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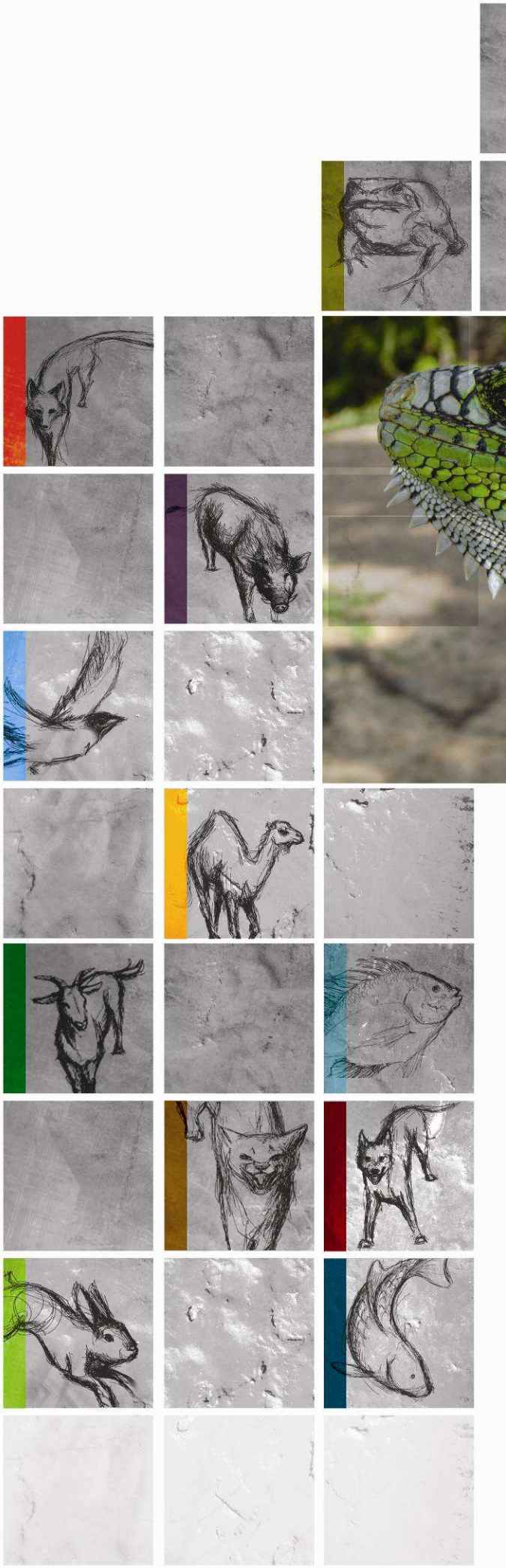
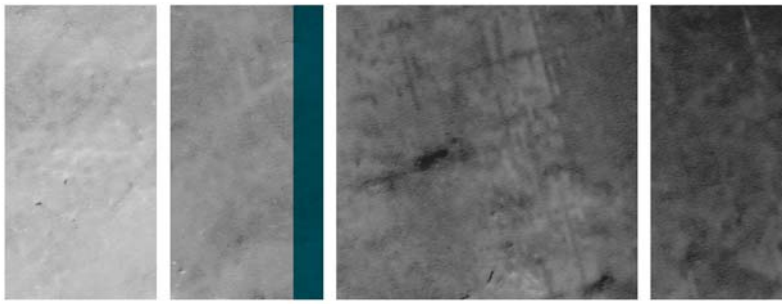


Detecting and preventing new incursions of exotic animals in Australia

Wendy Henderson
and Mary Bomford

Invasive Animals CRC



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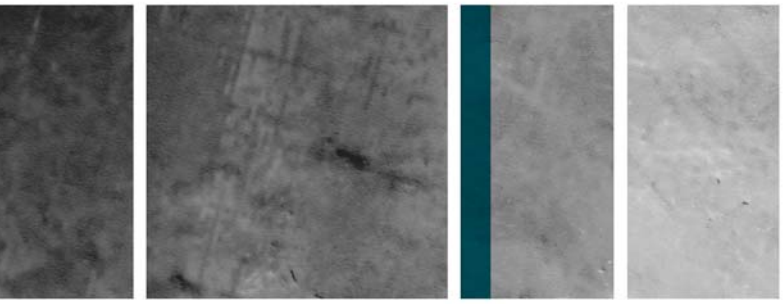
Invasive Animals Cooperative Research Centre

2011

An IA CRC Project



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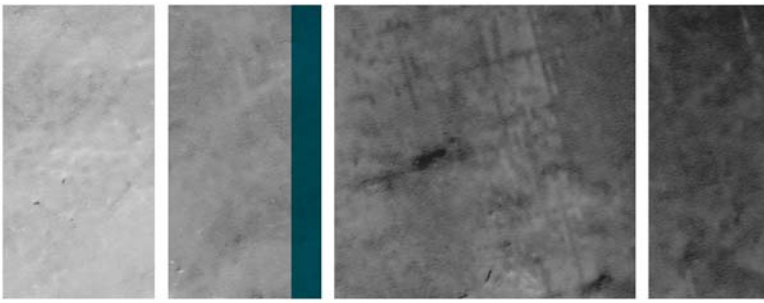

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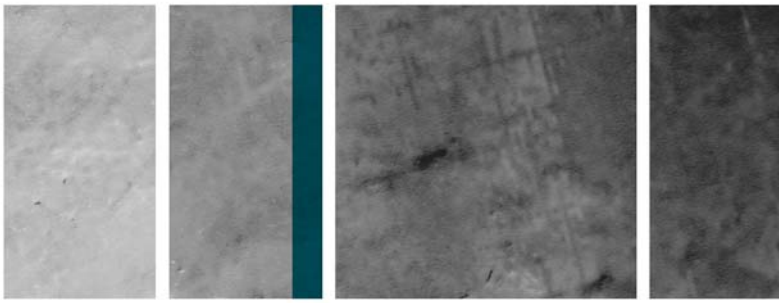

Summary

This report presents data on incursions and interceptions of exotic vertebrates in Australia that have occurred within the country and at the national border, over the past 10 years. It includes data on species (that are not widely established) found 'at large' in the environment, and seizures, surrenders and thefts from private keeping within Australia. It also includes data on animals intercepted entering the country as stowaways or in attempted smuggling incidents. Information on animal numbers and species and incident locations (at state/territory level) is presented, providing a national picture of which exotic vertebrates have been sighted at or within Australian borders. High-risk species are identified for future priority biosecurity actions, to prevent new pests establishing.

Data sources included state, territory and federal government agencies, the Zoo and Aquarium Association and online publications. Information varied in quantity and quality from the different sources, with some agencies having far more detailed information than others. The reporting of animal sightings and interceptions depends on (a) the general awareness of threats posed by exotic species and (b) the effectiveness of pest-related legislation and its implementation (which in turn is dependent on government resources).

Species already known to be emerging pests in Australia were the most commonly reported species detected at large. Such species include red-eared slider turtles (*Trachemys scripta elegans)*, spotted doves (*Streptopelia chinensis*), barbary doves (*Streptopelia risoria*), red deer (*Cervus elaphus*), fallow deer (*Dama dama*) and cane toads (*Bufo marinus*) in expanding ranges or new locations. Exotic reptiles including corn snakes (*Elaphe guttata*), boas (*Boa constrictor*) and red-eared sliders were the most common illegally kept species reported, although a wide variety of exotic reptiles were seized or surrendered. The most numerous smuggled species were fish and birds, although the majority of these were not identified to species level. Most smuggling incidents involved illegal reptiles (mainly snakes and turtles) and birds (mostly parrots). While fish and reptiles tended to be mostly brought in via post/cargo, birds (particularly eggs) were more likely to be smuggled in person. The most commonly reported intercepted stowaways were reptiles (mainly geckos) and amphibians (mostly toads).

All identified species were quantitatively assessed for their risk of establishing in Australia, using Bomford's (2008) risk assessment models. Some of the most frequently reported species were calculated to have an extreme or serious risk of establishing in Australia. Perhaps not surprisingly, species already occurring in wild populations (such as cane toads, Asian house geckos *Hemidactylus frenatus* and pond sliders *Trachemys scripta*) were assessed as having an extreme establishment risk rank (or ERR). Species that have not established in Australia but which were assigned a serious ERR and were detected at large in multiple jurisdictions include ferrets (*Mustela putorius*), house crows (*Corvus splendens*), barbary doves, Indian ringneck parakeet (*Psittacula krameri*) and corn snakes. One notable species reported in multiple cases of illegal private keeping is the green iguana (*Iguana iguana*), assigned an extreme ERR. Serious ERR

species reported most commonly as seized or surrendered from private keeping include corn snakes, boa constrictors, veiled chameleons (*Chamaeleo calyptratus*), and leopard geckos (*Eublepharis macularius*). Records of smuggling incidents include the extreme ERR species red-eared sliders and green iguanas. Species with a serious ERR that were detected in multiple smuggling incidents include corn snakes, boa constrictors, rainbow boas (*Epicrates cenchria*), rosy boas (*Lichanura trivirgata*), Horsefield's tortoises (*Testudo horsfieldii*), Californian kingsnakes (*Lampropeltis getula*) and leopard geckos. Extreme ERR stowaway species commonly intercepted by AQIS include Asian house geckos and cane toads. Many other extreme-ranked species were also reported by AQIS in single interception incidents. Serious ERR stowaway species frequently intercepted by AQIS include black-spined toads (*Bufo melanostictus*), Tokay geckos (*Gekko gecko*), flat-tailed house geckos (*Hemidactylus platyurus*) and Asiatic painted frogs (*Kaloula pulchra*). All of these species with high establishment risk should be priorities for future surveillance and compliance activities.

Some of the more commonly sighted species have been assessed in more detail for their potential to become pests should they establish in Australia. Species scientifically assessed to have significant pest potential include the Asiatic painted frog, black-spined toad, boa constrictor, cane toad, corn snake, Indian ringneck parakeet and pond slider turtle (including subspecies red-eared sliders) (Department of Agriculture and Food Western Australia unpublished, Massam et al 2010). In this report we suggest the green iguana also has high pest potential.

To prevent future incursions, vigilance is needed to reduce propagule pressure (the number of animals released) and the subsequent likelihood of species establishing in the environment. Legislation on the import and keeping of exotic animals is in force in each jurisdiction (and relevant biosecurity policy is still being developed in some states) but, as stated by the recent review of Australia's biosecurity (Beale et al 2008), some areas need increased resources. In particular, there is a need for improved capacity to collect, record and share information at a national level. Public awareness of importing and/or keeping high-risk animals needs to be raised, particularly of the consequences of such animals getting into the environment. Stronger penalties for smugglers and traders of illegal wildlife species could deter future incidents. Approved high-risk species should be kept in appropriately secure facilities and these should be regularly audited to ensure compliance. Preventing new pests from entering the wild and establishing will be far more cost effective than attempting to eradicate them after establishment.

Recommendations

1. A precautionary approach be taken to the keeping and import of all species with high pest potential.

2. Governments consider restricting/phasing out the private ownership of known high-risk species already in the country, where this is considered feasible.

3. Species identified in this report as having high pest potential be considered for addition to national lists being developed through the Vertebrate Pests Committee (VPC) for surveillance, eradication or other action as appropriate.

4. A national approach be taken to reduce the risk of new aquarium fish establishing in Australia, including risk assessments to determine establishment and pest potential for

potentially noxious species currently kept in Australia, and that VPC consider adding high-risk fish to the national surveillance list, eradication list or other list as appropriate.

5. An audit be conducted of existing scientific risk assessments in the various Australian biosecurity agencies, and revised assessments on species on the VPC *List of Exotic Vertebrate Animals in Australia* that have not been subjected to independent scientific risk assessments, and that these assessments include the feasibility of eradicating newly established populations.

6. Development and delivery of publicity and targeted, well-resourced education programs about:
    a. high-risk vertebrate species — for border personnel including couriers and dock/airport workers
    b. which species can be legally kept, the potential harm of releasing exotic species into the wild and acceptable alternatives for getting rid of unwanted animals (including fish) — for the general public and pet traders, pest management agencies, hobbyists and wildlife exhibitors/rehabilitators.

7. Better education be provided to traders and the judiciary on the risks posed by illegal trade in wildlife, and the application of stronger penalties, to more effectively deter future wildlife smuggling.

8. Adequate resourcing and promotion of hotlines for the public to enquire about or report exotic animals detected at large, or being illegally kept or traded.

9. Eradication attempts for established populations of red-eared sliders be treated as urgent and given adequate resources to complete the task.

10. Continued support for vigilance by border protection agencies to limit the success of illegal animal trade or stowaway introduction via this route.

11. Better resourcing (at state/territory and federal levels) to allow more complete and consistent reporting, coordination and communication of information on all animal incursions/interceptions across the biosecurity continuum, with priority to improve systems in the less well-resourced jurisdictions and to coordinate information at a national level.

12. A single, central reporting point for all detection data (including incursions and interceptions) to securely record both border and post-border information of exotic vertebrate species.

13. Cooperation between border and post-border agencies to develop a national listing of exotic vertebrate species detections at large, seizures and thefts and surrenders from private keeping, and stowaway interceptions, with consistent data being recorded for each incident report.

These recommendations should be progressed through the VPC.

Glossary

ABIN	Australian Biosecurity Intelligence Network
AELERT	Australasian Environmental Law Enforcement and Regulatory Network
AQIS	Australian Quarantine and Inspection Service
BioSIRT	biosecurity surveillance incident response and tracing
Customs	Australian Customs and Border Protection Service
DAFF	Australian Government Department of Agriculture, Fisheries and Forestry
detection	sighting of an animal, in the wild or seized, surrendered or stolen
DSEWPC	Australian Government Department of Sustainability, Environment, Water, Populations and Community
IA CRC	Invasive Animals Cooperative Research Centre
incursion	isolated population recently detected at large, not known to be established, but expected to survive for the immediate future
interception	an animal that has been detected and specifically dealt with by seizure, surrender, theft or euthanasia
propagule pressure	number of release events and number of animals released
VPC	Vertebrate Pests Committee
ZAA	Zoo and Aquarium Association

1. Introduction

Exotic incursions create the risk of establishing new pest populations that significantly impact our environment, economy or society. Incursions can result from escapes from captivity, deliberate releases, smuggling and unintentional stowaways on transport vehicles, containers, people or luggage. With the extent of global and local travel and trade, the risk of incursion events is increasing (Hulme 2009). There are many examples of animals that have accidentally or deliberately entered the environment in small numbers and established as pests (legal pets such as aquarium fish and aviary birds have certainly established pest populations in Australia; eg Lintermans 2004, Driessen et al 2006). One third of the world's most damaging aquatic invasive species are due to aquarium or ornamental releases (Secretariat of the CBD 2010). Propagule pressure (the number of release events and the number of animals released) is one critical aspect influencing where and when animals will establish a free-living population — the probability of establishment increases with the total number of individuals released (Hayes and Barry 2008).

This study examined records of incursions and incidents indicating risks of future incursions in Australia. An 'incursion' is defined here as an isolated population (not just an individual) recently detected at large, not known to be established, but expected to survive for the immediate future. Some incursions may persist and establish naturalised, sustaining populations. Of the exotic species that have naturalised, it has been estimated that about half have pest potential (Bomford and Hart 2002). Our aim was to determine which species potentially present the highest risks of new incursions in Australia.

The report presents data on detections of exotic vertebrates (that are not widely established) at large in Australia, and interceptions from illegal private keeping, smuggling events or stowaway incidents. For the purposes of this report, we define 'detection' in this context as any animal seen and reported. An 'interception' is a subset of 'detection' that has been specifically dealt with through the seizure, surrender, theft or euthanasia of an animal. Our data contain information on the species, numbers and locations of detections to provide a national picture of which exotic vertebrates have turned up at or within our borders.

The risk of each identified species establishing in Australia was assessed. The pest potential of a sample of species with high establishment risk was also determined. Recommendations are presented for improved record keeping, better inter-agency collaboration and greater public awareness of the threats posed by new incursions of exotic vertebrates, to reduce the risks of new pests establishing.

2. Methods

2.1 Data collation

Data was collated by directly emailing or telephoning representatives from relevant agencies. State and territory agencies included: Victoria Department of Sustainability and Environment (DSE), and Department of Primary Industries (DPI); Tasmania Department of Primary industries, Parks, Water and Environment (DPIPWE); Primary Industries and Resources of South Australia (PIRSA); Department of Agriculture and Food Western Australia (DAFWA), New South Wales Office of Environment and Heritage (OEH) and DPI; Biosecurity Queensland in Department of

Employment, Economic Development and Innovation; Northern Territory Department of Natural Resources, Environment, The Arts and Sport (NRETAS); and Australian Capital Territory's Territory and Municipal Services (TAMS) and Department of the Environment, Climate Change, Energy and Water. Australian Government Departments included: Sustainability, Environment, Water, Population and Communities (DSEWPC); Australian Customs and Border Protection Service (Customs); and Agriculture, Fisheries and Forestry (Australian Quarantine and Inspection Service, AQIS). Some data were also obtained from the Zoo and Aquarium Association (ZAA).

AQIS (http://www.daff.gov.au/about/media-centre/aqis-releases) and Customs media releases (http://www.customs.gov.au/site/page4281.asp) for the period 1999–2010 were searched for articles on smuggling or seizures of illegal wildlife. Other sources include general online news articles and TRAFFIC (the wildlife trade monitoring network) reports.

All data were separated into four 'detection categories' based on whether animals were reported as (1) at large, (2) from illegal private keeping in Australia, (3) illegal import incidents or (4) stowaway interceptions at the national border. We excluded reports of the following widespread species from our results tables: black rat (*Rattus rattus*), common blackbird (*Turdus merula*), domestic cat (*Felis catus*), domestic dog (*Canis lupus familiaris*), European starling (*Sturnus vulgaris*), house mouse (*Mus domesticus*), house sparrow (*Passer domesticus*), rock pigeon (*Columba livia*) and tree sparrow (*P. montanus*). We included these established species that have limited distributions or are still spreading in Australia: Asian house gecko (*Hemidactylus frenatus*), barbary dove (*Streptopelia roseogrisea*), cane toad (*Bufo marinus*), common myna (*Acridotheres tristis*), five-striped palm squirrel (*Funambulus pennanti*), Indian peafowl (*Pavo cristatus*) and mallard (*Anas platyrhynchos*).

