Future options for the management of rooks

(*Corvus frugilegus*)

Envirolink Advice Grant

899-HZLC75

Landcare Research
Manaaki Whenua

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Prepared for:

Horizons Regional Council

Palmerston North, New Zealand

September 2010

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Landcare Research Contract Report: LC52

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Contents

Summary

Project and Client

- Horizons Regional Council (HRC) is reviewing its current policy for rook management and sought advice from Landcare Research (Envirolink project HZLC75) on the damage caused by rooks and its value, and options for future control of rooks.

Objectives

- Review recent literature about the impacts of rooks and the costs of rook damage.
- Model the recovery of rook numbers and the spread of rook populations so that the consequences of proposed changes to rook control can be considered.
- Evaluate the environmental risks of the toxin DRC-1339 and its humaneness.
- Review fertility control as an alternative to lethal control of rooks.

Methods

- Published and unpublished information was sourced from various publications databases and personal contact with experts on rook ecology and control. Modelling the recovery of rook numbers and the spread of rook populations was undertaken using a source-sink population model. The potential distribution of rooks in New Zealand in the absence of control was estimated by mapping areas with suitable habitat, topography, and climatic conditions using a Geographic Information System. The potential rate of spread of rooks was estimated from published literature. The potential of various fertility control methods to manage rook populations was assessed by reviewing published literature.

Results

- Rooks damage a wide range of crops and pasture. Little recent information was found about the economic impacts of rooks in New Zealand or internationally. Rooks generally forage only a few km from the roost or rookery, but may travel >10 km to preferred foods. Changes in land use over the last 40 years are likely to have increased the area of habitat suitable for rooks.
- Modelling showed that rook populations would be capable of rapid growth in numbers if control stopped, and could reach carrying capacity in the Manawatu region within 10 years. In reality, the region-wide increase would likely happen more slowly because of the rooks' observed slow rate of geographical spread.
- Based on an analysis of suitable habitat, topography, and climatic conditions, much of New Zealand is vulnerable to colonisation by rooks. The potential rate of geographical spread of rooks is likely to be slow even if control were relaxed because rooks are social animals with limited tendency to disperse.
- DRC-1339 poses low to moderate risk of poisoning to species other than pest birds such as rooks. It degrades rapidly under normal environmental conditions, and does not

persist. It does not accumulate in birds or carcases. DRC-1339 appears to be relatively humane. Birds generally become comatose before death and die a quiet, apparently painless death.

- Reproductive control, e.g. using DiazaCon, may be useful for incorporation into integrated programmes for managing localised rook populations where eradication is not the desired goal.

Conclusions

- The lack of robust data on the historical and current value of rook damage precludes an evidence-based assessment of the relative costs and benefits of current rook control.
- The effect of changing patterns of cropping and land use over the last 40 years on the rate of spread of rook populations if control was relaxed is unclear.
- Rook populations have the potential to recover quickly in the absence of control and could reach carrying capacity for the region within ten years, although this is likely to occur more slowly because of rooks' limited dispersal behaviour.
- Much of New Zealand is vulnerable to colonisation by rooks. The potential rate of geographical spread of rooks is likely to be slow, however, even if control were to be relaxed.
- DRC-1339 poses low to moderate risk to the environment and non-target species. DRC-1339 appears to be relatively humane.
- Of the reproductive control methods reviewed, DiazaCon appears to have greatest potential for field use.
- Reproductive control may be useful for incorporation into integrated programmes for managing localised rook populations where eradication is not the desired goal.

Recommendations

Horizons Regional Council should:
- undertake an evaluation of the economic losses to rooks in the region.
- support the collection of data on rook biology and ecology specific to the Manawatu region for use in modelling.
- support the development of a spatial model of rook populations so that the rate of increase in rook numbers and geographic spread can be predicted with greater accuracy and precision.
- support the collection of welfare data on rooks poisoned with DRC-1339.
- support initial trials to assess the efficacy of DiazaCon for control of rook reproduction.

1   Introduction

Horizons Regional Council (HRC) is reviewing its current policy for rook management, which is total control leading eventually to eradication. To assist with its policy evaluation HRC sought advice from Landcare Research (Envirolink project HZLC75) on the damage caused by rooks and its value; the ecological and economic consequences of wholly or partly abandoning rook control; the environmental fate and humaneness of DRC-1339, the toxin most commonly used for control of rooks at rookeries; and alternative options for rook control, particularly the use of fertility control.

2   Background

Pest management is essentially a bio-economic issue in which the costs of pest control are weighed against the benefits (which may be economic, environmental, social and/or cultural). Rooks in the Manawatu region have been controlled for more than 30 years to mitigate damage to pastoral and cropping industries and to restrict their spread to other areas of New Zealand. In considering options for future rook control under the Regional Pest Management Strategy, HRC identified a number of questions about the assumptions used to justify region-wide rook control. A number of issues were also raised at public hearings relating to the proposed objective of eradication of rooks from the region, including targeted rather than region-wide control, the economic and environmental benefits and costs of alternative strategies, and the efficacy and acceptability of current control methods.

