Extent and impact of selected ecologically significant invasive species

Impacts of regionally significant invasive vertebrate pests, excluding fish: (indicator status: for advice)

Ideally, the impact of pest animals should be measured in terms of damage to valued resources rather than in terms of numbers or population density of pest animals. However, due to the difficulty and expense of measuring the impact of pest animals (particularly the long-term effects caused by herbivorous pest animals), pest animal population density will usually be measured enabling the pest animal population density and the resulting environmental damage to be related. This should lead to a situation where pest density:resource damage relationships are known for particular situations.

Why do we need to measure the impact of regionally significant vertebrate pests?

The major vertebrate pests cause direct short-term economic losses of at least $500 million per year (and quite possibly over $1 billion per year), mainly in lost agricultural production. Overgrazing and browsing by introduced herbivores also contribute to land degradation, which lowers the future productive capacity in many areas, but the economic cost of this degradation has not been estimated. In addition, grazing, predation and competition by non-native vertebrates are recognised as major threats to many endangered native species and communities. These costs have also not beenestimated. Some introduced species can also act as vectors or reservoirs for diseases affecting livestock, native species or people. This again is a largely unknown cost, although potentially a high one, particularly in relation to the impact of exotic diseases. These have trade and quarantine implications as well as direct costs due to mortality, morbidity and disease control measures.

There are at least 30 species of non-native pest vertebrates in Australia (see table below) and all areas of Australia have at least one pest animal (e.g. feral cats are distributed throughout Australia and rabbits and foxes occur in most parts of the mainland south of the Tropic of Capricorn). However, while it is clearly not economic, nor necessary, to establish a detailed sampling framework throughout the country, monitoring will be necessary where investment is occurring so that progress towards targets can be measured. Some States and Territories are establishing set transects and other monitoring frameworks, see Attachment A.

Introduced pest species in Australia

Main species of concern:	Species of moderate concern:
European wild rabbit (*Oryctolagus cuniculus*)	Feral buffalo (*Bubalus bubalis*)
Feral horse (*Equus caballus*)	Feral cattle (*Bos taurus)*
Feral donkey (*Equus asinus*)	European brown hare (*Lepus capensis*)
Feral goat (*Capra hircus*)	Black rat (*Rattus rattus*)
Feral pig (*Sus scrofa*)	Indian myna (*Acridotheres tristis*)
European red fox (*Vulpes vulpes*)	Mallard (*Anas platyrhynchos)*
Dingo/feral dog (*Canis familiaris*)	Rock dove (feral pigeon) *Columba livia*
Feral cat (*Felis catus*)	Spotted turtledove (*Streptopelia chinensis)*
House mouse (*Mus domesticus*)	Blackbird (*Turdus merula)*
European starling (*Sturnus vulgaris*)	House sparrow (*Passer domesticus)*
Cane toad (*Bufo marinus*)	European goldfinch (*Carduelis carduelis)*
Feral Camel (*Camelus dromedarius*)	Senegal turtledove (*Streptopelia senegalensi)*

Deer Family (*Cervidae*): chital deer (*Axis axis*), sambar (*Cervus unicolor*), rusa deer (*Cervus timorensis*), hog deer (*Axis porcinus*), red deer (*Cervus elaphus*) and fallow deer (*Dama dama*) are not currently major pests but they are increasing in range and numbers and could well become significant pests in the future.

Generalised distribution maps for the main species of concern are available through CSIRO and the Bureau of Rural Sciences (BRS).

How will monitoring the impact of pest animals assist in reducing environmental damage?

Adequate monitoring and uniform reporting regimes are essential precursors for effective targeting of environmental problem areas and to measure any reduction in the impact of regionally significant invasive vertebrate pest species. However, given that pest animal impact is often extrapolated from measures of pest animal density despite uncertainty about the relationship between pest density and resultingresource damagefor most situations, an adaptive management approach is often warranted. This may involve conducting some baseline monitoring (pest density, resource condition, flora composition, agricultural productivity etc) before implementing pest animal control. Control methods and their impact on pest animal density and any subsequent improvement in the environmental/ agricultural resource are carefully documented to determine trends over time. This will give an indication of the pest density:resource damage relationship (after accounting for seasonal and other factors) and the amount of control required to achieve a given pest animal density. The time required to provide reasonable certainty with such an adaptive management 'experiment' may vary from a year or two (e.g. response of lamb production or native species to fox baiting) to decades (e.g. change in rangeland flora composition resulting from herbivore management). This monitoring information will allow pest management approaches to be modified over time with the aim of continually improving effectiveness (i.e. adaptive management).

