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Eradication of the Russell Forest sika deer herd: a review and plan

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Summary

Project and client

- Northland Regional Council has been trying to eradicate a herd of sika deer (*Cervus nippon*) in Russell Forest for around 20 years, which established after an illegal release. Although the herd has been reduced to low numbers, eradication has not been achieved. Manaaki Whenua – Landcare Research was commissioned by Northland Regional Council to briefly review the history of sika deer control in Russell Forest and discuss new tools that may improve the efficacy of the eradication of this herd. The project was carried out between October 2019 and February 2020.

Objectives

- Provide a brief summary of the control history of sika deer in Russell Forest.
- Review the key requirements for eradicating pest animals, and discuss how these relate to the sika deer eradication programme in Russell Forest.
- Highlight survey and control methods that could improve the efficacy of the sika deer eradication programme.
- Provide recommendations for improving the sika deer eradication programme.

Results

- There are three key criteria that need to be met to achieve the eradication of pest animals:

1. the rate of removal exceeds the rate of increase at all population densities
2. immigration is prevented
3. all reproductive animals are put at risk.

- One of the key criteria necessary for eradicating sika deer from Russell Forest is not being met: all reproductive sika deer are not being put at risk of being killed by control staff. The reason for this is that some landowners have prevented Northland's deer control team from accessing private land to kill deer.
- Thermal imaging (TI) technology is increasingly being used for control and monitoring, using both ground- and helicopter-based methods. TI is also useful for confirming eradication, but it is expensive compared to ground hunters.
- Faecal DNA can accurately discriminate between multiple species of wild ungulates. It is also used for estimating sex ratios, population density and actual abundance. Faecal DNA may provide important information about the number of female versus male sika deer in Russell Forest, the minimum number of sika deer that remain in the herd (i.e. a minimum population estimate), and the spatial distribution of those individuals.
- Judas deer and acoustic monitoring devices have the potential to increase detection and kill rates of sika deer in Russell Forest. Both methods are likely to have greatest utility for the mop-up of survivors following attempted eradication (if access to all private land can be obtained).

Conclusions

- Currently not all private land can be accessed to control sika deer in the Russell Forest area. If all deer in Russell Forest cannot be put at risk of being shot by the deer control team (criterion 3), eradication will not be achievable, even if new detection technologies are, or become, available. If Northland Regional Council chooses to maintain a strategy of eradication, access to private land will need to be obtained through the appropriate legislative framework.
- New liberations of sika deer in Russell Forest are also a threat to the programme, especially if eradication is achieved. However, if access to private land can be obtained through the appropriate legislative framework, individual deer originating from new liberations can be located and killed, and their eradication confirmed.
- There are new or improved control and monitoring tools that could be useful for sika deer management in Russell Forest. In my opinion, however, these are of secondary importance to gaining access to all private land.

Recommendations

- If Northland Regional Council and its stakeholders want to keep eradication as the preferred strategy for sika deer in Russell Forest, legal advice should be sought to determine how best to gain access to sika deer on all private land.
- Northland Regional Council and its stakeholders should continue to proactively educate the Northland community about why deer are not wanted in the region and to rapidly respond to any further illegal liberations of sika deer (as described in the Northland region's wild deer response strategy; Speedy et al. 2016).
- Getting access to all private land through the appropriate legislative framework might be time consuming. In the interim, the deer control team should continue to shoot deer on permissible land tenures. In addition to a ground hunter, indicator dogs and ground- or aerially based TI equipment may be useful for detecting deer.
- If feral pigs and feral goats are preventing the deer control team from effectively targeting sika deer, Northland Regional Council and its partners should consider reducing pig and goat numbers to low levels, thereby reducing the likelihood that they will alert deer to the presence of control staff.
- Faecal DNA may be useful for managing sika deer in Russell Forest. Unless access to all private land can be gained, I do not consider faecal DNA a priority. However, a pilot trial, especially near the boundaries of private land, could determine the usefulness of this tool.
- Sika deer abundance and impacts are estimated to be low in Russell Forest. The deployment of Judas deer would be unlikely to substantially improve outcomes associated with annual sustained control. I suggest that this tool might have greater applicability if used to locate and kill the few individuals surviving an eradication attempt; i.e. if access to all private land can be gained. In the interim, a pilot trial determining the efficacy of the method may be warranted.
- Acoustic monitoring devices also have the potential to increase detections and kill rates of sika deer, and are likely to be less expensive than using Judas deer. I recommend that these devices be deployed, potentially in concert with camera traps, to assess their efficacy for increasing sika deer detections and kills.

