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RABBIT CALICIVIRUS: UPDATE ON A NEW BIOLOGICAL CONTROL FOR PEST RABBITS IN AUSTRALIA

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ABSTRACT: Rabbit calicivirus disease (RCD), also known as rabbit haemorrhagic disease, is being used to control wild rabbits in Australia. Deliberate release of RCD followed extensive non-target animal and human testing and consideration of some 472 submissions. A national monitoring and surveillance program is in place to quantify the impact of RCD on rabbits, rabbit damage, predators, competitors, and ecosystems. Preliminary data suggest wide spatial variation in RCD impact, from no observable effect to >90% mortality and marked response in competitors and vegetation. This paper provides an overview of rabbit impact in Australia, details of the considerations and testing that preceded a decision to release, and results of impact studies to date.

KEY WORDS: European rabbits, rabbit haemorrhagic disease virus, biological control

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INTRODUCTION

Biological control is the use of "parasites, predators and pathogens to regulate populations of pests" (Harris 1991). It has terrific appeal as an inexpensive and convenient form of control with low, if any, maintenance costs. However, many of the species introduced to control a pest have exerted little or no control or have become pests themselves. An international survey of biological control of weeds found 76% of agents failed completely, 6% were spectacularly successful, and 18% had limited success (Briese 1993). Biological control of vertebrate pests is less common than that of weeds, but also has a checkered past. In Australia, biological control has had complete failures; for example, releasing cats to control rabbits, possibly adding to the feral cat problem and releasing chicken cholera, which does not infect rabbits, for rabbit control (Rolls 1969), and one spectacular success, myxomatosis for rabbit control (Fenner and Ratcliffe 1965). Australia and New Zealand have also recently released a new agent, rabbit haemorrhagic disease, known as rabbit calicivirus disease (RCD) in Australia and New Zealand, to control rabbits. Rabbit calicivirus has been active in Australia since late 1995 and New Zealand since mid-1997, with variable effects on rabbit populations. In Australia, RCD continues to affect rabbit populations two years after its initial release and there are encouraging early signs of responses in vegetation and introduced predators, but it is too early to conclude how effective it will be in controlling rabbit damage. In this paper, the authors explore some general principles of biological control and pest management before describing the assessment, escape, release, and impact of RCD in Australia.

WHY USE BIOLOGICAL CONTROL?

Biological control appeals as a inexpensive and efficient means of controlling pests and the damage they cause. Biological control agents have the potential to be species-specific, making them safe for non-target species. They are also inexpensive to use because they are self replicating and naturalizing. These potential advantages are not without disadvantages; agents that are self-replicating are also unmanageable, their ability to naturalize also makes release irreversible, and testing species-specificity and safety contributes to significant start up costs. As well, any error may impose irreversible risks on people and other species. It is interesting to note that many of the cons are the reverse of the pros (Table 1).

Table 1. Pros and cons of biological control agents.

Pros	Cons
inexpensive	start up assessment costs
species specific	? human and other health risks
self-replicating	unmanageable
naturalizing	effectiveness declines
	uncertainty

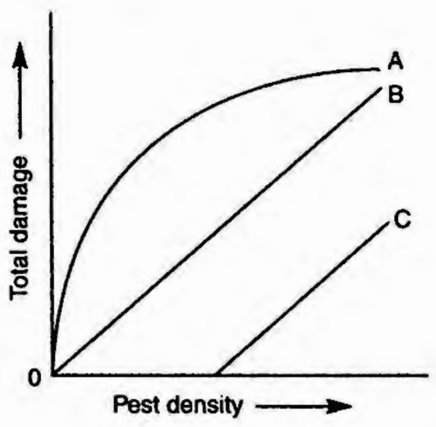
WHAT NEEDS TO BE CONSIDERED IN ASSESSING BIOLOGICAL CONTROL?