Monitoring method

Each of the States and Territories has a different monitoring and reporting regime. There is no current formalised framework for measuring pest animal distribution, population density and impact at the national level, although in the past decade, distribution and density data sets have been collated and generalised by BRS and CSIRO based on surveys of State/Territory and regional agencies.

Monitoring location

Regional surveys or questionnaires and/or the establishment of transects or stratified sampling could be used to obtain estimates of the distribution and population density of the main agricultural and environmental pest animals. This is the approach that is currently followed or which is being established in Victoria, New South Wales and Queensland. This information could then be collated into a State or Territory pest management information system (PMIS) as currently occurs in most States and Territories.

Even if such exercises are only conducted at a broad scale every five years in some States, this approach will provide reasonable information for policy development and funding allocation at a State and Federal level, as well as allowing government regional coordinators to compare pest animal population trends with those of neighbouring regions. However, local and regional pest control groups will require more detailed and frequent monitoring information on which to base more specific management decisions. For example, in higher rainfall areas, less mobile species such as rabbits can be managed (and therefore monitored) effectively over a relatively small area and a rabbit control group may only involve a dozen landholders. Such a group may need to collect spotlight transect rabbit counts three times a year (due to the high reproductive potential of rabbits) on each property to keep track of the rabbit population and, therefore, to assess the need for follow-up control. However, management of mobile species such as feral pigs and wild dogs needs to occur over a much larger area. Therefore the monitoring sampling rate (and probably frequency) will be lower and more generalised monitoring will feed into more generalised management decisions.

Monitoring frequency

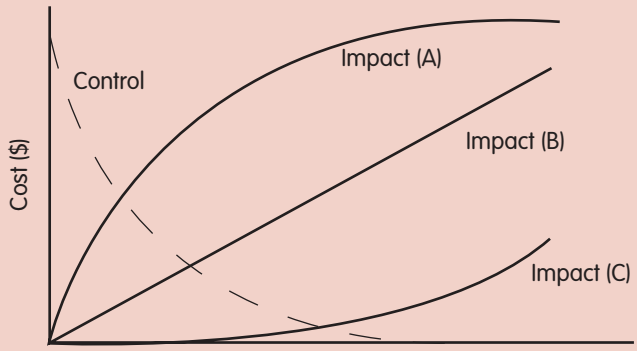
Monitoring frequency will vary from every few months to every five years depending on the species and the intensiveness of the management area. Under Australian conditions high inter-annual variability in climate can obscure trends in the population densities of even relatively long-lived, medium- to large-sized mammals. In some cases, annual censuses can be used to estimate annual rates of increase and pest density:resource damage can be determined if resources can also be estimated, or indexed, on an annual basis. For eruptive species (e.g. rodents) even annual censuses may be of little value as changes on a seasonal timeframe can be economically or environmentally important.

Data measurement method

The damage caused by pest animals should be monitored rather than just the population density. However, it is difficult to measure pest animal impact (particularly long-term land degradation) within localised research programs. Also, where damage due to grazing is being monitored, it is common for several species to contribute to grazing impacts and it is not feasible to separate the relative contributions of the different species. If it is impractical to monitor impacts and if the relationship between damage and absolute population size/pest

density (*N*) of the pest is known, then one can monitor *N* and use it to indicate damage. Possible relationships between population size and damage are shown in Figure 1. Figure 1 is an oversimplification, particularly as it assumes that damage (e.g. overgrazing) will be a function of pest density only, and ignores temporal and spatial variation in environmental conditions and variation in the population density of other species (e.g. in the rangelands, the potential for land degradation through overgrazing is likely to be heightened during drought and this might shift the impact curve from C to A).

Figure 1. Hypothetical relationships between pest density and the *per capita* cost of control (dashed line) and the *per capita* cost of damage or impact (solid lines).