1 Introduction

Northland region only has a few small populations of wild deer, and these are targeted for eradication. One of the key impediments to this strategy is the herd of sika deer (*Cervus nippon*) that was illegally liberated in Russell Forest in the late 1980s. Attempts to remove this herd have been ongoing for around 20 years. However, although the herd has been reduced to low numbers, eradication has not been achieved. Manaaki Whenua – Landcare Research was commissioned by Northland Regional Council to briefly review the history of sika deer control in Russell Forest and discuss new tools that could improve the efficacy of the eradication programme. This project was carried out between October 2019 and February 2020.

2 Background

Northland has historically been a deer-free region (Speedy et al. 2016). There were no known populations of wild deer in the region before the late 1980s (King 1990), but thereafter authorities identified small, localised populations of wild red deer (*Cervus elaphus*), wapiti (*C. canadensis*), sika deer, and fallow deer (*Dama dama*) (Fraser et al. 2000). Wild populations of deer in Northland originated from both farm escapes and illegal liberations (Fraser et al. 2000).

Most populations of wild deer in Northland were eradicated soon after they were detected. For example, 27 of 28 new populations detected in the 1990s were reported as having been eradicated by 2003 (Fraser et al. 2003; also see Sweetapple 2006). However, ongoing escapes from deer farms and illegal liberations have resulted in several new herds of wild deer in Northland: as of 2016 there were nine small herds (most probably with under 10 individuals per herd) (Speedy et al. 2016).

A priority population for eradication in Northland is the herd of sika deer in Russell Forest (which is primarily public conservation land, but also comprises some adjacent private land). The first illegal liberation of sika deer in Russell Forest was believed to have occurred in 1988 and purportedly comprised 12 individuals (Fraser 2005b), with a subsequent illegal release of sika deer sourced from the central North Island in 2015 (Speedy et al. 2016). This herd was designated as important for eradication by Northland Regional Council and its stakeholders because of the impact sika deer will have on indigenous vegetation in Russell Forest and their potential role as hosts of bovine tuberculosis (Coulston et al. 2008). Note that feral pigs (*Sus scrofa*) and feral goats (*Capra hircus*) also occur in Russell Forest, and both species have unwanted impacts on indigenous species. However, these species and their impacts are beyond the scope of this report.

In response to the emergence of wild deer populations in the Northland region, including sika deer in Russell Forest, the Department of Conservation (DOC), Northland Regional Council and TBfree New Zealand (now OSPRI) formed a deer control team in 1997 to manage populations of wild deer (Speedy et al. 2016). The deer control team has managed deer in Russell Forest since the team's inception (Figure 1).

Most sika deer in Russell Forest have been killed in the Ngaiotonga Scenic Reserve and land immediately adjacent to it (Fraser 2005b). Since 2010 the deer response team has been denied access to a few farms neighbouring the Ngaiotonga Reserve. Anecdotally, these private properties contain the most sika deer (Allan Gardiner, Wild Animal Control Services Ltd, pers. comm.), and this loss of access for control staff is reflected in the reduced number of kills by the deer control team after 2010 (Figure 1), although hunting effort also decreased at this time.