Deciding whether or not to implement biological control for a pest or weed species requires a scientific assessment of the safety and effectiveness of the proposed agent. It also requires a scientific assessment of the ecology of the pest species, the likely interaction of the agent and pest species, and options for integrating biological control with other management techniques (Briese 1993). This initial scientific assessment costs, often significantly, and the economics of a biological control program also need to be considered during the assessment.

Norton (1988) and O'Brien (1991) proposed that to be successfully adopted, new pest control methods and other land management practices need to be: technically possible, effective, practical, economically desirable, environmentally acceptable, politically acceptable, and socially acceptable. Successful biological control programs depend on more than scientific and technical input; they also require the support of land managers and the public.

HOW MUCH CONTROL IS ENOUGH?

The damage caused by the pest needs to be identified and some understanding reached of the nature of the relationship between pest density and damage, which is often not linear. The relationship may vary because of the nature of the pest action, the resource to be protected, and seasonal conditions (Braysher 1993). A linear relationship between pest density and damage, in which removing pests produced a corresponding direct reduction in damage is often assumed, but may be too simplistic (Figure 1b). For some pests, damage may remain low until a threshold density of pests is reached (Figure 1c). Under other conditions, pests may cause considerable damage, even at low densities (Figure 1a). For some pests, different relationships between density and damage will operate under different circumstances. This is likely to be true for rabbits as pests of pasture, rare native plants, and prey of feral cats and foxes.



Adapted from Bomford, M. in Parkes et al. 1996.

Figure 1. Theoretical relationships between pest density and damage. Figure 1a represents the situation where pests may cause considerable damage, even at low densities. Figure 1b represents a linear relationship between pest density and damage, in which removing pests produces a corresponding direct reduction in damage. Figure 1c represents where damage remains low until a threshold density of pests is reached. For some pests, different relationships between density and damage will operate under different circumstances.

Biological control agents, by their very nature, tend to be more active when the host is at high densities. Therefore, they are most likely to be effective when there is a minimum threshold density before damage is caused, less likely to be effective when the relationship is linear and least likely to be effective when the pest causes damage at very low densities.

Realistic objectives for the control program, based on an understanding of the damage/density relationship will also assist assessment. For example, with some pests the appealing idea of reducing the pest population may not result in any damage reduction.

WILL THE BIOLOGICAL CONTROL AGENT CONTINUE TO BE EFFECTIVE?

Biological control agents are likely to become permanent components of the environment. The advantage of this is that they can affect the pest over a considerable period from a single release and provide relatively inexpensive pest control. The disadvantages are that a decision to release a biological control agent is irreversible—the genie cannot be put back in the bottle! Myxoma virus, initially found in cottontail rabbits in the Americas and found to be lethal to European rabbits, was introduced into Australia in 1951 after more than 30 years research and now occurs in wild rabbits over vast areas of Australia. Myxomatosis, the disease caused by myxoma virus, involves unsightly and painful infections in the eyes and genitals and usually takes two weeks to kill. Given current thinking about animal welfare, myxomatosis is not an acceptable form of rabbit control to many, but there is no way of stopping its effects on wild rabbits.

Biological control agents may decline markedly in effectiveness over time. As part of the environment, biological control agents and their hosts are subject to the same evolutionary rabbits with genetic resistance to myxomatosis were detected and changes to the virulence of the myxoma virus were detected within two years (Fenner and Ratcliffe 1965). Over the next 45 years, the virus and rabbits have continued to evolve together, with the virulence of the virus continuing to change and Australian wild rabbits being selected for resistance to myxomatosis. This co-evolution not only means that the effectiveness of the control agent may decrease over time, but also compromises any later releases of the agent which would have to compete with less virulent field strains to control the host.

ARE BIOLOGICAL CONTROL AGENTS COST-EFFECTIVE?