2.2 Risk assessments

Many of the species listed in reports were identified by common names only. While we were able to ascribe scientific names to most species with reasonable confidence, for some we could not be absolutely certain (footnoted in our result tables), and others we could only identify to genus level.

Numbers of individuals detected and numbers of incidents are provided where possible. Some data sources only gave general estimates for these values. When summarising our data, we conservatively converted text to numbers as follows: 'unknown number' ≥1; 'individuals' ≥2; 'several' ≥3; 'many', 'regular', 'frequent' or 'small population' ≥10; 'population' or 'small populations' ≥20; and 'populations' ≥40.

We used Bomford's (2008) four-factor model for mammals and birds and Bomford et al's (2009) model for reptiles and amphibians (following instructions in Bomford 2008) to estimate the risk that species could establish exotic populations if viable propagules were released. Bomford's models are based on analyses of the outcomes of historical introductions of exotic species and climate matches and are used to calculate establishment risk ranks for each species as either low (0–4% of previously introduced species with this score have established), moderate (30–35% have established), serious (60–70% have established) or extreme risk (90–100% have established). Bomford's establishment risk assessments do not include a measure of propagule pressure because the models were developed for screening species to identify those with attributes making them most likely to establish, so that appropriate import and keeping restrictions could be placed on them.

The use of Bomford et al's (2009) model to estimate probability of establishment success for reptile and amphibian species required a measure of 'prop.species'; that is, the proportion of introduction events worldwide that were successful for each species. We used Kraus' (2009) database as the source of these data. Where fewer than three introduction events with known outcomes were available to calculate a prop.species value we substituted a 'prop.genus' value in the model. Prop.genus was determined by first the calculating the prop.species value of all species in the same genus with three introduction events with known outcomes. Introduction data for all other species in that genus (ie species introduced only one or two times) were combined into a single success rate value for these small introductions. Then the genus success rate was calculated as the average of the combined prop.species value for all the species in the genus plus the small species success rate value. This process prevented species that had large numbers of introductions having undue weighting in the prop.genus score. If there were fewer than three introduction events with known outcomes for species in the same genus, we used the same process to calculate a 'prop.family' value and substituted this for the prop.species value in the model. While Bomford et al (2009) found that both genus and family were correlated with introduction outcomes, our establishment probability estimates will be most reliable for species for which we obtained a prop.species value and least reliable for species for which we had to rely on a prop.family value. Footnotes to our results tables designate which prop.* value was used for each species. Five reptile and amphibian species were in families not included in Bomford et al's (2009) model, so for these species there were no 'family random effect' values we could use. 'Family random effect' accounts for systematic variation in invasion success between genera. We substituted the family random effect average value for all the families used in Bomford et al's (2009) model, so our estimates of probability of establishment for these five species are not corrected for any bias introduced by related genera, which will reduce their reliability. Footnotes to our results tables designate these five species.

3. Results

We received approximately 1753 reports in total, including at least 508 incidents for Victoria, 463 for New South Wales, 405 for Western Australia, 238 for Queensland, 63 for South Australia, 45 for Northern Territory, 25 for Tasmania and 6 for the ACT (figures are approximate since some incidents in each jurisdiction were generalised as 'frequent sightings', etc). The number of species reported in incidents from each jurisdiction was at least: 112 in New South Wales, 91 in Victoria, 74 in Western Australia, 61 in Queensland, 18 in South Australia, 16 in Northern Territory, 9 in Tasmania and 5 in the ACT (numbers are minima because many reports did not include species names but were identified to distinct genera or higher classification). A breakdown of these results into pre- and post-border detections and a brief analysis of reporting trends over the decade are given in the following sections.

3.1 Exotic vertebrates detected at large or in private keeping in Australia

Information detail and management:

The detail of information provided by different state and territory agencies varied considerably. For example, Victoria (Vic DPI and DSE) and Western Australia (DAFWA) had more extensive records than other states on incursions and compliance activities, detailing species, numbers, dates, locations and follow-up activities. Victoria had also mapped all incursion/interception data.

South Australia (DWLBC) had limited information on species detected at large, collected for cane toads, barbary doves and myna birds only. DWLBC is currently in the process of entering information related to confiscated animals (seizures) onto a computerised system. Information obtained from Northern Territory, New South Wales and Queensland relied largely on individuals' recall of incursion events. Biosecurity Qld has some formal records of recent compliance investigations and is developing an improved web-based information system to record all details of seizures and subsequent action by staff (eg prosecution, seizure and destruction). NSW DPI is retrospectively collating information on vertebrate pests detected at large for the last few years. NSW information is highly decentralised (dispersed among Livestock Health and Pest Authorities, DPI, National Parks, OEH, zoos and others) and largely unrecorded in any official capacity. Tasmania's information provided on species at large mainly covered species from the Australian mainland that have established naturalised populations.

Bird data also varied between jurisdictions, partly based on differences in state's regulation and which species are classed as pests. For example, Western Australia provided numerous incursion records for birds, but Victoria did not provide any bird data. Also, Northern Territory and Western Australia had records of bird species common to eastern Australia (eg house sparrows *Passer domesticus*, rock pigeons *Columba livia* and European starlings *Sturnus vulgaris*), not reported by eastern jurisdictions (and excluded from this study).

Exotic species detected at large:
Table 1 lists data collected on exotic animals reported at large between 1999 and 2010. Note that different exotic species may be classed as reportable pests in different jurisdictions and this may be reflected in data — for example deer are variably classed as pests or game in different states.

At least 14 mammal, 11 bird, nine reptile and three amphibian species were detected at large in the environment (Table 1). Most mammals reported in the wild were individuals, except ferrets (*Mustela putorius*) and two species of deer (*Cervus elaphus* and *Dama dama*), each of which were assessed as presenting serious risks for establishing in the wild (assigned a serious establishment risk rank (ERR)). Five-striped palm squirrels (*Funambulus pennanti*, moderate ERR) were also commonly reported in Perth, Western Australia. Of the birds not well established in Australia, Indian ringneck parakeets (*Psittacula krameri*), barbary doves (*Streptopelia risoria*), house crows (*Corvus splendens*) and Indian peafowl (*Pavo cristatus*) were the most commonly reported species. All of these species were assessed as having a serious ERR. By far the most numerous amphibian reported at large was the cane toad (*Bufo marinus*; extreme ERR). Red-eared sliders (*Trachemys scripta elegans,* extreme ERR) were the most common reptiles reported in the wild. Asian house geckos (*Hemidactylus frenatus*, extreme ERR) were also reported in multiple jurisdictions. Of species not known to have existing wild populations in Australia, corn snakes (*Elaphe guttata*, serious ERR) and Hermann's tortoise (*Testudo hermanni,* moderate ERR) were both reported at large in more than one jurisdiction.

Seized, surrendered or stolen:
Table 2 lists exotic vertebrates intercepted from private keeping. At least 12 mammal, 42 reptile, nine bird and three amphibian species were reported as seized, surrendered or stolen from private keeping (Table 2). At least 75 mammals were reported as seized or stolen, mostly in very low numbers (1–4) per incident. The palm squirrel (serious ERR) was the most commonly reported mammal seized from private keeping. Eight mammal species (17 animals plus an unknown number of blackbuck *Antilope cervicapra*) were seized or stolen from animal exhibitions

Table 1. Exotic vertebrate species detected at large in mainland Australia 1999–2010

Species identification	Common name	Risk of establishment (& risk score or P[establishment][1])	No. incidents	No. animals	Location
Mammals:					
Ailurus fulgens	red panda	low (2)	1	2	NSW
Antelope cervicapra	blackbuck	serious (10)	1	3	Qld
Arctictis binturong	bearcat	low (5)	1	1	Vic
Axis porcinus	hog deer	moderate (8)	1	?	NSW
Cervus elaphus	red deer	serious (10)	many	many	WA
Cervus timorensis	rusa deer	moderate (7)	≥2	≥2	WA
Dama dama	fallow deer	serious (10)	many	many	WA
Dendrolagus matschiei	Matschie's tree kangaroo	low (4)	1	1	SA
Funambulus pennanti	five-striped palm squirrel	moderate (6)	19	30	WA
Hexaprotodon liberiensis	pigmy hippo	low (4)	1	1	NT
Macaca mulata	Rhesus macaque	serious (9)	1	1	Vic
Macaca fuscata	Japanese macaque	moderate (6)	1	2	Qld
Mustela putorius	ferret	serious (10)	≥8	9 + populations	NSW, Tas, Qld
Saguinus oedipus	cotton-top tamarin	low (2)	1	3	NSW
Genus *Macaca*	macaque	-	1	1	SA
Birds:					
Acridotheres tristis	Indian myna	serious (9)	≥6	≥20 + populations	NSW, SA, WA, Tas
Alectoris graeca	chukar partridge	serious (10)	?	1	Tas
Anas platyrhynchos	mallard	extreme (11)	1	small populations	NSW
Ara ararauna	blue and gold macaw	moderate (6)	1	1	SA
Branta canadensis	Canada goose	moderate (7)	2	5	NSW
Corvus splendens	house crow	serious (9)	9	approx 17	NSW, WA
Pavo cristatus	Indian peafowl	serious (9)	many	small populations	NSW, Tas
Psittacula eupatria	Alexandrine parakeet	low (5)	6	7	WA
Psittacula krameri	Indian ringneck parakeet	serious (9)	96	approx 161	NSW, WA
Streptopelia chinensis	spotted turtle dove	serious (9)	many	individuals (ACT) and 1000s (NT)	ACT, NT
Streptopelia risoria or roseogrisea	barbary dove	serious (10)	≥44	≥ 158	NSW, SA, NT, WA
Genus *Agapornis*	lovebird	-	≥2	individuals	WA, NT
Reptiles:					
Alligator mississippiensis	Mississippi alligator	serious (0.447)	1	1	NSW
Boa constrictor	boa constrictor	serious (0.442)	3	4	Vic
Cuora flavomarginata	Chinese box turtle	moderate (0.19)	1	1	Qld
Elaphe guttata	corn snake	serious (0.808)	6	7	Qld, Vic
Hemidactylus frenatus	Asian house gecko	extreme (0.872)	≥ 4	2 + populations	ACT, Vic, Qld, NT

Species identification	Common name	Risk of establishment (& risk score or P[establishment][1])	No. incidents	No. animals	Location
Macroclemys temminckii	alligator snapping turtle	moderate (0.263)	1	1	NSW
Testudo hermanni	Hermann's tortoise	moderate (0.279)	3	3	SA, Qld
Trachemys scripta[2]	red-eared slider	extreme (0.961)	24	>235	ACT, NSW, Qld, Vic, WA
Varanus salvator	Asian water monitor	low (0.12)	1	1	Vic
Family Gekkonidae	gecko	-	1	1	Vic
Amphibians:					
Bufo marinus	cane toad	extreme (0.9)	many (>100)	individuals and populations, ≥ 643	NSW, Vic, WA, NT
Bufo melanostictus	black-spined toad	serious (0.48)	2	2	Vic, WA
Kaloula pulchra[3]	Asiatic painted frog	serious (0.565)	1	1	NSW
Order Anura	frog	-	1	1	Vic
Order Caudata	newt	-	1	1	Vic
Suborder Sauria	lizard	-	1	1	Vic

No records for fish detected at large were received. Not listed are several species that escaped enclosures and were at large within a zoo. Animals stolen from zoos and subsequently detected alive in the wild are reported in this table. All other zoo thefts are listed in Table 2.

1. Establishment Risk Scores of 1-13 were calculated for birds and mammals from Bomford (2008, p19). Probability of establishment scores of 0.00–1.00 were calculated for reptiles and amphibians at species level only, from Bomford et al (2009), using instructions in Bomford (2008, p55).

2. *Trachemys scripta* records identified subspecies *elegans* but the establishment risk rank was only assessed at species level.

3. No 'family random effect' value available for Microhylidae so substituted average 'familyre' value to calculate probability of establishment (see Methods section).

(zoos and a circus). The most numerous amphibian seized was the fire-bellied newt (*Cynops pyrrhogaster,* low ERR), including one incident with 84 animals. Of the seized/surrendered reptiles, the most commonly reported were corn snakes and boa constrictors (both assigned a serious ERR), including many reports of five or more snakes, up to 38 per residence. Red-eared sliders (extreme ERR) were another common seizure, including one incident of 22 turtles plus 27 eggs. The largest single seizure was of 86 exotic snakes of various species. Several of the seized snakes were deadly venomous species (rattle snakes, vipers and cobras), but most were non-venomous species. Green iguanas (*Iguana iguana,* extreme ERR), leopard geckos (*Eublepharis macularius*, serious ERR), veiled chameleons (*Chamaeleo calyptratus,* serious ERR) and Burmese pythons (*Python molurus,* moderate ERR), were also seized in multiple incidents in more than one state.

Table 2. Exotic vertebrate species seized, surrendered or stolen from private keeping in Australia 1999–2010

Species identification	Common name	Risk of establishment (& risk score or *P*[establishment][1])	No. incidents	No. animals	Location
Mammals:					
Acinonyx jubatus	cheetah	moderate (8)	1	1	Qld
Antilope cervicapra	blackbuck	serious (10)	1	?	SA
Cebuella pygmaea	pygmy marmoset	low (4)	1	4	NSW
Callithrix jacchus	common marmoset	moderate (8)	1	1	NSW
Funambulus pennanti	five-striped palm squirrel	moderate (6)	3	~50	NSW, Vic
Macaca fascicularis	crab-eating macaque	moderate (7)	1	1	Vic
Macaca fuscata[2]	Japanese pig-tailed macaque	moderate (6)	1	1	Vic
Macaca radiata	Bonnet macaque	low (4)	1	4	Vic
Mustela putorius	ferret	serious (10)	1	1	Qld
Saguinus oedipus	cotton-top tamarin	low (2)	3	4	NSW, Qld
Saimiri boliviensis	squirrel monkey	low (4)	1	1	SA
Suricata suricatta	meercat	moderate (6)	1	1	SA
Genus *Papio*	baboon	-	1	2	Vic
Suborder Strepsirrhini	lemur	-	1	1	Qld
Infraorder Simiiformes	monkey	-	1	3	Qld
Birds:					
Ara ararauna	blue and gold macaw	moderate (6)	3	4	NSW, Vic
Ara chloroptera	green-winged macaw	low (4)	1	2	NSW
Colinus virginianus	bobwhite quail	extreme (11)	1	7	WA
Lonchura malacca[3]	tricoloured nun	serious (9)	2	?	WA
Myiopsitta monachus	monk parrot	serious (10)	1	?	WA
Nandayus nenday	Nanday conure	serious (10)	1	?	WA
Padda oryziva	Java sparrow	moderate (7)	1	1	WA
Psittacus erithacus	African grey parrot	low (3)	1	2	NSW
Pyrrhura molinae	green cheeked conure	low (3)	1	?	WA
Reptiles:					
Alligator mississippiensis	Mississippi alligator	serious (0.447)	1	1	Vic
Bitis arietans[4, 5]	puff adder	extreme (0.932)	1	1	Vic
Bitis gabonica[4, 5]	Gaboon viper	moderate (0.308)	1	2	Vic
Boa constrictor	boa constrictor	serious (0.442)	≥79	153	NSW, Qld, Vic, WA
Boa dumerili[6]	Dumereil's ground boa	moderate (0.211)	1	3	Vic
Candoia carinata[4]	Solomon Island boa	low (0.069)	1	2	WA
Chamaeleo calyptratus[6]	veiled chameleon	serious (0.836)	10	15	NSW, Vic
Chelydra serpentina	common snapping turtle	extreme (0.914)	1	1	Vic
Coelognathus helena[4]	trinket snake	serious (0.436)	2	4	Vic
Corallus caninus[6]	emerald tree boa	low (0.087)	2	6	NSW, Vic
Cuora flavomarginata	Chinese box turtle	moderate (0.19)	1	1	Qld

Species identification	Common name	Risk of establishment (& risk score or *P*[establishment][1])	No. incidents	No. animals	Location
Daboia russeli[4,5]	Russell's viper	serious (0.585)	1	1	Vic
Elaphe bairdi[6]	Baird's rat snake	serious (0.453)	1	2	NSW
Elaphe guttata	corn snake	serious (0.808)	51	158 + 16 eggs	NSW, Qld, SA, Vic, WA
Elaphe obsoleta	rat snake	serious (0.476)	4	11	NSW. Vic
Epicrates cenchria[4]	rainbow boa	serious (0.421)	3	15	NSW, Vic
Eublepharis macularius[4]	leopard gecko	serious (0.778)	≥ 10	≥ 43	NSW, Vic
Eunectes notaeus[6]	yellow anaconda	moderate (0.331)	1	1	Vic
Geochelone carbonaria[6]	South American red-footed tortoise	serious (0.582)	1	3	NSW
Geochelone elegans[6]	Indian star tortoise	moderate (0.243)	1	2	WA
Geochelone sulcata[6]	African spurred tortoise	moderate (0.369)	1	≥ 1	NSW
Gongylophis colubrinus[4]	Kenyan sand boa	serious (0.42)	3	10	NSW, Vic
Hemidactylus frenatus	Asian house gecko	extreme (0.872)	3	6	Vic
Hemitheconyx caudicinctus[4]	African fat-tailed gecko	serious (0.409)	2	2	Vic
Heterodon nasicus[4]	western hognose snake	serious (0.711)	1	4	Vic
Iguana iguana	green iguana	extreme (0.904)	10	17	NSW, SA, Vic
Kinixis belliana[4]	Bell's hinged back turtle	serious (0.545)	1	1	WA
Lampropeltis alterna[6]	grey banded kingsnake	serious (0.798)	3	5	NSW, Vic
Lampropeltis getula[7]	kingsnake	serious (0.798)	4	32	NSW, Vic
Lampropeltis triangulum	milksnake	serious (0.748)	5	11	NSW, Vic
Lichanura trivirgata[4]	rosy boa	serious (0.454)	1	2	Vic
Macroclemys temminckii	alligator snapping turtle	moderate (0.263)	1	1	Vic
Mauremys reevsii	Chinese soft-shelled turtle	low (0.109)	1	3	NSW
Naja kaouthia[6]	monocled cobra	serious (0.616)	1	9	Vic
Ophiophagus hannah[4]	king cobra	serious (0.543)	2	6	NSW
Psuedemys suwanniensis[6]	Suuwanee river cooter	low (0.048)	1	1	WA
Python curtus[6, 8]	Borneo short-tailed python	low (0.065)	1	1	WA
Python molurus[9]	Burmese python	moderate (0.332)	11	14	NSW, Qld, Vic, WA
Python regius	royal python	low (0.102)	6	8	NSW, Vic
Terrapene ornata	ornate box turtle	moderate (0.343)	1	1	NSW
Testudo graecea	spur-thighed tortoise	serious (0.465)	1	1	WA
Trachemys scripta[10]	pond slider	extreme (0.961)	≥ 38	≥115 + 27 eggs	NSW, Qld, SA, Vic, WA, Tas
Genus *Chamaeleo*	chameleon	-	1	1	Vic
Genus *Crotalus*	rattle snake	-	3	9	Vic
Genus *Iguana*	iguana	-	3	13	Qld, SA, Vic

