Ecological blunders and conservation: the impact of introduced foxes and cats on Australian native fauna

M. C. Calver, D. R. King, D. A. Risbey, J. Short, and L. E. Twigg

Introduced predators are a world-wide concern. Case studies engross students, introduce the field of conservation biology, and support an option within some Australian curricula

Introduction

If, as one reviewer noted recently, 'conservation biology has now come of age' (Ginsberg and Balmford, 1995, p. 387) the same cannot be said of its treatment in secondary school textbooks. The first specialist university text appeared in 1993 and others have since followed, but many introductory secondary school biology books ignore conservation biology. Although isolated aspects are occasionally presented for a readership of educators (e.g. Keogh, 1995), they fail to emphasize the interdisciplinary nature of the subject. It is difficult to attempt a concise overview while awaiting secondary school textbook revision, but pertinent case studies from the literature highlight aspects of the discipline adaptable for classroom discussion and research by teachers wishing to introduce their students to the field.

Abstract

Many vertebrate extinctions followed the introduction of the exotic predators, the fox and the cat, to Australia. While experiments have confirmed the case against the fox as a serious threat to endangered species, there are no direct experimental links showing recovery of prey populations following culling of cat numbers. This, coupled with the emotional attachment of many people to cats, has led to some opposition to their control, especially when limitations on the freedom of pets to roam are proposed. The introduced predator case is a stimulating example for teaching aspects of the emerging discipline of conservation biology and highlights the interplay of bioethics, public opinion, and biological principles in conservation decision-making. Suggested classroom exercises allow students to compare and contrast experimental and non-experimental approaches to assessing predator impact, consider ethical issues in controlling predators for conservation, and reach their own conclusions on the impact of cats on local wildlife.

Key words: Foxes and cats, Australia, Native fauna.

One such example illustrating the complex question of the conservation impact of introduced animals is the ecological blunder committed when the exotic predators the European Red Fox *(Vulpes vulpes)* and the cat *(Felis catus)* were introduced to Australia. Their impact on Australia's unique vertebrate fauna is contentious, largely because of a predominance of circumstantial evidence and, until recently, a lack of convincing experimental studies. The issue is further complicated by concerns about the target specificity and ethical nature of control measures, especially when cats are involved. This is a particularly relevant teaching example in conservation biology, illustrating the complex issues involved and the role of ecological research in informing both the public and politicians. This paper outlines the Australian conservation record and the history of fox and cat introductions, concentrating on evidence for and against them as serious threats to indigenous wildlife and methods available for their control. Suggestions are given for exercises allowing students to explore some theoretical, practical, and ethical issues, and the experience of using one in an Australian senior biology class is described.

Australia's terrestrial vertebrate conservation record

Seventeen mammal species, three bird species, and one lizard species have been lost since European settlement in 1788. Most mammal extinctions occurred in arid regions and were confined to species in the 'critical weight range' of 35–5500 g (excluding bats) (Burbridge and McKenzie, 1989). These mammals could suffer predation or competition from introduced foxes and cats, and given that the decline began as the exotic predators spread, it is tempting to blame them for the extinctions. Some authors have done this, although often cautiously (e.g. King, Oliver, and Mead, 1981). The uncertainty stems partly from, until recently, a paucity of hard experimental evidence, and a range of plausible alternative hypotheses including climatic change, habitat degradation caused by introduced herbivores such as mice and rabbits, disease, deleterious consequences of pastoralism, changes in fire-patterns when aboriginal Australians ceased traditional management, and human persecution of species seen as threats to stock or valued for hunting. However, there remains a pressing need to determine the true role of exotic predators in the decline of Australia's vertebrate fauna for proper management of surviving species.

The fox in Australia

Foxes were brought to Australia for sporting purposes and first released near Melbourne, Victoria, in 1845 and again in the 1860s (Strahan, 1983). They bred and dispersed rapidly, no doubt encouraged by the proliferation of an excellent food source in European rabbits, *Oryctolagus cuniculus,* introduced in 1858. Foxes range across the southern two-thirds of the continent including desert, woodland, pastoral zones, and urban areas, but have not become established in the tropical north, nor on many off-shore islands including Tasmania. There is no larger predator on the mainland except the dingo *(Canis familiaris dingo),* since the wolf-like thylacine *(Thylacinus cynocephalus)* and the Tasmanian Devil *(Sarcophilus harrisii)* were already restricted to Tasmania before European settlement.