The development of biological control programs involves high initial costs for testing, which need to be weighed against the potential long term benefits. The duration and magnitude of the benefits are unknown, and probably unknowable, in advance. Nevertheless, estimates can often be made. Reasonably accurate estimates of the cost of establishing a biological control program can usually be made. If the biological control program needs to be integrated with other control measures, the costs of the integrated control program also need to be considered. Less accurate are estimates of the potential value of the program in reducing pest damage, often based on poor estimates of the damage caused by the pest and the great difficulty involved in estimating how much damage will be prevented, and for how long. For many pests, other economic factors also need to be considered such as the potential resource value of the pest. Feral goats, pigs and wild rabbits in Australia are sold domestically and exported as game meat. These industries are relatively small when compared to the damage caused by the pests but they have potential to expand and any biological control program will compromise these industries. All these factors need to be taken into account when considering the economic desirability of biological control programs and unless the costs and benefits are vastly different, the assessment can be problematic.

WHAT DOES THE AUSTRALIAN PUBLIC THINK ABOUT BIOLOGICAL CONTROL?

In Australia, the public were invited to provide submissions indicating support or opposition to the release of rabbit calicivirus, and to comment on any possible adverse effects on people, groups, or the environment from controlling rabbits or releasing the virus. Of the 472 responses, there was overwhelming support for releasing RCD, 78% supporting release and 9% opposing. A similar exercise in New Zealand found the public was much more evenly divided. The support in Australia reflects widespread community recognition that rabbits are significant agricultural and environmental pests (Williams et al. 1995).

The main concerns raised by the public were: the species specificity of RCD (i.e., that it could infect species other than rabbits); that the predators of rabbits would turn on native animals and livestock; and effects on the rabbit industries and animal welfare concerns.

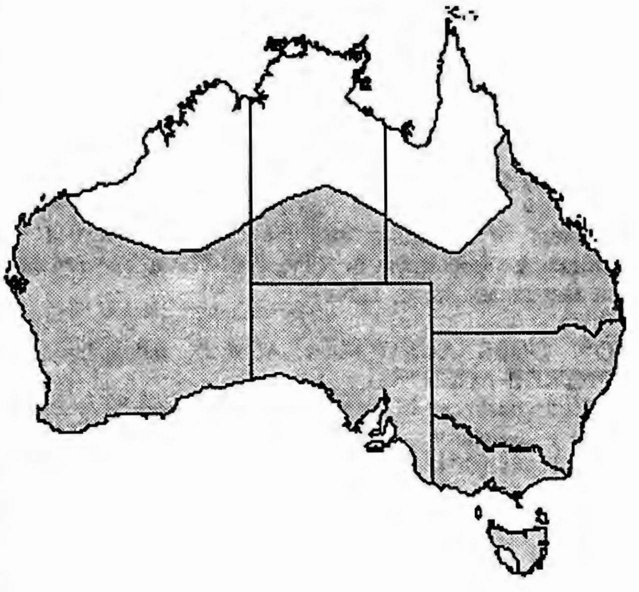
WHY ARE RABBITS A PEST IN AUSTRALIA?

Rabbits are considered a pest to both agriculture and the environment in Australia. They are an introduced species which established in the wild in 1859 when wild rabbits were introduced to be hunted and rapidly bred and spread. Rabbits have since spread through almost every environment south of the Tropic of Capricorn, except in dense forests, on black soil plains, and above 1,500 meters (see Figure 2) (Williams et al. 1995).

Rabbits harm agriculture by competing with stock for pasture, especially during drought; damaging crops, forestry and tree plantations; contributing to land and vegetation degradation; and costing farmers for pest control. On the environmental side, rabbits damage native flora; compete with native fauna; the predators of rabbits attack native fauna; and rabbits contribute to soil erosion, land degradation, and reduction of water quality.

Sloane et al. (1988) estimated the loss to wool production in Australia due to rabbits as $90 million per year. The total cost to the nation is less certain, with estimates as high as $600 million per year (Wilson 1996), although this estimate is considered too high (Foster and Telford 1996).