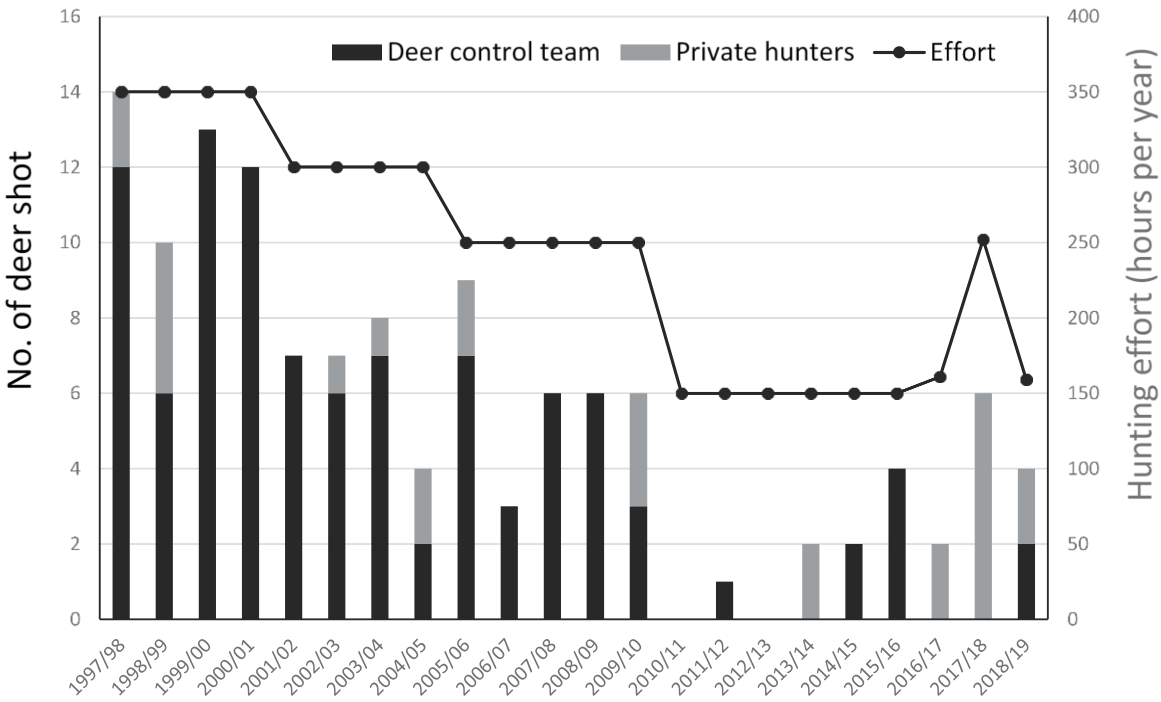

Figure 1. The history of sika deer (*Cervus nippon*) control and hunting effort in Russell Forest since the inception of professional deer control conducted by the Northland deer control team in 1997. The number of sika deer shot in each financial year is divided into deer shot by the control team (black portion of bars) and deer shot by private hunters (grey portion of bars). Three sika deer were also shot by DOC staff prior to 1997. The data are from Allan Gardiner, Wild Animal Control Services Ltd, and Glen Coulston, Good Wood Aotearoa Ltd (both former DOC employees and past and current managers of the Northland deer control team, respectively).

Note: most kills by private hunters are anecdotal and have not been verified. As hunting effort in Russell Forest declined since sika deer control first began, the trends in the number of deer shot annually may not reflect actual changes in deer numbers.

The sika deer eradication programme in Russell Forest has been going for around 20 years. It has been successful in that sustained control has kept the number of sika deer and their impacts low. It has also prevented the geographical spread of sika deer. However, the primary objective of eradication has not been achieved. This is largely due to the violation of one of the criteria necessary for eradication: all target animals need to be put at risk by the methods being used (Bomford & O'Brien 1995; Parkes & Panetta 2009).

I provide a detailed discussion of the key requirements for eradicating pest animals in the Results (below), but it is worth noting here that unless the deer control team has access to all areas that currently provide a refuge for sika deer, eradication is unachievable. For example, the Whakawhiti and Puhinui watersheds on the northern side of Russell Forest form a large part of the private land to which access has been denied (Allan Gardiner, Wild Animal Control Services Ltd, pers. comm.). Combined, these catchments cover over 1,000 hectares, much larger than the average male (534 hectares) and female (103 hectares) sika deer home ranges estimated from the central North Island (Nugent & Speedy, in press). Therefore, it is likely that some sika deer will never (or only rarely) enter land on which the deer control team can permissibly shoot them.

In theory, access to private land can be obtained through the appropriate legislative framework (especially the Biosecurity Act 1993), although I do not discuss the legal mechanisms for accessing private land for pest control as it is beyond the scope of this report.

3 Objectives

- Provide a brief summary of the control history of sika deer in Russell Forest.
- Review the key requirements for eradicating pest animals, and discuss how these relate to the sika deer eradication programme in Russell Forest.
- Highlight survey and control methods that may improve the efficacy of the sika deer eradication programme.
- Provide recommendations for improving the efforts to eradicate sika deer from Russell Forest.