3   Objectives

- Review recent literature about the impacts of rooks and the costs of rook damage
- Model the recovery of rook numbers and the spread of rook populations so that the consequences of proposed changes to rook control can be considered
- Evaluate the environmental risks of the toxin DRC-1339 used for rook control and its humaneness
- Review fertility control as an alternative to lethal control of rooks.

4   Methods

Searches of various internet databases were undertaken to identify relevant references on rook ecology, population biology, impacts, and control methods. The bibliographies of these references were also scanned for other useful publications. Additional information on the environmental risks and humaneness of DRC-1339 was sought from colleagues at the APHIS-USDA National Wildlife Research Center, Colorado, who were involved with the initial research and registration of DRC-1339 in the USA. Additional information on rook damage and economic costs was sought by email from CJ Feare, an expert on rooks formerly with the Wildlife Section, DEFRA, UK, and New Zealand rook experts Jim Coleman and Dick Porter. The information derived from these searches was used to formulate responses about the impacts of rooks and the costs of rook damage, the environmental risks and humaneness of DRC-1339, and fertility control products as an alternative to toxins for rook control.

Modelling the recovery of rook numbers and the spread of rook populations in and adjacent to the Horizons Region was undertaken using a source-sink population model. This represents a scenario in which rook population control ceases within the Horizons Region, causing their numbers there to increase, while population control continues in adjacent regions. When the population reaches the carrying capacity of the Horizons region, rooks begin to emigrate from Horizons Region (the *source* population) to adjacent areas (the *sink* population). Migration into the Horizons region from surrounding areas is also assumed to occur.

Inputs for the model were estimates of:

- Numbers of rooks in a) Horizons Region, and b) adjacent regions, before the cessation of rook control
- The carrying capacity of Horizons Region (the maximum number of rooks the area could support)
- The annual birth rate of rooks in a) Horizons Region, and b) adjacent regions
- The annual death rate of rooks a) under current population control measures, and b) without population control
- The migration rate of rooks between Horizons Region and adjacent areas.

Estimates of these parameters were taken from published literature, as well as operational reports and plans from Horizons Regional Council. The parameter estimates used were as follows:

- Current numbers of rooks in Horizons Region, based on the most recent available estimate (Horizons Regional Council 2006), were taken to be 5000. Numbers in adjacent regions were assumed to be similar.
- Carrying capacity, based on estimates of historical rook densities in and adjacent to Horizons Region (Porter et al. 2008), was estimated at about 5 rooks km^{-2}. This corresponds to approximately 100 000 rooks in Horizons Region.
- Annual birth rate in all areas was calculated using an average fledging rate of 1.5 (NPCA 2006). Since breeding adults represent approximately 66% of total population numbers (Bull & Porter 1975), birth rate was estimated to be 0.33*1.5 = 0.5.
- Death rate under current population control measures was estimated at 0.8 (Horizons Regional Council 2004).
- Natural death rate (in the absence of population control) was estimated at 0.2 (based on 70% juvenile mortality, then 10% thereafter (NPCA 2006)).
- In the absence of data on migration, the rate of migration between regions (i.e. between source and sink populations and vice versa) was estimated arbitrarily at 0.1 (i.e. 10% of birds per year)

Because these parameter estimates are approximations, we tested whether the predictions of the model were consistent under a range of alternative parameter values using sensitivity analysis. Each of the parameters was varied over a wide range of values (higher and lower than those described above) to determine how this would affect the predictions of the model.

The potential distribution of rooks in New Zealand (in the absence of population control) was estimated by mapping areas with suitable habitat, topography, and climatic conditions using a Geographic Information System (GIS). Native forest and wetland habitats, in which rooks are rarely recorded (Robertson et al. 2007), were excluded from the potential distribution, as were areas above 450 m elevation since Bull and Porter (1975) found that most rookeries occurred below 150 m ASL, although one was located 430 m ASL. Since rooks have been recorded near the northern and southern extremes of the two main islands (Robertson et al. 2007), we assumed that there are no latitudinal limits to their potential distribution in New Zealand, an assumption supported by the fact that rooks are found throughout the United Kingdom (British Trust for Ornithology 2010).

The potential rate of spread of rooks was estimated from published literature on their movements and dispersal distances (Langham & Porter 1991; NPCA 2006), as well as historical records of their spread from points of introduction in Hawke's Bay and Canterbury (Bull 1957; Coleman 1971; Bull & Porter 1975; Porter et al. 2008).

5 Results

5.1 Economic impacts of rooks

Rooks are recorded as damaging a wide range of crops in New Zealand, including cereals, maize, corn, peas, broad beans, pumpkins, potatoes, nuts (walnuts, acorns), and fruit such as apples (Porter et al. 1994; NPCA 2006). Rooks also damage pastures by tearing out grasses and probing for invertebrates, which can expose the soil to erosion and promote weeds (McLennan & MacMillan 1983).