As a result of these impacts and costs, extensive rabbit control is undertaken using poisoning with 1080 (sodium monofluoroacetate), warren destruction ("ripping"), and exclusion fencing. Myxomatosis is also widespread and exerts significant population control in some areas. Despite these actions, rabbits remain widespread pests and are declared "noxious" throughout Australia (Williams et al. 1995).



Source: Williams et al. 1995

Figure 2. Distribution of rabbits in Australia.

WHAT IS RABBIT CALICIVIRUS?

Viral haemorrhagic disease of rabbits (VHD) was first detected in China in 1984 in rabbits imported from Germany (Liu et al. 1984). It spread rapidly across Asia and Europe killing millions of rabbits, particularly farmed rabbits, until the late 1980s when effective vaccines were developed. It also spread to wild rabbit populations in Europe. In Europe and Asia, VHD was considered a production problem for rabbit farming and a conservation problem for wild rabbits and their predators. It was thought to be spread by humans, food, bedding and rabbit-to-rabbit contact (Morisse et al. 1991). Insects were also known to be capable of spreading VHD (Gehrmann and Kretzschman 1991).

The causative agent of viral haemorrhagic disease has now been shown to be a member of the calicivirus family, known in Australia and New Zealand as rabbit calicivirus. A similar syndrome, also caused by a calicivirus, is found in hares; European brown hare syndrome (Morisse et al. 1991). Adult rabbits infected with rabbit calicivirus in the laboratory become progressively quieter from 18 to 24 hours after infection, develop a temperature, and become comatose and die quietly 6 to 12 hours later. The death rate, especially in adult farmed rabbits, can be as high as 90% (Morisse et al. 1991), although rabbits younger than eight weeks tend to have higher survival rates.

WHY LOOK AT RCD FOR AUSTRALIA'S RABBITS?

A potential new biological control agent for wild rabbits held considerable appeal in Australia. It had the potential to supplement the waning effectiveness of myxomatosis, would be species-specific and less costly than conventional techniques such as ripping rabbit warrens, poisoning, fumigation, and fencing.

In 1989, the Conservation Ministers of Australia agreed to start investigations into RCD, which was spreading rapidly across Europe and Asia, to assess its potential as a biological control agent for rabbits. Following this promising initial assessment in both the laboratory and field, the Agriculture and Conservation Ministers of Australia and New Zealand agreed to continue the assessment in Australia. The main events in that assessment are in Table 2.

HOW DOES AUSTRALIA ASSESS BIOLOGICAL CONTROL AGENTS?

Biological control agents in Australia can be assessed using a legislative process, defined in the Biological Control Act 1984. The process requires the unanimous agreement of the Commonwealth, State and Territory, and New Zealand Agriculture and Resource Management Ministers, known as the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), to commence the process of nominating biological control agents and targets by seeking public comment. The Minister is required to consider the public submissions, a task which he has delegated to the Bureau of Resource Sciences.

The Biological Control Act requires that the Minister be satisfied that the nominated pest (target) causes harm, that it is controllable by biological means, and that any harm caused by controlling the pest is less than the benefit from failing to control the pest. Similarly, for the proposed agent, it needs to be able to control the pest and any harm caused from releasing the agent, other than that from controlling the pest, needs to be less than the harm from not controlling the pest, or using other means to control the pest. The main issues raised in the submissions are considered below.

The Bureau of Resource Sciences recommended to the Minister that the requirements for agent and target organisms were met, and the Minister consulted his ARMCANZ colleagues to make the relevant declarations. ARMCANZ members unanimously agreed to declare rabbits a target organism and RCD agent organisms in September 1996. Similar declarations were later made in all States and the Northern Territory to authorize release in those jurisdictions.

IS RCD SAFE?

