production of likelihood ratings and prioritisation of species for risk management. **7a.** Development of specific models for bird, mammal, reptile and amphibian species at Australian level. 7b. If necessary, collection of empirical data.	Sep-11 Jan-12	Up-scaled models.	Development of specific Australian-scale models for birds, mammals, reptiles and amphibians. Completion of collection of data.	Not completed project concluded
8. Consideration of species list by the VPC. Possible addition of species to the National Surveillance and Alert Lists. **8a.** Extension of models and lists.	Mar-12 Apr-12	Increased public awareness about the risks the listed species pose primarily to agriculture, as well as the environment and the community (if appropriate). Posting of the priority list on feral.org.au and the IA CRC website, and as a contribution to the National Surveillance and Alert Lists and the VPC's List of Exotic Animals. Notification of publication of the lists and their message will be made via media releases, newsletter articles, email list servers, presentations, participation in organisation training courses, distribution at industry shows and events, etc. Publicity via the VPC, the Australian Pest Bird Network and the Aliens List Server.	Consideration of species list by the VPC. Media releases, website links, newsletter articles.	Not completed project concluded
9. Preparation of extensive project report and journal	Jun-12	Completed project report and journal article.	Completed project report and journal article.	Final. report provided

article.				

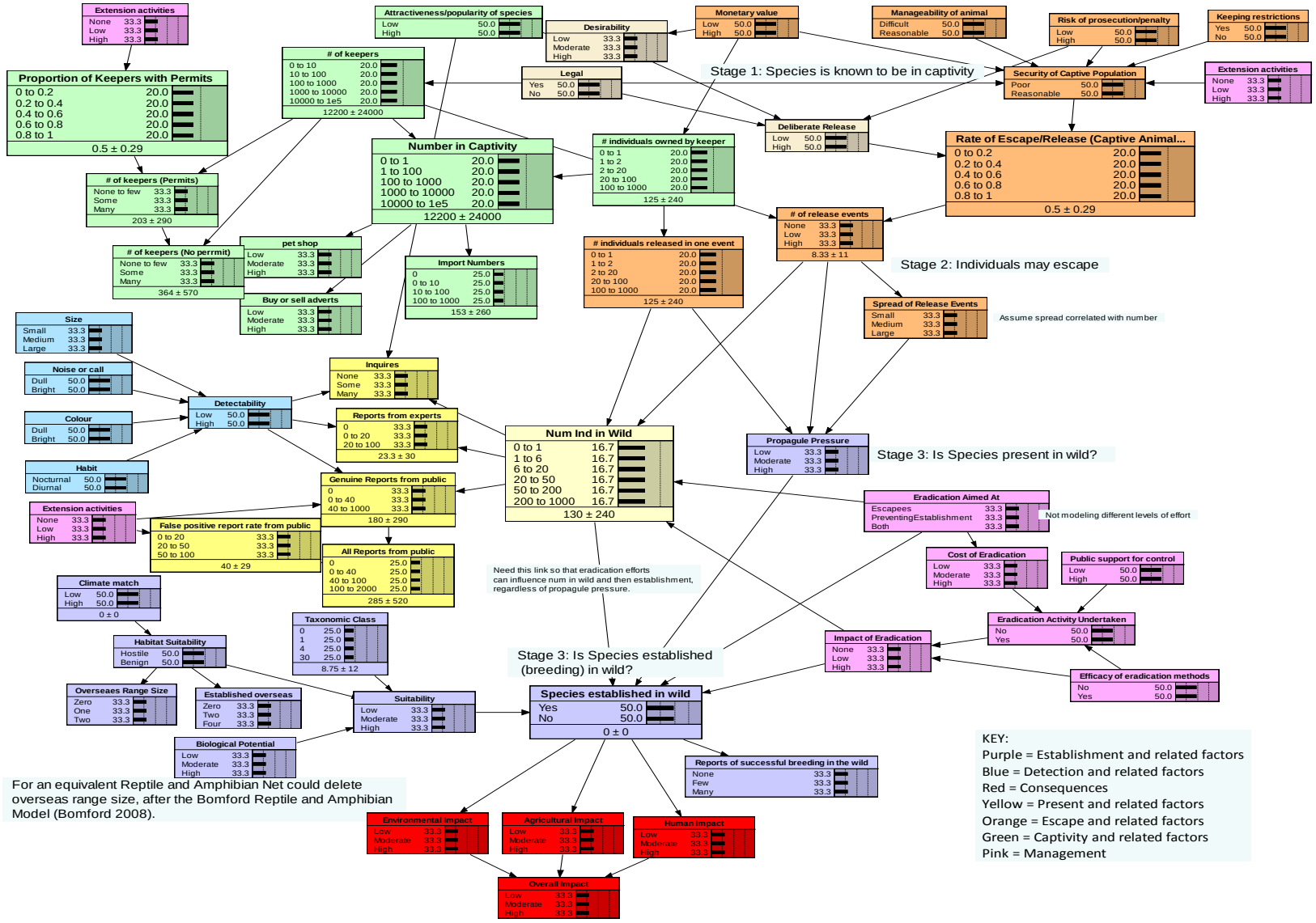
9. Statement of expenditure to date (if there is significant under-expenditure – i.e. less than 75% of projected expenditure spent – provide an explanation; also provide an explanation for any significant – >10% – variation to individual budget components relative to original contract budget). Include supporting documentation.