Species identification	Common name	Risk of establishment (& risk score or *P*[establishment][1])	No. incidents	No. animals	Location
Genus *Lampropeltis*	kingsnake	-	1	3	Vic
Genus *Lamprophis*	African house snake	-	1	1	Vic
Genus *Naja*	cape cobra	-	1	3	Vic
Genus *Pituopis*	bull snake	-	1	2	Vic
Genus *Thamnophis*	garter snake	-	2	2	Vic
Genus *Trachemys*	pond slider	-	1	1	WA
Family Viperidae	horned viper	-	1	2	Vic
Amphibians:					
Ambystoma mexicanum	axolotl	low (0.115)	1	1	Tas
Bufo marinus	cane toad	extreme (0.9)	1	4	Vic
Cynops pyrrhogaster	Japanese fire-bellied newt	low (0.09)	2	91	Vic
Genus *Bombina*	fire-bellied toad	-	1	?	NSW
Family Salamandridae	European newt	-	1	5	Vic
Fish:					
Genus Channa	snakehead	-	1	?	NSW
Subfamily Serrasalminae	piranha	-	≥2	?	SA
Class Chondrichthyes	freshwater shark	-	1	?	NSW

1. Establishment Risk Score calculated for birds and mammals from Bomford (2008, p19).
Probability of establishment calculated for reptiles and amphibians at species level only, using Bomford et al (2009) and instructions in Bomford (2008, p55).
2. *Macaca fuscata* was identified only by common name 'Japanese pig-tailed macaque', but we assumed it was the Japanese macaque.
3. *Lonchura malacca* records identified one incident each for subspecies *atricapilla* and *malacca* but the establishment risk rank was only assessed to species level.
4. 'Prop.family' value used to calculate probability of establishment (see Methods section).
5. No 'family random effect' value available for Viperidae so substituted average 'familyre' value to calculate probability of establishment (see Methods section).
6. 'Prop.genus' value used to calculate probability of establishment (see Methods section).
7. *Lampropeltis getula* records identified three incidents for subspecies *californiae* and one incident (one animal) for subspecies *floridana* but the establishment risk rank was only assessed to species level.
8. Python curtus record identified subspecies *breitensteini* but the establishment risk rank was only assessed to species level.
9. *Python molurus* record identified subspecies *bivittatus* but the establishment risk rank was only assessed at species level.
10. *Trachemys scripta* records all identified subspecies *elegans* but the establishment risk rank was only assessed at species level.

3.2 Exotic animals intercepted at the national border

Information detail and management:

Information on animals detected entering the country illegally or accidentally was mostly supplied by personnel in Customs (Intelligence) and AQIS (Compliance and Enforcement, and Science Operations), and by online media sources. AQIS has a national incidents database for interceptions at the border, although the focus of this tends to be on plant pests and pathogens: information on vertebrates was extracted, but data is limited to intercepted animals that were selected for further processing — other animals may have been destroyed on site without identification or reporting. AQIS information was only available back to 2003, and does not include details of the number of animals per incident, or whether the incident involved a smuggling or

stowaway event. However, AQIS and Customs data were cross referenced to avoid duplication of known smuggling records. It is assumed the majority of remaining AQIS records are of stowaways, since only three common records were identified. Additional information on amphibians was obtained from scientific journal publications. DSEWPC's Compliance and Enforcement Branch and International Wildlife Trade sections deferred to Customs for information on detections, since their memorandum of understanding means field work (including seizures) is generally handled by Customs officials.

Illegal imports:
Table 3 lists the exotic vertebrates detected in illegal import incidents. At least 27 reptile, 10 bird and two mammal species were identified (Table 3). No amphibians were reported. At least 355 birds were illegally imported, mostly parrots (low ERR) and poultry smuggled as eggs concealed on passengers (1–52 eggs per incident). Some poultry eggs were also unwittingly purchased online and posted from international destinations. At least 155 snakes were detected in smuggling incidents; nearly all of these were found in international mail items. The most numerous species were corn snakes (*Elaphe guttata*), rainbow boas (*Epicrates cenchria;* both species with a serious ERR) and Burmese pythons (*Python molurus;* moderate ERR). At least 17 species of turtle were detected on passengers, in luggage and in the mail; 1–7 turtles per incident, with the exception of 60 red-eared sliders (*Trachemys scripta elegans*) found in one passenger's luggage. Only five mammals (one plantain squirrel, *Callosciurus notatus,* in the mail and four chinchillas on a passenger) were reported in smuggling incidents. Over 7000 fish were detected as illegal imports from 16 incidents, mostly in air cargo and aquarium imports. Most fish were unidentified to species level, but included 'catfish' (148) and 'arowanas' (20). Passenger incidents included 51 fish worn in a modified apron, and 85 catfish concealed in luggage. Only about half the Customs reports had an incident location recorded. Of these, 44% of reports came from Sydney interceptions, 26% from Melbourne, 17% from Brisbane and 9% from Perth/Fremantle.

Stowaways:
Table 4 lists intercepted stowaways recorded for exotic vertebrates since 2003. Statistical analysis of the species not established in Australia demonstrates that of the four detection categories (or introduction pathways), stowaways pose the highest risk for new species establishing (Henderson et al, in press).

The breakdown of numbers of intercepted animals from AQIS records is as follows:

- ≥582 reptiles (including 23 identified species)
- ≥ 186 amphibians (including 16 identified species)
- ≥165 birds (including five identified species, but most were identified to Class level only)
- ≥ 28 mammals (including one identified species)
- four fish (none identified to species level).

Victoria had the highest number of reported AQIS interceptions (34% or 311 incidents), followed by New South Wales (26%; 236 incidents), Queensland (21%; 194 incidents) and Western Australia (16%; 146 incidents). The other states and territories had much lower numbers of reported incidents: Northern Territory (27), Tasmania (four), South Australia (two) and the ACT (one).

Table 3. Exotic vertebrates intercepted as illegal imports at the border 1999–2010

Scientific name	Common name	Risk of establishment (& risk score or *P*[establishment][1])	No. incidents	No. animals	Location found	Location arriving from	Arrival information
Mammals:							
Callosciurus notatus	plantain squirrel	low (3)	1	1	Sydney	Bali	in mail
Genus *Chinchilla*	chinchilla	-	1	4	Brisbane	New Zealand	on passenger
Birds:							
Anser anser (domesticated)		low (4)	1	2 eggs	Melbourne	Dubai/ Turkey	on passenger
Ara ararauna	blue and gold macaw	moderate (6)	2	11 eggs	Perth, Sydney	Bali, Thailand	on passenger
Ara manilata	red-bellied macaw	low (3)	1	1 egg	Sydney	Thailand	on passenger?
Ara severa	chestnut fronted macaw	low (4)		2 eggs	Sydney	Thailand	on passenger?
Cacatua moluccensis	Moluccan cockatoo	low (1)	1	2 eggs	Sydney	Thailand	on passenger?
Eos bornea	red lory	low (1)	1	2 eggs	Perth	Bali	on passenger
Lorius lory	black capped lory	low (1)	1	5 eggs	Perth	Bali	on passenger
Poicephalus senegalus	West African parrot	low (4)	1	10	Sydney	Netherlands	on passenger
Pseudeos fuscata	dusky lory	low (1)	1	2 eggs	Perth	Bali	on passenger
Psittacus erithacus	African grey parrot	low (3)	1	8 eggs	Sydney	Thailand	on passenger?
Genus *Eos*	lory		1	2 eggs	Perth	Bali	on passenger
Genus *Psittaculirostris*	fig parrot	-	1	3 eggs	Perth	Bali	on passenger
Genus *Trichoglossus*	lorikeet	-	1	2 eggs	Perth	Bali	on passenger
Subfamily Loriinae	lory	-	1	1 egg	Sydney	Thailand	on passenger?
Family Psittacidae	parrot	-	6 (52 eggs in one case)	154 eggs	Brisbane, Melbourne, Perth, Sydney	Bali, Singapore, South Africa	on passenger
Family Columbidae	pigeon	-	4	11 birds	Melbourne	Dubai/ Turkey	on passenger, in luggage and in mail
Order Galliformes	poultry	-	5	≥ 107 eggs	Melbourne, Sydney	Israel, United Kingdom, Viet Nam	on passenger, in luggage and unwittingly imported
Order Passeriformes	Asian finch	-	1	2	Sydney	Singapore	in luggage
Class Aves	bird	-	4	6 birds + 22 eggs	?Melbourne, Sydney	China, Taiwan, Viet Nam	on passenger or in luggage

Scientific name	Common name	Risk of establishment (& risk score or *P*[establishment][1])	No. incidents	No. animals	Location found	Location arriving from	Arrival information
Reptiles:							
Astrochelys radiata[2]	radiated tortoise	low (0.151)	1	1	unknown	China	on passenger or in luggage
Boa dumerili[3]	Dumerils boa	moderate (0.211)	1	8	unknown	Sweden	in mail
Boa constrictor	boa constrictor	serious (0.442)	2	3	Port Adelaide, NSW	Greece, United Kingdom	in mail
Candoia carinata[2]	Pacific boa	low (0.069)	1	3	NSW	unknown	unknown
Chrysemys picta	painted turtle	serious (0.463)	1	1	Sydney	China	on passenger or in luggage
Corallus caninus[3]	emerald tree boa	low (0.087)	1	2	Melbourne	Sweden	in mail
Cuora amboinensis?[3]	Malaysian box turtle	moderate (0.194)	1	1	Fremantle	Malaysia	retained in zoo
Elaphe bairdi[3]	Baird's rat snake	serious (0.453)	1	2	NSW	unknown	unknown
Elaphe guttata	corn snake	serious (0.808)	2	29	NSW	United Kingdom	in mail
Elaphe taeniura?	stripe-tailed rat snake	serious (0.692)	1	1	Sydney	Sweden	in mail
Epicrates cenchria[2]	rainbow boa	serious (0.421)	3	13	Adelaide, NSW	Sweden + unknown	unknown
Eublepharis macularius[2]	leopard gecko	serious (0.778)	2	5	Sydney	Sweden, United Kingdom	in mail
Geochelone carbonaria[3]	South American red-footed tortoise	serious (0.582)	1	3	unknown	Chile	on passenger or in luggage
Geochelone elegans[3]	Indian star tortoise	moderate (0.243)	1	2	Fremantle	unknown	unknown
Gongylophis colubrinus[2]	East African sand boa	serious (0.42)	1	1	Sydney	United Kingdom	in mail
Iguana iguana	green iguana	extreme (0.904)	2	5	NSW	United Kingdom + unknown	in mail
Kachuga tentoria[2]	Indian tent tortoise	moderate (0.304)	1	1	NSW	unknown	unknown
Kinosternon subrubrum	Eastern mud tortoise	serious (0.433)	1	1	NSW	unknown	
Lampropeltis getula	kingsnake	serious (0.798)	3	6	Sydney, NSW	Sweden, United Kingdom	in mail
Lampropeltis triangulum[4]	milk snake	serious (0.748)	1	2	unknown	United Kingdom	in mail
Lichanura trivirgata[2]	rosy boa	serious (0.454)	2	2	Sydney	United Kingdom	in mail
Macroclemys temminckii	alligator snapping turtle	moderate (0.263)	2	3	Melbourne + unknown	Indonesia, Italy	in mail + unknown

Scientific name	Common name	Risk of establishment (& risk score or *P*[establishment][1])	No. incidents	No. animals	Location found	Location arriving from	Arrival information
Mauremys reevesii	Chinese soft shell turtle	low (0.109)	1	1	Fremantle	unknown	unknown
Python molurus[5]	Burmese python	moderate (0.332)	2	12	NSW + unknown	Sweden	in mail
Python regius	royal python	low (0.102)	3	7	unknown	Italy, Sweden, United States	in mail
Python reticulatus	reticulated python	moderate (0.181)	1	1	Sydney	United States	in mail
Rhacodactylus ciliatus[2]	New Caledonian Guichenot's giant gecko	moderate (0.237)	1	3	Sydney	United Kingdom	in mail
Sternotherus carinatus[2]	razor back musk turtle	moderate (0.175)	1	1	Sydney	China	on passenger or in luggage
Sternotherus minor[2]	North American loggerhead musk turtle	low (0.088)	2	6	Sydney	Hong Kong + unknown	in luggage
Sternotherus odoratus[2]	common musk turtle	serious (0.447)	1	1	Sydney	China	on passenger or in luggage
Testudo graeca	spur-thighed tortoise	serious (0.465)	1	1	WA	United Kingdom	unknown method of import, sent to zoo
Testudo hermanni	Hermann's tortoise	moderate (0.279)	1	4	unknown	Sweden	in mail
Testudo horsfieldii[3]	Horsefield's tortoise	serious (0.521)	3	7	Brisbane + unknown	Sweden + unknown	in mail
Testudo kleinmanni[3]	Egyptian tortoise	low (0.109)	1	1	NSW	unknown	
Trachemys scripta[6]	red-eared slider	extreme (0.961)	5	≥ 67	Brisbane, Fremantle, Sydney	Singapore, Thailand	in luggage + unknown
Varanus salvator	Asiatic water monitor	low (0.12)	1	1	NSW	United States	in mail
Genus *Cerastes*	horned viper	-	1	1	unknown	Italy	in mail
Genus *Crotalus* or *Sistrurus*	rattle snake	-	1	2	unknown	Sweden	in mail
Genus *Eryx*	sand boa	-	2	5	Sydney, NSW	Sweden + unknown	in mail
Genus *Iguana*	iguana	-	2	≥ 2	Brisbane	Thailand, United Kingdom	in luggage and mail
Genus *Lampropeltis*	kingsnake	-	1	2	unknown	Sweden	in mail
Genus *Python*	python	-	2	≥ 19	Brisbane	Thailand, Netherlands	on passenger and in luggage
Genus *Uromastyx*	North African agamid	-	1	2	Sydney	United Kingdom	in mail
Family Gekkonidae	gecko	-	1	10	Melbourne	unknown	in luggage

Scientific name	Common name	Risk of establishment (& risk score or *P*[establishment][1])	No. incidents	No. animals	Location found	Location arriving from	Arrival information
Order Squamata	snake	-	6	34	Sydney + unknown	Sweden, Thailand, United Kingdom, United States	on passenger or in luggage and in mail
Order Testudines	turtle	-	7	≥ 16	Melbourne, Sydney + unknown	Argentina, China, Egypt, Indonesia, South Africa, Taiwan, Viet Nam	on passenger, in luggage, in mail
Fish:							
Genus *Scleropages*	arawana	-	4	20	Sydney, Melbourne	Viet Nam, Singapore + unknown	on passenger, in luggage + unknown
Order Siluriformes	catfish		3	148	Melbourne	Hong Kong, Singapore	on passenger, in luggage
Class Osteichthyes	fish	-	9	>6975	Brisbane + unknown	mostly SE Asia and Sri Lanka	mostly air cargo

1. Establishment Risk Score calculated for birds and mammals from Bomford (2008, p19). Probability of establishment calculated for reptiles and amphibians at species level only, using Bomford et al (2009) and instructions of Bomford (2008, p55).
2. 'Prop.family' value used to calculate probability of establishment (see Methods section).
3. 'Prop.genus' value used to calculate probability of establishment (see Methods section).
4. *Lampropeltis triangulum* record identified subspecies *campbelli,* but the risk of establishment was only assessed to species level.
5. *Python molurus* records identified subspecies *bivittatus,* but the risk of establishment was only assessed to species level.
6. *Trachemys scripta* records identified subspecies *elegans,* but the risk of establishment was only assessed to species level.