Our search of the New Zealand and international literature for the last 10 years found comparatively few references about rooks, and no recent economic analyses of the costs of rook damage and control. Most recent interest in the United Kingdom and Europe, the native range of rooks, has centred on changes in rook distribution and numbers and foraging behaviour in relation to farming practices and landscape and climate change (e.g. Marchant & Gregory 1999; Griffin & Thomas 2000; Henderson et al. 2004; Mason & MacDonald 2004; Gimona & Brewer 2006). The single historical study of costs of rook damage we located (Feare 1974) estimated costs of damage by rooks but did not consider the costs of rook control.

The feeding behaviour of rooks is reasonably well described. Feare (1978) compared rook feeding behaviour and crop damage in areas of Scotland and England with differing cropping patterns. He concluded that rooks in both areas caused damage to crops primarily when preferred, alternative foods were not available (e.g. when food was scarce) or when food intake needed to be increased (e.g. during the breeding season). Food shortage usually occurred when grain was not available and grassland invertebrate populations were low, or when fields were covered in snow. Studies in New Zealand suggest a similar pattern (Coleman 1971; Porter 1979; Purchas 1980). Rooks are generally omnivorous, feeding mainly on pastoral and cultivated land, and cereal crops. Grassland invertebrates form a significant part of their diet, especially when nestlings are being fed. In summer rooks switch to feeding on crops when invertebrates become scarce as the ground dries out (Porter 1979; Purchas 1980).

Damage to crops by rooks in New Zealand was recorded as early as 1915 (Bull 1957), but despite a history of rook control in New Zealand stretching back to that time, we found few published accounts of the economic costs of rook damage to the productive sector, and most of those provided little detail as to how costs had been determined. An undated paper refers to a survey of rook damage in the eastern Hawke's Bay Pest Board district before 1986. From 402 replies, 187 ratepayers (46.5%) reported some form of damage that they attributed to rooks. The loss of yield and cost of control for the 187 growers was estimated by questionnaire to be $153,901 for the 1969/70 cropping season. This same survey, as reported by Flynn (1979), referred to losses to rooks of $98,000 in 1968/69 and $150,000 in 1969/70. Porter (1987) commented that in the early 1960s rooks in Hawke's Bay were doing substantial damage, and estimates of the damage were hazy but seemed to be about $200,000 per year.

Purchas (1980) evaluated the need for rook control at the time of his study on the Heretaunga Plains, Hawke's Bay, based on information about their feeding behaviour. He observed rooks spent only about 6% of feeding time in summer and less than 2% in other seasons eating newly sown or ripening seed of crops; more damage was done at sowing than at ripening; rooks continued to flock at a feeding site if undisturbed; crops with large seeds planted at regular spacings were more vulnerable; for maize, he estimated a flock of 100 rooks could remove all seed from 1 ha over a 15-day period. Although Purchas (1980) commented such conditions would seldom occur in Hawke's Bay, and grower losses were consequently likely to be much less, he still recommended the use of scaring devices to minimise crop losses.

Various authors (e.g. Porter et al. 2008) note that rook control from the 1970s onwards in New Zealand has eliminated severe economic losses (although local damage may still be significant for individual farmers). Commenting on rooks in the UK, Chris Feare noted (email 7 April 2010), "Rooks don't seem to be regarded as much of a problem here these days". A new type of damage caused by rooks was reported recently from Ireland, involving damage to the plastic-film covering on baled silage during storage in the field (McNamara et al. 2002); a number of remedies were tested experimentally but no cost benefit analysis was reported. We are not aware of any reports of similar damage in New Zealand.

A beneficial effect of rooks, through feeding on soil and crop invertebrate pests, has been suggested, but remains contentious (Purchas 1980). McLennan & MacMillan (1983) assessed the impact of rooks on the larvae of the grass grub (*Costelytra zealandica*). Rooks were estimated to eat 15–22% of larvae in two fields, but that level of predation was insufficient to prevent further loss of pasture production caused by grass grubs or to stop the next generation of larvae increasing to severely damaging levels. McLennan and MacMillan (1983) concluded that there were no measurable economic benefits from rook predation of grass grub larvae but that there were significant costs associated with the ripping up of turf to expose the larvae. Damaged areas were still visible after 7 months or, in some cases, had been colonised by weeds. Rooks also feed on other invertebrate pests, but McLennan and MacMillan (1983) found little quantified evidence of benefit.