Foxes soon spread into pastoral areas and complaints of predation on lambs followed. Concerns were also raised about the impact of predation on wildlife. Dietary studies (e.g. Phillips and Catling, 1991) confirmed that foxes ate native animals. However, diet varied with prey availability and exotic animals such as rabbits, sheep carrion, and mice predominated, with fewer native mammals, birds, lizards, frogs, invertebrates, and plants eaten.

It is difficult to determine the impact of foxes on native animal populations from dietary data alone. The strongest case that can be built is largely circumstantial, based on the inclusion of native species in fox diets and the decline in the distribution of many species coinciding with fox arrival, while populations isolated from them remained unaffected (e.g. King *et al.,* 1981).

However, more conclusive experimental evidence against the fox has been collected and we have selected the experiment of Kinnear, Onus, and Bromilow (1988) as a detailed example. The black-footed Rock-Wallaby *(Petrogale lateralis),* which was very abundant in the early years of settlement, is now rare over much of south-western Australia. Kinnear *et al.* (1988) monitored five remnant populations in the central wheatbelt of Western Australia and found that they declined or remained static over the period 1979–1986, although reproductive rates were high, there was no evidence of disease and animals maintained their condition during drought. Fox predation was implicated circumstantially as a factor in this decline, so fox control by shooting and baiting was instigated for two populations for four years from 1982, the other three populations serving as untreated experimental controls. The rock-wallaby populations protected by fox-baiting increased substantially, while two controls declined and a third rose slightly. The researchers concluded that fox predation was a factor in the current decline of rock-wallabies and that predator control was a feasible management option. Studies such as this have stimulated active and successful fox control programmes as part of fauna management in Western Australia, with strong recoveries occurring in a range of species.

However, there is still a need for economical, target-specific control measures that meet concerns over culling animals and possible dangers to non-target species. Currently, baiting with 1080 toxin is used widely. In south-western Australia it exploits the resistance to 1080 of indigenous fauna which have had long exposure to fluoroacetate, the toxic principle of 1080, both in native vegetation and in the bodies of herbivores which had fed on toxic plants (Calver and King, 1986; Twigg and King, 1991). Substantial efforts are also being made to develop a target specific bio-sterilant for foxes which, if successful, would achieve a high level of control without raising the emotive issue of poisoning amongst wildlife activists (Beeh, 1992). Overall, the combined circumstantial and experimental evidence against foxes is powerful and their active friends are few. However, the cat situation is more complex.

The cat in Australia

Feral cats might have entered Australia well before European settlement, arriving with northern traders such as the Malays or from European shipwrecks. They are now established in all Australian habitats including rainforest, desert, and alpine areas, aided by their ability to survive without drinking water and the abundance of rabbits for food. They are solitary and shelter in abandoned rabbit burrows, hollow logs or dense thickets, and their home ranges vary in size according to food availability, habitat type, and sex. Breeding peaks in spring and late summer with up to two litters of two to seven kittens born each year. Young reach sexual maturity after about one year. They have no natural enemies except foxes and dingoes but maintain stable populations, probably because of nutritional stress on sub-adults.

The capacity of cats to kill native wildlife is unquestioned, but whether this predation has a significant impact on prey population sizes or distributions is harder to determine. Jones and Coman (1981) established that introduced mammals (mainly rabbits) comprised 45-85 per cent of the diet, native mammals made up 2-40 per cent and reptiles, fish, amphibians, and invertebrates were less important. Birds were major foods at all sites studied, but the species identified in stomachs were common ones. However, none of this catalogue of destruction proves that cats depress the population levels of native animals in mainland Australia. Advocates of cat control have highlighted the well-documented impact of introduced cats on the fauna of off-shore islands throughout the world and their more recent role in frustrating attempts to reintroduce native fauna to wildlife reserves in the Australian arid zone (Christensen and Burrows, 1994), but the case of such insular prey populations may not apply to widespread declines across mainland Australia (Low, 1996). Dickman *et al.* (1993) implicated cats in the decline of native vertebrates using circumstantial evidence, arguing that they were present in most parts of Australia when vertebrate extinctions began, preceding foxes, rabbits, and major habitat destruction.

Assessing cat impact and possibilities for control is complicated by the interrelationships of cats and humans. Cat lovers may extend the affection they feel for their pets to feral animals, and fear for the impact of diseases and baits used to control them on their pets. Additionally, it is estimated that one household in three in Australia owns at least one cat and they kill a wide array of wildlife. Simple techniques such as attaching a bell to a cat's collar are ineffective deterrents (Paton, 1991).

