ISSN 1447-4980
Miscellaneous Publication 04/2005

Department of Agriculture

THE STATUS AND IMPACT OF THE RAINBOW LORIKEET *(TRICHOGLOSSUS HAEMATODUS MOLUCCANUS)* IN SOUTH-WEST WESTERN AUSTRALIA

February 2005

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February 2005

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EXECUTIVE SUMMARY

Rainbow lorikeets *Trichoglossus haematodus moluccanus* were first recorded in Perth in 1968 and the population was thought to have originated from fewer than 10 birds that were either deliberately released or had escaped from aviaries. Since the early 1960s, the population has increased exponentially and spread rapidly over 174 km^2 of the metropolitan area. The population now numbers an estimated 8,400 birds and is expanding in range at a rate of 0.7 km per year.

Rainbow lorikeets are highly mobile, have generalised feeding and breeding requirements and can quickly adapt to exploit new feeding and breeding resources. They have taken advantage of the year-round supply of native and exotic food plants available in Australia's major cities and are expanding in number and distribution in Brisbane, Sydney, Melbourne, Canberra, Adelaide and Perth.

The rainbow lorikeet is regarded as either a pest of agriculture or an unwanted organism in New Zealand, the Northern Territory, Queensland, the Australian Capital Territory, Victoria, Tasmania and South Australia. It is also a major pest of agriculture in the Northern Territory, Queensland and the fruit growing regions of the Adelaide Hills in South Australia.

Analyses conducted in this study show that the feral rainbow lorikeet population in Perth poses an extreme risk to the State's social, environmental and agricultural values. Rainbow lorikeets cause a nuisance in the form of noise, damage to backyard fruit crops and fouling of outdoor areas and vehicles with droppings. The large roosting flock of over 1000 birds near Perth domestic airport may also pose a risk of bird-strike to aircraft. The lorikeets also exclude native birds from feeding resources and nesting sites, kill the nestlings of other bird species and carry Psittacine beak and feather disease in the liver (once infected), which they can spread to native lorikeets and parrots.

Lorikeets are a serious pest of cherries, apples, pears and stone fruit and a very serious pest of grapes in Australia and this study showed that the potential for rainbow lorikeets to spread outside the Perth metropolitan area is high. Thus, the lorikeets pose an extreme threat to Western Australia's $245 million fruit, nut and grape growing industry.

An integrated pest management program must be developed to: restrict the population to the Perth metropolitan area, and reduce the number of birds in the population from an estimated 8400 in 2004 to an estimated 5000 by 2020. The management program should include the following objectives:

1. Investigate sources and obtain the funding required to manage the population.
2. Estimate the number of birds in the Perth population, establish its distribution and locate major roost sites.
3. Alter the status of the rainbow lorikeet in south-west Western Australia so that it is a declared pest in the metropolitan area (alter to A2; 'subject to eradication in the wild' south of the 20th parallel of latitude, and A5; 'numbers to be reduced/controlled' in the Perth metropolitan area).
4. Investigate methods of population reduction in the metropolitan area and document their effectiveness.
5. Educate the public on the impacts of rainbow lorikeets and the need for control.
6. Eradicate rainbow lorikeets that are sighted outside the metropolitan area.

7. Investigate and document the effectiveness of methods for the mitigation of agricultural damage.
8. Conduct a cost/benefit analysis of the damage caused by rainbow lorikeets and lorikeet control.
9. Develop a molecular approach to population control and management.
10. Review standards for the import and keeping of rainbow lorikeets to reduce the risk of aviary escapes.

1. INTRODUCTION

The feral population of rainbow lorikeets *Trichoglossus haematodus moluccanus* in south-west Western Australia probably originated from aviary escapees or deliberate releases in the early 1960s (Coyle 1988; Higgins 1999; Long 1981). Since that time the population has increased exponentially (Lamont 1996) and has spread over much of the metropolitan area. The rainbow lorikeet is a declared pest of agriculture in the South-West Land Division, excluding the Perth metropolitan area (*Agriculture and Related Resources Protection Act 1976*), a nuisance in suburban Perth (M. Massam[i] pers. comm.) and a threat to the biodiversity in south-west Western Australia (Department of Environment and Heritage 2004; Lamont 1996). In the mid 1990s, amid growing public concern about the impact of the lorikeets, Lamont (1996) called for: research and monitoring into the ecology and range extension of the lorikeets; assessment of the impacts of the lorikeets in the south-west; and the development of effective control measures.

In response to concern from community conservation groups and the general public, the Rainbow Lorikeet Working Group WA was established in February 2004 to formulate the aims and objectives to manage the raxinbow lorikeet population in south-west Western Australia. The working group consists of representatives from the Agriculture Protection Board, the Department of Conservation and Land Management (CALM), the Department of Agriculture, the Western Australian Museum, a member of State parliament, the Western Australian Fruit Growers Association, the Department of Local Government and Regional Development, Birds Australia Western Australia and the United Bird Societies of WA. This report was commissioned by the Rainbow Lorikeet Working Group WA to: summarise what is known about the rainbow lorikeet for reference by the working group; examine the status and management of the rainbow lorikeet in other regions; assess the threats posed by the feral population in south-west Western Australia; and formulate the aims and objectives for an integrated pest management program.

2. BACKGROUND

Following is a summary of what is known about the biology and ecology of the rainbow lorikeet from observations and studies conducted in Perth and other regions.

2.1 Taxonomy and relationships

The generic name for the rainbow lorikeet *Trichoglossus* refers to the brush-like papillae at the tip of the tongue and the specific name haematodus refers to the blood-red colouring of the plumage (Higgins 1999). Other names for the rainbow lorikeet include the blue-bellied lorikeet, blue mountain lorikeet, blue mountain parrot, Swainson's lorikeet, coconut lory, rainbow lory and orange-naped lorikeet (Higgins 1999).

Both the rainbow lorikeet and the red-collared lorikeet have bright red on the underwings, breast, eye and bill and blue on the head, forewings and belly (Johnstone and Storr 1998; Morcombe 2000). The red-collared lorikeet is distinguished by an orange-red collar, while the rainbow lorikeet has a greenish-yellow collar (Johnstone and Storr 1998; Morcombe 2000). The red-collared lorikeet is endemic to northern Australia from the Kimberley in Western Australia to the Top End of the Northern Territory (Johnstone and Storr 1998; Morcombe 2000). The scaly-breasted lorikeet is a green parrot with a red bill and red underwings, but is smaller than the rainbow lorikeet and does not have a blue head and underbelly (Higgins 1999; Morcombe 2000). The scaly-breasted lorikeet is endemic to the east coast of Australia and occurs in Victoria and on the east coast of the Northern Territory, Queensland and New South Wales (Higgins 1999; Morcombe 2000).

In eastern Australia, rainbow lorikeets are frequently seen with scaly-breasted lorikeets and may also flock with musk lorikeets *Glossopsitta concinna* and little lorikeets *Glossopsitta pusilla* (Higgins 1999). None of these lorikeets are endemic to south-west Western Australia, but scaly-breasted and musk lorikeets have also been seen at large in Perth as a result of escapes from aviaries (Barrett *et al.* 2002; Blakers *et al.* 1984; Johnstone and Storr 1998).