Data analysis and interpretation

For most pest species, in most circumstances, the relationship between population density and damage is largely unknown. However, due to the impracticalities of directly measuring impacts, monitoring usually involves population assessments as a basis for management decisions.

Monitoring is expensive and results need to be firmly linked to management actions. Efficient management can be achieved by pinpointing the appropriate time and place to intervene based on the results of monitoring. Hence decisions about the timing and type of monitoring need to be made at the local level to inform management (e.g. a threshold for managing predation on an endangered prey species will depend on the relative population densities of predator—or predation rate—and prey and the nature of the interaction). In reality, however, changes in the abundance of pest species can never be measured, or predicted, with precision, and the relationship between damage and pest abundance also has considerable uncertainty and may change over time.

Indices of abundance

An index *I* of population size (or density) is an attribute that changes in a predictable manner with changes in absolute population size *N* (or density). *I* may be a count of signs (e.g. the density of tracks or the number of open burrow entrances) which indicate that the species of interest is present or a direct count of individuals of the species (e.g. the number of feral goats seen per km along a road or counted in a fixed strip of ground [transect] from an aircraft). Strip-based direct counts of animals are best viewed as indices of population size as they typically underestimate *N* because observers do not see all individuals. Indices are useful for tracking relative abundance only if the relationship (b) between *I* and *N* remains fairly constant in different surveys (e.g. the number of kangaroos counted along a road does not change significantly as a result of changes in visibility due to different vegetation cover).

A wide range of technical and extension material is available relating to pest animal monitoring. At the national level, the BRS pest animal guidelines (see 'Further information' section below) provide general guidance for the major pests of agriculture. More specific information is available at the State and Territory level although there are often differences in methodology between different jurisdictions. BRS has recently contracted a project to develop a national monitoring guide in conjunction with the Vertebrate Pests Committee (VPC).

Questionnaires about impact of pest species

Questionnaires about pest animal damage are useful in setting research and management priorities over large areas. Face-to-face interviews, phone interviews and mail surveys can all be used to gather information about damage to resources. Mailed surveys can be used over larger areas and have the lowest cost per response. All questionnaires have potential biases. These biases can occur when a proportion of the targeted sample do not respond, the survey is conducted after too much time has lapsed or when respondents overestimate or underestimate damage. To be applicable in most situations estimates or rankings of damage should be correlated with actual damage assessed in the field by trained observers using direct measures.

Robustness and quality assurance

This will depend on the survey method used. See later section for monitoring methods for different species.

Data collation/calculation method

This will depend on the survey method used. See later section for monitoring methods for different species.

It is not always necessary to establish both spatial consistency (required for comparing population densities at different locations at the same time) and temporal consistency (required for measuring rates of change at a particular location) under monitoring programs.

Feral herbivores

For large feral herbivores (horses, donkeys, cattle, camels, goats, buffalo and pigs) broad-scale monitoring can be achieved efficiently through aerial surveys, using either fixed wing aircraft or helicopters and either strip or line transects. Aerial survey data incorporate bias. Survey parameters (e.g. height, velocity and strip width) have varied among surveys although comparisons can usually be made over time and between areas when b, and therefore *N*, has been estimated. Factors affecting bias (e.g. observer, group size and habitat) can be identified and corrected using double counting and modelling.

Rabbits

Spotlight transect counts are the most popular method of monitoring rabbit populations, the data serving as indices of relative abundance. Spotlight counts seem to be a reliable method to detect changes in rabbit abundance arising from management actions such as poisoning, predator removal or the introduction of disease.

Predator species

Broad-scale monitoring is likely to be limited to an assessment of presence or absence or an abundance rank for cats, foxes and dogs. Track-based methods appear most appropriate as they offer reasonable precision and are time efficient. However, given the imprecise and highly variable relationship between predators and their impacts on prey species, measuring impacts is often a far more desirable approach for monitoring predators than monitoring their presence or abundance. Impacts can include measures of survival rates of endangered prey species or variations in lambing percentages with and without predator control.