In summary, there is no convincing experimental evidence demonstrating recovery of wildlife populations on mainland Australia following cat control. However, the circumstantial evidence is strong because of the coincidence of cat arrival and the decline of populations of native mammals, especially since cats were established in mainland Australia before other environmental perturbations accompanying European settlement were felt. Furthermore, the undeniable evidence for the destructive impact of cats on island wildlife shows that they could do the same in the wildlife refugia that are really 'islands' within mainland Australia. If these arguments are accepted as grounds for control, there remain the special problems of dealing with the objections of cat lovers and regulating domestic pets.

While it is unrealistic to eliminate feral cats from mainland Australia, it is possible to do so on islands and to cull them in important reserves. However, hunting and trapping are extremely labour intensive and may not be very successful when cat densities are low, while shooting is limited in areas of dense vegetation. Baiting is more economical and 1080 toxin offers target-specificity in parts of Australia, although cats are difficult to bait. The introduction of diseases into feral populations could provide a rapid impact over large areas but might create a backlash from pet owners.

None of these methods addresses the destruction caused by domestic cats in urban areas, although the actions of Sherbrooke council on the outskirts of Melbourne provide a model for concerned municipalities (Beeh, 1992). It requires cat registration with animals marked with microchips inserted under the skin, offers a reduction in registration fees for desexed animals, controls pet movement, and imposes a night-time curfew. However, the effectiveness is still unclear (Anderson, 1994) and some cat owners throughout Australia remain concerned about restrictions on their pets, the perceived cruelty of controlling feral cats, and the image of their pets.

Suggested classroom exercises

Strengths and weaknesses of ecological experimentation

Experimental tests of predictive hypotheses are powerful tools in ecological research, although they are often logistically difficult and not all ecological problems are amenable to experimentation. Students can focus on this question by studying the approaches and conclusions of King *et al.* (1981) and Kinnear *et al.* (1988) to the question of fox predation on native Australian mammals. King *et al.* (1981) used current and historical data on the distribution of three species of rat-kangaroos *(Bettongia* spp.) to argue that their narrowing distributions were the result of fox predation (figure 1), which essentially relies on circumstantial evidence. Kinnear *et al.* (1988) experimentally reduced fox numbers in two rock-wallaby populations and compared the trends to three control populations in which foxes were not culled (table 1).

Students could be given both data sets and asked to assess the validity of the data and the conclusions drawn. Drawing line graphs emphasizes the trends at the different sites. Some teaching points are that the