2.2 Description and field identification

The rainbow lorikeet is the largest of the Australian lorikeets and is 26 to 31 cm in length, 46 cm in wingspan and 120 to 130 grams in weight (Higgins 1999; Johnstone and Storr 1998). The species is characterised by blue, green and orange markings and a loud screeching call (Higgins 1999). The markings do not vary on a seasonal basis or between the sexes (Porter 1992), but juveniles are duller than adults (Higgins 1999) and have a dark brown bill (Forshaw 1969). In flight, rainbow lorikeets appear slim with angular back-swept finely pointed wings, combined with a tapered tail (Higgins 1999). The flight of the rainbow lorikeet is swift and direct and they are active birds that twist and turn in the tree-tops (Higgins 1999).

Rainbow lorikeets roost in large, noisy, communal groups of sometimes thousands of birds (Higgins 1999). These flocks leave the roost at dawn and break up into smaller foraging flocks of 10 to 50 birds (Higgins 1999). Mean flock sizes for rainbow lorikeets recorded near the Queensland-New South Wales border region by Cannon (1984a) were 2.9 (range 1-20, n = 226) when feeding, 3.4 (range 1-37, n = 507) when flying and 4.7 (range 1-30, n = 292) when perching.

2.3 Distribution and habitat

The rainbow lorikeet occurs in south and east Indonesia, east through New Guinea, the Solomon Islands, Vanuatu, New Caledonia and the north and east of Australia (Figure 1, Higgins 1999). In Australia, the rainbow lorikeet occurs from northern Queensland and along the east coast to Eyre Peninsula in South Australia (Figure 1; Higgins 1999). An isolated feral population occurs in Perth (Figure 1; Higgins 1999). Globally, the rainbow lorikeet inhabits a wide range of wooded habitats including tropical rainforest, monsoon forest, open and closed sclerophyll forest, woodland, heathland and the street trees of suburban parks and gardens (Higgins 1999).

2.4 Diet and feeding

The rainbow lorikeet is a generalist feeder because it feeds on a large variety of plants. For example, in the Queensland-New South Wales border region the lorikeets fed on 43 different plant species (Cannon 1984c) and on the coastal fringe of Darwin they fed on 37 different plant species (Hasebe and Franklin 2004). They also feed on the commercial crops of flowering coconuts, ripening sorghum, corn and fruit trees in orchards and gardens (Hasebe and Franklin 2004; Higgins 1999; Lim *et al.* 1993).

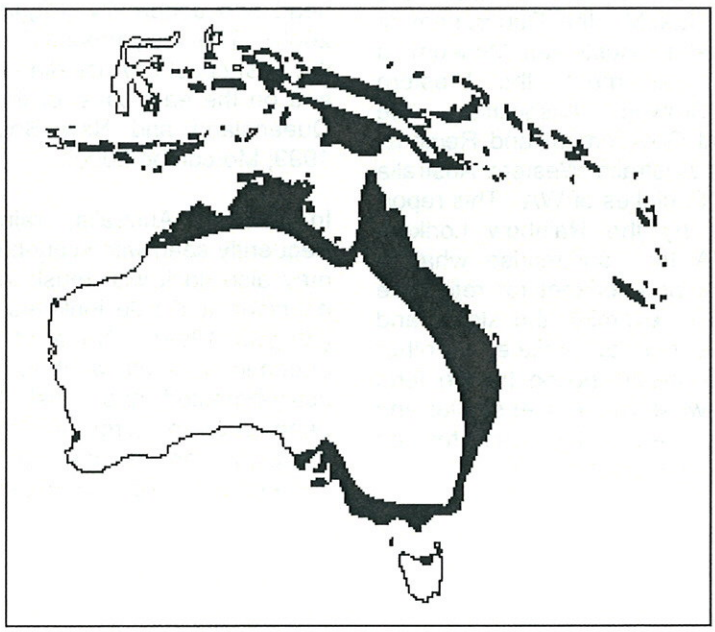

Figure 1. Distribution of the rainbow lorikeet species complex *Trichoglossus haematodus* (modified from Barrett *et al.* 2002; Forshaw 2002).

In temperate regions, most of the diet of the rainbow lorikeet (87 per cent) is made up of flowers of the Myrtaceae, Proteaceae and Xanthoroaceae families (Cannon 1984c).

They commonly feed in the outer foliage of flowering trees such as *Eucalyptus* spp., *Banksia* spp., *Melaleuca* spp., *Callistemon* spp. and *Grevillia* spp. (Higgins 1999). The lorikeets feed on flowers, fruits, leaf buds, berries, seeds, insects (beetles, wasps, thrips, ants and weevils) and the larvae of flies, weevils and moths (Bell 1966; Bell 1968; Cannon 1984c; Hasebe and Franklin 2004; Lamont 1996).

Rainbow lorikeets are aggressive toward other birds using the same food sources and can dominate over miners *Manorina* spp., red wattlebirds *Anthochaera carunculata*, little wattlebirds *A. chrysoptera*, friarbirds *Philemon* spp., New Holland honeyeaters *Phylidonyris novaehollandiae* and scaly-breasted lorikeets, but red wattlebirds can also dominate over rainbow lorikeets (Higgins 1999). For instance, records show that when feeding in the same eucalypt in Linfield NSW, red wattlebirds fed throughout the canopy while rainbow lorikeets were relegated to the outer parts of the canopy (Bruce 1973).

2.5 Reproduction

The pair and family unit form the basic social structure in rainbow lorikeets and breeding adults are resident within a 35 km radius of major roosts (Polkanov and Keeling unpublished manuscript; Porter 1992). The breeding season varies widely between regions, depending on climate and resource availability, but generally occurs from August to January in southern Australia (Higgins 1999). Australia-wide, rainbow lorikeets have been recorded breeding in every month except March (Higgins 1999).

Rainbow lorikeets are adaptable to a range of nesting sites (Long 1990). They can nest in the natural hollows of tall trees such as *Eucalyptus* spp., *Angophora* spp. and *Melaleuca* spp. (Higgins 1999), excavated nests in palm stems (Lamont 1996) and the burrows and crevices of overhanging rock (Poy-Yai Islet, Papua New Guinea) (LeCroy *et al.* 1992). Several pairs often nest in the same area or in the same tree and rainbow lorikeets will also nest in the same tree with other species of birds (Higgins 1999).

Rainbow lorikeets reach sexual maturity after two years (Porter 1992) and pairs probably form a lifetime bond (Higgins 1999). Prior to mating, pairs engage in courtship feeding and investigate a number of hollows before one is chosen (Higgins 1999). The nest is in a hollow limb or hole in a tree up to 25 m above the ground and usually has a layer of wood dust at the bottom (Higgins 1999). A clutch of two eggs is laid at intervals of two to three days (Porter 1992), approximately 30 to 80 cm from the nest entrance (Higgins 1999). The female incubates the eggs for 23 days and is fed by the male in the morning and evening (Higgins 1999; Porter 1992). Fledglings leave the nest at around 45 days and the parents continue to feed the young for a period of two to three weeks after fledging (Higgins 1999; Porter 1992). A pair of rainbow lorikeets can produce up to three broods in a season and individual birds can live for over 20 years in the wild (Higgins 1999). After breeding, rainbow lorikeets congregate into large flocks (Higgins 1999).