Table 4. Exotic vertebrates[1] detected as stowaways entering Australia 2003–2010

Identification	Common name	Establishment Risk Rank (& risk score or *P*[establishment][2])	No. incidents	No. animals	State/territory intercepted	Origin of import	Arrival information
Mammals:							
Tupaia belangeri	tree shrew	low (5)	1	≥1	Qld	Thailand	by ship
Genus *Mus*	mouse	-	5	≥5	NSW, Vic, WA	Singapore, Thailand, United Arab Emirates, Zimbabwe	by air and ship
Genus *Rattus*	rat	-	6	≥7	NSW, NT, Qld, Vic, WA	France, Indonesia, Papua New Guinea, Paraguay, Philippines + unknown	by air and ship
Order Chiroptera	bat	-	9	≥9	NSW, Vic, WA	North Korea, Spain, Thailand, United States, Viet Nam + unknown	by air and ship
Order Rodentia	rodent	-	3	≥3	Qld, Tas, Vic	Singapore, United States + unknown	by ship
Class Mammalia	mammal	-	3	≥3	Vic, WA	Hong Kong, Taiwan + unknown	by ship

Identification	Common name	Establishment Risk Rank (& risk score or *P*[establishment][2])	No. incidents	No. animals	State/territory intercepted	Origin of import	Arrival information
Birds:							
Acridotheres cristatellus	crested myna	serious (9)	1	1	NSW	Hong Kong	on board plane
Coturnix coturnix	common quail	serious (9)	1	≥1	Qld	Australia	by air
Gallus gallus	red junglefowl	moderate (8)	1	≥1	Qld	Australia	by ship
Psittacula eupatria	Alexandrine parakeet	low (5)	1	≥1	WA	unknown	by air
Sylvia atricapilla	blackcap	low (5)	1	≥1	Vic	Germany	used parts, by ship
Genus *Columba*	pigeon	-	1	≥1	NSW	unknown	by ship
Genus *Sula*	booby	-	1	≥1	Qld	Mexico	by ship
Family Hirundinidae	swallow	-	1	≥1	Qld	Indonesia	by ship
Order Passeriformes	bird	-	1	≥1	Vic	United States	by ship
Class Aves	bird	-	154	≥155	NSW, Qld, Vic, WA	many	by air and ship
Reptiles:							
Anolis carolinensis	Carolina anole	extreme (0.97)	1	≥1	Vic	New Zealand	by air
Anolis sagrei	brown anole	extreme (0.95)	1	≥1	Vic	United States	in machinery/ spare parts, air cargo
Calotes versicolor	changeable lizard	serious (0.774)	6	≥6	NSW, Qld, Vic	India, Singapore, Thailand + unknown	eg tyres, timber, steel deliveries by air and ship
Chondrodactylus bibronii	Bibron's thick-toed gecko	serious (0.717)	1	≥1	WA	unknown	container, by ship
Elaphe quadrivirgata[3]	Japanese four-lined ratsnake	low (0.09)	1	≥1	Qld	Japan	in new vehicle, by ship
Gehyra mutilata	skin-shedding gecko	serious (0.410)	6	≥6	NSW, NT, Qld, Vic	Australia, Indonesia, Malaysia, Thailand + unknown	timber/ instrument, containers, by air and ship
Gekko gecko	tokay gecko	serious (0.484)	11	≥11	QLD, Vic, WA	Bhutan, East Timor, Indonesia, New Caledonia, Philippines, Thailand, Viet Nam + unknown	timber, soil, containers by air and ship
Gekko japonicus	giant gecko	moderate (0.381)	1	≥1	NSW	China	spare parts, by ship
Gekko monarchus[3]	spotted house gecko	moderate (0.20)	4	≥4	NSW	Malaysia, Singapore	container, personal effects, wood by ship
Hemidactylus flaviviridis	yellow-bellied house gecko	extreme (0.951)	1	≥1	NSW	United Arab Emirates	by air

Identification	Common name	Establishment Risk Rank (& risk score or *P*[establishment][2])	No. incidents	No. animals	State/territory intercepted	Origin of import	Arrival information
Hemidactylus frenatus	Asian house gecko	extreme (0.871)	188	≥204	Vic, WA, Qld, NT, NSW, Tas, SA	Australia, Bangladesh, Brunei Darussalam, Cambodia, Chile, China, Christmas Islands, Cocos Islands, East Timor, Fiji, Hong Kong, India, Indonesia, Lao PDR, Malaysia, Myanmar, New Zealand, Pakistan, PNG, Philippines, Pitcairn, Samoa, Singapore, Solomon Islands, Switzerland, South Africa, Taiwan, Thailand, Timor-Leste, Tonga, Vanuatu, Viet Nam + unknown	eg bags, baskets, containers, timber, personal effects, cut flowers by ship, mail and air
Hemidactylus platyurus[3]	flat-tailed house gecko	serious (0.654)	10	≥11	NSW, NT, Qld, Vic	Indonesia, Singapore, Thailand + unknown	eg timber, plastic, car parts deliveries, by air and ship
Hemidactylus turcicus	turkish gecko	extreme (0.98)	2	≥3	Qld, Vic	Israel, United States	by air and ship
Iguana iguana	green iguana	extreme (0.904)	1	≥1	NT	Panama	by ship
Lepidodactylus lugubris	mourning gecko	serious (0.465)	6	≥6	ACT, NSW, Qld	Fiji, Malaysia, PNG + unknown	bags, containers, by air and ship
Lycodon aulicus	wolf snake	extreme (0.884)	1	≥1	Vic	Taiwan	container, by ship
Mauremys reevesii	Chinese soft-shelled turtle	moderate (0.22)	2	≥2	NSW	China	by air
Pseudotrapelus sinaitus[4]	Sinai agama	serious (0.66)	1	≥1	NT	East Timor	personal effects, by air
Python molurus	Burmese python	moderate (0.332)	1	≥2	Qld	Thailand	by air
Python reticulatus	reticulated python	moderate (0.18)	1	≥1	Vic	Malaysia	timber, by ship
Regina grahamii[4]	Graham's crayfish snake	serious (0.53)	1	≥1	Qld	United States	machinery/ parts, by air
Tarentola chazaliae[3]	helmeted gecko	serious (0.442)	1	≥1	NSW	Morocco	personal affects, by ship
Trachemys scripta	pond slider	extreme (0.96)	3	≥3	NSW, Qld	China, Hong Kong	eg used vehicle, by air
Genus *Anolis*	anole	-	4	≥4	NSW, Qld, WA	United States	by air, mail and ship
Genus *Boiga*	cat snake	-	1	≥2	NSW	Australia	by ship
Genus *Calotes*	garden/ forest lizard	-	1	≥1	Qld	China	by ship
Genus *Ctenotus*	skink	-	1	≥1	Qld	China	by air

Identification	Common name	Establishment Risk Rank (& risk score or *P*[establishment][2])	No. incidents	No. animals	State/territory intercepted	Origin of import	Arrival information
Genus *Cuora*	box turtle	-	1	≥2	Qld	Thailand	by air
Genus *Elgaria*	alligator lizard	-	1	≥2	Qld	United States	by ship
Genus *Gehyra*	dtella gecko	-	11	≥11	NSW, NT, Vic	Indonesia, Malaysia, New Zealand, Singapore, Thailand, Viet Nam + unknown	by air and ship
Genus *Hemidactylus*	house gecko	-	31	≥31	NSW, NT, Qld, Vic, WA	Australia, China, East Timor, Fiji, Indonesia, Japan, Malaysia, Papua New Guinea, Samoa, Singapore, Taiwan, Thailand, Timor-Leste, United Arab Emirates + unknown	by air and ship
Genus Lepidodactylus	scaly toed gecko	-	2	≥2	Vic, WA	Indonesia + unknown	by ship
Genus *Mabuya*	long tailed skink	-	1	≥1	NSW	Thailand	by air
Genus *Varanus*	monitor	-	1	≥1	WA	unknown	by ship
Family Agamidae	agamid	-	3	≥3	WA	India, Italy + unknown	By air and ship
Family Colubridae	nonvenomous snake	-	1	≥1	Vic	Czech Republic	by ship
Family Emydidae	pond turtle	-	1	≥1	NT	Indonesia	by ship
Family Gekkonidae	gecko	-	207	≥216	NSW, NT, Qld, SA, Vic, WA	many	by air, mail and ship
Family Scincidae	skink	-	12	≥14	NSW, Qld, Vic, WA	Australia, Indonesia, New Zealand, Peru, Samoa, Thailand + unknown	
Family Typhlopidae	blind snake	-	1	≥1	Qld	Vanuatu	by air
Order Squamata	reptile	-	7	≥8	Qld, Tas, Vic, WA	China, Indonesia. Malaysia, Papua New Guinea, Singapore, Thailand, United Kingdom, Vanuatu + unknown	by air and ship
Class Reptilia	reptile	-	1	≥1	Qld	Indonesia	by ship
Amphibians:							
Buergeria robusta[4,5,6]	-	serious (0.434)	1	1	unknown	China	container, by ship
Bufo marinus[7]	cane toad	extreme (0.90)	22	≥30	NSW, Qld, Vic	Fiji, Indonesia, Solomon Islands, Sri Lanka, United States	eg timber, personal effects, container, by air and ship
Bufo melanostictus[5,8]	black-spined toad	serious (0.48)	75	≥79	NSW, Qld, Vic, WA	Brunei, China, India, Indonesia, Malaysia, Thailand, United States	eg stone, straw, personal effects, baggage, containers by air and ship

Identification	Common name	Establishment Risk Rank (& risk score or *P*[establishment][2])	No. incidents	No. animals	State/territory intercepted	Origin of import	Arrival information
Bufo rangeri[3]	ranger's toad	serious (0.79)	2	≥3	Vic	Mali, South Africa	timber, personal effects, by air
Bufo stomaticus[3, 8]	Indus Valley toad	serious (0.70)	1	1	SA	India	luggage
Bufo viridis[8]	European green toad	serious (0.65)	1	1	Adelaide	Italy	roof tiles shipment
Chiromantis xerampelina[4]	foam-nest frog	extreme (0.99)	1	≥1	Qld	South Africa	personal effects, by ship
Hoplobatrachus chinensis[3]	Chinese bullfrog	extreme (0.97)	1	≥1	NSW	China	by air
Hyla cinerea	green tree frog	serious (0.67)	1	≥1	Qld	United States	timber/boat, by ship
Hyla japonica[3, 8]	Japanese tree frog	low (0.14)	1	1	NSW	Japan	used car, by ship
Hyla squirella[3]	squirrel tree frog	moderate (0.34)	1	≥1	Qld	United States	by ship
Hyla versicolor[3]	grey tree frog	moderate (0.307)	2	≥2	NSW, SA	United States	spare parts, by ship
Hymenochirus curtipes[4]	western dwarf clawed frog	moderate (0.28)	1	≥1	NSW	United States	by air
Kaloula pulchra[8,9]	Asiatic painted frog	serious (0.565)	18	≥20	NSW, Qld, Vic, WA	Cambodia, China, Malaysia, Singapore, Thailand, Viet Nam + unknown	by air and ship
Osteopilus septentrionalis	Cuban tree frog	moderate (0.197)	3	≥3	Qld	United States	timber/boat, by ship
Pelobates syriacus[4]	eastern spadefoot	moderate (0.37)	1	≥1	WA	Bulgaria	timber, by ship
Platymantis vitiensis[4]	Fiji tree frog	serious (0.79)	3	≥3	NSW	Fiji	by air
Polypedates leucomystax[8]	common tree frog	extreme (0.92)	1	1	NT ?	Brunei and East Timor	unknown
Polypedates megacephalus[3]	Hong Kong whipping frog	serious (0.84)	1	≥1	Vic	China	nursery stock, by ship
Schimaderma carens[4, 8]	African split-skin toad	serious (0.73)	1	1	WA	South Africa	luggage, by air
Genus *Bufo*	toad	-	2	≥2	NSW, Vic	China + unknown	by air and ship
Genus *Hoplobatrachus*	frog	-	1	≥1	NSW	unknown	by air
Genus *Rana*	frog	-	3	≥3	Qld, WA	Afghanistan, Malaysia, United States	by air and ship
Genus Rhacophorus	tree frog	-	1	≥1	Qld	Viet Nam	by ship
Family Bufonidae	toad	-	7	≥8	NSW, Qld, Vic, WA	China, Fiji, India, Malaysia, Thailand + unknown	by air and ship
Family Hylidae	tree frog	-	13	≥13	NSW, NT, Qld, WA	China, Indonesia, Japan, Malaysia, South Africa, Thailand, United States, Viet Nam, Zambia + unknown	by air and ship

Identification	Common name	Establishment Risk Rank (& risk score or *P*[establishment][2])	No. incidents	No. animals	State/territory intercepted	Origin of import	Arrival information
Family Ranidae	frog	-	1	≥1	WA	South Africa	by air
Order Salientia	frog/toad	-	16	≥16	NSW, Vic, WA	China, France, Philippines, Singapore, Thailand, United States + unknown	by air and ship
Class Amphibia	amphibian	-	6	≥6	NSW, Qld, Vic, WA	China, Indonesia, Thailand	by air and ship
Fish:							
Family Synbranchidae	swamp eel	-	1	≥1	Vic	Hong Kong	by air
Order Angulliformes	eel	-	1	≥1	Vic	China	by air
Class Osteichthyes	bony fish	-	2	≥2	Vic, Qld	China	by air and ship

1. It is assumed these incidents relate to stowaways, since cross referencing with Customs smuggling records only revealed three incidents common to AQIS and Customs datasets (these three incidents were excluded from this table). All data were provided by AQIS unless otherwise indicated (see notes 5, 7-9). Precise numbers of animals were not provided in AQIS records. Data on well-established species (*Columbia livia, Felis catus, Mus musculus, Passer domesticus, Passer montanus* and *Rattus rattus*) are excluded.
2. Establishment Risk Score calculated for birds and mammals from Bomford (2008, p19). Probability of establishment calculated for reptiles and amphibians at species level only, using Bomford et al (2009) and instructions of Bomford (2008, p55).
3. 'Prop.genus' value used to calculate probability of establishment (see Methods section).
4. 'Prop.family' value used to calculate probability of establishment (see Methods section).
5. Source: M. Tyler, personal communication.
6. No 'family random effect' value available for Microhylidae or Rhacophoridae so substituted average 'familyre' value to calculate probability of establishment (see Methods section).
7. Source: White and Shine (2009).
8. Source: Tyler and Knight (2009).
9. Source: Tyler and Chapman (2005).

About three quarters of AQIS interception incidents (699 incidents, 76%) involved stowaways from sea arrivals (including at least 401 reptile, 156 bird, 120 amphibian, 21 mammal and one fish incident). Approximately one fifth (218 incidents, 24%) of the interceptions were from air arrivals (including at least 143 reptile, 59 amphibian, eight bird, and five mammal and three fish incidents). Only five incidents (approx. 0.5%) involved interceptions from international mail (four reptile incidents and one mammal incident). At least 80% of the interceptions where living/dead status was recorded (631 of 780 incidents) involved live animals.

Many AQIS-reported stowaway animals arrived in personal belongings: 'personal effects' and 'baggage' were the most frequently recorded commodities (82 incidents, or 12%) in the 706 AQIS incidents where a specific commodity was detailed. Machinery (52 incidents, 7%) and plant material (37 incidents, 5%) were other specified commodities. Other listings only recorded much more general commodity terms such as 'boat/ship, 'container', 'animal residue', 'live animal', and 'infestation'.

By far the most commonly intercepted stowaways identified to species level were Asian house gecko (*Hemidactylus frenatus*, 188 incidents) and black-spined toad (*Bufo melanostictus,* 71 incidents). The next most frequent species were cane toad (*Bufo marinus*), flat-tailed gecko (*Hemidactylus platyurus*), Tokay gecko (*Gekko gecko*), and Asiatic painted frog (*Kaloula pulchra*), each with 10–22 recorded incidents. Stowaways were reported from a large variety of source regions (Africa; China/Taiwan; Europe; India; Middle East; North, South and Central America; Pacific and southeast Asia). Of the 704 AQIS incidents in which a source country was reported, the most common sources were Indonesia (112 incidents), Thailand (72 incidents), China (63 incidents), United States (63 incidents) and Singapore (51 incidents).

3.3 Data trends over the decade

All detection data for which a date was provided was compared between years, to determine whether any obvious trends exist (Table 5; note these data include reports of established species to reflect reporting effort).

For animals that have not established in Australia and were reported at large over the decade, there was a significant increase in the number species (for analysis, see Henderson et al, in press). For animals seized and surrendered post border, there was a significant peak (Henderson et al, in press) in the number of incidents and species reported in 2004, the year of a national Exotic Reptiles Amnesty.

The number of recorded smuggling incidents showed a general decrease over the decade, but there was no significant difference in the number of species detected (for analysis, see Henderson et al, in press). The number of animals smuggled per year fluctuated with no clear pattern.

For stowaway interception reports, there was a slight peak apparent in 2007, but there was no significant difference in the number of species detected per year (for analysis, see Henderson et al, in press). However, only about half (47%) of the AQIS incident reports had the animal identified to species level.

Table 5. Numbers of reports, species and animals per year for all data specifying a date

Data category	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
At large:											
no. reports	≥2	≥9	≥10	≥19	≥20	≥22	≥34	≥32	≥40	≥65	≥90
no. species	2	7	3	8	9	11	≥9	8	13	11	18
no. animals	≥1	≥25	≥15	≥78	≥83	>55	>158	≥111	≥116	≥118	≥269
Seizures/ surrenders post-border:											
no. reports	3	5	19	27	35	62	22	37	16	22	33
no. species	6	3	13	12	20	≥23	10	14	9	≥9	≥14
no. animals	15	7	≥62	66+11 eggs	≥187 +5 eggs	215	62+27 eggs	80	≥36 + ≥4 fish	40	216 + unknown fish
Illegal imports:											
no. reports	18	19	10	13	5	11	14	6	4	8	7
no. species	12	≥12	≥8	8	4	9	13	12	≥6	≥7	≥12
no. animals	78 animals + 548 fish	132 + 85 fish	27	≥50 + 915 fish	15 + 2920 fish	136 + 1200 fish	53 + 1459 fish	33	26	28 + 15 fish	86 + 1 fish
Stowaways:											
no. reports	-	-	-	-	49	129	147	107	170	152	127
no. species	-	-	-	-	≥12	≥17	≥19	≥17	≥26	≥21	≥22
no. animals	-	-	-	-	≥57	≥137	≥148+ ≥1 fish	≥112	≥177+ ≥1 fish	≥160	≥130+ ≥1 fish

These data were tabulated to reflect reporting effort and include all reports specifying a year, including data on well-established species.

4. Discussion

There are many examples of exotic species becoming naturalised in Australia following localised incursions. Examples include red-eared slider turtles (*Trachemys scripta elegans*, Kraus 2009), Asian house geckos (*Hemidactylus frenatus*, Newberry and Jones 2007), ostrich (*Struthio camelus,* Bomford and Hart 2002) and five-striped palm and grey squirrels (*Funambulus pennanti and Sciurus carolinesis,* Peacock 2009). Estimates place the number of exotic freshwater fish that have established in Australian via the ornamental fish trade between 22 and 30 species (Lintermans 2004, Corfield et al 2008). Aviary-released birds have also established wild populations (eg Australian mainland natives in Tasmania (Driessen et al 2006). Of the 81 species or more of exotic vertebrates established in the Australian environment, over 30 are pests (Bomford and Hart 2002). Shine et al (2000) suggest that for management purposes every exotic species should be treated as potentially invasive, unless otherwise indicated.