The economic impact of rooks also has a spatial component which would need to be considered in any decisions to withhold rook control from low risk areas. The issue is the area over which rooks forage, which in turn delimits the likely sphere of crop and pasture damage. Published studies suggest during breeding (from September to December in New Zealand) rooks usually forage within 1–2 km of the rookery. At other times of the year rooks may forage up to 20 km, but more normally 3-10 km, from their night-time roosts, depending on the spatial availability of highly preferred foods. Disturbance of rookeries, for example by

poisoning or shooting, may result in the wide dispersion of surviving birds (Dunnet & Patterson 1968; Coleman 1971; Patterson et al. 1971; Purchas 1980; Langham & Porter 1991; NPCA 2006).

5.2   Modeling rook populations

Numerical population growth

Population modelling showed that rooks have the potential to increase rapidly in the absence of control. Using the parameter estimates described above, the model predicts that rooks in the Horizons Region (as represented by the red line in Figure 1) have the potential to reach the assumed carrying capacity of 100 000 birds in less than 10 years. The increase is, however, likely to happen more slowly because of the rook's observed slow rate of geographical spread (see below). When the region's population reaches carrying capacity, it will begin to act as a source of migrants to the population in adjacent (sink) areas. As shown in Figure 1, this has the potential to cause very rapid population increases in adjacent regions.
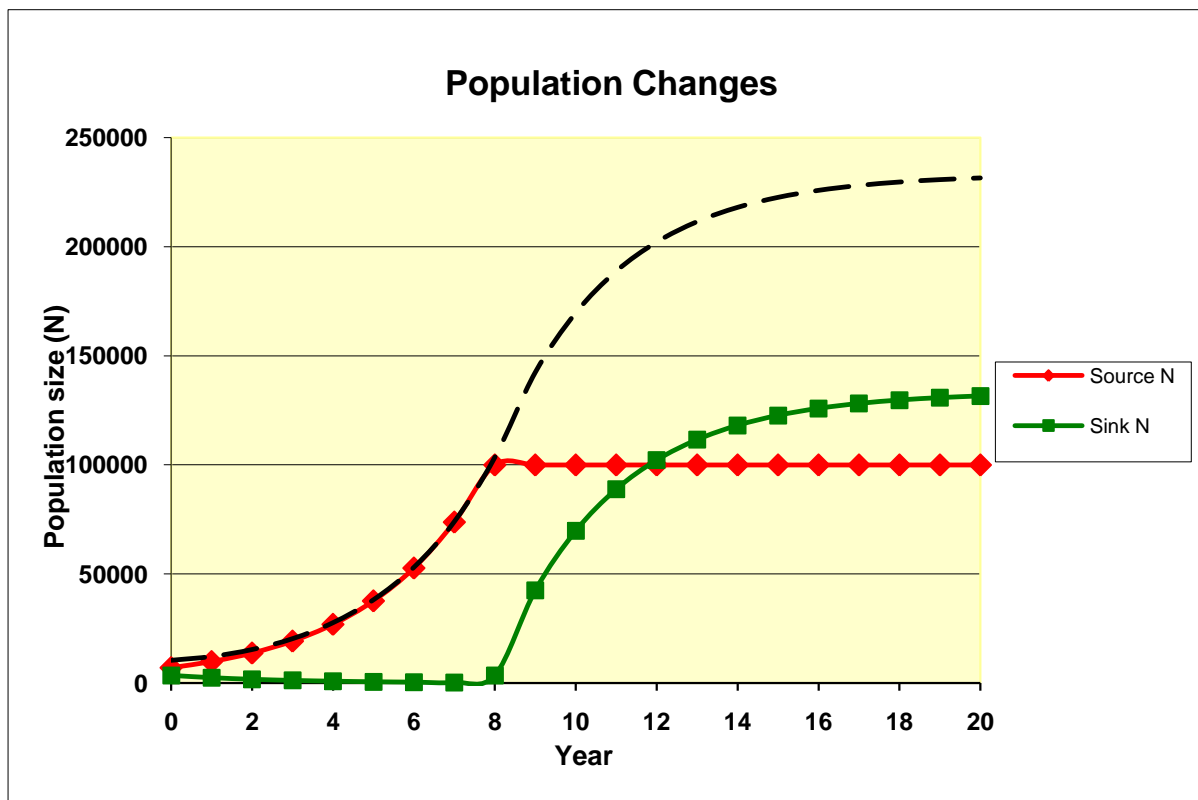

Figure 1 Population modelling predicting the numbers of rooks in the Horizons Region (Source N) in the absence of population control. The estimated carrying capacity of 100 000 birds would be reached in less than 10 years. After that time, the Horizons Region would begin to act as a source of migrant rooks, causing a rapid increase in rook populations in adjacent areas (Sink N).