Bird pest species

Direct estimates of damage caused by birds are usually more appropriate than estimates of bird numbers. Estimating damage caused by birds without counting and evaluating all crops on a property requires taking a representative sample and predicting total damage. Direct measures of damage include weighing, counting and visual estimates. These methods are usually appropriate for cereal and fruit crops. Visual estimation is rapid and is the most widely used method to obtain measures of bird damage to agricultural crops. This involves a visual estimation of damage, with or without a ranking scale, and requires experienced observers. Counting or weighing the number of damaged and undamaged samples within a crop is usually used to calibrate visual estimation methods. Where damage is patchy within a crop, stratification is needed to increase precision and decrease sampling effort and this often requires complex sampling techniques and statistical analysis to give valid estimates. In most cases estimates of direct loss expressed as a percentage will be a sufficient basis for management decisions. However, these estimates are likely to be conservative when there is a high percentage of pecked or partially damaged fruit.

Rodents

Either abundance or damage measures may be appropriate for rodents. Mouse numbers are highly variable and managers need advance warning when a 'mouse plague' is likely to erupt so they can take appropriate action in advance to protect crops, stored produce and equipment. Trapping rates give an index of abundance but trapping is usually too time consuming to be practical. Bait cards (grid-marked squares of vegetable oil-soaked paper) can give a coarse index of mouse numbers. Mouse abundance is roughly proportional to the average number of grid squares chewed away by mice when the bait cards are left in a crop overnight. Other rough indices of rodent abundance are counts of active burrow entrances or tracks in a set metre-wide 100 metre transect. Direct methods for measuring rodent damage are crop-specific (e.g. the percentage of chewed tillers or the percentage of chewed grain heads in random plots). Direct measurements require skill and for most grain crops damage levels less than 10% are difficult for untrained observers to quantify. This is largely because damage tends to be patchy and its assessment requires complex sampling techniques and statistical analysis to give valid estimates. Damage to crops prior to ripening may not translate into yield losses (e.g. young rice plants can compensate for damage to up to 60% of growing tillers). Damage to stored produce or equipment can be estimated by counting the number of items eaten, chewed or infested.

Monitoring and reporting products

Most reporting currently occurs at the regional and State or Territory levels. This may involve submission of hard copy reports of distribution and density for respective pest animal species to the relevant State or Territory agency which then collates the data into a computerised PMIS which includes a GIS mapping program. These maps will then be returned to the regions so they can gauge their management performance over time relative to other regions. Ideally such processes would be internet based to facilitate a rapid and responsive flow of information between regional and State and Territory offices and back again.

Proposed responsibilities

Data collection

When targets are set as part of the planning process it is also necessary to ensure that effective monitoring arrangements will be available. This does not mean that the regional body setting the target has to undertake the actual monitoring itself although it could choose to do this. In many cases the most cost-effective and efficient option will be to use existing monitoring programs being undertaken by State agencies or similar bodies. Many forms of pest animal monitoring require specialist skills and equipment (e.g. aerial surveys, identification of 'sign' such as faeces, scratch/dig marks or hair tubes, and measuring impact) and will require guidance or direct input from State or Territory agency personnel and, in some cases, species experts. Other forms of monitoring (e.g. rabbit spotlight transect counts) can be conducted by landholders and regional groups guided by written instructions.

Data analysis and interpretation

Data collation, analysis, recording and distribution are clearly best conducted centrally by the respective State and Territory agencies, preferably using computerised PMIS. Ideally, if using similar PMIS, this data would then be able to be collated at the national level (e.g. by the National Feral Animal Control Program of the Natural Heritage Trust). However, State and Territory agencies have been consulted through the VPC on this matter in the past and, without considerable financial incentive, it is unlikely that State/Territory PMIS will be made sufficiently uniform in the near future.

However, for local and regional pest animal control groups, differences in data collection and collation at the State level may be less of a concern. Such groups need to develop a scientifically valid monitoring regime involving the minimum detail and frequency that is likely to be required to assess the performance of a pest control program for their particular pest species and geographic situation. This information will be required to measure the progress of such investments in pest animal control in reaching their targets.

Links to other indicators

This indicator may be relevant to those for native vegetation condition and extent, and those for significant native species and ecological communities where vertebrate pests may represent a threat.

Further information

Caughley J, Bomford M, Parker B, Sinclair R, Griffiths J & Kelly D 1998, *Managing Vertebrate Pests: Rodents*, Bureau of Resource Sciences and Grains Research and Development Corporation, Canberra.