The global trade in wildlife involves billions of live animals, with animals being collected from wild populations in more than 190 countries around the world, and many others being bred in captivity, primarily to supply the demand for pet and hobby animals (Smith et al 2009). It is inevitable that there will be increasing interest in importing exotic wildlife into Australia, by both legal and illegal means. Our study has demonstrated that a wide range of exotic vertebrates has been detected in the environment as individuals or populations. The number of species reported at large has significantly increased between 1999 and 2009 (Henderson et al, in press). Even more species have been intercepted as sources of potential environmental incursions (seized, surrendered, stolen, smuggled and stowaway animals). Statistical analysis of our data for species not established in Australia demonstrates that of all the terrestrial vertebrate taxa, reptiles pose the most significant risk of establishment (Henderson et al, in press). Although Henderson et al were unable to include fish in their analyses, freshwater fish probably pose an even higher risk of establishment than reptiles, based on their recent establishment history and the number of exotic fish species detected at large (Lintermans 2004, Corfield et al 2008, Bomford et al 2010). Of the four detection categories (or introduction pathways), we assessed stowaways as posing the highest risk for new species establishing for terrestrial vertebrates (Henderson et al, in press) and illegal imports posing the highest risk for fish.

4.1 Species with a high risk of establishment

The species that pose the highest risk of establishing new exotic populations are those with a high establishment risk rank (ERR) that are also detected in multiple incidents or involving high numbers of individuals. Propagule pressure (numbers of individuals released and numbers of release events) is the factor most strongly associated with establishment of exotic vertebrates (Hayes and Barry 2008, Lockwood et al 2009).

Many species that were frequently sighted within Australian borders had extreme or serious ERRs. Species that are not currently established but were detected in multiple jurisdictions and/or in multiple detection categories include: barbary doves (*Streptopelia risoria*), boa constrictors, corn snakes (*Elaphe guttata*), ferrets (*Mustela putorius*), green iguanas (*Iguana iguana*), house crows (*Corvus splendens*), Indian ringneck parakeets (*Psittacula krameri*), leopard geckos (*Eublepharis macularius*) and veiled chameleons (*Chamaeleo calyptratus*). The multiple reports indicate these species are likely kept in high numbers around the country and should be high priorities for future surveillance and compliance efforts.

Species with extreme or serious risks of establishment have also been repeatedly intercepted at the national border by Customs and AQIS. Such smuggled species include: corn snakes, eastern kingsnakes (*Lampropeltis getula*), Horsefield's tortoises (*Testudo horsfieldii*), rainbow boas (*Epicrates cenchria*) and red-eared sliders. High-risk stowaway species frequently intercepted include Asian house geckos, Asiatic painted frogs (*Kaloula pulchra*), black-spined toads (*Bufo melanostictus*), cane toads (*Bufo marinus*), flat-tailed house geckos (*Hemidactylus platyurus*) and Tokay geckos (*Gekko gecko*). Many extreme-ranked species were also reported by AQIS in single interception incidents. All the serious and extreme ERR species should be high priorities for future pre- and post-border surveillance.

There are estimated to be over 20 million pet fish kept in Australia (McNee 2002). The rate of establishment of exotic freshwater fish species in Australia is increasing: nine species of exotic freshwater fishes had established by 1967, 19 species by 1997 and 34 species by 2004 (Lintermans 2004). Many of the species currently kept as ornamentals and pets in aquaria and

garden ponds have the potential to establish in the wild (Natural Resource Management Ministerial Council 2006).

4.2 Species with high pest potential

Many of the species listed in this report have been ranked by the Vertebrate Pests Committee (VPC) on a rudimentary level for their risk of establishing populations, their risk to human safety and their risk of becoming a pest (VPC 2006). These three assessments are combined to assign an overall pest potential, with a VPC Threat Category of extreme, serious or moderate. Rigorous scientific assessments have been conducted for about 130 exotic species (some of which are not listed by VPC 2006; for example see Massam et al 2010).

Exotic mammals ranked as extreme pest threats that were reported at large include: red (*Cervus elaphus*) and fallow deer (*Dama dama*), ferret, pygmy hippo (*Hexaprotodon liberiensis*) and five-striped palm squirrels (VPC 2006, Massam et al 2010). The blackbuck (*Antilope cervicapra*) is also a significant pest concern: it has a serious ERR and a high climate match to northern Australia (Figure 1). An unknown number of blackbuck were reported as seized or stolen from private keeping (Table 2). Blackbuck are native to the Indian subcontinent and in the past when the species was abundant and widespread in India it was hunted as a pest because it raided crops. Large exotic populations of blackbuck are established in Argentina and Texas in the United States, and blackbuck also established in the wild in Western Australia last century, but later became extinct (Long 2003). A small number of illegally released blackbuck persisted in Cape York Queensland before being eradicated (Csurhes and Fisher 2010).

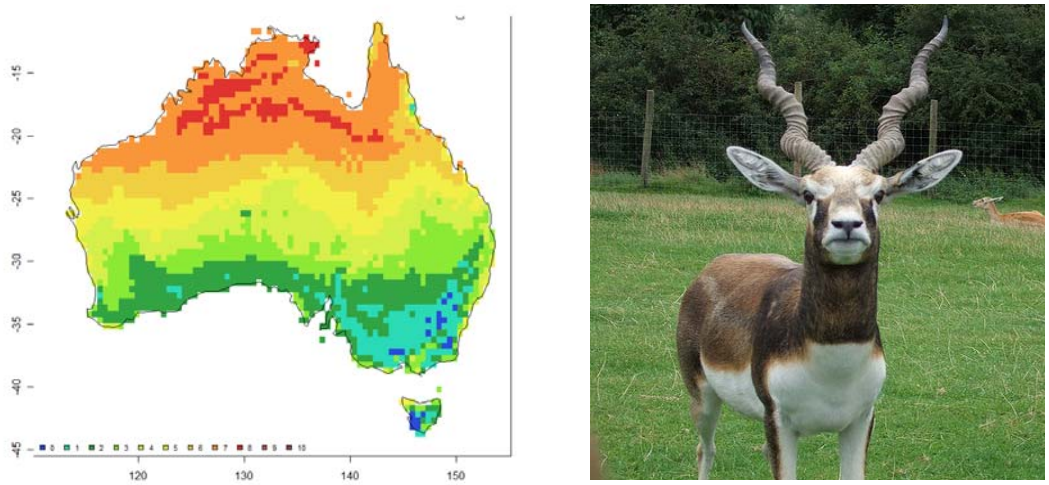

Figure 1. CLIMATCH output (left) for blackbuck *Antilope cervicapra* (right) in Australia. Light orange and hotter colours (representing areas with Level 6 and better climate matching) are likely suitable for a species to establish and spread if other habitat factors (suitable food supply, breeding and shelter sites, and low predator and competitor pressure) are favourable (Bomford 2008, Bomford et al 2009). *Photo: Flickr* (http://www.flickr.com/photos/demoncheese/4327084447/).

Birds of extreme pest threat reported at large include Canada geese (*Branta canadensis*), common mynas (*Acridotheres tristis*), Indian ringneck parakeets, Alexandrine parakeets (*Psittacula eupatria*) and Indian peafowl (*Pavo cristatus,* VPC 2006). Blackbirds (*Turdus merula*), house crows, pigeons (*Columba livia*), sparrows (*Passer domesticus* and *P. montanus*) and starlings (*Sturnus vulgaris)* are extreme threat species (VPC 2006) reported in western and

northern states where they are less common than eastern Australia. The Indian ringneck parakeet is a noisy species with a loud squawking call that is native to the Indian sub-continent and central Africa. It has established many exotic populations in Europe, the Middle East, the Americas and Japan. The species has a high climate match to much of northern Australia and coastal areas on the rest of the continent (Figure 2) and has a serious ERR. The Indian ringneck readily adapts to living in both urban and agricultural areas. This species is widely kept in Australia as a cage bird and there were 96 incidents of it being reported at large (Table 1), and two reports of it breeding in the wild in Western Australia (DAFWA 2007). The species is a major pest of agriculture in both its native and introduced range, raiding grain and oilseed crops and storages and also many types of fruit and nut crops. It has the potential to cause economic damage in Australia and also to compete with native parrot species for nest holes and food (DAFWA 2007).

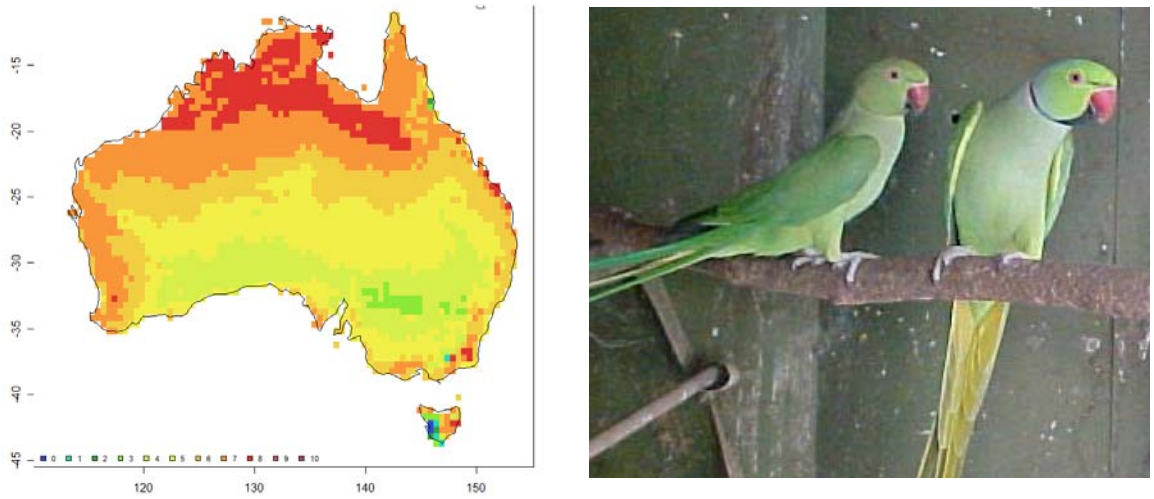

Figure 2. CLIMATCH output (left) for Indian ringneck parakeet *Psittacula krameri* (right) in Australia. Light orange and hotter colours (representing areas with Level 6 and better climate matching) are likely suitable for a species to establish and spread if other habitat factors (suitable food supply, breeding and shelter sites, and low predator and competitor pressure) are favourable (Bomford 2008, Bomford et al 2009). *Photo: Arthur Orford.*

Extreme pest-threat amphibians reported at large include cane toads and black-spined toads (VPC 2006, Massam et al 2010). The black-spined toad was detected at large at least twice (Table 1) and was also intercepted at least 75 times as stowaways in four states (*B. melanostictus* Table 4). Our risk assessment showed that this toad has a high climate match to the northern half of Australia (Figure 3). It has a broad diet, is very adapatable, can invade urban areas and secretes toxins, giving it the potential to be both a social and an environmental pest in Australia (Page et al 2008, Massam et al 2010). The Asiatic painted frog is another amphibian with extreme pest potential (Massam et al 2010). This species was intercepted at least 20 times in four states (*K. pulchra* Table 4).

Red-eared sliders are an extreme pest-threat reptile (VPC 2006) frequently reported in multiple detection categories. We obtained detection records for >27 individuals at large across four states (*T. scripta elegans,* Table 1), ≥115 individuals (plus 27 eggs) seized, surrendered or stolen from private keeping (Table 2) and possibly >60 animals smuggled into the country (Table 3). This species is listed by the International Union for Conservation of Nature on its *'100 of the World's Worst Invasive Alien Species'* list (Lowe et al 2000) because of its pest potential. *T. scripta* has an

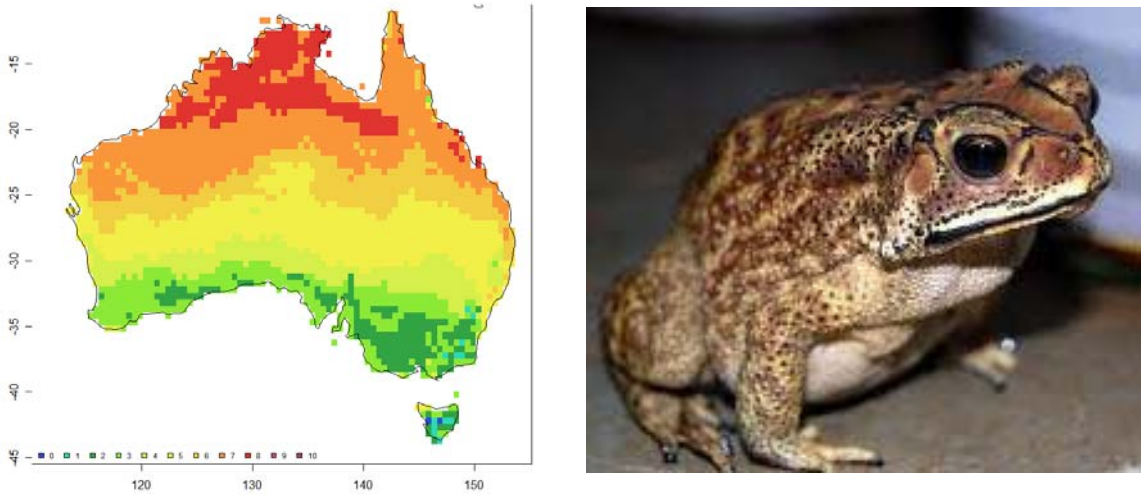

Figure 3. CLIMATCH output (left) for black-spined toad *Bufo melanostictus* (right) in Australia. Light orange and hotter colours (representing areas with Level 6 and better climate matching) are likely suitable for a species to establish and spread if other habitat factors (suitable food supply, breeding and shelter sites, and low predator and competitor pressure) are favourable (Bomford 2008, Bomford et al 2009).*Photo: Flickr* (*http://www.flickr.com/photos/digitalclickclick/1257570018/).*

extreme ERR and a high climate match to nearly 98% of the Australian continent (Figure 4). It has established exotic populations on all the world's major continents except Antarctica. *T. scripta* can aestivate to help survival during drought, hot spells and bushfires and can move at least 1.6 kilometres away from permanent water (Franklin 2007). Therefore, the species has the potential to spread right across Australia wherever freshwater habitats are available. Breeding populations have been discovered in both New South Wales and Queensland, and while eradication is being attempted, the outcome is as yet uncertain (O'Keefe 2006). Once established, *T. scripta* could compete aggressively with native turtles for food, basking sites and nesting sites and also prey on hatchlings of native species (DAFWA 2009).

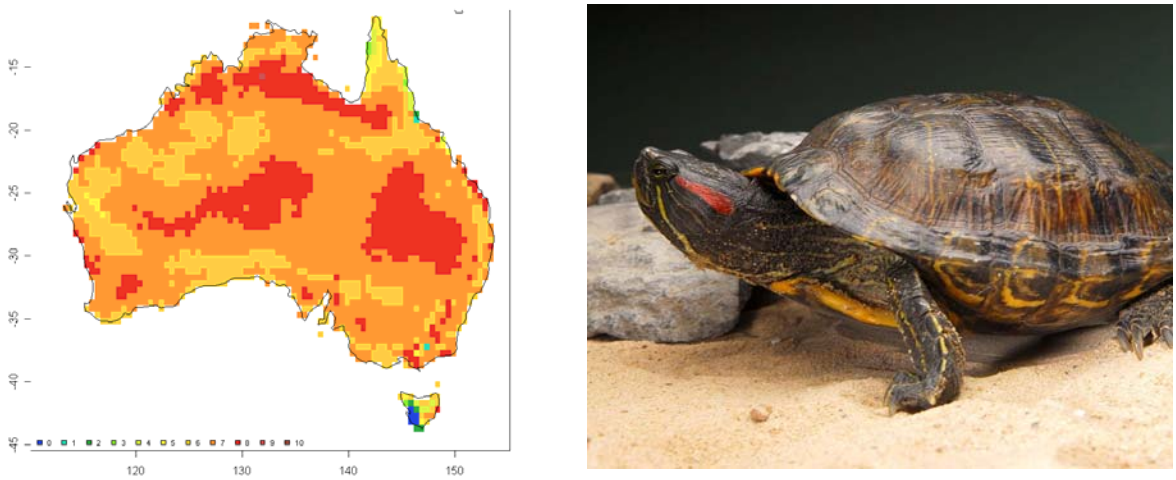

Figure 4. CLIMATCH output (left) for red-eared slider *Trachemys scripta* (right) in Australia. Light orange and hotter colours (representing areas with Level 6 and better climate matching) are likely suitable for a species to establish and spread if other habitat factors (suitable food supply, breeding and shelter sites, and low predator and competitor pressure) are favourable (Bomford 2008, Bomford et al 2009). *Photo: Biosecurity Queensland, Dept of Employment, Economic Development & Innovation.*

Due to the high potential for *T. scripta* to spread and cause harm, we recommend eradication attempts be treated as urgent and given adequate resources wherever the species is detected at large. If new populations are not eradicated soon after their establishment the probability of success is likely to be extremely low. Public awareness about this species in Australia is currently low. We recommend priority be given to educating the public, particularly through media coverage, about the risks posed by red-eared sliders, so that people are less likely to keep or release them, and are more likely to recognise and report sightings.

Corn snakes, another reptile frequently reported in multiple detection categories, are considered to pose a serious pest threat to Australia (Massam et al 2010). This species was reported multiple times in multiple jurisdictions, at large and seized/surrendered (*E. guttata,* Tables 1 and 2). Our assessment shows that *E. guttata* has a high climate match to most of the Australian mainland (Figure 5). It is a generalist predator that preys on a wide range of insects, amphibians, lizards, small mammals and birds and has the potential to become a widespread and abundant invasive pest in Australia (Fisher and Csurhes 2009). *Boa constrictor* is another serious-threat species repeatedly taken from illegal keeping (153 individuals were taken or surrendered, Table 2). This snake has a very high climate match to the northern half of Australia (Figure 6) and has the potential to harm people, and domestic and native animals that may become prey (Massam et al 2010).