   Statement of expenditure submitted 30 April 2012.

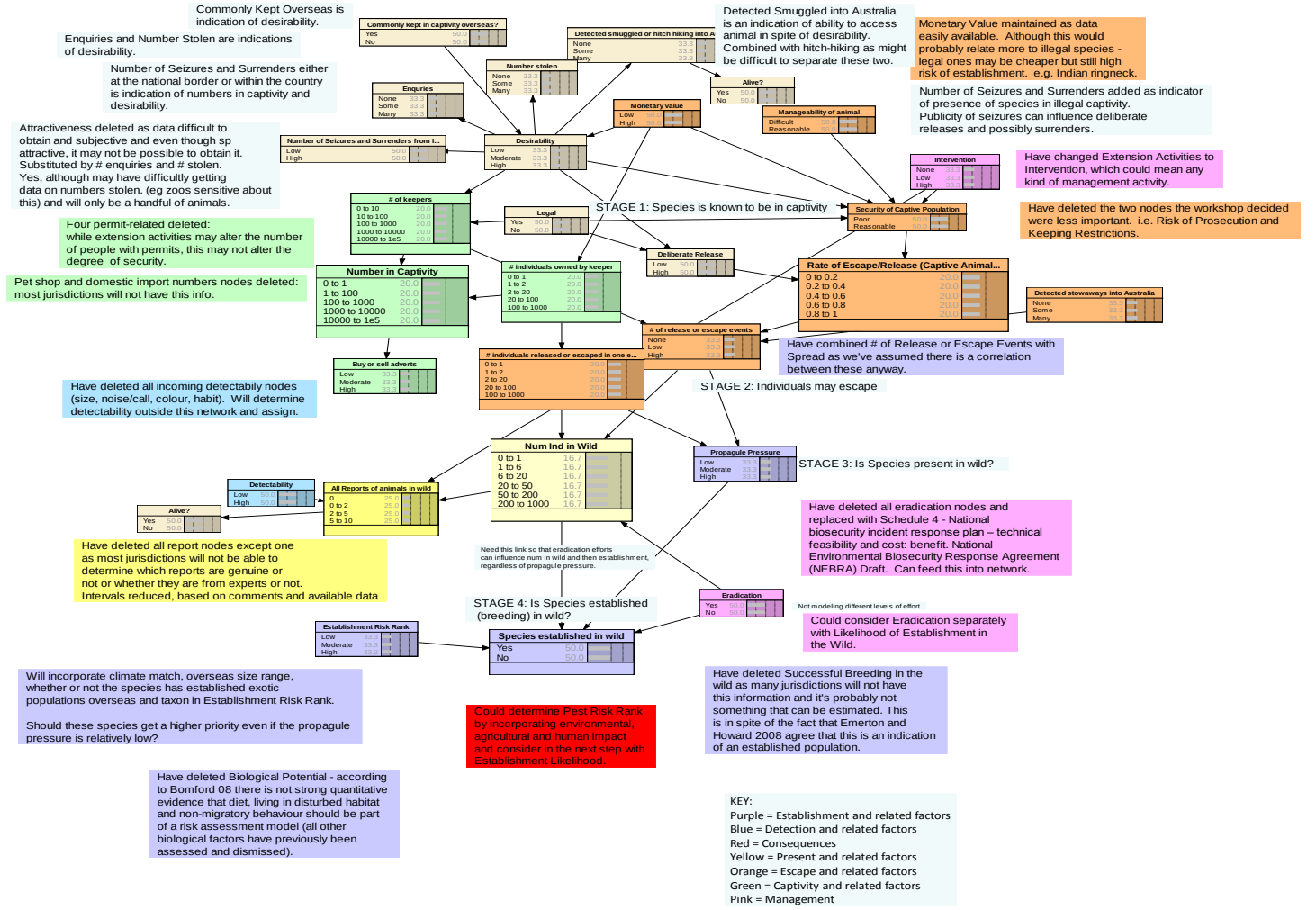
Appendix 1 – Pre workshop BB Network



Appendix 2 – Workshop BB network



Appendix 3 – Post workshop simplified BB Network



Appendix 4 - Preliminary List of Species

Common Name	Scientific Name	VPC Threat Category or Establishment Risk Rank	Justification
Alexandrine parakeet	*Psittacula eupatria*	Extreme VPC Threat Category, needs updating	Reported in wild in WA, Hawaii and the UK.
American bison	*Bison bison*	Extreme VPC Threat Category	Numbers held in Vic and possibly in illegal trade, several requests for keeping in WA.
Barbary dove	*Streptopelia roseogrisea*	Serious VPC Threat Category, needs updating	Reported in wild in WA, NSW, SA and Vic, established in wild in NT
Blackbuck	*Antilope cervicapra*		Previously feral in WA, possibly in illegal trade in Vic.
Boa constrictor	*Boa constrictor*	Extreme Establishment Risk Rank	Multiple seizures and/or surrenders in Victoria, Queensland and WA, found in the wild in Victoria
Bonnet macaque	*Macaca radiata*		In illegal trade in Vic.
Burmese Python	*Python molurus*	Extreme Establishment Risk Rank	Seizures in Victoria, Queensland and WA
Cobra spp.	*Naja* spp.	-	Multiple seizures and/or surrenders in Victoria
Corn snake	*Elaphe guttata*	Moderate Establishment Risk Rank	Multiple seizures and/or surrenders in Victoria, Queensland and WA, found in the wild in Victoria and possibly Queensland
Crab-eating macaque	*Macaca fascicularis*	-	In illegal trade and circuses in Vic, held in some parks in WA.
European Newts	several genera	-	Multiple seizures and/or surrenders in Victoria
Green iguana	*Iguana iguana*	-	Multiple seizures and/or surrenders in Victoria, requests for keeping in WA.
Green-cheeked conure	*Pyrrhura molinae*	Moderate VPC Threat Category, needs updating	Regularly seized entering WA
Hamadryas Baboon	*Papio hamadryas*	-	In illegal trade in Vic, previously held in WA.
Hedgehog	*Erinaceus europaeus*	Extreme VPC Threat Category, needs updating	Possibly present in QLD
Herman's tortoise	*Python molurus*	Serious Establishment Risk Rank	Seizures Queensland and SA, proposed for entry to Australia