Sensitivity analysis

Sensitivity analysis showed that the predictions of the model are robust to variation in parameter estimates. Large changes in the parameters result only in differences of a few years in the predicted time for the population to reach carrying capacity ('saturation time'). For example, varying estimates of current population numbers from 1000 to 10 000 birds did not change the predicted pattern of population growth, but saturation time varied from 6 years to 12 years. Similarly, varying the estimated carrying capacity from 50 000 to 200 000 birds resulted in estimated saturation times of between 6 and 10 years. Varying the annual birth rate from 0.3 to 0.7 reduced the saturation time from 15 to 5 years. Varying the natural death rate from 0.1 to 0.4 increased saturation time from 6 to 15 years, while varying the migration rate from surrounding populations into the Horizons region from 0.01 to 0.3 shortened saturation times from 10 to 5 years. Finally, varying the death rate under population control from 0.6 to 0.9 had no effect on the length of time before the population in Horizons Region reached carrying capacity.

Geographical spread of rooks

The approximate potential distribution of rooks in New Zealand is shown in Figure 2. The potential rate of geographical spread of rooks if population control were to be relaxed is probably slow. Although long-distance dispersal events can occur (up to 500 km), these seem to be rare and involve very small numbers of birds (Bull 1957). More typically, rooks remain within a relatively small area, foraging up to 20 km from their roost site (NPCA 2006), but usually more closely. For example, Coleman (1971) found that rooks in Canterbury usually fed 0.5 – 3.5 km, but occasionally up to 13.6 km from their roost. Similarly, the greatest recorded distance moved by a marked rook in Hawke's Bay was 16.5 km (Langham & Porter 1991). Mobility may be influenced by the proximity of productive and preferred feeding sites. For example, rooks in Canterbury flew further to feed on preferred foods such as cultivated cereals and walnuts (Coleman 1971).

Bull and Porter (1975) remarked that the most striking feature of the rook's historical spread in the North Island was its slowness. For example, the rate of spread between Napier and Woodville (separated by 129 km) was estimated to be 1.3 km/year, while estimated rates of spread between other locations on the North Island varied between 0.8 and 4.8 km/year (Bull & Porter 1975). Similarly, the westward spread of rooks from Christchurch between 1925 and 1952 averaged about 0.8 km/year (Bull 1957). In the 1970s, rooks in Hawke's Bay increased their range by an average of 420 km^2 each year (Porter et al. 2008). However, the area of New Zealand covered by crops and pasture has increased since the mid-20th century (Ministry for the Environment 2010). As these habitats are preferred by rooks, rates of spread today could be more rapid than these historical estimates. Conversely, however, the change in land use may mean that rooks do not need to fly as far as previously to find preferred foods, in which case spread might proceed more slowly than previously.

These historical rates of spread suggest it would take many decades for rooks to occupy all suitable habitats in New Zealand, even in the absence of control. Indeed, the rate of spread may be slower when rookeries are left undisturbed. Several authors have noted that control measures hastened the historical spread of rooks by forcing birds to disperse when their nesting sites were disturbed (Bull 1957; Coleman 1971; Bull & Porter 1975).

Figure 2 The potential distribution of rooks in New Zealand. Areas shown in red could potentially be inhabited by rooks if population control was ceased. Areas in white are deemed unsuitable due to their elevation or habitat type.

5.3   DRC 1339 environmental risks and humaneness

Compound DRC-1339 was developed as an avicide due to its differential toxicity to animals. It is unique in that it has selective high toxicity to most pest birds such as starlings, blackbirds, rooks, crows and magpies. It is considered relatively safe to humans and domestic animals (except poultry). Toxicity appears to be low to moderate to most mammals (DeCino et al. 1966, Schafer 1981; Schafer & Bowles 1985, Schafer 1991), small granivorous birds (Shefte et al. 1982), and most avian predator and scavenger species (Schafer 1972; Schafer et al. 1983).

The biochemical mechanism behind the toxic action of DRC-1339 is not clearly understood. It is thought that once ingested it is readily absorbed into the bloodstream and rapidly hydrolysed in the liver to 3-chloro-p-toluidine which is believed to be the toxic metabolite (Ramey et al. 1994). In sensitive birds the mode of action is thought to be irreversible kidney and heart damage (Eisemann et al. 2003). Clinical signs of poisoning include hypoglycaemia, depletion of liver glycogen, an excessive build up of uric acid in the plasma and a selective loss of protein from the kidneys (Mull et al. 1972). Build up of uric acid causes necrosis and circulatory impairment, resulting in death from uremic poisoning and congestion of the major organs (DeCino et al. 1966; Ramey et al. 1994). In less sensitive species the mode of action is quite different and requires 10–100 times more DRC-1339 for lethality; the central nervous system is depressed resulting in cardiac or respiratory arrest and a quiet death usually occurs in 2–10 hr. Central nervous system depression is reversible in non-sensitive mammals and raptors, and can be successfully treated symptomatically (USDA 2001).

The first symptoms of poisoning are an increase, followed by a sharp decrease, in water intake. About four hours before death the birds cease to eat or drink and become listless and inactive. They perch with their feathers ruffled (as if cold) and appear to doze. As toxicosis progresses their breathing rate increases slightly and breathing becomes more difficult. Most birds become comatose before death and time to death varies from 3 to 50 hours depending on the quantity of toxicant ingested. Convulsions, spasms, or distress calls have not been observed and birds die a quiet, apparently painless death; so DCR-1339 is perceived to be a humane toxicant (Schwab et al. 1964; Timm 1983). Poisoned birds are recognisable by their fluffed-out feathers and feet tucked inside the lower breast feathers (DeCino et al. 1966; Nelson 1994).