2.6 Predators and diseases

Records of the predation of rainbow lorikeets are scarce but the lorikeets use 'sentries' when feeding in flocks (Higgins 1999), indicating that they are predated by raptors. Birds fall silent, freeze and 'crane-peer' when threatened and react to raptors with flight and alarm calls (Higgins 1999).

One record of bilateral necrotizing pectenitis causing blindness in a rainbow lorikeet has been recorded in an aviary bird (Raidal 1997). In addition, once infected, although they may make a clinical recovery, rainbow lorikeets and scaly-breasted lorikeets carry Psittacine beak and feather disease in the liver (Department of Environment and Heritage 2004). Release of rescued rainbow lorikeets thus poses a threat of Psittacine beak and feather disease to wild lorikeet and parrot populations (Department of Environment and Heritage 2004).

2.7 Behaviour

Flocks of rainbow lorikeets are highly mobile and can travel more than 50 km from the roost to feeding sites (Porter 1992). They fly high and rarely go to ground because the wing loadings and aspect of their wings makes landing and take-off from the ground difficult (Higgins 1999). The birds spend 70 per cent of their time in the outer foliage of tall trees among dense foliage or hollow branches

(Higgins 1999). The majority of the morning and afternoon is spent feeding and the birds rest in the foliage during the middle of the day (Higgins 1999). The lorikeets drink surface water and also drink and bathe in water trapped in leaves or interlocking palm fronds (Forshaw 1969).

Rainbow lorikeets require about 250 kJ to meet their daily energy requirements (Cannon 1979). Based on this model, Cannon (1979) calculated that they could meet their daily field energy requirements by foraging for only 2.5 hours per day, because they visit 30 to 40 flowers per minute (Cannon 1979). However, these calculations may have overestimated the number of flowers required per day because they were based only on the pollen component of the flowers (Cannon 1979), whereas the entire flower forms the major component of the diet (Cannon 1984c; Lamont 1996). Thus, the lorikeets could probably meet their energy requirements in less than 2.5 hours per day.

The behaviour, reproductive cycle and community organisation of rainbow lorikeets is correlated with seasonal flowering patterns (Porter 1992). For example, in a study in south-east Queensland by Porter (1992), breeding adults resided within a 35 km radius of foods and the birds flew up to 60 km on a daily basis to feed. During autumn and winter when food was most abundant, non-breeding birds roosted in one flock, while breeding birds (including breeding males) roosted in the nest hollow (Porter 1992). In spring and summer, when food resources were scarce, the population was more dispersed (Porter 1992).

The vocal repertoire of the rainbow lorikeet includes a: high pitched wheeze of the fledgling; protest call when disturbed at nesting or feeding sites (accompanied by wing flapping and side-ways movements of the head); location call; warble by pairs when feeding, resting and preening; and scouting call made in flight when searching for other birds or food (Higgins 1999).

3. STATUS AND POPULATION MANAGEMENT

Rainbow lorikeets were known as a pest of orchard crops such as apples, pears and soft summer fruits in eastern Australia in the early 1900s (Mathews 1916-17; North 1912). These populations suffered localised declines during the early 1900s as a result of habitat loss and the loss of commercial fruit trees for residential development (e.g. Waterhouse 1997). However, the lorikeets became re-established and populations increased in distribution and number with the maturation of trees planted in streets, parks and gardens in residential areas (e.g. Waterhouse 1997).

The rainbow lorikeet is becoming more common in the populated areas of Australia such as Brisbane, Sydney, Melbourne, Canberra, Adelaide and Perth (Lamont 1996; Shukuroglou 2004; Veerman 1991; Waterhouse 1997). The rainbow lorikeet was one of the 40 most frequently recorded species in Australia during recording for the New Atlas of Australian Birds from 1998 to 2002 (Barrett *et al.* 2002). The reporting rate for the rainbow lorikeet had increased by 20 per cent or more throughout much of its range since the first *Atlas of Australian Birds* from 1977 to 1981 (Blakers *et al.* 1984) and there were no regions of Australia where the rate had decreased between the two atlases (Barrett *et al.* 2002).

Studies have shown that rainbow lorikeets are more common in modified areas than in bushland. For example, of 1517 observations of rainbow lorikeets during a survey in the Queensland - New South Wales border region, 420 were in urban areas, 944 were in open agricultural areas and 153 were in forested areas (Cannon 1984c), demonstrating that nearly 90 per cent of sightings were in modified habitats. Modelling in Melbourne showed that rainbow lorikeets were more likely to be found in residential areas and parklands than in remnant vegetation and rural areas (Shukuroglou 2004).

Assessing the impact of the rainbow lorikeet on commercial crops is difficult because the damage caused by birds in orchards is rarely quantified (Bomford and Sinclair 2002). However, lorikeets are a serious pest of cherries, apples, pears and stone fruit and a very serious pest of grapes in Australia (Bomford and Sinclair 2002). Sections 3.1-3.7, below, show that the rainbow lorikeet is regarded as either a pest of agriculture or an unwanted organism in New Zealand, the Northern Territory, Queensland, the Australian Capital Territory, Victoria, Tasmania and South Australia. The rainbow lorikeet is a major pest of agriculture in the Northern Territory, Queensland and the fruit growing regions of the Adelaide Hills in South Australia. Following is a summary of the status of rainbow lorikeets in other regions and a discussion of attempts by government agencies to manage feral, pest and unwanted populations.

3.1 New Zealand

A series of releases, that were not authorised under the *New Zealand Wildlife Act 1953*, began in suburban Auckland in about 1992 by a breeder whose motive was to 'benefit New Zealand wildlife and make the country more attractive to tourists' (Polkanov and Greene 2000). The population was provided with supplementary food by the breeder and grew to a breeding population of around 50 birds by 2000 (Polkanov and Greene 2000). The New Zealand Department of Conservation assessed the potential biodiversity, primary production and disease risk posed by rainbow lorikeets in New Zealand (Greene 1998). Although the Department of Conservation had mostly circumstantial evidence of the impacts of rainbow lorikeets in New Zealand from case studies in Australia, they took the precautionary principle and concluded that the risk of establishment was high and that the potential to damage crops was significant (Polkanov and Keeling 2001). As a result of the assessment, the rainbow lorikeet was declared an 'Unwanted Organism' under the *Biosecurity Act 1993* (Polkanov and Greene 2000). The rainbow lorikeet was also added to the fifth schedule of the *New Zealand Wildlife Act 1953* which resulted in the removal of protection by default (Polkanov and Keeling 2001).

By 2000 the wild rainbow lorikeet population had spread over a span of 70 to 80 km and was estimated to number 150 to 200 birds (Polkanov and Greene 2000). The Department of Conservation assessed the feasibility of mist netting, narcotisation, shooting and trapping to remove the birds and concluded that live trapping was the only viable option (Polkanov and Keeling 2001). Accompanied by a public education campaign, the Department of Conservation began a recapture program for feral rainbow lorikeets in late January 2000 (Polkanov and Greene 2000). The program had good public support, with the exception of the Rainbow Parrot Trust, which rebutted most of the potential threats outlined by the Department of Conservation (see http://www.rainbow.org.nz/). As part of the recapture process, the lorikeets were live captured and passed on to aviculturists for sale on the domestic and international market (Polkanov and Greene 2000).