Choquenot D, McIlroy J & Korn T 1996, *Managing Vertebrate Pests: Feral Pigs*, Bureau of Resource Sciences, Canberra.

Dobbie W, Berman D & Braysher M 1993, *Managing Vertebrate Pests: Feral Horses*, Bureau of Resource Sciences. Canberra.

Fleming P, Corbett L, Harden B & Thomson P 2001, *Managing the Impacts of Dingoes and other Wild Dogs*, Bureau of Rural Sciences, Canberra.

Parkes J, Henzell R & Pickles G 1996, *Managing Vertebrate Pests: Feral Goats*, Bureau of Resource Sciences, Canberra.

Saunders G, Coman B, Kinnear J & Braysher M 1995, *Managing Vertebrate Pests: Foxes*, Bureau of Resource Sciences, Canberra.

Williams K, Parer I, Coman B, Burley J & Braysher M 1995, *Managing Vertebrate Pests: Rabbits*, Bureau of Resource Sciences, Canberra.

Attachment A.

Existing monitoring and data management

Victoria

Victoria has set up a series of randomly chosen rabbit transects as part of an indicator of catchment health using a scoring scale based on rabbit activity, derived fromactive warren entrances, and potential to increase, rather than actual rabbits seen or counted.

In Victoria, the Integrated Pest Management Information System (IPMIS) is a recording, evaluation and reporting database used by all regional staff involved in pest plant and animal activity. IPMIS can be linked to a GIS to capture pest animal information on a property, a regional and State-wide basis. Information from IPMIS is used as part of regional and Departmental reporting processes to Government to be measured against specified targets.

Parks Victoria has monitored vegetative responses to changes in rabbit grazing at their Hattah Lakes National Park site since the introduction of Rabbit Haemorrhagic Disease (calici virus). Parks Victoria also monitors fox populations and impacts across a variety of sites and situations.

New South Wales

There have been three previous feral animal mapping exercises undertaken in NSW (in 1979, 1985 and 1996). The latter two produced maps detailing broad variation in pest densities. In 1985 the census concentrated on feral pigs; the 1996 census involved the development of a wider set of pest animal maps. These maps have been used as a guide to pest distributions and exotic disease preparedness. NSW Agriculture recently (2002-03) conducted another more detailed survey (involving a face to face survey for greater accuracy) to make use of the knowledge of staff undertaking field-based pest animal duties across the State.

Rapid field appraisal of pest animal density relies on animal sightings and sign (ie. scats, tracks, traces and damage) according to a modified 'Dekkers' system which uses one set of density criteria for all species. This method is faster and cheaper than taking more scientifically robust measurements along set transect lines and is appropriate for general indications of pest distribution/density and trends.

Geographic information systems (GIS) were used for capturing, collating, handling, storing and displaying the mapping data of the most recent survey (2002–03). The objective of the mapping exercise was to map the distribution and density of each species within the geographical area for which the participant had detailed knowledge. This required the preparation of suitable local area maps prior to the interview process. These consisted of large A0 maps (ranging in scale from 1:250 000 to 1:500 000) showing roads, rivers, railways, land tenure and localities overlaid on high resolution satellite imagery (Landsat 7 ETM). The combination of overlays and the satellite backdrop allowed participants to easily locate features within their area and to describe pest animal and habitat associations as accurately as possible. A 5 km x 5 km array (grid) was generated and overlaid on the maps and participants were asked to provide a single density estimate per grid cell. Smaller A3 replica maps were produced to record data. A

GIS database has now been established which can be used for comparison with future surveys. It will also allow the production of maps in any pest animal emergency and to establish reference points for ongoing pest animal control activities

South Australia

Feral goats in the dingo-free rangelands south of the dog fence in South Australia are aerially surveyed annually as part of the Department for Environment and Heritage's (DEH) kangaroo management program. Presence-or-absence data have been collected since 1978 and density data since 1989. The survey covers about 207 000 km^2 at a sampling intensity of 1.3%. However, this information is not used in the management of goats in the rangelands. Data are held by DEH.