DRC-1339 is an organochlorine, but it does not appear to have the persistence or the tendency to accumulate in the food chain found in other organochlorines, such as DDT. There are, however, only very limited data on the environmental fate of DRC-1339. Aerobic soil metabolism has been examined using a loam soil with high organic matter (8.2%) instead of the sandy loam or silt loam soil recommended for accredited testing. Within two days over 70% of the DRC-1339 was bound to the organic matter and the half life was calculated to be 25.3 hr. This is thought, however, to be indicative of binding to the soil organic matter rather than a measure of DRC-1339's potential to degrade under aerobic conditions (USEPA 1995). Absorption/desorption and aged leaching studies have been conducted and, while the data suggest that fresh and aged DRC-1339 residues are not mobile in soil, the experiments were considered by the USEPA to be inadequate to accurately assess leaching and mobility in soils (USEPA 1995). DRC-1339 degrades rapidly when exposed to moisture, sunlight, heat, or UV radiation, and it is highly soluble in water (91g/L) but does not hydrolyse. Photo-degradation to 3-hydroxy-p-toluidine (HTP) occurs in water with a half-life of 6.5 – 41 hr, depending on

the season. In summary, these data suggest that DRC-1339 is rapidly degraded in soils, does not persist, and will not migrate (USDA 2001).

DRC-1339 is rapidly metabolised in the body, does not accumulate, and its metabolites are quickly excreted from the body before the bird dies. Therefore dead or dying birds pose little risk of secondary poisoning to non-target predator or scavenger species (Knittle et al. 1990; Cunningham et al. 1979). Numerous laboratory and field studies have been conducted to assess these risks and there is only one documented case of secondary poisoning of crows that fed on gut contents of pigeons killed by baits containing DRC-1339 (Schafer 1984).

5.4 Fertility control products

Rooks generally nest in colonies of 20–150 nests, often in tall pines and eucalypts. They are seasonal breeders and usually lay three to five eggs per clutch between late August and late September (Purchas 1979). Incubation takes 17–18 days. If the nest or all eggs are lost, rooks may lay a replacement clutch up until the end of October. Pairs that successfully raise a fledging(s) do not rebreed that season. Rook young are fed by the adults in the nest up until November-mid December. Due to high egg and nestling losses associated with nest loss in storms, aggression from non-paternal male rooks, starvation, and predation usually only one or two chicks from each clutch survives to leave the nest (Purchas 1979). Rooks can live for more than 20 years but a more typical lifespan is about 6 years (British Trust for Ornithology 2010).

Egg and nest destruction

Interfering with the egg laying or hatchability of the egg can reduce the reproductive success of birds and has the advantage of being relatively non-invasive, technically simple, humane and with a high level of public acceptability. Egg removal for commercial sale was used to restrict growth and expansion of black swan populations on Lake Ellesmere, Canterbury, in the 1950s and 1960s (Miers & Williams 1969; Williams 1979). However, egg removal alone will often encourage immediate re-laying unless eggs are replaced with hardboiled or dummy eggs (Miers & Williams 1969; Baker et al. 1993). The addling of eggs (by shaking or pricking) and leaving the eggs in situ will increase the time to and reduce the likelihood of clutches being re-laid. The pricking of eggs with a needle has been used to control small local populations of water fowl although a small proportion of eggs (<10%) may still hatch (Baker et al. 1993). Pricking allows bacteria to enter the egg and causes desiccation of the contents (French & Parkhurst 2001). Compared to addling, egg oiling (with liquid paraffin, white oil or corn oil) is more effective (100% effective in Canada geese; Baker et al. 1993), 91% effective in ring-billed and herring gull (Christens & Blokpoel 1991)) and birds are less likely to immediately abandon treated clutches to re-lay. Egg oiling has been shown to be highly effective in reducing breeding in pigeons (Pigeon Control Resource Centre 2009), herring gulls and ring billed gulls (Christens & Blokpoel 1991) and Canada geese (Baker et al. 1993). It has been most successful for small local populations where dispersal of unsuccessful breeding birds to alternative nesting sites does not cause additional problems.

Nest destruction, like egg destruction, is a relatively inexpensive technology, though time consuming to apply, and may help to control small local pest populations. The technique was used to control double-crested cormorants in America, and reduced their negative impacts on the nesting habitats of other colonial water birds and fish stocks (Farquhar et al. 2002).