4 Results

4.1 Control history

Northland Regional Council aims to eradicate sika deer from Russell Forest. Alternative management options include ‘do nothing’, ‘prevent geographical spread’, ‘fence vulnerable assets so deer cannot access them’, and ‘sustained control’.

Deer management in Russell Forest has been in the form of ongoing sustained control (Figure 1). This has resulted in low numbers of deer on public conservation land and other land where the deer control team is permitted to hunt, and probable higher, but unknown, numbers of deer on private land on which access has been denied.

Sustained control has probably been sufficient to prevent unwanted impacts caused by sika deer to assets in Russell Forest and to prevent widespread range expansion. In this regard, the management of sika deer in Russell Forest has been successful. However, a key difference between sustained control and eradication is that the former requires funding and control in perpetuity, whereas the latter does not (provided no further illegal releases occur). This is the rationale Northland Regional Council and other stakeholders have used for their sika deer eradication programme in Russell Forest. It is also the rationale I use in this report for focusing on eradication rather than sustained control.

4.2 Key requirements for eradication

Eradication requires a number of conditions to be met, as well as a set of constraints that need to be managed before a project is started. These conditions and constraints have been organised into six criteria to help managers determine when eradication is feasible, or if some alternative management option, such as sustained control, is more suitable (Bomford & O'Brien 1995):

1 The rate of removal exceeds the rate of increase at all population densities.

2 Immigration is prevented.

3 All reproductive animals are put at risk.

4 There is a suitable social, political and economic environment.

5 Deer can be detected at low densities.

6 Discounted benefit–cost analysis favours eradication over control.

Of these, criteria 1–3, and arguably 4, are regarded as *crucial* to the success of eradication efforts, whereas criteria 5 and 6 are considered *desirable*.

The criteria necessary for eradication have previously been described and discussed in Northland's deer management context (e.g. Fraser et al. 2003; Latham 2016), but I reiterate them here because they determine the feasibility of eradication. Note that I discuss the criteria in a slightly different order to that used by Bomford and O'Brien (1995).

It cannot be sufficiently emphasised that if the crucial criteria necessary for eradication are not met, a discussion about the most suitable control tools and monitoring methods for achieving *eradication* becomes moot. In other words, if the crucial criteria are not met, eradication will be unachievable. However, new technologies may increase the efficacy of the current model of sustained control and are therefore worth discussing.

1 The rate of removal exceeds the rate of increase at all population densities

The deer control team must be able to remove sika deer from the population faster than the rate at which deer are replaced, and this must be achievable at any population density (Bomford & O'Brien 1995; Parkes & Panetta 2009). Although intuitively obvious, this criterion is important for two reasons (Bomford & O'Brien 1995).

First, populations subjected to control usually compensate with high breeding and survival rates because of an increase in available resources. Fraser (2005b) has modelled the rate of increase of sika deer in Russell Forest. He assumed a starting population of six individuals (three male and three female), an intrinsic rate of increase of 0.33 (i.e. a doubling time of a little over 2 years) for unhunted sika deer, and restricted access for the deer control team resulting in an inability to target these deer for five successive years. The results showed the starting population would increase to around 31 individuals in those 5 years (8, 12, 16, 22, and 31 in years one to five, respectively). If this herd is topped up by further illegal liberations, then clearly these estimated population increases will be even greater. In this example, the deer control team needs to be able to remove deer at a faster rate than these six deer can replace themselves and increase the population size. In Russell Forest, the ability to do this is largely affected by access (see criterion 3).

The second reason this criterion is important is because the number of deer killed per unit effort usually declines as the density of deer declines (Crouchley et al. 2011). Previous eradication programmes have shown that this results in substantially higher costs per kill at low deer density compared to higher densities (Nugent & Arienti-Latham 2012). This has implications for criterion 4, especially in terms of having adequate funding for the full duration of the eradication programme, including validating eradication.

2 Immigration is prevented

The risk of sika deer recolonising Russell Forest once eradicated must be zero, or at least manageable (e.g. by quickly removing individuals if a new incursion occurs, or fencing to prevent the pest accessing the controlled area). If sika deer can naturally move into Russell Forest from adjacent areas outside the area targeted for eradication, or additional human-assisted liberations occur, eradication will be unachievable or transient (Bomford & O'Brien 1995).