In total, 94 birds were recovered from the wild using big drop-door cage traps, small drop-door cage traps, automatic split-perch traps and capture of tame birds by hand (Table 1) (Polkanov and Keeling unpublished manuscript). Honey-water, lorikeet wet and dry mixes, fresh flowers, apples, oranges and peaches were used to lure the birds into the traps (Polkanov and Keeling 2001). Of the 94 birds recaptured, 63 were trapped by the Department of Conservation (Table 1), 27 were trapped by bird keepers and four were killed by cats or collisions with windows (Polkanov and Keeling unpublished manuscript). The most effective traps for recapturing the rainbow lorikeets were the big drop-door cage traps and sliding door cage traps (Table 1). The automatic split-perch trap was the most effective trap for recapturing small groups (one by one) and individual birds (Table 1) because it is a compact, lightweight and portable trap that provides weather protection for the call bird (Polkanov and Keeling 2001).

Table 1. Methods used by the Department of Conservation to capture rainbow lorikeets in New Zealand (after Polkanov and Keeling 2001)

Methods of capture	Number of birds	Per cent of birds
Big drop-door cage trap	30	48
Sliding-door cage trap	13	21
Small drop-door cage trap	4	6
Automatic split-perch trap	14	22
By hand	2	3
Total	63	100

As a result of the trapping program, no large flocks of rainbow lorikeets were recorded in the wild in 2000 and 2001 (Polkanov and Keeling 2001). According to Polkanov and Keeling (2001), the Department of Conservation was successful in preventing rainbow lorikeets from becoming established in New Zealand because they had sufficient funding, a mandate for the trapping program and a high degree of public support. The small size and restricted distribution of the population would also have been important factors contributing to the success of the trapping program (Bomford 2003).

Rainbow lorikeets continue to arrive in the wild in New Zealand from hand-reared tame birds, aviary birds and possibly deliberate releases (Polkanov and Keeling 2001). The Department of Conservation accepts that there will always be rainbow lorikeets in the wild in New Zealand as a result of deliberate or accidental releases (Polkanov and Keeling unpublished manuscript). They aim to control the number of birds below a self-sustaining population level and to prevent escapes of captive birds via: public education; banding; limiting breeding in aviaries; and setting minimum standards for aviary security (Polkanov and Keeling unpublished manuscript). Rainbow lorikeets can still be kept in secure aviaries in New Zealand, but they must not be released from captivity (Polkanov and Greene 2000).

3.2 South Australia

The National Parks and Wildlife Service, South Australia, declared that the Adelaide rosella *Platycercus elegans adelaidae*, musk lorikeet and rainbow lorikeet may be humanely destroyed by commercial orchardists and vineyard owners, their employees and agents without a permit during a trial period from 14 December 2000 to 30 June 2001 (National Parks and Wildlife 2001b). Shooting was restricted to selected council areas in fruit growing regions (National Parks and Wildlife 2001b). The fact sheet that was distributed was accompanied by a 'Code of Practice for the Humane Destruction of Birds by Shooting in South Australia' (National Parks and Wildlife 2001a) which outlined the protocol for the safe and humane shooting of the birds.

The Bird Care and Conservation Society (BCCS), South Australia raised shooting of the birds as an issue for discussion (see http://www.adam.com.au/tasygeos/consiss.htm). Their major objection was that the number of birds in the population had not been established and that the number of birds shot was not recorded by the National Parks and Wildlife Service, because the shooting was not conducted under a licence. Vignerons responded by stating that they rarely used shooting and employed other methods to control birds such as netting and scaring (see http://www.adam.com.au/tasygeos/consiss.htm for media articles). The South Australian Government no longer supports the control of parrots and lorikeets by unlicensed shooting in South Australia (R. Sinclair[ii] pers. comm.).

3.3 Northern Territory

A postal survey of primary producers was conducted for vertebrate pest damage of 49 crop species in the Northern Territory in 1993 (Lim *et al.* 1993). A total of 24 vertebrate pests were ranked on the basis of the number of reports of damage during the survey (Lim *et al.* 1993). Rainbow lorikeets were the second most commonly reported pest of fruits (n = 28 fruits assessed) after the black flying fox Pteropus alecto and the most commonly reported pest of vegetables (n = 10 vegetables assessed) followed by the galah Cacatua roseicapilla (Lim *et al.* 1993). Rainbow lorikeets were the fifth most commonly reported pest of field crops, flowers and ornamental species (n = 11 crop, flower and ornamental species assessed) after the galah, sulphur-crested cockatoo *Cacatua galerita*, little corella *Cacatua pastinator* and red-tailed black-cockatoo Calyptorhynchus banksii macrorhynchus (Lim *et al.* 1993).

Each pest species was ranked, out of a total of 24 vertebrate pest species assessed, based on the number of reports of damage to a range of fruit or vegetable species (Lim *et al.* 1993). Rainbow lorikeets had the biggest impact on (brackets show ranking by number of responses out of a total of 24 vertebrate pest species assessed) mango (2), rambutan (1), papaw (5), carambola (3), jackfruit/breadfruit (5) and abiu (5) (Lim *et al.* 1993). Rainbow lorikeets can cause catastrophic losses to the $2 million a year rambutan growing industry in the Northern Territory (Lim and Diczbalis 1997). The farmers also reported damage by rainbow lorikeets to banana, custard apple, guava, melon, okra, snake bean, other beans, sorghum and sesame (Lim *et al.* 1993).

Farmers nominated trapping and permanent netting as the most effective methods of control for rainbow lorikeets (Lim *et al.* 1993). The least effective methods nominated were electric wires, flickering reflective and coloured tapes, rotating mirrors, plastic hawks, hawk-eye bird scarers, humming scare line and carbide gun (Lim *et al.* 1993). Variable results were obtained from shooting, scarecrows, animal cadavers, throw-over nets and partial netting (Lim *et al.* 1993).

3.4 Queensland

In Queensland, large flocks of rainbow lorikeets damage sorghum, often in mixed flocks with scaly-breasted and musk lorikeets (Higgins 1999). Rainbow lorikeets are generally considered to be an asset for tourism in Queensland where large numbers are attracted for tourist displays via feeding stations (Cannon 1984b; Hasebe and Franklin 2004).

3.5 Tasmania

The rainbow lorikeet is considered a pest by the Department of Primary Industries, Water and Environment (Nature Conservation Branch) in Tasmania (see http://www.rpdc.tas.gov.au/soer/indicator/50/index.php). However, of 44 environmental pest species nominated, only six have been formally declared via legislation and the rainbow lorikeet is not among them. Groups of rainbow lorikeets periodically arrive in Tasmania from the mainland as a result of aviary escapes and they feed on street trees but are not known to breed in Tasmania (see http://www.rpdc.tas.gov.au/soer/indicator/50/index.php).

3.6 Victoria and the Australian Capital Territory

The *Atlas of Australian Birds* reported that the distribution of rainbow lorikeets had declined south of about 30° and west of the Great Dividing Range between 1977 and 1981 (Blakers *et al.* 1984). However, Veerman (1991) disputed this observation, pointing out the change was not in abundance, but rather in recording rate and demonstrated that the distribution and abundance of rainbow lorikeets had actually increased in south-east Australia (Canberra and Melbourne) between 1978 and 1988.