In 1991 the virus was imported into the microbiologically secure Australian Animal Health Laboratories to test its species specificity and effectiveness. Thirty-three non-target species were inoculated with a dose of rabbit calicivirus and subsequently tested by a range of tests for signs of infection (Table 3). The tests used for detecting RCD were clinical signs of disease, sentinel rabbits, antibody detection by indirect and competition enzyme linked immunosorbent assays, polymerase chain reaction and histological examination of tissues. Suspicious tissues found by histological examination could be subjected to specific immunofluorescence and immunoperoxidase staining, however, no tissues from non-target species have required this testing. These tests did not detect any infection of any non-target species by rabbit calicivirus. RCD was found to be 98% effective in killing adult Australian and New Zealand laboratory and captured wild rabbits (Lenghaus et al. 1994).

A literature review of the testing of non-target species by laboratories overseas found 14 studies in which 26 non-target species were tested with no reports of disease caused by rabbit haemorrhagic disease in any non-target species (Bureau of Resource Sciences 1996).

WILL RABBIT CALICIVIRUS HARM PEOPLE?

Despite the wide international occurrence of RCD and corresponding human exposure, there is no evidence of illness or disease in humans. Since there was considerable concern raised about the possibility of humans being infected with rabbit calicivirus and there were no specific studies of human health in the literature, the Australian Government commissioned a study to compare people exposed to RCD with a similar group not exposed. The study consisted of serological assessment and a health questionnaire of participants, and a survey of international laboratories working with the virus.

The study found all blood samples were negative to antibodies to rabbit calicivirus and no difference was found between those exposed to the virus and those not exposed. There was also no difference found in illnesses reported from the two groups. The overseas laboratories which replied to the survey did not report any illness associated with exposure to rabbit calicivirus, and where any testing for antibodies has been done, all reported negative results (Anon 1996).

WHAT ABOUT THE RABBIT INDUSTRIES?

Rabbit industries in Australia have concentrated on harvesting wild rabbits, mainly in the arid inland areas. The best cuts of meat are used for human consumption, the off-cuts for pet food and the fur from the pelts for hats, including the famous Akubra, with a small number of pelts used for clothing. The size of the industry varies, depending on the season and disease. The export market for Australian rabbit meat increased in the late 1980s, thought to be due to the effects of RCD in China and Europe, and decreased markedly from 1992, due to drought. The total value of Australia's wild rabbit industries is estimated at $9.1 million for rabbit meat and byproducts, and $10.7 million wholesale for hat production. The industry is thought to employ the equivalent of 68 full time shooters and 70 meat processes (Foster and Telford 1996). The rabbit meat industry virtually ceased following the escape of RCD in 1995.

Table 2. Main events in assessing RCD in Australia and New Zealand.

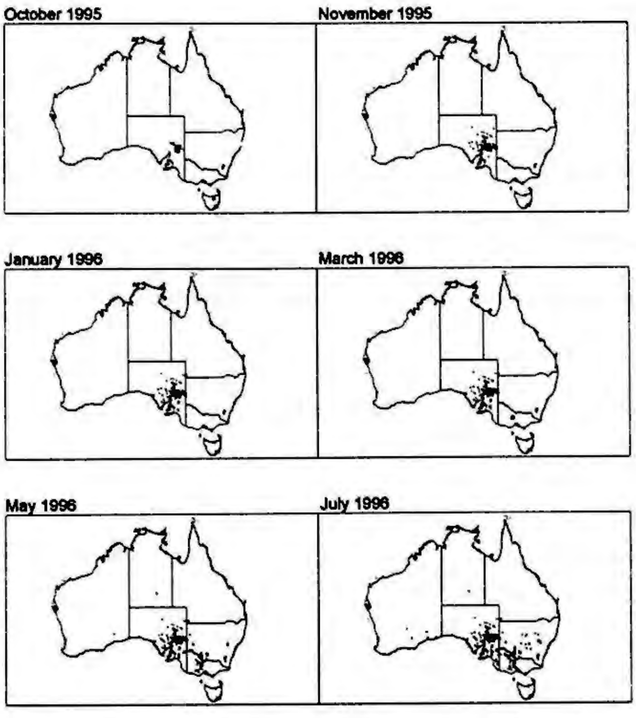
Date	Event
1984	RCD discovered in China
1984-1988	RCD spreads rapidly in Europe and Asia.
1989	Australian conservation ministers agree to investigate RCD for rabbit control by studying the effects and biology in Europe
1991	RCD imported for laboratory tests in Australia
March 1995	Island field trials commence in Australia
September 1995	RCD escapes from trial site and spreads across South Australia
September 1996	ARMCANZ Ministers authorize release of RCD
October 1996	Official releases of RCD commence
July 1997	New Zealand government decides not to introduce RCD
August 1997	RCD discovered in New Zealand