In Russell Forest all sika deer, irrespective of land tenure, are targeted for eradication. There are no other source populations of this species in the Northland region (Speedy et al. 2016; Nugent & Speedy, in press). Therefore, so long as the deer control team can get access to all properties containing sika deer (criterion 3), immigration should not be a key factor in the successful eradication of sika deer herd in Russell Forest. However, further illegal liberations may occur, and these animals should be targeted for removal as soon as they are detected.

3 All reproductive animals are put at risk

Removal techniques for large pest species, such as sika deer, rarely kill all individuals in one attempt. Usually a population is knocked down by one or more methods of control and attempts are then made to mop up survivors, often using additional control methods (see, for example, Crouchley et al. 2011).

However, although all individuals need not be killed in one attempt (Bomford & O'Brien 1995; Parkes & Panetta 2009), all reproductive individuals need to be put at risk by the method(s) being used. Note that for species like deer it is preferable to remove as many individuals as possible at each control attempt so that survivors do not have the opportunity to learn to avoid controllers, or develop an aversion to the control methods used.

The primary control method for sika deer in Russell Forest is shooting conducted by the deer control team (Speedy et al. 2016). Various tools are sometimes used in concert with shooting by the team to increase efficacy, such as thermal imaging (TI) technology and indicator dogs. Nevertheless, shooting is the main method of control and, in theory, all deer can be put at risk using this method.

In practice, not all deer are put at risk because the deer control team does not have access to all areas where sika deer occur in the Russell Forest area. Private properties that have denied access to control staff have created refuges for sika deer. If the deer control team cannot access all properties with sika deer, eradication will not be feasible unless deer on properties that have denied access also use land that can be accessed by control staff. The home range and movement ecology of sika deer in Russell Forest are unknown, but it is likely that some sika deer live entirely on properties with restricted or no access for the deer control team.

It has also been suggested that pigs and goats might alert sika deer to the presence of control staff, thereby resulting in an inability to put all deer at risk of being shot (Glen Coulston, Good Wood Aotearoa Ltd, pers. comm.). If this is the case, then interference by pigs and goats also affects criterion 3. I suggest three possible solutions for overcoming this. First, substantially reduce the numbers of pigs and goats before targeting sika deer for eradication, thereby reducing the likelihood that other pest species will alert sika deer to the presence of control staff. Second, use a control method other than shooting (i.e. one that is not affected by the presence of pigs and deer). However, even if an alternative control method is identified, e.g. foliage bait gel, it would be unlikely to achieve eradication without being used in concert with shooting. Third, if pigs and goats cannot be reduced to low numbers (e.g. because of a lack of funding, or social licence to operate), and therefore sika deer cannot be effectively targeted, the best option is to move from a strategy of eradication to one of sustained control.

As mentioned above, access to private land can be obtained through the appropriate legislation and, so long as interference from pigs and goats is manageable, this would result in all sika deer in the Russell Forest area being put at risk. If access to all properties cannot be obtained, eradication of the herd is unlikely to be successful, and the best model to mitigate the impacts (or potential future impacts) of sika deer in Russell Forest is sustained control.

4 There is a suitable social, political and economic environment

Bomford and O’Brien (1995) emphasise the social and political aspects of this criterion. Here I also cover the economic aspect of this criterion, because having sufficient funding for the full duration of an eradication programme, including its validation phase, is critical for success and its importance cannot be overstated.

The allocation of public funds for pest control is usually determined by central government or regional councils. This allocation is often based on pest management strategies, which, in turn, are influenced by the views of the wider community (Parkes & Murphy 2003). Having social licence to conduct management such as the eradication of sika deer from Russell Forest can be as important to the success of the programme as having sufficient funding (Bomford & O’Brien 1995; Parkes & Panetta 2009).

While the strategy for managing wild deer in Northland Region has buy-in from most stakeholders, some landowners and recreational hunters are responsible for deliberate releases of deer and then subsequently protecting them by denying access to private land for control staff (Speedy et al. 2016). A community awareness programme has been developed by Northland Regional Council (with support from DOC, OSPRI, deer farmers, conservation NGOs, and the NZ Game Animal Council) to educate the public about Northland's deer management strategy (Speedy et al. 2016). Although educating the public about the strategy is important, some stakeholders or individuals will continue to liberate and/or protect populations of wild deer in the region, primarily to provide them with a huntable resource.