At the Australian Research Centre for Urban Ecology (University of Melbourne), Bachelor of Science Honours student Pavlina Shukuroglou recently modelled habitat use by rainbow lorikeets in Melbourne. She found that the lorikeets were most likely to be present in areas of medium tree cover and medium road density (suburban areas) and that the lorikeets nested outside the metropolitan area because exotic street trees did not have suitable hollows (Shukuroglou 2004).

3.7 New South Wales

Rainbow lorikeets were common in Sydney at the time of European settlement, but declined during the early 1900s due to habitat loss (Waterhouse 1997). They became established in Sydney again as trees in streets, parks and gardens matured (Waterhouse 1997). The lorikeets no longer had to travel long distances between food sources because they had access to reliable food from native and introduced plants throughout the year (Waterhouse 1997). The major foods used by rainbow lorikeets in Sydney were a mix of native and exotic species and varied with season, but the coral tree *Erythrina variegata* was a major food source (Waterhouse 1997). Planted exotics provided the bulk of the foods in all seasons, but were not suitable for nesting because they did not contain hollows (Waterhouse 1997). The lorikeets nested in the hollows of blackbutt *Eucalyptus pilularis* and rusty gum *Angophora costata* in small bushland reserves (Waterhouse 1997). Probably as a result of the limited supply of hollows, the rainbow lorikeets also nested in trees occupied by feral honeybees *Apis mellifera* and other urban birds such as the southern boobook *Ninox novaeseelandiae*, sulphur-crested cockatoo, eastern rosella *Platycercus eximius*, galah, dollarbird *Eurystomus orientalis* and common mynah *Acridotheres tristis* (Waterhouse 1997). The rainbow lorikeets were observed chasing common mynahs and pied currawongs *Strepera graculina* (both dominant species) from potential nest sites (Waterhouse 1997).

Rainbow lorikeets were added to the list of native bird species that can be kept and traded without a licence under the *National Parks and Wildlife Act 1974* in 2003 (see http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Rainbow+lorikeet+and+red-capped+parrot+added+to+licence+exemption+list).

4. THE RAINBOW LORIKEET IN SOUTH-WEST WESTERN AUSTRALIA

4.1 Origin

Rainbow lorikeets were originally thought to have reached Perth by crossing the Nullarbor from Eyre Peninsula in South Australia (Storr 1973). However, because of the lack of food and water and harsh environmental conditions in the Nullarbor region, this seems unlikely (Coyle 1988; Higgins 1999). Although the precise source of the rainbow lorikeet population in Perth is unknown, it seems more likely that it originated as a result of releases from captivity. For example, six or seven birds originated on Rottnest Island in 1960 after an application for permission to release them was declined (Coyle 1988). A small colony of up to nine birds existed for some years in Kings Park and Long (1981, pp. 243) stated that "...some reports have indicated that they may have escaped from a captive colony kept in or near the University of Western Australia".

4.2 Distribution

The first published record of rainbow lorikeets in Western Australia was at Harvey, about 140 km south of Perth, in 1964 and these birds were probably aviary escapees (Sedgwick 1973). Rainbow lorikeets were first recorded in Perth in 1968 (Storr 1973) and initially became established in the suburbs of Mosman Park, Scarborough and South Perth (Figure 1, Coyle 1988). At the same time, the lorikeets were sometimes recorded further afield in areas such as Gooseberry Hill and Safety Bay (Smith 1978; Storr 1973).

In the 1970s, rainbow lorikeets were most commonly observed in the established suburbs of Crawley, Shenton Park, Nedlands, Claremont, Floreat Park and Daglish (Anon 1977; Smith 1978; Storr 1973). The range of the rainbow lorikeet expanded rapidly with the spread of suburban development (Recher 1997; Recher and Serventy 1991) during the 1980s and had extended north to Wanneroo, south to Jandakot and west to Maylands by the early 1990s (Figure 2; Burbidge 1992). A survey in 1995 showed that rainbow lorikeets were established along the entire metropolitan coast from Fremantle to Mullaloo and inland along the Swan and Canning Rivers (Figure 2; Lamont 1996).

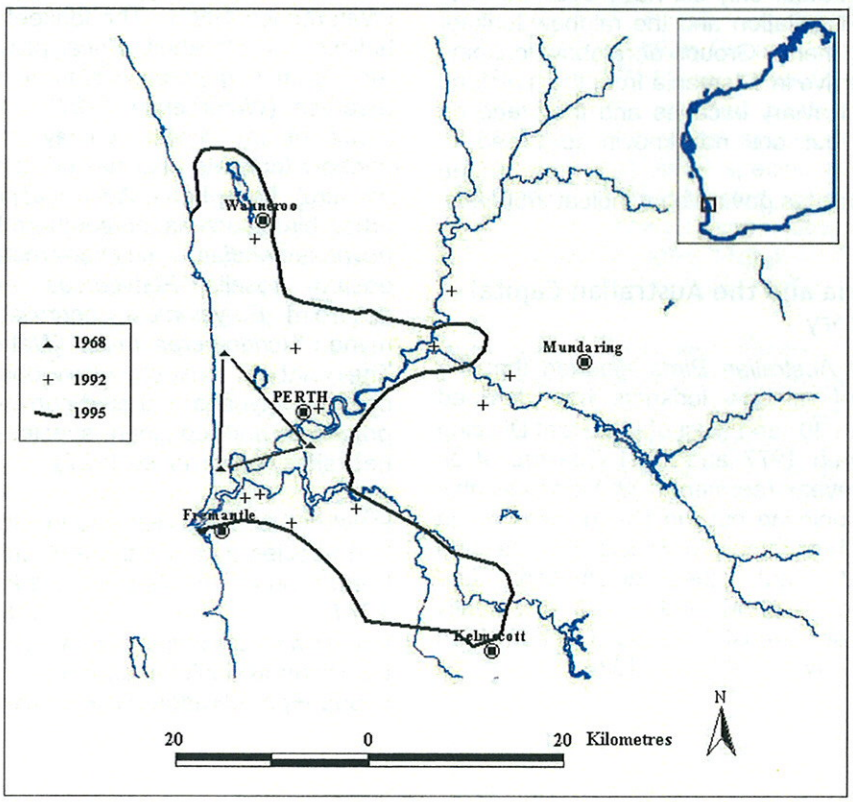

Figure 2. The distribution of the rainbow lorikeet in Western Australia for 1968 (after Coyle 1988), 1992 (after Burbidge 1992) and 1995 (after Lamont 1996). The information in this figure has been taken from Lamont (1996, Figure 7, p. 44).

During a Birds Australia Western Australia Birdwatch survey from Sunday 20 October to Saturday 26 October 2003, very high numbers of rainbow lorikeets were reported at Cottesloe, Lake Monger, Churchlands, Carine, Craigie, Perth Zoo and Perth Airport (Birds Australia Western Australia 2003). High numbers of rainbow lorikeets were reported for most of the inner metropolitan area and outer suburbs such as Wanneroo in the north, and Armadale in the south-east (Birds Australia Western Australia 2003).

The survey showed that rainbow lorikeets occurred from Wanneroo in the north to Chidlow in the east and Mandurah in the south (Birds Australia Western Australia 2003).