In general, reproductive control by egg or nest destruction is labour intensive, requires persistence to be effective, and is likely to be suitable only for small areas and where nest sites are easily accessible. Nest and egg destruction is unlikely to be suitable for rooks, which nest high in trees, as nesting sites must be easily recognisable and accessible for the method to be cost effective. Repeated clutch loss may also likely to lead to rooks dispersing to recolonise other sites, as has been suggested for rooks following lethal control (Porter et al. 2008) and for gulls following clutch reductions (Ickes et al. 1998).

DiazaCon

The chemical 20, 25-diazacholesterol (also known as DiazaCon™, SC-12937, and ornitrol) is a cholesterol analogue that inhibits cholesterol synthesis and blocks steroid hormone production. It has been investigated as a contraceptive in several bird species and has been shown to reduce cholesterol levels in quail (*Coturnix coturnix*) (Yoder et al. 2004), (ring-necked doves (*Streptopelia risoria*), brown headed cowbirds (*Molothrus ater*) (Yoder et al. 2005), rose-ringed parakeets (*Psittacula krameri*) (Lambert et al. 2010), monk parakeets (*Myiopsitta monachus*) (Yoder et al. 2007), American crows *(Corvus brachyrhyncus)* (Yoder et al. 2005), and mallards (*Anas platyrhynchos*) (Yoder et al. 2006). Effects on reproductive performance have not been tested in cowbirds or crows because of captive breeding constraints for these species. Treatment with DiazaCon dramatically decreased egg production and hatchability in monk parakeets, rose-ringed parakeets, mallards and quail. Treatment affects the reproductive performance of both males and females. Feeding pigeons (*Columba livia*) with 0.3 g of active ingredient on grain for 11-16 days stopped fertile egg production for up to 5 months (Wofford and Elder 1967). Feeding free ranging redwing blackbirds for 26 days with ornitrol-coated (0.1% wt/wt) cracked corn reduced their breeding success by 49% (Lacombe et al. 1986). The consumption of about 33 mg/kg DiazaCon for 5 days by monk parakeets reduced egg production by 59% and no chicks were hatched for at least 2 months (Yoder et al. 2005). Exposure of mallard to about 65 mg/kg DiazaCon in 5–6 doses decreased egg production by more than 90% and reduced hatchability to 0%. Results between species vary. For field use, success is most likely when the breeding period of the target species is limited to a short period of the year. For instance, in areas where pigeons breed all year round repeated treatments may be required. The rook has a limited breeding season with egg laying confined to a 2-month period in spring so may be a suitable candidate for contraceptive control using DiazaCon. Success would require that a suitable formulation and delivery system for free-living rook populations be developed to ensure sufficient exposure and so that any risks to non-target species can be minimised. The product has not been registered for use in New Zealand and approval would need to be sought from ERMA and ACVM for its use as a rook control agent.

Nicarbazin

Nicarbazin is a mixture of 4, 4'-dinitrocarbanilide and 2-hydroxy-6, 6-dimethylpyrimidine that has been commonly used as a treatment for coccidiosis in broiler chickens for many years. However, when fed to layer hens (*Gallus domesticus*), it significantly reduces egg laying and hatchability (Jones et al. 1990). Nicarbazin appears to reduce the viability of eggs by disrupting the structure of the vitelline membrane around the yolk. There are no identified effects on male fertility. Diets containing 100 ppm nicarbazin reduced the hatchability of hens' eggs to <1% after 6–10 days of treatment (Jones et al. 1990) and four days treatment of chickens with 50 ppm reduced hatchability from 93 to 31% (Hughes et al. 1991). The

duration of feeding needed to achieve maximum impact on hatchability appears to vary between species. Quail given feed treated with 125 ppm nicarbazin (estimated dose of 36 mg/kg) for 25 days showed reduced hatchability with a maximum reduction to 0% egg hatchability at 28 days (Bynum et al. 2005). Nicarbazin does not persist in serum for longer 2–6 days after feeding stops, depending on species, and reproductive performance returns to normal.

In field studies free feeding of semi-soft, wheat-based baits containing 2500 ppm nicarbazin (OvoControl-G®, Innolytics, LLC (Long Valley, New Jersey US)) to Canada geese (*Branta canadensis*) reduced egg hatchability by 36% compared with control sites (Bynum et al. 2007). Similarly, when pigeons were fed daily with 5000 ppm baits (OvaControl-P®) egg viability was reduced by 59% (Avery et al. 2008). Baits containing nicarbazin have been registered with the U.S. Environmental Protection Agency as reproductive inhibitors for use in Canada geese and pigeon populations. The products have not been registered for bird control in New Zealand although the active ingredient nicarbazin is registered as an anticoccidial agent for poultry. Approval would need to be sought from ERMA and ACVM for its use for reproductive control of wildlife. The utility of nicarbazin would need to be validated for rooks as there appears to be variation in absorption and therefore contraceptive potential between avian species (Yoder cited in Maudlin & Miller 2007). However, nicarbazin is unlikely to have an application in the fertility control of rooks, as to be effective it is required to be fed daily throughout the breeding period. Delivery techniques to minimise impacts on non-target native species would also be required.