Table 3. Australian and New Zealand testing of non-target species for infection with rabbit haemorrhagic disease virus (Bureau of Resource Sciences 1996).

Australian and New Zealand Species Tested	Imported Species Tested
Bush rat (*Rattus fuscipes*)	Horse
Spinifex hopping-mouse (*Notomys alexis*)	Cow
Plains rat (*Pseudomys australis*)	Deer
Fat-tailed dunnart (*Sminthopsis crassicaudata*)	Sheep
Northern brown bandicoot (*Isoodon macrourus*)	Goat
Brush tailed bettong (*Bettongia pencillata*)	Pig
Tammar wallaby (*Macropus eugenii*)	Dog
Brushtail possum (*Trichosurus vulpecula*)	Cat
Long billed corella (*Cacatua tenuirostris*)	Fox
Silver gull (*Larus novaehollandiae*)	European brown hare (*Lepus capensis*)
Brown falcon (*Falco berigora*)	Ferret
Emu (*Dromaius novaehollandiae*)	Rat
Eastern blue-tongue lizard (*Tiliquia scincoides*)	Mouse
New Zealand lesser short tailed bat (*Mystacina tuberculata*)	Fowl
North Island brown kiwi (*Apteryx australis*)	Feral pigeon
Short-beaked echidna (*Tachyglossus aculeatus mantelli*)	
Southern hairy-nosed wombat (*Lasiorhinus latirons*)	
Koala (*Phascolarctos cinerous*)	

THE ESCAPE

Field testing of RCD in wild rabbits began on Wardang Island in March 1995. These trials were designed to examine the effect of RCD on rabbits in the Australian environment. They showed that RCD can be transmitted between Australian wild rabbits living in warrens and between warrens. In October 1995, RCD escaped from the island to mainland Australia and then rapidly spread over a large area of South Australia and into parts western New South Wales and southwest Queensland by December 1995 (Figure 3). Virus activity declined over the summer months but, in March 1996, RCD became active in central Victoria and spread in that state. The reasons for the escape have not been conclusively established, but insect vectors are considered most likely to be responsible.



Source: Bureau of Resources Sciences 1996 report

Figure 3. Maps of the spread of RCD from November 1995.

RELEASES

In October 1996, RCD release was authorized by all Australian governments with all mainland states making releases that year. Tasmania did not release RCD, but it was reported in the northern part in December 1996 and spread slowly. Releases in other areas of Tasmania have also been made without the rapid and spectacular effect seen in the arid areas where RCD escaped.

WHERE IS RCD NOW?

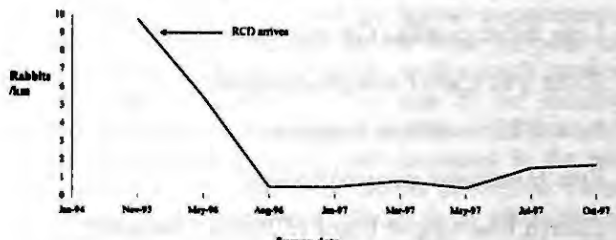
From the initial escape and the more than 700 subsequent releases of RCD, the virus is now thought to be distributed roughly over the entire distribution of rabbits in Australia, with the possible exception of north-western Australia (Figure 2).

HOW DOES RCD SPREAD?