Birds Australia Atlas data from 1998 to 2003 showed that the rainbow lorikeet population had spread north of Wanneroo to Nowergup Lake, north-east to Henley Brook, east to Stoneville, Lake Leschenaultia and Chidlow and south to Thomsons Lake and Forrestdale Lake (Figure 3). Rainbow lorikeets occurred over 174 km^2 of the metropolitan Perth region (Figure 3).

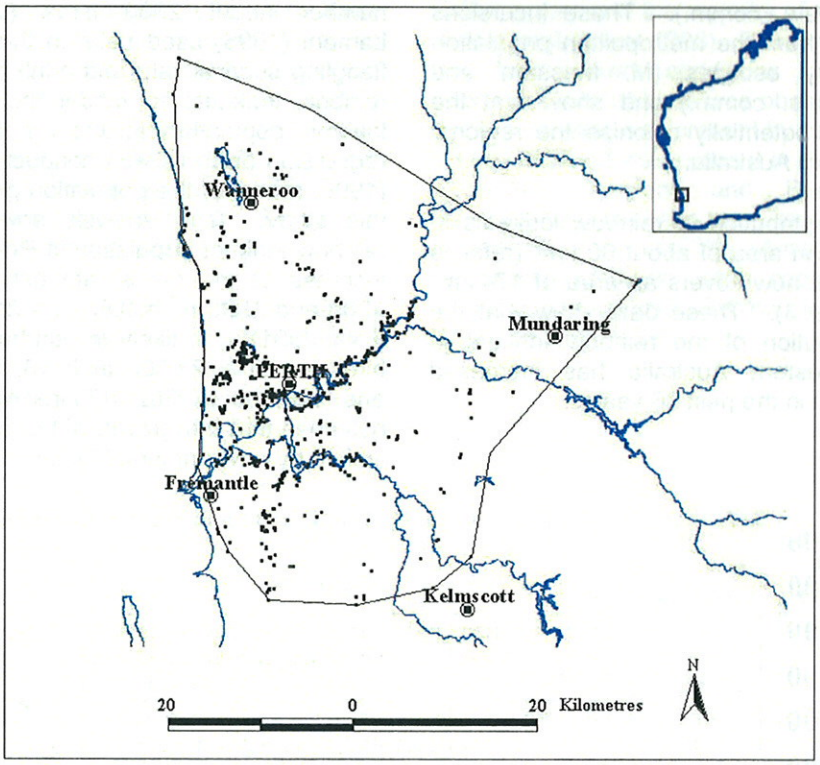

Figure 3. **Birds Australia Atlas records of rainbow lorikeets from 1998 to 2003 for the Perth region, showing observation points and generalised distribution.**

4.3 Potential for spread

Bioclimatic modelling, together with an assessment of habitat and agricultural production predicted that rainbow lorikeets could most readily establish in the south-western subdistricts of Menzies, Warren and Drummond (Lamont 1996, 1997). Within these subdistricts, suitable areas for the establishment of the lorikeets included Bunbury, Nannup, Manjimup, Frankland and Albany (Lamont 1996, 1997). Rainbow lorikeets have already been recorded outside the Perth metropolitan area at Esperance, Mandurah (Birds Australia unpubl. data), Coolgardie (Chapman and Hazelden 1994), Boddington, Boyup Brook, Bunbury, Carnamah, Katanning, Williams, York and on Rottnest Island (M. Massam[i] pers. comm.). These incursions resulted either from the metropolitan population or from aviary escapes (M. Massam[i] and P. Mawson[iii] pers. comm.) and show that the lorikeets could potentially colonise the regional areas of Western Australia.

In 1968, the distribution of rainbow lorikeets in Perth covered an area of about 60 km^2 (refer to Figure 2) and it now covers an area of 174 km^2 (refer to Figure 3). These data show that the area of distribution of the rainbow lorikeet in south-west Western Australia has increased about three-fold in the past 36 years.

The mean radius of the distribution is currently around 28 km (refer to Figure 3), representing a rate of spread of 0.697 km per year from their point of origin over the past 36 years. If the distribution of rainbow lorikeets continued to spread at the current rate, the population could reach from Perth to Bunbury (176 km) by about 2080 and from Perth to Albany (409 km) by about 2245.

4.4 Population size

The Agriculture Protection Board estimated that the population of rainbow lorikeets in Perth numbered 54 in 1984 and more than 1000 in 1994 (Lamont and Burbidge 1996). A survey conducted in 1995 estimated the population to number about 2000 birds (Lamont 1996). Lamont (1996) used data on the breeding rate, fledgling survival rate and adult mortality rate of rainbow lorikeets to model the growth of the lorikeet population in metropolitan Perth. A regression analysis was conducted on Lamont's (1996) model of the population growth as part of this study. The analysis sowed that if the rainbow lorikeet population in Perth continued to increase at the same rate estimated between 1965 and 1995 (r^2 = 0.99, n = 31, F = 4161.05, P < 0.0001), it is likely to number around 8,400 birds in 2004, 23,000 in 2010, 53,000 in 2015 and 123,000 in 202 (Figure 4). This model assumes that the growth of the population is not limited by environmental factors.

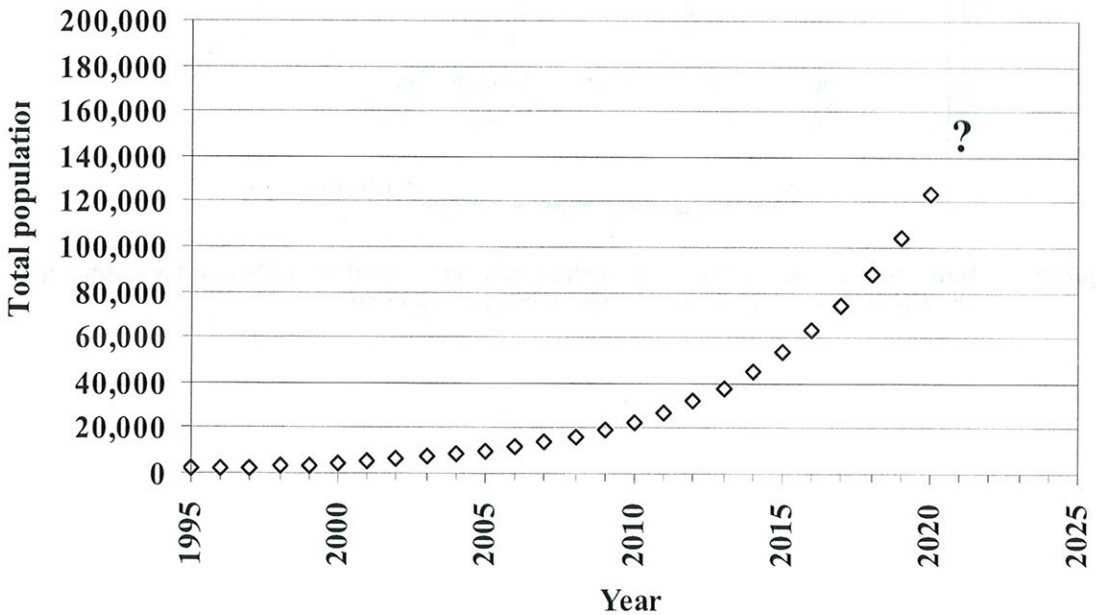

Figure 4. **Model of the number of rainbow lorikeets present in the Perth metropolitan area as a function of year from 1995 to 2020. The population model was based on estimates presented by Lamont (1996) for the period between 1965 and 1995. The regression equation was log(y) = 1.012+0.073x (r^2 = 0.999, n = 31, F = 41614.05, P < 0.0001), where y is the total population and x is the year.**

4.5 Habitat and feeding

In metropolitan Perth rainbow lorikeets occur in open woodland habitats with mature exotic vegetation in association with open water features such as rivers and lakes (Lamont 1996). The trees common to the long established suburbs in which rainbow lorikeets thrive include the lemon-scented gum *Eucalyptus citriodora*, coral tree, fig *Ficus* spp., date palm *Phoenix canariensis*, cotton palm *Washingtonia fillifera* and Norfolk Island pine *Araucaria heterophylla* (Lamont 1996).