Immunocontraception

Vaccines targeting key reproductive proteins and peptides such as gonadotrophin releasing hormone (GnRH) and zona pellucida (ZP) egg coat have been shown to be effective in reducing reproductive performance of a range of mammalian species when delivered by injection (Maudlin & Miller 2007). Immunisation against mammalian GnRH was effective in inhibiting reproduction in cowbirds (Thompson et al. 1994) and avian GnRH was successful in reducing fertility of starlings and a small proportion of treated quail (Yoder et al. 2004). There is little known about the effectiveness of vaccines targeting the avian vitelline membrane around the egg yolk (closest equivalent structure to the mammalian ZP egg coat). Immunisation of hens against brushtail possum ZP proteins had no effect on egg laying or hatchability of chickens (Duckworth et al. 2008). Treatment with a potential avian contraceptive vaccine targeting chicken riboflavin carrier protein did not decrease egg production of quail (Yoder et al. 2004). Deployment of immunocontraceptive technologies to free-living populations of birds, such as the rook, would require development of an effective bait delivery system. Techniques to facilitate oral delivery of immunologically based contraceptives are being researched by several groups but pose significant challenges that have as yet not been overcome.

Impact of fertility control

Hands-on methods, such as egg and nest destruction, would only be effective for controlling small localised populations where nests are accessible. Bait-delivered control agents, such as DiazaCon, offer advantages because control can be achieved without personnel having to identify individual nests. For a long-lived species, such as the rook, reproductive control alone is unlikely to result in rapid population decreases. Modelling suggests that reduction in

the clutch size (from 6 to 2 eggs per clutch) reduces recruitment of mute swans by 50% but this would be partially compensated for by increased immigration and higher survival rates. Allowing for increased immigration, a 95–100% reduction in hatchability would reduce Canada geese (Barnard 1991) or mute swan populations (Watola et al. 2003) by 25–30% over 10 years but is unlikely to lead to eradication. Reproductive control may be useful for incorporation into integrated programmes for managing localised rook populations where eradication is not the desired goal. One potential strategy is to use lethal control to reduce existing populations, after which reproductive control could be used to maintain population numbers at a manageable size.

6   Conclusions

- The lack of robust data on the historical and current value of rook damage precludes an evidence-based assessment of the relative costs and benefits of current rook control.
- The potential foraging area of a colony left uncontrolled may extend from c. 15 to >100 square kilometres around the rookery or roost.
- Changing patterns of cropping and land use over the last 40 years may have increased habitat suitable for rooks in the region. The effect of this on the rate of spread of rook populations if control was relaxed is unclear.
- Rook populations have the potential recover quickly in the absence of control and could reach carrying capacity for the region within ten years, although this is likely to occur more slowly because of rooks' limited dispersal behaviour. The predictions of the model were generally robust to variation in parameter estimates.
- Based on an analysis of suitable habitat, topography, and climatic conditions, much of New Zealand is vulnerable to colonisation by rooks. The potential rate of geographical spread of rooks is likely to be slow, however, even if control was to be relaxed.
- DRC-1339 poses low to moderate risk of poisoning to species other than pest birds such as rooks. It degrades rapidly under normal environmental conditions, and does not persist. It is mostly excreted from the body before rooks die, and so does not accumulate in birds or carcases.
- DRC-1339 appears to be relatively humane, although such data have not been collected for rooks. Birds generally become comatose before death, convulsions, spasms, or distress calls have not been observed, and birds die a quiet, apparently painless death.
- Egg oiling may be effective for rook control but only for small local populations where dispersal of unsuccessful breeding birds to alternative nesting sites will not cause additional problems.
- Both DiazaCon and Nicarbazin are likely to reduce breeding success of rooks, but the former appears to have greater potential for field use. A suitable formulation and delivery system for free-living rooks would need to be developed to ensure efficacy and to minimise risks to non-target species. DiazaCon is not registered for use in New Zealand and approval would need to be sought from ERMA and ACVM for its testing and ultimate use for rook control.
- Reproductive control may be useful for incorporation into integrated programmes for managing localised rook populations where eradication is not the desired goal. Lethal control could be used to reduce existing populations, after which reproductive control could maintain population numbers at a target level that minimised impacts.

7 Recommendations

Horizons Regional Council should

- undertake an evaluation of the economic losses to rooks in the region.
- support the collection of data on rook biology and ecology specific to the Manawatu region for use in modelling.
- support the development of a spatial model of rook populations so that the rate of increase in rook numbers and geographic spread can be predicted with greater accuracy and precision.
- support the collection of welfare data on rooks poisoned with DRC-1339.
- support initial trials to assess the efficacy of DiazaCon for control of rook reproduction.

8 Acknowledgements

Thanks are due to Jim Coleman and Dick Porter for advice about rook management, and to Bruce Warburton for comments on the draft report, which was edited by Anne Austin.

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