In Northland the political and economic environment appear suitable for the eradication of sika deer from Russell Forest. There is also strong support from most stakeholders, and therefore social licence for the deer control team to operate. However, the lack of buy-in from key individuals means that this critical criterion is not being met, thereby rendering eradication currently unachievable.

5 Deer can be detected at low densities

This criterion states that all individuals surviving control should be detectable, and once detected, they should be killed before the population can increase. If they cannot be detected, there is no way to determine if eradication efforts are effective, or to determine if eradication has been achieved (Bomford & O'Brien 1995).

Annual control of sika deer in Russell Forest commenced shortly after their release in 1988 and so they have never been present at high densities (Speedy et al. 2016). There is scant information about sika deer numbers on private properties that have prevented access to the deer control team. However, deer densities are also likely to be low in these areas, otherwise dispersal from private land to public conservation land would probably be reflected by a higher number of sika deer killed by control staff in recent years (i.e. since 2010, Figure 1), especially near the boundaries of these private properties.

Although the actual abundance of sika deer is unknown, Figure 1 suggests that the deer control team can reliably detect and kill sika deer at the assumed low density at which they occur. Moreover, there are precedents for the eradication of deer from other forested mountainous areas in New Zealand; for example, red deer from Anchor Island (1,130 ha) and Secretary Island (8,100 ha) in Fiordland (Crouchley et al. 2011; Norm MacDonald, DOC, unpubl. data). Therefore, so long as all reproductive individuals can be put at risk (criterion 3), eradication of sika deer from Russell Forest is technically feasible.

Detection probability and surveillance sensitivity for different survey methods for mammalian pests have previously been assessed (e.g. Samaniego-Herrera et al. 2013; Anderson et al. 2017; Latham et al. 2019). These studies have shown that there are survey methods suitable for detecting mammalian pests at low densities, and therefore that eradication can be validated with a high level (e.g. 0.95) of certainty.

It is important to note that validating eradication with a high level of certainty can be expensive (at least if the control area is large). For example, Latham et al. (2019) compared the costs of surveillance using different methods to achieve a 95% probability of eradication for Bennett's wallaby (*Notamacropus rufogriseus*). They found that a ground hunter with dogs cost about $3.00 per hectare, camera traps $8.00 per hectare, and helicopter-based survey methods over $20.00 per hectare.

6 Discounted benefit–cost analysis favours eradication over control

Although the benefits of management may be achievable without eradication, discounted benefit–cost analysis (i.e. future economic benefits compared to immediate economic benefits) usually favours the one-off costs of eradication over the ongoing costs of sustained control. However, sustained control may be more cost-effective than eradication for reducing damage if discount rates are comparatively high (Bomford & O'Brien 1995). Similarly, the target species may provide economic benefits that provide a rationale against eradication being the best management option (e.g. wild game meat; Ramsay 1994).

The strategy for deer management in Northland is eradication of all wild deer (Speedy et al. 2016). Although sika deer on private land in the Russell Forest area may provide hunting opportunities for a few individuals, they do not provide economic benefits to the region. Moreover, eradication will eliminate any potential unwanted impacts that sika deer might have on indigenous plants if their densities were to increase. Eradication will also prevent them from dispersing into new areas.

Although eradication is expensive, it is a technically feasible management option for sika deer in Russell Forest (if access to all land can be obtained), which, if successful, will eliminate further management costs and protect indigenous vegetation from sika deer (but not the impacts caused by pigs and goats).

4.3 New tools for achieving eradication

Latham (2016) has summarised some new or improved technologies that may be useful for managing sika deer in Russell Forest. Since then, research or management has further assessed the efficacy of some of these control or monitoring methods, including for mammalian pests in New Zealand. Therefore, here I expand on the Latham (2016) report by discussing the potential utility of new monitoring and control methods for managing sika deer in Russell Forest based on the findings from recent studies.

I discuss the methods below assuming that ground hunting (with or without indicator dogs) will be the primary control method, and that new technologies will (i) potentially increase the efficacy of ground hunting, (ii) serve as secondary control methods, or (iii) be used to monitor the sika deer population or confirm eradication. I also assume that the deer control team will gain access to all land occupied by sika deer and therefore that eradication is achievable. This may not be the case, at least in the immediate future. However, most of the methods I discuss will also have relevance to a strategy of sustained control.