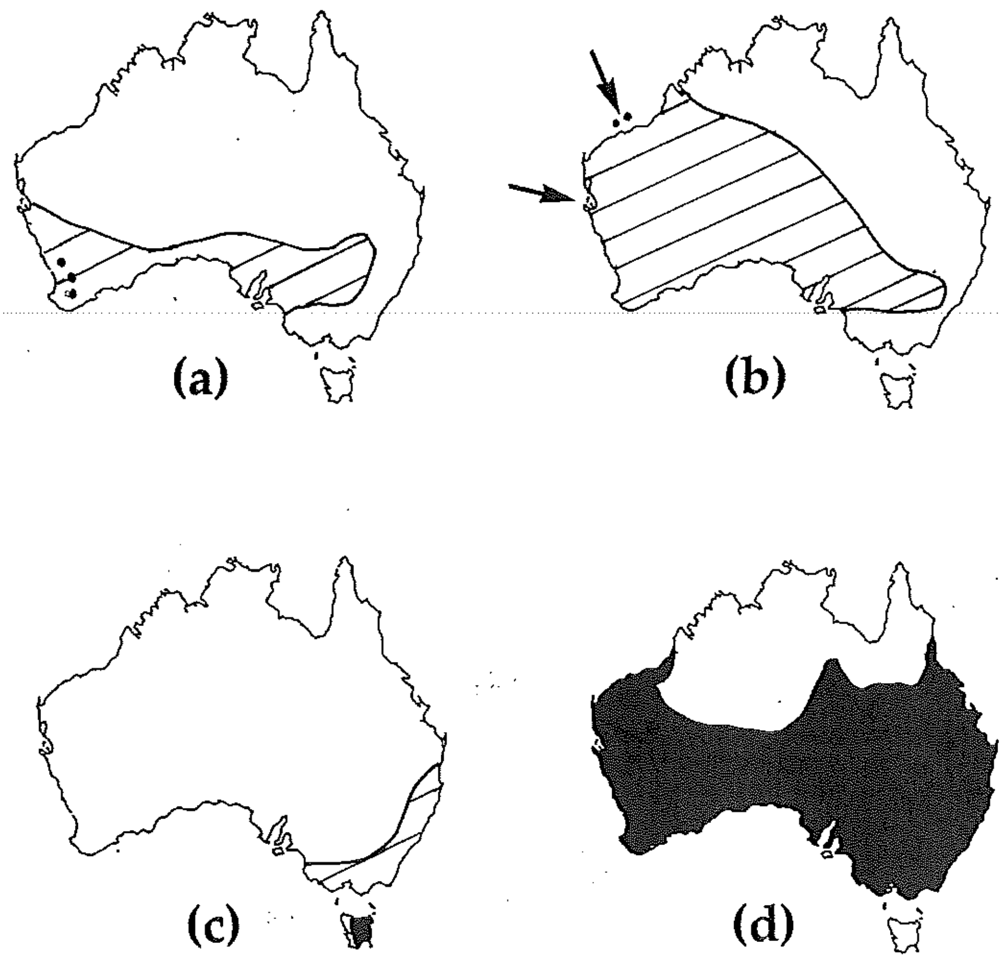

Figure 1 Present distribution (solid zones) and distribution at European settlement (hatched zones) for the Brush-tailed Bettong *Bettongia penicillata* (a), the Burrowing Bettong *Bettongia lesueur* (b), the Tasmanian Bettong *Bettongia gaimardi* (c), and the Red Fox *Vulpes vulpes* (d). Note that (i) only the present distribution of the Red Fox is shown since it was not introduced until c. 50 years after settlement, and (ii) that the Burrowing Bettong is now restricted to the arrowed islands off the Western Australian coast. King *et al.* (1981) argued that reductions in bettong distribution are strong circumstantial evidence for the impact of fox predation on bettongs. (Maps adapted from those in Strahan (1983) with kind permission.)

distributional data could arise from alternative hypotheses such as the impact of habitat degradation by agriculture, disease, or another introduced animal such as the rabbit. However, wide extrapolation from the experimental data can be questioned: do they not apply only to one prey species under particular conditions? Depending on students' background and statistical sophistication, teachers could introduce more subtle consideration of experimental design and statistical analysis by considering criticisms of the work (Caughley and Gunn, 1996, p. 259).

Table 1 Estimated population sizes for rock-wallaby populations at five sites in Western Australia between 1979 and 1986. Fox control began at Nangeen and Mt Caroline in 1982. The other three sites were controls. (Data from Kinnear *et al.*, 1988.)

Year	Site				
	Nangeen	Mt Caroline	Sales' Rock	Querekin	Tutakin
1979	18	10	32	–	–
1980	21	–	34	7	–
1981	26	–	22	–	–
1982	29	13	22	–	–
1983	–	–	–	5	7
1984	51	22	37	–	–
1986	69	42	44	1	6

We ran this exercise with senior secondary students (16–17 years of age) studying introduced animal impact on Australian ecosystems, which is part of the senior biology syllabus in Western Australian secondary schools. The major positive point was the facility with which the students generated hypotheses to explain the decline in indigenous fauna. They were also quick to design controlled experiments to investigate predator impact by either culling predators from an experimental plot relative to an untouched control or by introducing predators to a pristine area, but failed to grasp the importance of replication without prompting. No student raised any objection to the culling of introduced predators as a conservation measure. This might reflect the current profile of the issue in the Australian media and the attitudes of students elsewhere would make an interesting contrast.

Ethics of control

Is it ethically right to destroy exotic predators to protect native species, or conduct experimental studies on predation that may cause suffering to experimental subjects? The information in this paper and in Calver and King (1986) could be the basis for a class debate, one team arguing for control and the other against predator regulation. Other scenarios can be posed: is control acceptable to protect crops, livestock, or human health?