In the Perth region, rainbow lorikeets feed on pollen and nectar, foliage, fruit, the seeds of pines *Pinus* spp. and sheoaks *Allocasuarina* spp. [such as *A. obesa* (Stranger 1993)] and flower parts such as petals and stamens (Lamont 1996). They also glean invertebrates such as lerp and psyllids from the leaves and twigs of jarrah *Eucalyptus marginata* and tuart *E. gomphocephala* (Lamont 1996). These invertebrates may provide the carbohydrates and proteins required for nestlings during the breeding season (Lamont 1996).

During a survey conducted in 1995, rainbow lorikeets fed on 26 species of plant (Lamont 1996) and the most common foods used by the lorikeets in the Perth region (66%) were endemic eucalypts, exotic eucalypts and fleshy-fruited plants (Table 2).

4.6 Reproduction

Rainbow lorikeets nest in the hollows of native eucalypts such as jarrah and tuart in Perth (Lamont 1996), but they also commonly nest on the platforms formed by the fronds of date and cotton palms, where they sometimes excavate a nest (Lamont 1996). Rainbow lorikeets are particularly reliant on nesting in palms in suburbs where hollows are in shortage, such as Kings Park and West Perth (Lamont 1996).

In the Perth region, rainbow lorikeets begin breeding earlier in the year than in the eastern states because the climate in Perth is mild in comparison with other cities (Lamont and Burbidge 1996). Breeding takes place from June to December and the majority of nestlings fledge in August (Lamont 1996). Pairs may breed twice per year when conditions are favourable because a pair of birds was observed courting in June, a nestling was present by early August and a second brood was present in the same nest in December (Lamont and Burbidge 1996). Rainbow lorikeets have been recorded nesting in the same tree as the Australian ringneck *Barnardius zonarius*, galah and the introduced laughing kookaburra *Dacelo novaeguineae* in Perth (Lamont 1996).

Table 2. Composition of the diet of rainbow lorikeets in Perth (after Lamont 1996)

Category	Examples	Number of observations	Per cent of observations
Endemic eucalypts	Tuart *E. gomphocephala*, marri *Corymbia calophylla*, flooded gum *E. rudis* and jarrah *E. marginata*	38	22.6
Exotic eucalypts	Spotted gum *E. maculata*, lemon-scented gum *E. citriodora*, sugar gum *E. cladocalyx*	35	20.8
Fruiting plants	Figs *Ficus* spp., lily pily *Acmena smithii*, palms	37	22.0
Coral tree	*Erythrina* spp.	21	12.5
Bottlebrush	*Callistemon* spp.	17	10.1
Invertebrates	Lerp and psyllids	3	1.8
Other		17	10.1
Total		**168**	**100**

4.7 Predators and diseases

Among the known predators of rainbow lorikeets in the Perth region are the brown goshawk *Accipter fasciatus*, peregrine falcon *Falco peregrinus* and the Australian raven *Corvus coronoides*, which raids nests (Lamont 1996). Psittacine beak and feather disease affects rainbow lorikeets (Department of Environment and Heritage 2004), including those in Perth (P. Mawson[iii] pers. comm.), but it is not known what proportion of the population is affected. One record of bilateral necrotizing pectenitis causing blindness in a rainbow lorikeet has been recorded in an aviary bird by a Perth veterinarian (Raidal 1997). Nocardiosis is a disease caused by opportunistic primary infection of the lower respiratory tract following inhalation of the bacteria *Nocardia asteroides* (Raidal 1997). *N. asteroides* is widely distributed in soil and organic material and can also affect humans (Raidal 1997).

4.8 Status and legislation

The rainbow lorikeet is listed as 'acclimatised fauna' under a Wildlife Conservation (Acclimatised Fauna) Notice, 15 September 1992 (*Wildlife Conservation Act 1950*). Acclimatised fauna means "fauna living in a wild state as a result of being released or escaping from confinement or because it is the immediate or remoter offspring of fauna that has been released or has escaped from confinement". Rainbow lorikeets can be 'taken' (shot or live-trapped) on private property in the South-West Land Division, without the need to obtain a licence from the Department of Conservation and Land Management in accordance with an Open Season Notice, 25 August 1989 (*Wildlife Conservation Act 1950*). The Lorikeets must be taken in a manner that does not cause damage to trees and persons trapping or attempting to trap the lorikeets must be licensed under the *Wildlife Conservation Regulations 1970*. Rainbow lorikeets may be kept in captivity only by a person holding a Regulation 12 aviculture licence costing $10.00 per annum (*Wildlife Conservation Regulations 1970*).

The rainbow lorikeet is also a declared pest of agriculture in the South-West Land Division, excluding the Perth metropolitan area, under the *Agriculture and Related Resources Protection Act 1976* (Department of Agriculture 2004a). To prevent the lorikeets from establishing new populations in the wild, any lorikeets that are sighted outside the metropolitan area should be humanely destroyed or reported to the Department of Conservation and Land Management or the Department of Agriculture (Lamont and Massam 2002).

5. IMPACT OF THE RAINBOW LORIKEET IN SOUTH-WEST WESTERN AUSTRALIA

5.1 Pest risk assessment

A number of factors can be used to predict the probability of a feral species becoming a pest if it establishes a wild population in a region where it is not endemic (Bomford 2003). These include: pest status in other regions; degree of climate match between their natural range and the area into which they have been introduced; geographical range size; population density in other regions; taxonomic group; known predators and diseases; competitors; foraging ecology; and affinity with humans (Bomford 2003). Based on these factors, a computer based pest risk assessment and climate matching model (Bomford 2003) was used to assess the pest risk posed by rainbow lorikeets in south-west Western Australia. The assessment was conducted at the Vertebrate Pest Research Section of the Department of Agriculture, south-west Western Australia. The risk assessment showed that the threat posed by rainbow lorikeets to Western Australia was extreme (the highest possible category) because its risk of becoming established outside its current range was high and the risk of the species being a pest to agriculture, the environment or the public was extreme.

5.2 Social impacts

The Department of Agriculture, Western Australia regularly receives calls from the public about the nuisance caused by rainbow lorikeets in south-west Western Australia. These calls report noise, damage to fruit crops, fouling of outdoor areas and vehicles with droppings, competition with other species and requests for assistance with control (M. Massam[i] pers. comm.). The first record of rainbow lorikeets damaging backyard fruit crops was an observation of the birds eating seedless red grapes in the suburb of Trigg in January 2000 (Lamont 2000). The lorikeets have since been reported feeding on suburban backyard fruit crops, including grapes, figs, pears, apricots, nectarines, loquats and mulberries (M. Massam[i] pers. comm.).