4.3.1 Thermal imaging

Thermal imaging (TI) cameras have been used for monitoring wildlife for over 20 years (Gill et al. 1997; Havens & Sharp 1998). Recent technological improvements in TI have resulted in greater confidence in estimates of population sizes obtained from various ground and aerial survey designs using TI (e.g. Wäber & Dolman 2015).

Fraser et al. (2003) and Latham (2016) found little or no utility in using TI cameras for monitoring populations of sika deer in Russell Forest because deer numbers are exceedingly low. However, TI technology has three potential uses in Russell Forest. First, a TI camera mounted on a helicopter may be useful for detecting and subsequently killing (if used alongside a shooter) sika deer in open or semi-open habitats used by them. Second, it may be a suitable tool (potentially used in concert with other survey methods) for confirming eradication. Third, handheld TI units and rifle scopes may improve the efficacy of ground hunters.

TI cameras have recently been used to assess the detection rates of medium- to large-sized mammalian pests in New Zealand, such as ground and aerial surveys for Bennett's wallaby in South Canterbury (Latham et al. 2019; Pete Caldwell, Boffa Miskell Ltd, unpubl. data), and sika deer in Russell Forest, Northland (Munn 2019). These studies suggest that TI cameras can detect individuals from low-density populations (Munn 2019) and yield detection rates similar to or better than other commonly used survey methods (e.g. ground hunters and helicopter-based aerial observers) if they are used under optimal conditions (Latham et al. 2019; Pete Caldwell, Boffa Miskell Ltd, unpubl. data).

TI is affected by direct solar radiation, which causes 'wash-out' of captured images and an inability to identify animals in the camera footage. Latham et al. (2019) found that TI cameras performed poorly in open habitats and on aspects prone to direct sunlight. However, they also found that TI performed comparatively well in open habitat if surveys were conducted in early morning (or late evening) on days with adequate cloud cover and a low ambient temperature (<10° C).

Latham et al. (2019) also found TI cameras performed comparatively well in forest, possibly because of the larger temperature difference between warm-bodied animals and the cool temperate forest floor. However, detection rates are likely to decrease as canopy closure increases and obscures the ability to view objects on the forest floor (Graves et al. 1972; Wäber & Dolman 2015; Hambrecht et al. 2019). To my knowledge, the utility of aerially operated TI cameras relative to different levels of canopy closure in Russell Forest, is unknown.

In addition to assessing detection rate, Latham et al. (2019) assessed the detection probability and surveillance sensitivity of a TI camera operated from a helicopter. Detection probability differs from detection rate in that it considers how many individuals were seen from a population of a known size; in other words it yields data on the number of animals that were seen relative to a *known number of animals* that were available to be seen. This information is critical for modelling proof of eradication (e.g. Anderson et al. 2013, 2017) and will be essential for confirming sika deer eradication from Russell Forest, if and when sika deer management in that area reaches this stage.

Latham et al. (2019) found the detection probability and surveillance sensitivity for a TI camera operated from a helicopter were low compared to a ground hunter with dogs (the median detection probabilities were 0.22 and 0.54, respectively). However, the detection probabilities for the TI camera were slightly higher than for helicopter-based observers not using TI. These results translated into high costs ($42.00 per hectare) for confirming eradication of wallabies using a TI camera, compared to a cost of $3.00 per hectare using a ground hunter with dogs. Despite this, there are capacity and time issues associated with using a ground hunter that are likely to make this method impractical for surveying large areas (c. 10,000 ha or more) (Latham et al. 2019). TI cameras operated from a helicopter are likely to be important for monitoring these larger areas.

Hand-held TI units and rifle scopes are increasingly being used for ground-based shooting of mammalian pests (Gardiner 2015; Bengsen et al. in press), including sika deer in Russell Forest (Glen Coulston, Good Wood Aotearoa Ltd, current manager of the Northland deer control team, pers. comm.). Although this technology is purported to increase detection and kill rates, there are sparse data to support this (Bengsen et al. in press). Despite this, I recommend that TI technology continue to be used by the deer control team in Northland, but with effort (GPS track files, or at least number of hours hunted) and kills recorded while using it (if this is not already being done). If comparable data are collected by the team when they are not using TI, then the difference in efficacy of hunting with and without TI can be quantified.