Possible arguments for the 'affirmative' team include: adequate evidence shows introduced predators are a menace, unique indigenous fauna are of greater value than introduced predators, the potential economic value of indigenous animals (e.g. through 'eco-tourism') is sufficiently great to ensure that they be preserved, and we have a moral obligation to conserve unique species for future generations. The 'against' team could argue: the case against introduced predators is mainly circumstantial with limited direct experimental evidence, poisoning is cruel, predators are useful in controlling introduced herbivores such as rabbits, and it is always ethically wrong to kill wildlife. The debate format alerts students to the complexity of the issues and shows that rhetoric as well as fact can be important in convincing others.

The impact of domestic cats on wildlife

Students can also address the question of wildlife killed by domestic cats. Within the school community they might question staff and other students about animals caught by pet cats, and try to quantify the range of prey. It might be useful to ask cat owners whether or not their pets wore bells, and to compare the data on the effectiveness of bells in reducing predation to those of Paton (1991) shown in table 2. Discussion could then centre on whether or not the problem of cat predation was significant, and what action, if any, would it be reasonable for pet owners to take.

The above approach is not a manipulative experimental one and students could be asked to consider what limitations (if any) this poses to their conclusions. They might also attempt to modify the approach to see if they can devise an experimental solution.

Table 2 Proportions of cats with and without bells which killed birds, mammals, and reptiles in three different localities. (Data from Paton, 1991.)

Locality	Birds		Mammals		Reptiles	
	With bell	No bell	With bell	No bell	With bell	No bell
Suburbs	0.62	0.59	0.60	0.58	0.20	0.25
Country towns	0.55	0.72	0.58	0.61	0.58	0.40
Rural	0.25	0.54	0.56	0.58	0.38	0.38
Total	0.47	0.62	0.58	0.59	0.39	0.34

Table 3 Cumulative water vole and mink Activity Indices (AI) at 20 sites, 1985-1986. (Data from Woodroffe, Lawton, and Davidson, 1990.)

Water vole AI (tracks m^{-1} $month^{-1}$)	Mink AI (tracks m^{-1} $month^{-1}$)
70	1
70	0
18	0
8	0
96	0.1
61	0.1
11	1
31	1
9	5
25	1.5
9	6
0.5	3.5
23	0.1
17	6
31	7.5
16	6.5
2	7.1
18	4.5
6	2
14	15

The impact of feral mink on water voles in England

Teachers in the UK may wish to use an example closer to home, based on data of Woodroffe *et al.* (1990). Feral mink *Mustela vison* prey upon water voles *Arvicola terrestris* in English waterways, but their impact on water vole numbers is arguable. However, water voles leave characteristic runs along the banks of rivers and both their tracks and those of mink can be identified in these runs and used to construct activity indices (AI) for both species. Table 3 shows indices for 20 river sites in a National Park. Students could be asked to plot water vole AI against mink AI and to decide if water vole activity declined in the presence of mink. The weak negative correlation may not convince everyone that mink suppress water vole activity. Some students may point out that correlation does not imply causation, or even that lower water vole activity may simply mean that a population is more cautious. Harder to deduce is the possibility that water voles become agitated in the presence of mink and that the AI of survivors increases.

Such difficulties in interpretation can arise unless a strict experimental format is followed. Students could discuss formats for a controlled experiment and then consider the range of logistical, ethical, and legal problems they might encounter implementing it! Woodroffe *et al.* supplemented the AI study by radio-tracking voles. At one site three of eight radio-tracked voles were killed by mink, two died in burrows (presumably of natural causes), one was taken in a burrow by an unknown predator, and two disappeared without trace. Students could consider what weight, if any, to give to these data. Finally, they could consider whether it was appropriate and possible to protect water voles by controlling mink.

Conclusion

The integrated, problem-solving approach of conservation biology gives rise to useful, topical teaching examples. Many of these are suitable for classroom use now, without waiting for their inclusion in future textbook revisions.

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The authors

M. C. Calver (to whom all correspondence should be addressed) is a Senior Lecturer in Biological Sciences at the School of Biological and Environmental Sciences, Murdoch University, Murdoch, Western Australia 6150. E-mail: calver@cleo.murdoch.edu.au D. R. King and L. E. Twigg are Research Scientists at Vertebrate Pest Research Services, Bougainvillea Avenue Forrestfield, Western Australia 6058. E-mail: DennisK@APB.agric.wa.gov.au D. A. Risbey is a postgraduate student at the School of Biological and Environmental Sciences, Murdoch University (see above). J. Short is Principal Research Scientist at CSIRO Division of Wildlife and Ecology, LMB 4, PO Midland, Western Australia 6056. E-mail: Jeff.Short@per.dwe.csiro.au