Indian ringneck parakeet	*Psittacula krameri*	Extreme VPC Threat Category, needs updating	Reported in wild in WA, feral populations in Hawaii, the UK and Europe
Japanese fire-bellied newt	*Cynops pyrrhogaster*		Multiple seizures and/or surrenders in Victoria
Kingsnake species	*Lampropeltis* spp.	-	Multiple seizures and/or surrenders in Victoria
Monk parakeet	*Myiopsitta monachus*	Extreme VPC Threat Category, needs updating	Seized entering WA, feral populations in Florida and Texas
Nanday conure	*Nandayus nenday*	Extreme VPC Threat Category, needs updating	Seized entering WA, feral populations in Florida
Northern palm squirrel	*Funambulus pennantii*	Draft Risk assessment Extreme VPC Threat Category (not endorsed)	Illegal keeping in Vic, legal keeping in NSW, previous outbreaks.
Peach-faced lovebird	*Agapornis roseicollis*	Serious VPC Threat Category, needs updating	Reported in wild in WA, feral in Hawaii
Rainbow boa	*Epicrates cenchria*	-	Multiple seizures and/or surrenders in Victoria
Red-eared slider	*Trachemys scripta*	Extreme Establishment Risk Rank	Multiple seizures and/or surrenders in Victoria, seizures in WA, SA and Queensland, found in the wild in WA.
Rhesus macaque	*Macaca mulatta*	-	In circuses in Vic. Previously held in parks and circuses in WA.
Trinket or beauty snake	*Elaphe taeniurus*	Moderate Establishment Risk Rank	Multiple seizures and/or surrenders in Victoria
Water buffalo	*Bubalus bubalis*	-	Numbers held in Vic and possibly in illegal trade, numbers kept in WA and a report of a feral herd.

Appendix 5 – Specifications used for building the workshop BB network (PDF - double click to open)

Prioritising Vertebrate Pests on the Brink of Introduction and Establishment Using Bayesian Networks

Pre-workshop BBN information

Aim: combine of establishment risk data with introduction effort information and factors that may affect the probability of escape or willful release to more accurately predict the likelihood of establishment in the wild of selected species.

For each node provide the following information:

- A concise definition, including performance measures.
  - A performance measure is the response variable i.e. the variable you use to measure the node. Sometimes this is obvious…
- Is the node discrete or continuous? A discrete node is one which can only take certain values (e.g. Yes or No, Present or Absent) whereas a continuous node can take any value (i.e. length). We then discretize the continuous variables into states.
- States
  - For each node, what are the states of interest? This can be difficult for continuous variables, but keep in mind to only distinguish states that you think are important. There is a tricky balance to make between retaining enough complexity, but keeping the model simple enough that you can fill out the Conditional Probability Tables.
- Data availability
  - Given the incoming nodes, do you have data to populate or estimate the relationships in the model?
- Incoming nodes
  - What are the parent nodes (incoming links) for each node?

For each node you also need to provide information on (maybe put together another set of tables?):

- Assumptions.
  - This will help to fill out the Conditional Probability tables. For instance, I have assumed that if you select that the species is illegal in the model, then all (unregulated) keepers in the community are 'Illegal keepers', and the 'Public keepers' node will read "none'. That is a pretty obvious one, but there may be others, like 'If General security' is 'Low', then Pr(Escape) = High.
- Knowledge Gaps
  - This extends from the Data availability column but needs to be fleshed out. Are there relationships in the model that we are uncertain about? Do you need to collect data in order to resolve uncertainty in the model?
  - So for instance, at present the Pr(detection) and Pr(escape) nodes are extremely uncertain. I think at this stage our estimates of detection will not improve without targeted experiments, but we need to leave this in because it is important and can be resolved at a later stage. I am unsure whether what happens with the Pr(Escape) node – it will probably always be pretty uncertain because estimates of the number of public keepers, illegal keepers and general security will probably always be estimated broadly. At the moment the only measurable indicator we have (for the number of keepers) is the number of buy/sell advertisements. Are there other indicators we can measure?

Bibliography

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