Since the early 1990s, feral goat, fox, cat and rabbit numbers have been monitored in the central and northern Flinders Ranges as part of DEH's Operation Bounceback program. Foxes are controlled using 1080 baits, rabbits controlled via warren destruction and RHD (calici virus) and goats removed through shooting and mustering. Foxes, cats and rabbits are monitored using vehicle transects and goats are monitored from the air. Data are held by DEH.

Pigs are monitored and controlled in the Innamincka Regional Reserve and along parts of the Murray River. Aerial surveys of camels, donkeys and horses are conducted in the Simpson Desert with some control undertaken in conjunction with neighbouring landholders. Vehicle transects are regularly driven in and around many DEH parks and reserves across South Australia that undertake some level of fox and rabbit control.

Feral goat and rabbit densities have been estimated annually since 1979 from rates of dung deposition in one small part of the Gammon Ranges National Park in South Australia. The work is part of an investigation into the effects of exotic and native herbivores on the growth and regeneration of arid zone perennial vegetation and has allowed the relationship between damage and pest density to be estimated. Data are held by the Animal and Plant Control Commission.

The Animal and Plant Control Commission has recently developed and implemented a uniform database (Pest 2000+) for recording animal and plant infestations from the local animal and plant control board level down to the individual property level.

Australian Capital Territory

In the ACT, transects of rabbit densities have been established in specific locations for over 20 years. These are monitored at least twice a year. Transect counts of wild dog activity within Namadgi National Park are conducted twice yearly as part of the NSW/ACT Wild Dog project. In recent years, permanent bait stations for wild dog and fox control have been established and records of bait take are maintained. Records of bait take from pig baiting trails have been maintained for almost 20 years.

Records of feral animal activity or transect counts have been entered into a database and, more recently, included within the geographic information system (GIS) maintained by Environment ACT. Funding has recently been provided to develop an Integrated Nature Conservation Plan (INCP) for the ACT. The INCP

includes an interactive database that will provide for the collection and reporting of data, including recording vertebrate pest activity, the control actions undertaken in response to pest animal damage and the results of ongoing monitoring.

Queensland

In Queensland, information on the distribution of declared animal pests is obtained annually through a State-wide survey. The density of each species is assessed on the basis of 50 km squares using the expert knowledge of field staff. No information is collected on declared pest animal impacts, either agricultural or environmental. Queensland has a comprehensive computerised Pest Management Information System ('PestInfo') for pest animal and plants.

Western Australia

WA iscurrently mapping the distribution and abundance of large pest animals (excluding broadly distributed rabbits and foxes) on a property-by-property basis with staff from the Department of Agriculture (DAWA) and Dept Conservation and Land Management (DCLM) conducting face-to-face interviews. Properties include private and public land (land administered by DCLM) greater than 10 ha in size, but it excludes large tracts of Unallocated Crown Land in the arid interior of the State. The formal survey approach is comparable to that undertaken by NSW Agriculture. Capturing the data at a single point of time allows trends in populations to be examined at some future point of time (e.g. in five years) by replicating the survey. This approach has been used successfully by NSW Agriculture to demonstrate, for example, trends in the distribution and abundance of feral pigs in NSW.

All regular property inspections are entered into the DAWA Field Reporting System which has been incorporated into the Client and Resource Information System (CRIS). Information from the larger surveys as described above is being captured in an MS Access database and displayed using Geomedia (GIS). Then it is incorporated into the CRIS system.

Northern Territory

The Northern Territory conducts systematic aerial surveys to assess the distribution and density of large feral animals and to monitor the implementation of feral management programs.

The Northern Territory conducts systematic aerial surveys to assess the density and distribution of large feral animals at the regional level. All sightings are GPS logged. Populations are estimated and density maps produced. Data is maintained by Parks and Wildlife, Dept of Infrastructure, Planning and Environment.

Tasmania

Tasmania does not have a set program in place for the monitoring of rabbits. Wild Animal Management Officers of the Department of Primary Industries, Water and Environment inspect properties and give advice on rabbit control in response to complaints.

The Fox Free Task Force presently investigates all reported sightings of foxes in Tasmania with sightings logged and mapped.

Parks and Wildlife Service undertake annual transect counts throughout the State each year. These surveys collect information on native species including pademelons, Bennetts wallaby and brushtail possums that are considered 'pests' in certain instances.

The main database and mapping activity is associated with fox sightings and baiting activity under the fox eradication program.