In Perth, rainbow lorikeets roost in ornamental figs and palms (Higgins 1999), where they can cause a nuisance in the form of damage to the plants, and noise. Rainbow lorikeets also potentially pose a threat at Perth airport. A large flock of more than 1000 rainbow lorikeets roosts in trees at the domestic terminal (W. Rutherford[iv] pers. comm.) and this population has the potential to cause problems such as excessive noise, fouling of cars and buildings and aircraft bird-strike.

5.3 Environmental impacts

The feeding and nesting requirements of rainbow lorikeets closely overlap with those of native birds such as the purple-crowned lorikeet *Glossopsitta porphyrocephala*, regent parrot *Polytelis anthopeplus*, red-capped parrot *Purpureicephalus spurius*, western rosella *Platycercus icterotis* and Australian ringneck (Forshaw 1969; Lamont 1996; Long 1990). In urban and suburban areas, rainbow lorikeets frequently nest in bushland reserves where nesting hollows are scarce (Lamont 1996; Waterhouse 1997) and thus competition for hollows is potentially high.

Rainbow lorikeets dominate (Bruce 1973; Cannon 1984a) and aggressively protect feeding and nesting resources (Higgins 1999, R. Johnstone pers. comm.; Lamont 1996), thereby excluding native species. They are known to dominate feeding resources over large and aggressive species such as wattlebirds, honeyeaters and lorikeets (Higgins 1999) in other states, and corellas *Cacatua* spp. in Western Australia (P. Hussey[v] pers. comm.). In south-west Western Australia, rainbow lorikeets displace other birds such as the galah, Australian ringneck (Chapman and Hazelden 1994; Lamont 1996; Larcome 2003), endangered Carnaby's cockatoo *Calyptorynchus latirostris* (R. Johnstone[vi] pers. comm.) and the introduced laughing kookaburra (M. Massam[i] pers. comm.) from potential nest sites. They also kill and expel the nestlings of Australian ringnecks before taking over the nest (Lamont 1996).

Little is known about the effects a gregarious and aggressive species like the rainbow lorikeet may have on mammals that shelter and nest in hollows and more research is required on the subject. One observation of dead Gould's wattled bats *Chalinolobus gouldii* in the Perth suburb of Girrawheen suggested that the young bats probably died in the hollow of a large jarrah tree and had been expelled when rainbow lorikeets prepared the hollow for nesting (Start 1998).

In addition to monopolising feeding and breeding resources, rainbow lorikeets also pose a potential disease risk to wild lorikeet and parrot populations (and those kept in aviaries) because, once infected, they are carriers of Psittacine beak and feather disease (Department of Environment and Heritage 2004).

5.4 Agricultural impacts

Lorikeets are a serious or very serious pest of cherries, apples, pears, stone fruit and grapes in Australia (Bomford and Sinclair 2002) and evidence from other states (refer to Section 3) shows that rainbow lorikeets are a potential threat to agriculture in Western Australia. Section 3 showed that the rainbow lorikeet is a major pest of agriculture in the Northern Territory, Queensland and the fruit growing regions of the Adelaide Hills in South Australia. The rainbow lorikeet is also one of the highest ranked vertebrate winged pests of fruits, vegetables and field crops, flowers and ornamental species in the agricultural regions of the Northern Territory (Lim *et al.* 1993). Large flocks damage sorghum in Queensland (Higgins 1999) and can also cause catastrophic losses to the $2 million a year rambutan growing industry in the Northern Territory (Lim and Diczbalis 1997).

Rainbow lorikeets pose an extreme threat to Western Australia's $245 million (Department of Agriculture 2004b) fruit, nut and grape growing industry (refer to Section 5.1). The number of records of fruit damage by rainbow lorikeets in Perth was minimal during the mid and late 1900s (Lamont and Burbidge 1996), perhaps because during that time orchards were being replaced by residential settlements. However, the lorikeets have recently been reported damaging commercial table grape crops in the Swan Valley (M. Massam[i] pers. comm.).

6. MANAGEMENT OF THE RAINBOW LORIKEET IN SOUTH-WEST WESTERN AUSTRALIA

The community and government agencies have a number of options to manage the rainbow lorikeet population in south-west Western Australia as discussed below.

6.1 Do nothing

According to Lamont (1996), inaction by government agencies while numbers were low was one of the major contributors to the establishment and spread of the feral rainbow lorikeet population in south-west Western Australia. Analyses in this report have shown that left unchecked, rainbow lorikeets are likely to continue to spread in number and distribution with the spread of suburban development. The feral rainbow lorikeet population in south-west Western Australia poses an extreme risk to the State's social, environmental and agricultural values and thus, the do nothing option is inappropriate and undesirable, particularly outside the metropolitan area.

6.2 Eradicate the feral population

Eradication of the rainbow lorikeet population from south-west Western Australia is probably not feasible for three reasons. First, the population is large (an estimated 8400 birds), widespread (174 km^2) and occurs over a range of land tenures, so its eradication would be logistically difficult and very expensive. While there have been many eradications of introduced vertebrates from islands, no campaign against any widely established exotic vertebrate species has ever been successful on any continent, despite numerous large-scale attempts (Bomford 2003; Bomford and O'Brien 1995; Dahlsten 1986; MacDonald *et al.* 1989; Usher 1989). Second, because rainbow lorikeets may be kept by licensed aviculturists in Western Australia, the feral population has a source of new incursions from hand reared/tame birds, aviary birds and possible deliberate releases. Third, many of the techniques used to humanely eradicate pest birds, such as trapping, poisoning and shooting, may not be safe or suitable for use in all parts the metropolitan area.

6.3 Restrict the feral population to the metropolitan area and reduce the number of birds in the population

Restricting rainbow lorikeets to the metropolitan area and reducing the number of birds in the population is the most desirable management option. This option is the most likely to prevent the establishment of wild populations in regional Western Australia and to prevent potential damage to agriculture, the environment and the public. However, this option will have a significant cost requiring funding from both government and non-government sources.

7. RECOMMENDATIONS

An integrated pest management program must be developed to: restrict the population to the Perth metropolitan area and reduce the number of birds in the population from an estimated 8400 in 2004 to an estimated 5000 by 2020. The management program should include the following objectives:

1. Investigate sources and obtain the funding required to manage the population.
2. Estimate the number of birds in the Perth population, establish its distribution and locate major roost sites.
3. Alter the status of the rainbow lorikeet in south-west Western Australia so that it is a declared pest in the metropolitan area (alter to A2; 'subject to eradication in the wild' south of the 20th parallel of latitude, and A5; 'numbers to be reduced/controlled' in the Perth metropolitan area).
4. Investigate methods of population reduction in the metropolitan area and document their effectiveness.
5. Educate the public on the impacts of rainbow lorikeets and the need for control.
6. Eradicate rainbow lorikeets that are sighted outside the metropolitan area.
7. Investigate and document the effectiveness of methods for the mitigation of agricultural damage.
8. Conduct a cost/benefit analysis of the damage caused by rainbow lorikeets and lorikeet control.
9. Develop a molecular approach to population control and management.

10. Review standards for the import and keeping of rainbow lorikeets to reduce the risk of aviary escapes.

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