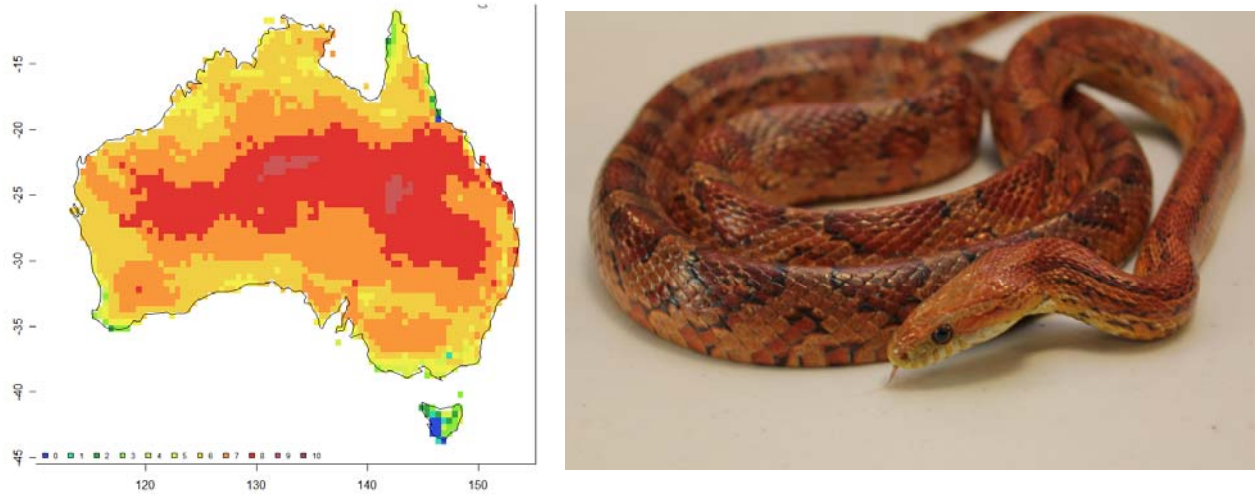

Figure 5. CLIMATCH output (left) for corn snake *Elaphe guttata* (right) in Australia. Light orange and hotter colours (representing areas with Level 6 and better climate matching) are likely suitable for a species to establish and spread if other habitat factors (suitable food supply, breeding and shelter sites, and low predator and competitor pressure) are favourable (Bomford 2008, Bomford et al 2009). *Photo: Vic Dept Sustainability and Environment.*

The green iguana (*Iguana iguana)* is a reptile with an extreme ERR and a high pest potential that was detected in multiple incidients in multiple pathways/categories. There were 10 incidences of this species being kept illegally in Australia (Table 2), two incidents of it being smuggled (Table 3) and two incidents of it as a stowaway (Table 4). One female *I. iguana* was recently (April 2011; not included in our dataset) captured at large in Townsville Queensland, presumed a released or escaped pet (S. Csurhes, Biosecurity Queensland, pers comm). Our assessment showed *I. iguana* has a high climate match to much of northern Australia and coastal areas on the rest of the continent (Figure 7). It occurs in high concentrations in established exotic populations in

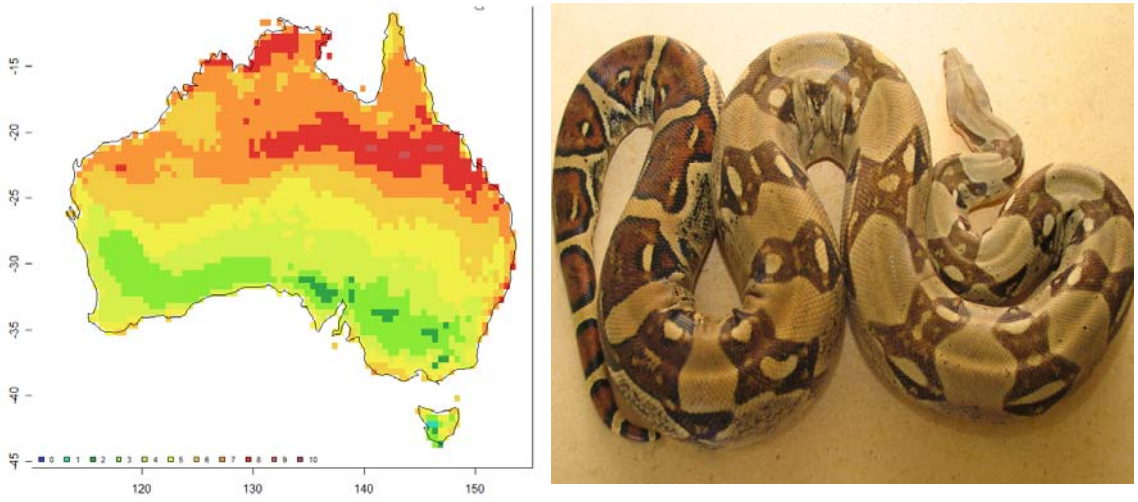

Figure 6. CLIMATCH output (left) for *Boa constrictor* (right) in Australia. Light orange and hotter colours (representing areas with Level 6 and better climate matching) are likely suitable for a species to establish and spread if other habitat factors (suitable food supply, breeding and shelter sites, and low predator and competitor pressure) are favourable (Bomford 2008, Bomford et al 2009). *Photo: Vic Dept Sustainability and Environment.*

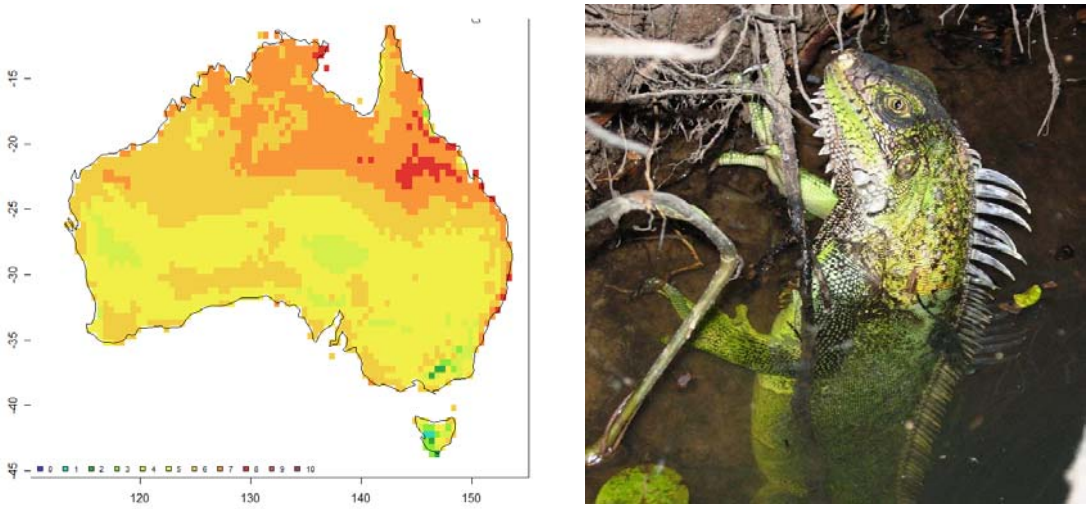

Figure 7. CLIMATCH output (left) for green iguana *Iguana iguana* (right) in Australia. Light orange and hotter colours (representing areas with Level 6 and better climate matching) are likely suitable for a species to establish and spread if other habitat factors (suitable food supply, breeding and shelter sites, and low predator and competitor pressure) are favourable (Bomford 2008, Bomford et al 2009). *Photo: Elizabeth A Roznik.*

Florida, where it damages garden plants, is a dispersal agent for invasive plants (it eats and defecates seeds), and also uses the nesting sites of the native burrowing owl *Athene cunicularia* (McKie et al 2005, Meshaka et al 2007). *I. iguana* has a broad diet, preying on insects, lizards and other small animals, nestling birds and eggs. It also digs large burrows that cause soil erosion and undermine sea and canal walls (Meshaka et al 2007). *I. iguana* is also reported to pose an airstrike hazard (Engeman et al 2005, Meshaka et al 2007) and large adults can inflict powerful bites and scratches on people.

Many of the exotic ornamental fish species that are kept in Australia have the potential to cause extinctions of native fish species and other environmental harm should they establish and spread in the wild (Arthington et al 1999, Natural Resource Management Ministerial Council 2006, Corfield et al 2008). Unfortunately, because few fish were identified to species level in the records we obtained, we were unable to assess the pest potential posed by the large numbers of fish detected, particularly intercepted as illegal imports.

The VPC is in the process of developing national surveillance and eradication lists for high pest-risk species, to facilitate a coordinated response to future incursions. We recommend the species included in this section be considered for addition to these national lists as appropriate. We further recommend that a national approach be taken to reduce the risk of new aquarium fish establishing in Australia, including risk assessments to determine establishment and pest potential for potentially noxious species currently kept in Australia, and that VPC consider adding high-risk fish to the national lists.

4.3 Disease risk

Although the risk of exotic diseases from illegal and accidental introductions was not covered by our study, it should not be underestimated. Imported animals can carry diseases that affect livestock, native wildlife and people (Smith et al 2009). One example is the 2003 monkeypox virus outbreak affecting at least 72 people in the United States, resulting from the import of African rats for pets (Smith 2009). Green tree pythons (*Chondropython viridis*), detected in an Australian smuggling incident, were found to contain a novel ranavirus that could have harmed native snake species (Hyatt et al 2002). In New Zealand, smuggled lizards were found to carry *Salmonella* and protozoa not previously found in that country (Derraik and Phillips 2010). Pythons kept in captivity are known carriers of inclusion body disease, which can infect native species (Carlisle-Nowak et al 1998). The pet trade in tadpoles is reported to be facilitating the spread of the chytrid fungus *Batrachochytrium dendrobatidis* (devastating to many amphibian species) around New Zealand (Derraik and Phillips 2010). Ectoparasitic mites (potential disease vectors) were noted on 17% of stowaway geckos entering New Zealand (Gill et al 2001). The keeping of exotic pets is one factor identified as contributing to the emergence of zoonotic diseases which affect both animals and humans (Chomel et al 2007). Illegal trade of exotic wildlife, both terrestrial and aquatic, has been shown to directly result in the introduction or spread of many different pathogens (Kahn et al 1999, Karesh et al 2007, Corfield et al 2008, Gomez and Aguirre 2008, Biosecurity Australia 2009).

4.4 Issues with private keeping

The pet trade, intentional releases and exhibit releases (escapes or thefts) combine to form the primary pathways by which exotic reptiles and amphibians have been transported and naturalised in recent decades (Kraus 2009). Releases have been mostly either deliberate or due to failure to keep animals securely contained (Kraus 2009). The aquarium trade and hobbyists have been the primary source of exotic freshwater fish that have established in Australia in recent decades (Lintermans 2004). Pet abandonment has become one of the most challenging pathways to address in biosecurity (Secretariat of the CBD 2010).

The illegal pet trade continues to be a significant problem source of potential incursions. Online trade has opened a new and accessible avenue to facilitate the illegal trade of pets, presenting an increasing threat to biosecurity (Derraik and Phillips 2010). The housing of exotic pets in low-

security conditions will inevitably lead to accidental or deliberate releases, particularly if these species are dangerous or become large and/or difficult to keep. Buyers' awareness of what species are permitted is also a problem in some cases. Public education and government pressure to post information on internet purchasing sites may help with issues of awareness, but the task of regularly monitoring internet transactions is probably beyond government capacity.

A contingent of knowledgeable illegal traders persists. Australia prohibits the trade of all exotic herpetofauna, but a recent study on illegally traded reptiles revealed dangerous species such as alligators, cobras, vipers and rattlesnakes are being privately kept, and that the majority of trade occurs between breeders within Australia rather than smuggling new imports (Dustin Welbourne, Canberra Reptile Sanctuary, pers comm). Our data from seizures/surrenders from private keeping demonstrate the popularity of reptilian species such as Burmese pythons (*Python molurus*), corn snakes, king snakes, boas (various *Boa*), iguanas, leopard geckos and red-eared sliders. Our study assessed many of these as having a serious or extreme risk of establishment. Multiple incidents in multiple Australian states suggest the chance of future environmental release of these species from irresponsible pet ownership is high.

The establishment of Burmese pythons in Florida (United States) is believed to have stemmed from the release of a small number of founder snakes (Wilson et al 2010), probably unwanted pets. This species is now a significant pest in the Everglades region, threatening local wildlife and public safety. Over 1680 snakes have been removed from Everglades National park since 2000 (US Department of the Interior 2011). This example demonstrates how a small propagule can result in a significant pest problem given the right conditions. Wilson et al (2010) also state that for pythons and other species with low inherent detection probabilities, action during early phases of an invasion is critical for preventing pest establishment.

The keeping of legal but high-risk species under inappropriate security is another problem that needs to be addressed. The *Guidelines for the Import, Movement and Keeping of Exotic Vertebrates in Australia* (NRMSC 2004) state that extreme-ranked species should not be permitted into the country, although in reality such species are occasionally permitted for import and keeping, and many high-risk species are already kept here. Indian ringneck parakeets are one example of a legal, extreme pest-threat species that has previously established populations in the wild from aviary releases (DAFWA 2007). Many ornamental fish species that have high pest potential or that have not had their pest potential assessed are also kept and traded and there is no consistency between mechanisms or controls across regulatory agencies to deal with the serious issue of noxious aquatic pests, with the exception of a few species (Natural Resource Management Ministerial Council 2006). We recommend governments consider restricting/phasing out the private ownership of known high-risk species already in the country, where this is considered feasible.

Those who benefit from the import and keeping of exotic species are usually not those who bear the costs of control/eradication attempts or other consequences if animals establish pest populations following escapes or releases. Rather, invasive species eventually end up costing society in general (Perry and Farmer 2011). A mechanism addressing these issues is outlined by Perry and Farmer (2011), focusing mainly on initiatives at the local level. They propose that funds collected from the trade could support (1) a national resource centre; (2) professional local education and response teams, focusing on pet store owners, hobbyist organisations, and first responders; (3) incentives to encourage pet stores to take back unwanted animals; (4) a tracking system for identifying and penalising owners of released animals; and (5) a rapid-response

system in the event of a release. These authors focussed on reptiles and amphibians, but similar principles could be applied to other exotic taxa.

In addition to these private-keeping issues, there are issues regarding the security of containment at zoos and pet shops, demonstrated by thefts and escapes reported in the media. The keeping of high-risk animals for research purposes is also contentious amongst some pest-management agencies. Tension exists between zoo owners, researchers and other stakeholders requesting exotic animal imports, and pest management/environmental agencies wanting to prevent perceived unnecessary risks. The Zoo and Aquarium Association (ZAA) is collaborating with the VPC and working on improving current policies and practices for exotic species management. This is a commendable step forward, as nationally agreed standards for secure facilities, compliance audits of these facilities, and contingency planning for response to animal escapes, will improve trust and transparency between the different stakeholders, and improve biosecurity outcomes.

4.5 Smuggling and stowaways

In contrast to many other countries, current legislation and particularly pre-import screening related to live imports arriving in Australia is proactive and well developed (Secretariat of the CBD 2010). However, stowaways and smuggling across the Australian border remain significant pathways of introduction. Customs data from the past decade show a steady number of species continue to be detected in smuggling incidents, particularly bird eggs concealed on people, and reptiles concealed in mail or luggage items. Smuggling of aquarium fish is increasing, with an estimated 600,000 fish or more being illegally imported in each year (Lintermans 2004). Most smuggling reports in this study originated from interceptions in Sydney. This is perhaps not surprising, given Sydney airport receives Australia's highest international passenger traffic and most international mail and sea cargo (BITRE 2007, Airports Council International 2011). We recommend vigilance by border protection agencies and post-border pest management agencies be continually supported to limit the success of illegal animal trade via this route.

Alacs and Georges (2008) assessed the scale and enforcement of wildlife crime in Australia between 1994 and 2007. Most seizures were minor, with less than 1% resulting in prosecution of the people involved. Of cases prosecuted, a third were for attempted import, with reptiles targeted most (43% of import cases), then birds (26%). Most prosecutions resulted in a fine only, and this was consistently less than the black-market value of the seized animals. Although prison sentences increased over the period studied, prosecutions generally brought lower consequences than in other countries, despite Australia having stricter legislation (Alacs and Georges 2008). The maximum allowable penalty for smuggling wildlife is a fine of $110,000 and/or 10 years prison. Failure to declare animals or goods can result in a fine of up to $66,000 or 10 years prison. Available reports showed the highest penalty actually received was $10,000 and two years in prison for smuggling 23 eggs of a rare species (Alacs and Georges 2008). However, penalties are generally substantially lower than this example. We recommend better education of traders and the judiciary, and stronger penalties, to more effectively deter future wildlife smuggling, decreasing the risk of more exotic animals entering Australia.

AQIS data indicated that three quarters of the reported stowaways arrived by sea, and a significant number (12%) were associated with travellers' personal belongings. Most reported interceptions (80%) involved live animals. In addition, almost a fifth (19%) of AQIS vertebrate records were reported from post-quarantine detection points, providing an indication of reports

from the general public once they have passed the border. Analysis of data presented here indicates that the stowaway pathway presents the greatest current risk of predicted establishment (Henderson et al, in press). Faster transport vehicles and increasing international trade and travel will inevitably lead to increasing numbers of stowaways arriving at the border. Continued public awareness campaigns and border vigilance are obviously of genuine benefit to Australia's biosecurity. We also recommend educating border personnel about high-risk vertebrate species, including the importance of identifying and reporting intercepted animals.

4.6 Risk assessment modelling

Predicting species invasions is complex, with many scientific uncertainties regarding whether species will establish or spread and their potential impacts (Leprieur et al 2009). Risk modelling cannot absolutely determine whether or not an introduced exotic species will establish a wild population, or if it does, what impact it will have (Aquatic Nuisance Species Taskforce 1996). The best that can be achieved is to estimate the likelihood that a species will establish and its potential to cause harm. There can be no certainties about which species could establish and become pests if they are released. Due to uncertainties in the process and the potentially costly and irreversible consequences of mistakes (particularly where subjective judgements must be made), we support Leprieur et al's (2009) recommendation that a precautionary approach be taken to the keeping and import of all species with high pest potential.

We recommend an audit of existing scientific risk assessments in the various Australian biosecurity agencies. We also recommend revised assessments on species on the VPC list that have not been subjected to independent scientific risk assessments. Many fish species in the ornamental fish trade are not on the current national permitted species lists and have not been assessed for potential risk to the Australian environment (Moore et al 2010).