RCD is spread by rabbit fleas and mosquitoes (Lenghaus et al. 1994). Following the rapid spread across Australia, other vectors have also been sought. Bushflies have been shown to spread RCD in the laboratory, and many other bush and blow fly species have tested positive to the presence of viral RNA. The role of these insects in virus transmission in not yet known.

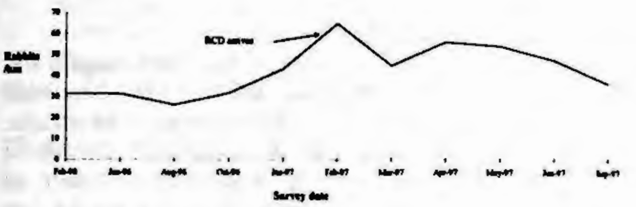
WHAT EFFECT IS RCD HAVING?

At the national scale, the impact of RCD on rabbit populations has been variable, from the initial spectacular epizootic in some regions, with mortality rates around 90%, to the patchy, less obvious impact in other areas following releases. For example, Erldunda in the Northern Territory measured declines during the initial epizootic of about 90% (Figure 4), while rabbits numbers in parts of the Western Slopes of New South Wales continued to increase after RCD arrived (Figure 5). RCD has been found to be more effective in arid and semiarid areas (rainfall less than 300 mm per year) than in the wetter areas. RCD recurs with three roughly annual epidemics recorded at a site in the Flinders Ranges, South Australia, and two recorded at Lake Burrendong, New South Wales. The mortality rate recorded at the Flinders Ranges site was over 90% in the initial epizootic, but much less in the later episodes. In other areas, the effect of RCD has not been obvious (Table 4).



Based on data supplied by Centralian Land Management Association and Parks and Wildlife Commission of the Northern Territory.

Figure 4. Rabbit numbers during initial RCD epizootics, Erlunda, Northern Territory.



Based on data supplied by Dr Glen Saunders, New South Wales Agriculture.

Figure 5. Rabbit numbers during initial RCD epizootics, Central Tablelands, New South Wales.

Australia's wild rabbit populations also support a number of predators, both imported and native. The major imported predators are feral cats and foxes, and the major native predators are dingoes and birds of prey. Studies at two sites have shown that feral cat numbers have declined as rabbit have become less common, with some evidence that a similar fate met foxes. There has been some concern that the breeding of birds of prey would be affected by RCD, as was reported with myxomatosis in 1951 (Olsen and Marples 1992), but successful breeding of wedge-tailed eagles has been reported from at least one site.

Most of the benefits reported from the decline in rabbit populations are from the Flinders Ranges where RCD has been active for the longest. In that area, where rabbit numbers remain low, the recruitment of some native plant species, low bluebush (*Maireana astrotricha*), mulga (*Acacia aneura*), narrow-leafed fuchsia-bush (*Eremophilia alternifloria*) and miljee (*Acacia oswaldii*), regeneration of bullock bush (*Alectryon oleifolius*) and emu bush (*Eremophilia longifloria*) and recovery of needlewood (*Hakea leucoptera*), quandong (*Santalum acuminatum*), and maireana and acacia species have occurred. Other reports from the Kinchega National Park in New South Wales are of regeneration of purple wood (*Acacia carnei*), rosewood (*Alectryon oleifolius*), and belah (*Casuarina cristarta*) (Anononymous 1997). Given the ability of rabbits to damage even mature vegetation, the long-term survival of this vegetation will depend on the length of time the rabbit populations are held low. In contrast, the Coorong in South Australia has had low rabbit populations for over a year due to RCD, but no signs of regeneration of a specific species, sheoak (*Allocasuarina verticillata*) have been found. In other areas of Australia, such as Hattah in Victoria and Erldunda in the Northern Territory, seasonal and rainfall events are thought to be more important for plant growth and regeneration (Anonymous 1997).