We also recommend that these risk assessments include the feasibility of eradicating newly established populations. The chance of successful eradication is determined by many variables (Bomford and O'Brien 1995, Simberloff 2003, Bomford 2008) but some species have attributes that can make eradication extremely difficult. For example, *Chelydra serpentina* is a large snapping turtle which has an extreme ERR and a high climate match to much of southern and central Australia (Figure 8). This species has been kept illegally in Australia (Table 2). Eradication could be difficult because snapping turtles are crepuscular or nocturnal, dull coloured and relatively secretive, and spend most of their time underwater lying on the bottom, making them difficult to detect (Franklin 2007). In winter they burrow deep into the mud at the bottom of ponds to hibernate. Their clutch size of 20–30 eggs gives them the potential for rapid population growth (Franklin 2007). Hence this species is unlikely to meet the criteria required for successful eradication listed by Bomford and O'Brien (1995). Another example, the corn snake, is highly mobile and has the ability to hide under any object and to climb trees, making detection difficult (Fisher and Csurhes 2009). If this species established in the wild, early detection and eradication would be highly unlikely. Such species should be given a high priority for biosecurity-related activities.

4.7 National awareness raising

A priority to reduce the frequency of intentional and accidental releases is the development of targeted and well-resourced public education programs (Wittenberg and Cock 2001, Lintermans 2004). Improved public education is needed on which species can be legally kept and about the

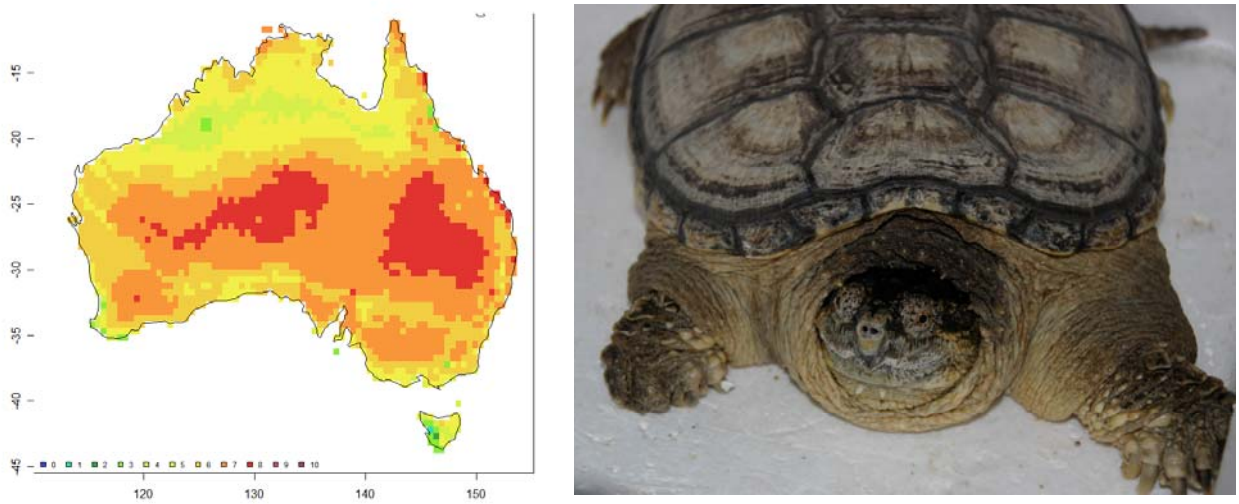

Figure 8. CLIMATCH output (left) for common snapping turtle *Chelydra serpentina* (right) in Australia. Light orange and hotter colours (representing areas with Level 6 and better climate matching) are likely suitable for a species to establish and spread if other habitat factors (suitable food supply, breeding and shelter sites, and low predator and competitor pressure) are favourable (Bomford 2008, Bomford et al 2009). *Photo: Vic Dept Sustainability and Environment.*

environmental consequences of releasing exotic species into the wild. Issues include responsible pet ownership, appropriate management of permitted species, use of courier services (eg taking precautions to avoid interstate stowaways), and reporting or surrendering of illegal animals, particularly high-risk species.

Public awareness about the environmental consequences of releasing aquarium fish is currently low. Between 12 and 14% of Australians are thought to keep aquaria and there are estimated to be around 2000 species in the ornamental fish trade nationally, most of which are exotic to Australia (Corfield et al 2008, Moore et al 2010). It is inevitable that some of these ornamental fish get released into natural waterways. We support the communication strategy developed by Moore et al (2010) for engaging the ornamental fish trade on the issue of proper disposal of unwanted fish. We recommend priority be given to publicity on the potential harm caused by releasing exotic aquarium fish and to educating people about acceptable alternatives for getting rid of unwanted fish.

National pest alerts (informative brochures) have been published for some key high-risk species: barbary dove, common myna, Canada goose, domestic ferret, house crow, Indian ringneck parakeet, Pacific rat (*Rattus exulans*), red-eared slider, red-whiskered bulbul and rusa deer (DAFWA 2007–2010). Alerts on other deer (including sambar *Cervus unicolor* and hog deer *Axis porcinus*) and squirrels (including grey squirrel *Sciurus carolinensis* and five-striped palm squirrel *Funambulus pennanti*) are currently being prepared. Information documents on some frequently seized species are also being developed through the Australasian Environmental Law Enforcement and Regulators Network (AELERT).

These communication efforts need to be supported and continued. Information should be disseminated to a wide range of groups including pest management agencies, pet traders, hobbyists, wildlife exhibitors/rehabilitators, couriers, dock/airport workers and the general public. Publicity on, and opportunities for, surrendering illegal or unwanted animals (rather than releasing them) may be useful. The National Exotic Reptile Amnesty held in 2004 (DEH 2004) is likely

responsible for the statistically significant increase we observed in numbers of species seized/ surrendered in that year compared to the rest of the decade (Henderson et al, in press).

Hotlines for the public to enquire about or report exotic animals detected at large, for sale and so on need to be adequately communicated and resourced. The National Animal Pest Alert Freecall number 1800 084 881 is a number agreed to by all states (through the VPC), although the states differ in what department the call goes to, and that department's procedure for handling such calls. It is actually a national Plant Health Australia number. Other related phone numbers are listed in Appendix 1.

4.8 Data consistency and information sharing

Our study shows the amount and quality of information on incursions, interceptions, seizures and surrenders varies significantly in different jurisdictions, reflecting the resources available for recording and collating it. Information made available for this study was often spread among several different agencies within a single jurisdiction, and information exchange between these agencies apparently lacked coordination. Of particular concern was the lack of records and identifications of fish in all four detection categories. We recommend better resourcing to allow improved documentation and coordination of information on all animal incursions/interceptions across the biosecurity continuum (at state/territory and federal levels).

These findings are consistent with Beale et al's (2008) review of Australia's quarantine and biosecurity systems, which highlighted problems with state/territory and Commonwealth agencies' biosecurity approaches. Of particular relevance to this study, a submission from Victoria stated that 'Disparities exist with regard to staffing levels, deployment, surveillance mechanisms and data management, and need to be addressed.' (Beale et al 2008, p16). Such disparities are clear from the differences in data quantity and quality we received.

The Beale review recommends increased resources for pre-border risk management and post-border monitoring, surveillance and management, which should help address some of these disparities. It recommends the establishment of a National Biosecurity Authority and states that:

> 'Risk management needs to be backed by strategic intelligence that is reliable and constantly updated. To support this, the National Biosecurity Authority should include an intelligence gathering unit, with a particular focus on the region and Australia's trading partners. The Authority should improve information gathering on border interceptions and also establish a post-border monitoring and surveillance program for national priority exotic pests and diseases.'

The Beale review also recommends improved collaboration between agencies pre- and post-border, specifically including national agreement on information sharing between jurisdictions:

> 'Recommendation 9: A National Agreement on Biosecurity…should provide for:... full and automatic information sharing between jurisdictions …including information collected through pre-border intelligence activities, border controls (such as interception data) and information gathered through monitoring and surveillance programs.'

Similarly, Recommendation 49 states that: 'The National Biosecurity Authority should work with other countries and the states and territories to share pest and disease intelligence…' Further, 'information and analysis obtained from pre-border, border and post-border biosecurity activities should be made available for use by state and territory governments, industry and research organisations. This should be…supported by a biosecurity risk information sharing protocol and

data sharing infrastructure' (Recommendation 54). Investment into redeveloping biosecurity information technology systems to enable such information sharing was also recommended (Recommendation 55).

While the Beale review stated connectivity with other border agencies (particularly Customs) is needed, we stress that connectivity between *all* relevant agencies is crucial to effective biosecurity – AQIS, Customs, other areas of DAFF, SEWPAC and state/territory agencies (environment and primary industry related). Existing networks such as AELERT could be better utilised to facilitate these connections. The newly established Australian Biosecurity Intelligence Network (ABIN) could play a key role in connecting agencies through a secure 'community space' or similar information technology structure. ABIN may provide a useful option for the management and storage of all detection information, possibly through use of the BioSIRT (biosecurity surveillance incident response and tracing) database. This database is currently being used in many states to centrally record emergency disease outbreaks, and even for more routine surveillance operations.

For pre-border information, AQIS and Customs could take a leading role in data coordination, in conjunction with SEWPAC and state/territory agencies, possibly through AELERT. AQIS has a national incidents database that contains records of border interceptions, although it tends to focus on plant pests and diseases, lacking strength in data on vertebrates. This could be better linked with Customs' and SEWPAC's information on smuggled animals that have been intercepted at the border, to provide useful data for biosecurity managers conducting risk assessments and pathway analyses.

With regards to post-border activities, we agree with Beale et al (2008) that it should be a priority to improve systems currently in place in the less well-resourced jurisdictions and to coordinate information at a national level. Arrangements for reporting outbreaks of priority pests and diseases are currently underway through the National Environmental Biosecurity Response Agreement. However, it is uncertain where species already present in the country will fit into this framework. Again, ABIN may provide a useful portal for securely recording post-border information of species detected at large or seized/surrendered from private keeping. Alternatively, the existing AELERT network's website may be an appropriate starting point to house a national list of post-border seizures and surrenders of illegal exotic species.

We recommend a single, central reporting point for all detection data (including incursions and interceptions) for Australia to enable the most effective biosecurity outcomes. Nationally agreed data fields and a single site for data storage should be a priority in the short term. In the longer term, biosecurity agencies should aim for a single data entry system that can be interrogated by different jurisdictions according to their needs.

4.9 National workshop on information management

Collaboration between the jurisdictions on the issues of nationally recording and sharing biosecurity information is occurring. As a follow-up action to this study, the IA CRC held a national workshop on information management for incursions and interceptions in Canberra on 13 April 2011. The workshop proceedings are provided in Appendix 2. It was agreed that data from all related jurisdictions should be regularly collated onto a secure centralised website, under the governance of the VPC, to enable information to be shared at a national level. The forum recommended that VPC write to constituent members to ask for data to be sent at least quarterly

to a VPC community space on ABIN, to build a national surveillance database by 2012. The quarterly submission should at least include the following fields, subject to further refinement:

- scientific name
- common name (linked list to scientific name to avoid confusion and error)
- number of animals
- sex of animal/s, if known
- form of animal/s, if known (juvenile, adult, egg)
- how animal was detected (in-wild observation; seizure from private premises, at airport, at seaport; stowaway at airport, at seaport; advert)
- status of animal/s when detected (live, dead, euthanased on seizure)
- location of incident (latitude/longitude if possible, or nearest town and postcode otherwise)
- date of incident
- submitter (including a departmental identifier)
- incident identification number
- pathway information (source country, known associated illegal activities, etc).

It was recommended that these fields be refined to a 'National Vertebrate Pest Animal Standard'. We suggest that an additional point be included to include the fate of the animal/s (eg rehoused in zoo, euthanased). These issues and actions should be progressed through the VPC.

5. Conclusion

Once an exotic species has been introduced to a new country, there is no such thing as zero risk of escape or release. The risk posed by an individual pet owner, hobby collector or zoo, who may keep just a few animals of any species will usually be small. However, when this risk is multiplied by hundreds or thousands of collectors and pet owners, and decades of keeping, then releases and escapes are inevitable. Every additional exotic species that is kept adds to the risk, especially species widely kept in low-security collections. Increasing numbers of escapes or releases drive up both propagule pressure and colonisation pressure (Hayes and Barry 2008, Lockwood et al 2009) and hence lead to new exotic species establishing. A review of the pest status of exotic vertebrates in Australia and elsewhere suggests that about half of species become pests following establishment (Bomford and Hart 2002, Bomford 2003).

When an exotic species establishes a breeding population, and numbers build up and spread beyond the area of introduction, eradication attempts will be expensive and unlikely to succeed (Mack et al 2000, Simberloff 2003, Keller et al 2007). No eradication campaign has ever been successful for any widespread, continental, exotic vertebrate population. In addition, eradication attempts may harm non-target species and face opposition by animal-rights groups (Myers et al 2000, Perry and Perry 2008). Dealing with an exotic species incursion should be rapid and comprehensive, as with dealing with an exotic disease outbreak; there are many parallels in the response process (Woolnough 2010).

This study has demonstrated there is a wide variety of exotic species intercepted entering Australia, and being kept or released illegally within our borders. Novel exotic species (that have not widely established) have also been detected at large, as individuals or small populations. Many of these species have potential to significantly impact the environment, economy or society. Some of the documented seizures from private keeping involved dozens of animals from a single

residence (such as corn snakes, boas, red-eared sliders and squirrels), showing immediate potential for high propagule pressure. The data we have presented is unlikely to be the whole picture, due to technical issues (eg database interrogation) or incomplete reporting systems. However, it is indicative of the range of exotic vertebrate species turning up in Australia and at the border.

Preventing incursions is by far the most cost-effective way to prevent future pest damage. A key action to prevent new pests is therefore to limit the chance of establishment by minimising the propagule pressure. Potential entry pathways need to be identified and policies introduced/ improved to reduce the threat they pose, including targeted education and possibly updating legislation and regulations (Hulme et al 2008). Preventing further high-risk imports destined for private keeping, and enforcing robust containment conditions on any high-risk exotics already here will help prevent new pest problems arising. The public needs to understand the importance of keeping animals secure, and of surrendering unwanted animals rather than releasing them. National agreement on pest species (dispensing with the inconsistencies between jurisdictions), and standardised, effective reporting of these species will also improve current practices. Better information exchange between agencies, continued vigilance pre- and post-border and public education will enable earlier identification of and response to potential threats. These are keys to detecting and preventing further incursions.

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Appendix 1. Phone numbers and pest animal alerts

Relevant phone numbers for each jurisdiction are listed below. Some states have dedicated resources to pest animal alerts and enquiries (eg Victoria and WA), while others are more general agency phone numbers.

National: National Animal Pest Alert Freecall 1800 084 881 is a national number used by all states, although the states differ in what department the call goes to, and that department's standard procedure for handling such calls. It is actually a national Plant Health Australia number.

ACT: Canberra Connect Ph 13 22 81.

Vic: DPI / DSE Customer Service Centre to report illegal import of animals Ph 136 186.

NSW: DPI Aquatic Pest hotline Ph 02 4916 3877, Environment Line 131 555.

NT: There are hotlines for Marine Wildwatch and Yellow Crazy ant detections, but no specific phone number for terrestrial animals.

Qld: Biosecurity Queensland Ph 13 25 23

SA: Ph 1800 084 881 is directed to the NRM Biosecurity Unit, Biosecurity SA via Plant Health in Primary Industries & Resources SA. Direct phone number for NRM Biosecurity Unit is 08 8303 9620.

WA: Ph 1800 084 881 is redirected to the Pest and Disease Information Service.

DAFF: Emergency Animal Disease Watch Hotline for pests and diseases (although this is primarily used to report disease) is Ph 1800 675 888.

Customs and Border Protection: Hotline for suspected smuggling activities is Ph 1800 06 1800.

AQIS: REDLINE for breaches of Australian quarantine, export or food inspection laws is Ph 1800 803 006.

Pest Alert brochures

National Animal Pest Alert brochures have been developed for a number of high-risk species: common (Indian) myna, house crow, Indian ringneck parakeet, domestic ferret, rusa deer and red-eared slider, Canada goose, red-whiskered bulbul and barbary dove. The alerts were produced with support of the Australian Government's Bureau of Rural Sciences and are endorsed by the VPC and relevant state and territory authorities. The brochures feature pictures and detailed descriptions of the pests, and information on their biosecurity, distribution, biology and risk management. The alerts are available on the website of the WA Department of Agriculture and Food (http://www.agric.wa.gov.au/PC_93140.html) and feral.org au (http://www.feral.org.au).

Appendix 2. Workshop Proceedings: Managing information on vertebrate incursions and interceptions at a national level

13 April 2011, Belconnen Premier Inn, Canberra

Summary

A national workshop was held by the Invasive Animals Cooperative Research Centre in April 2011, to work out how biosecurity-related agencies can nationally share information on incursions and interceptions of exotic vertebrates. Currently, there are inconsistencies in the type and amount of information collected by different jurisdictions, and this information is not generally shared between agencies. As a result, there is no national picture of exotic vertebrate incursions (animals found at large) and interceptions (animal seizures, surrenders and stowaways). The workshop aimed to recommend a standard for reporting and a centralised reporting point where information can be shared.

It was agreed that data from all related jurisdictions should be regularly collated onto a secure centralised website, under the governance of the Vertebrate Pests Committee (VPC), to enable information to be shared at a national level. The forum recommends VPC write to constituent members to ask for data to be sent at least quarterly to a VPC community space on ABIN, to build a national surveillance database by 2012. The quarterly submission should be in spreadsheet format, and at least the following fields should be included, subject to further refinement:

- scientific name
- common name (linked list to scientific name to avoid confusion and error)
- number of animals
- sex of animals, if known
- form of animals, if known (juvenile, adult, egg)
- status of animals (live, dead, euthanised on seizure)
- location of incident (latitude/longitude if possible, or nearest town and postcode otherwise)
- date of incident
- submitter (including a departmental identifier)
- incident identification number
- how animal was detected (in-wild observation; seizure from private premises, at airport, at seaport; stowaway at airport, at seaport; advert)
- pathway information (source country, known associated illegal activities, etc).

These fields should be refined to a National Vertebrate Pest Animal Standard.

Introduction

The Detection & Prevention Program of the Invasive Animals Cooperative Research Centre (IA CRC) held a national workshop to recommend improvements to managing incursion and interception information for exotic vertebrates. Specifically, the aims of the workshop were to recommend:

1. A standard for reporting interception and incursion data for all jurisdictions, including fields of data to record (identification, location, numbers, date, etc).
2. A central reporting point (eg secure GovDex site or community space within ABIN).
3. A system for routinely reporting and alerting interceptions and post border incursions nationally.

The workshop was held on 13 April 2011 in Canberra. Participants from biosecurity-related agencies of the Commonwealth, state and territory governments and New Zealand's Department of Conservation attended. Representatives of the Australian Biosecurity Intelligence Network

(ABIN), the National BioSIRT Program, Atlas of Living Australia (ALA) and Australian Registry of Wildlife Health (ARWH) presented on their various systems and options available to the group for managing information. A summary of the IA CRC projects involved with nationally mapping pest animals was presented. An explanation of the Australasian Environmental Law Enforcement and Regulators Network (AELERT) was also presented. Current processes and issues involved with recording and managing information on incursions and interceptions were discussed. The group proposed a path forward to improving consistency, security and sharing of information on a national level.

The workshop was run to progress an IA CRC project on developing a national picture of vertebrate incursions and interceptions. It was also held to progress the Vertebrate Pests Committee (VPC) Incursions Working Group, who's terms of reference include developing a national incursion response plan for exotic vertebrates and within this, a standardised template for reporting incursions.

This workshop summary includes:

- a summary of current jurisdictional information management
- recommendations for a path forward to national data sharing
- workshop participants — Appendix A
- the workshop agenda — Appendix B.

Current information management by jurisdictions:

A brief summary of information management systems currently used by each jurisdiction was compiled into the table below. Although most jurisdictions collate information on exotic vertebrates in terms of 'what', 'where' and 'when', the level of detail and the format in which information is kept varies widely. There is currently no system in place to present this information at a national level, and jurisdictions do not generally share their information with other agencies. Some agencies use web-based systems (eg Qld and Victoria), while others have less formal systems in place (eg spreadsheets, emails). Several agencies are currently reviewing their biosecurity information management and developing improved systems (eg Northern Territory, Tasmania, New South Wales).

Jurisdiction	Data fields	Format	Other details
NSW	Compliance data • species • common name • location • number • some dates • other (as provided by 3rd party) At-large data: • common name species • date • location (latitude, longitude) • number • how recorded (email, formal dept document, court case, etc) • dept involved • how incursion was dealt with (surveys, eradication,	At-large info under development, incl web-based survey and spreadsheet. No formal system for compliance data.	• multiple depts involved • info from police etc on any illegal species found • seizures data not currently stored centrally by OEH (some confiscation info stored by zoos or SEWPAC)

Jurisdiction	Data fields	Format	Other details
NSW (cont'd)	prosecution, failed due to escape) • follow-up action (targeted monitoring, media release/public education etc) • further info		
Queensland	• species • common name • location • number • some dates (year)	Pest Central, web based, using Spatial Pest Attribute Standard	• compliance and incursions data in separate dept sections, plus local govts
Northern Territory	• scientific name • common name • location (GPS) • date (year) • informant • other	no formal system, but developing BioSIRT	• multiple depts involved
Victoria	• species • common name • location (inc map, GPS) • numbers • date • surrendered/seized or found in the wild • other – actioning officer, report status, response category	tracking database on Microsoft Sharepoint platform, has spreadsheet functionality (BioWeb)	• multiple depts involved • 'List of concern' species focus
Western Australia	• species • common name • location • numbers • date • confirmed/unconfirmed • other - contact	incident database, but under review – BioSIRT or other system	• multiple depts involved • was dedicated DAFWA project to collate data for past decade
South Australia	• common name • location • numbers • date (year)	under review and development	• mynas, cane toads, barbary doves, plus some seizures information • separate dept sections involved
Tasmania	• common name • approx numbers • approx location • approx date (year)	database, shared network server, or spreadsheet -under review	• incl mainland species • separate dept sections involved
ACT	• date, time of incursion • type of incursion • if identified by diagnostics • what action was taken to eradicate it. •	Spreadsheet in dept	Some info on older incursions being managed by another Branch of the Division are kept by them.
Customs (interceptions-seizures)	• some species id • common name • numbers	spreadsheet – wildlife data extracted from intelligence and	

Jurisdiction	Data fields	Format	Other details
Customs (cont'd)	• arrival location (city port) • source country • dead/alive • date • passenger/mail	investigation databases	
AQIS (interceptions-stowaways)	• some species id (but many only Class) • location (state only) • date • source country • dead/alive • air/ ship / mail • commodity (flowers, timber etc)	incident database (but difficult to interrogate for vertebrates)	• very few species ids • focus on plant pests and pathogens • no numbers recorded (but most are individuals) • stowaway vs smuggling incident not recorded
SEWPAC Compliance/ investigations	Wildlife trade seizures: • common name • species name • location • number • source country • reason for seizure • CITES or native or Live Import • if traded in Aust - State • other	Seizure Notice form information in database. Also reports of suspected breaches of the EPBC Act on spreadsheet. Installing a C&E database later this year.	
ZAA	Confiscations taken into zoos: • species • number • zoo location • date • outcome (kept, euth etc) Census information: • zoo name, • current holdings (male/female/unknown) • planned holdings over next 5 years • relevant info to VPC, CITES, IUCN or ZAA species management	Confiscations in spreadsheet Regional/census website database - govt and ZAA members	

Discussion points:

A centralised reporting point:
The group discussed the merits of a shared community space using ABIN's IT infrastructure. It was agreed this type of secure website could enable sharing of information on incursions and interceptions from all related agencies. Such a site would be governed by the VPC. An application form to create a community space was provided by ABIN's CEO Joanne Banyer.

There was some discussion about how BioSIRT would fit within this context, as many agencies are already using or developing BioSIRT for surveillance and reporting. It was agreed that ABIN could provide a secure data storage and contact point, and if necessary BioSIRT could be linked in at a future stage.

Fields of data:
A discussion was held on what fields of data would be useful to share at a national level, including agencies involved with seizures of prohibited species (eg Customs, SEWPAC, state/territory environment depts) and managing environmental incursions (eg state/territory primary industries departments). The workshop emphasis was on the need for information to assess potential biosecurity risks, both pre- and post-border. The group agreed on a minimum set of data fields, as outlined below. However, further work will be needed to refine the details of this list into nationally standardised terms. It was agreed that current national data standards related to animal management should be looked into, to see if they can be adopted or adapted for incursion and interception data. Relevant standards include those used by the ALA (which agree with BioSIRT's), Queensland's Spatial Pest Attributes Standards, and the National Animal Health Information System.

Recommendations:

It was agreed that data from all related jurisdictions should be regularly collated onto a secure centralised website to enable information to be shared at a national level.

The forum recommends VPC write to constituent members (and AQIS, Customs and other relevant bodies) to ask for data to be sent at least quarterly to a VPC community space on ABIN, to build a national surveillance database by 2012. [In the first instance this timeframe was set as a trial. If successful, the database should continue to be updated on an ongoing basis.]

The quarterly submission should be in spreadsheet format. It is suggested that at least the following fields should be included, subject to further refinement*:

- scientific name
- common name (linked list to scientific name to avoid confusion and error)
- number of animals
- sex of animals, if known
- form of animals, if known (juvenile, adult, egg)
- status of animals (live, dead, euthanised on seizure)
- location of incident (latitude/longitude if possible, or nearest town and postcode otherwise)
- date of incident
- submitter (including a departmental identifier)
- incident number
- how animal was detected (in-wild observation; seizure from private premises, at airport, at seaport; stowaway at airport, at seaport; advert)
- pathway information (source country, known links to illegal trade etc).

* The suggested fields need to be refined and developed into a National Vertebrate Pest Animal Standard. The use of 'pick lists' for some fields was recommended to avoid confusion or inconsistency. Standard terms and definitions will be needed for these lists and fields. A decision will also need to be made which of these fields are essential, and which are optional extras. There needs to be a balance between collecting data quickly and easily (particularly for field officers) and providing details considered important for risk analyses.

Appendix 2A. Workshop participants

Joanne Banyer	Aust Biosecurity Intelligence Network (ABIN)
Luke Bond	Dept Sustainability, Environment, Water, Population & Communities (SEWPAC) – Investigations, and AELERT
Phill Cassey	University of Adelaide
Peter Dinan	Territory & Municipal Services ACT
Mike Dore	Australian Customs and Border Protection Service
Linda Crawley	Dept Environment and Climate Change NSW
Gregory Haywood	SEWPAC – International Wildlife Trade
Robyn Henderson	Dept Industry & Investment NSW
Wendy Henderson	Invasive Animals Cooperative Research Centre (IA CRC)
Donald Hobern	Atlas of Living Australia
Carolyn Hogg	Zoo & Aquarium Association
Frank Keenan	Biosecurity Qld
Lloyd Kingham	Facilitator, Dept Industry & Investment NSW
Gilian Lee	National BioSIRT Program
Mark Livermore	SEWPAC – Investigations (and ex AQIS)
Simon Martin	Dept Primary Industry Vic
Damian McRae	SEWPAC – Environmental Biosecurity
Elaine Murphy	Dept Conservation New Zealand, and IA CRC
Viv Read	Dept Agriculture & Food WA
Karrie Rose	Aust Registry Wildlife Health
Monica Staines	Dept Agriculture, Fisheries & Forestry (DAFF) - Post-border Biosecurity Policy
Andrew Tomkins	Dept Resources NT
John Virtue	Biosecurity SA
Peter West	Dept Trade & Investment, Regional Infrastructure & Services NSW
Naomi Wolfe	SEWPAC - Intelligence

Appendix 2B. Workshop agenda

Date: 13 April 2011

Venue: Canberra – Belconnen Premier Inn, Benjamin Way, Belconnen

9:00	Arrivals
9:15 – 9:30	Welcome, context, rules — Wendy Henderson and Lloyd Kingham
9:30 – 9:45	ABIN: secure information sharing, current uses and future directions — Joanne Banyer (CEO, ABIN)
9:45 – 10:00	BioSIRT: functions, current uses and future directions — Gilian Lee (National BioSIRT Program)
10:00 – 10:15	WildHealth Project: a working community space on ABIN — Karrie Rose (Aust Registry Wildlife Health)
10:15 - 10:30	FeralScan Project and national information sharing for pest vertebrates: initiatives, progress and future directions — Peter West (NSW DII)
10:30 – 10:45	Morning tea
10:45 – 11:00	Atlas of Living Australia — Donald Hobern (ALA)
11:00 – 12:40	Questions and comments re presentations. Discussion of agencies' different approaches. Each agency to provide a brief summary beforehand of the type of data they currently collect (eg incursions vs seizures, confirmed vs unconfirmed sightings, which species), what format it is in (database, spreadsheet, emails, etc), fields of data (date, scientific name, location etc), and where the data is housed (web, private network etc).
12:40 - 13:30	Lunch
13:30 - 13:40	AELERT network — Luke Bond (SEWPAC)
13:40 – 15:30	Path forward — discussion of questions:

- Do we need a central information point for national incursion and interception data?
- Where would we house such information? a GovDex site? Community space with ABIN? linked to FeralScan website? other ideas?
- Who would host/maintain the site/lists? OCVO not interested, VPC doesn't have resources, DAFF Biosecurity Services Group? ABIN? Long-term sustainability of host? Resources for this?
- What sort of reporting/storage system would be best to use? BioSIRT? Other database? or could jurisdictions use their own system but house information on a single shared site/ community space?
- What fields of data should be collected? Species scientific name, location, number, live/dead, confirmed sighting, action taken, other information? Confirmed vs unconfirmed sightings?
- What species should be reported? How can unidentified species be dealt with?

- Can we clearly distinguish between incursion and interception data to avoid misinterpretation? Stowaways vs seized?
- How can we engage/ facilitate agencies to share knowledge?
    - use existing networks such as AELERT, ABIN? Others?
    - cross link between jurisdictions and agencies, including ZAA
    - cross link between compliance and environmental data (since interceptions/seizures could be seen as potential species for future environmental incursions – advises post border biosecurity policy and operations)
    - establish a community of expertise/knowledge?

15:30 – 15:45 Afternoon tea

15:45 – 16:30 Discussion continued.
Final recommendations for:

1. A standard for reporting interception and incursion data for all jurisdictions, including fields of data to record (species identification, location, numbers, date, terminology etc).
4. A central reporting point (eg secure GovDex site or community space within ABIN).
5. A system for routinely reporting and alerting interceptions and post border incursions nationally. (Recommendation for quarterly/6-monthly updates? Resources for this?)
4. Next steps? VPC endorsement? Write-up distribution/ format? Other actions?

16:30 – 16:45 Workshop close

Background issues:

- No central reporting point = no national picture for informing biosecurity.
- Each state, territory and Commonwealth dept (SEWPAC, Customs, AQIS) collects information in different formats (emails, spreadsheets, incompatible databases, etc).
- Data may be spread between, or held by, different agencies (eg primary industries vs environment, or compliance vs agency/section dealing with at-large animals).
- Different detail and fields of data are collected by different jurisdictions/agencies.
- Data is collected for different species in different jurisdictions:
    - different species are classed as pests, regulated differently (eg birds)
    - some jurisdictions record established species appearing in new areas (eg deer, toads, sparrows) whereas others record a more limited number of species
    - Western Australia records instances of some species common in eastern states (eg sparrows, starlings, blackbirds)
    - Tasmania records species appearing from mainland
    - fish are not adequately covered.
- Resources available vary considerably in different jurisdictions.
- Unconfirmed sightings may or may not be counted as incursions or reported.
- AQIS information on interceptions
    - difficult to extract from their incident database
    - only includes specimens selected for identification - may not be comprehensive for exotic vertebrates (their main focus is on plant pests and diseases)
    - many species are not identified beyond Class level
    - unknown how many animals involved per incident
    - AQIS has concerns that interception data may be perceived as actual incursions (leading to trade implications or persecution by media etc).

Appendix 2C. Presentations

1. ABIN: secure information sharing, current uses and future directions — Joanne Banyer (CEO, ABIN)

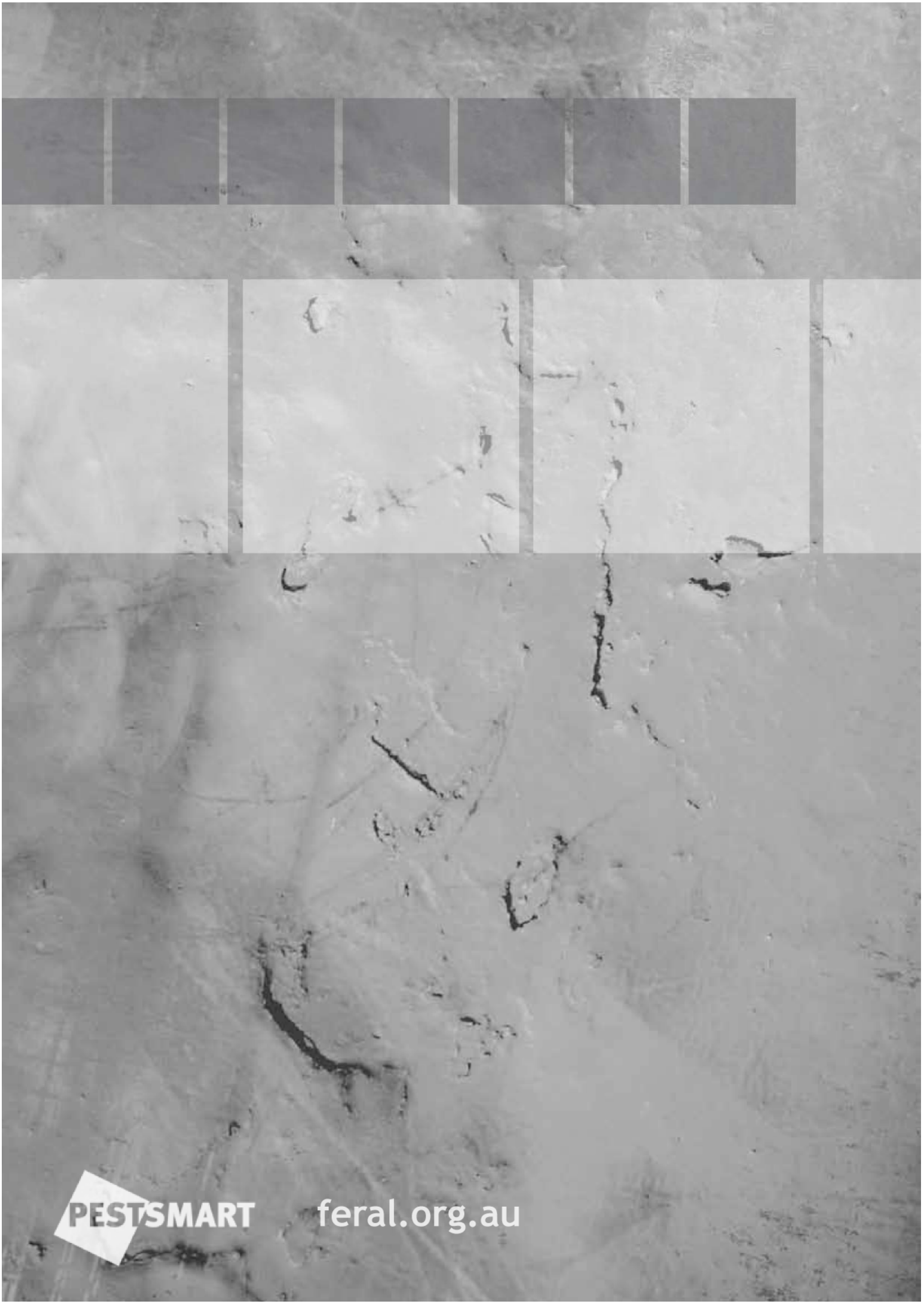
2. BioSIRT: functions, current uses and future directions — Gilian Lee (National BioSIRT Program)

3. WildHealth Project: a working community space on ABIN — Karrie Rose (Aust Registry Wildlife Health). See WildHealth Community Space demonstration video at http://www.youtube.com/watch?v=1RBTMpWV_e0

4. FeralScan Project and national information sharing for pest vertebrates: initiatives, progress and future directions — Peter West (NSW DII)

5. Atlas of Living Australia — Donald Hobern (ALA)

6. AELERT network — Luke Bond (SEWPAC)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