To study the impact of RCD, and to determine how it can best be used by land managers for rabbit control, the governments established two complementary programs; the epidemiology program to study the disease and its transmission and a National Monitoring and Surveillance program to track the spread of the disease and study the impact on rabbit populations and on agriculture and the environment. The National Monitoring and Surveillance Program has more than 60

Table 4. Results of RCD releases in Australia.

State/Territory	Number of Release Sites	Obvious* RCD Activity	No Obvious RCD Activity	RCD Activity Not Known
Australian Capital Territory	8	2 (25%)	3 (38%)	3 (38%)
New South Wales	485	269 (56%)	132 (27%)	84 (17%)
Northern Territory	9	2 (22%)	5 (55%)	2 (22%)
Queensland	83	25 (30%)	5 (6%)	53 (64%)
South Australia	28	--	--	28 (100%)
Tasmania	15	1 (7%)	--	14 (93%)
Victoria	116	67 (58%)	31 (27%)	18 (15%)
Western Australia	41	11 (27%)	16 (39%)	14 (34%)
Total	785	377 (48%)	192 (24%)	216 (28%)

*Obvious RCD activity indicates that observant visitors to the area would be aware of significant rabbit deaths associated with RCD activity in the area.

Source: RCD Monitoring and Surveillance Program, State and Territory vertebrate pest agencies.

study sites across the country. The program is run by State and Territory pest control agents, with results collated nationally by the Bureau of Resource Sciences.

WHAT IS THE FUTURE OF BIOLOGICAL CONTROL, PARTICULARLY FOR VERTEBRATE PESTS?

The use of biological control for weeds in Australia continues, with two more weed species currently being considered for biological control. Research into fertility control of vertebrate pests, including mice, rabbits, and foxes, by a self replicating biological control agent which sterilizes the host continues. The proposed biological control agents are viruses, which can be species specific, and they will be genetically modified to cause sterility. Myxoma is the virus chosen for rabbits, but finding one specific to foxes is more difficult. This research is novel, but carries a high risk of failing to produce a suitable, effective agent.

New Zealand is also pursuing biological control of possums by searching for viruses in the possums native habitat, Australia; using a virus isolated in New Zealand (Wobbly Possum Syndrome Virus), possibly genetically modifying it; and virally vectored sterility.

IS RCD AN EFFECTIVE BIOLOGICAL CONTROL?

Generally RCD is considered effective, but how does RCD rate against the principles detailed earlier for biological control agents? Spreading RCD has been found to be technically possible, although research into less expensive, simpler techniques continues. RCD has been effective in reducing some rabbit populations drastically, with the effects lasting for at least two years. Since the long term impact of RCD on the environment and agriculture is not known, it is difficult to judge now the economic impact of RCD. Political acceptability was found with the unanimous support for use of RCD in Australia of Commonwealth, State, Territory and New Zealand Agriculture and Resource Management Ministers, and bipartisan support at the Commonwealth level. The public comment in Australia strongly supported the use of RCD. Early reports of regeneration, recruitment, and recovery of native vegetation are promising, although it is too early to detect the long-term effect on the environment. However, the long-term risk to the predators of rabbits, and through them to native animals, was considered during the assessment as much less than the possible long term benefit if the damage rabbits cause is reduced.

CONCLUSION

In Australia the technical feasibility and practicability of biological control agents tends to be well assessed. The escape of RCD from island quarantine experiments highlights both the problematic nature of biosecurity under field-relevant conditions and the difficulty of determining precisely how the agent will perform in the field. While all aspects of safety can be directly assessed before release, efficacy assessments are necessarily indirect.

When there is public concern, a legislative mechanism to test social and political acceptability is available and was used with RCD. Rabbit calicivirus has been active in Australia since November 1995.

The impact on rabbit populations has generally been spectacular in arid and semiarid areas, and more variable in wetter areas of Australia. Early reports of regeneration of native flora and declines in introduced predators are promising, although it is too early to determine the long-term benefit to native fauna and flora.

ACKNOWLEDGMENTS

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