Using TI units at night is likely to increase detection rates, but flying at night in a helicopter has significant regulatory constraints imposed by the Civil Aviation Authority (CAA). To address this issue, several groups have been developing drone-based capability, and this technology might provide a cost-effective option for searching for deer. If a deer is detected there are no options available for killing that animal from the drone (c.f. from a helicopter). Some pilot trials have been completed using drone-based TI to survey for European rabbits (*Oryctolagus cuniculus*) (Bruce Warburton and Chris Niebuhr, Manaaki Whenua – Landcare Research, unpubl. data), and a proposal is being developed by Manaaki Whenua – Landcare Research to run similar trials for Bennett's wallabies for Environment Canterbury.

4.3.2 Faecal DNA

Faecal DNA is a useful method for identifying cryptic or rare species of mammals (Ramón-Laca et al. 2014; Spitzer et al. 2019). For example, it has been used to accurately discriminate between 10 different species of wild ungulates in New Zealand (Ramón-Laca et al. 2014). Unless there is evidence that there may be species other than sika deer and feral goats in Russell Forest, the use of faecal DNA is likely of little value for sika deer management, especially as other monitoring tools such as camera traps are cheaper and easier to deploy to confirm the presence of deer species other than sika deer.

However, faecal DNA has also been used within a spatial capture–recapture framework to estimate population density and abundance; for example, white-tailed deer (*Odocoileus virginianus*, Goode et al. 2014; Poutanen et al. 2019); pronghorn antelope (*Antilocapra americana,* Woodruffe et al. 2016). These studies found this approach yielded improved density, abundance, and/or sex ratio estimates of their study species and recommend it as a useful method for tracking responses to management actions.

It is possible that collecting faecal DNA from sika deer in Russell Forest and analysing it within a spatial capture–recapture framework may be useful for deer management in that area. However, a reasonable number of fresh faecal pellet groups need to be located (e.g. >350 pellet groups; Goode et al. 2014) and individual pellets sampled from these for robust estimates of density and abundance to be obtained. I suspect that finding enough pellet groups that will yield adequate precision for abundance estimates will be challenging in the Russell Forest situation. Nevertheless, faecal DNA has the potential to provide important information about the number of female versus male sika deer, the minimum number of sika deer that remain in the herd (i.e. a minimum population estimate), and the spatial distribution of these individuals. This information would be useful for sika deer management in Russell Forest, but the cost of collecting the information relative to its utility must be considered.

Knowing where survivors are could help build a tentative map of their home ranges if sufficient pellet groups (yielding usable DNA) were able to be located. This information may help control staff focus their effort in areas where deer are most likely to be, thereby potentially increasing kill rates. In practice, I suggest this information might be a 'nice to have' rather than a 'need to have' for the sika deer programme in Russell Forest, especially as control staff will already have a reasonable picture of where survivors are located based on field sign (faecal pellets, tracks, antler rubs, scrapes, etc), assuming it is correctly differentiated from goat sign. However, faecal DNA may help to build a picture of how many individual sika deer occur around the boundaries of private land that the deer control team cannot permissibly shoot on. This information could provide some indication of the number of sika deer on land where access has been denied compared to other land tenures. Moreover, it may yield useful data about the number of individual deer that move in and out of refuges created by private land, potentially identifying good areas to focus hunting effort and thereby increase kill rates.

DNA (from hair samples and faecal pellets) has also been used as a tool for determining if new detections at a site known to have had a wild population (but thought since to have been eradicated) represent survivors of the original population or a new incursion (e.g. Crouchley et al. 2011). This may be a useful tool for sika deer management in the Northland region if the control staff can reduce the Russell Forest herd to a level where it is believed to have been eradicated. That is, if eradication has been declared for sika deer in Russell Forest but a sika deer (or faecal pellets) is subsequently detected, DNA may help to determine if the deer was a survivor of the eradication attempt or originates from a new liberation.

Although faecal DNA may provide useful information for sika deer management in Russell Forest, in my opinion it should not be considered a critical priority. Key to achieving eradication is obtaining access to all land occupied by sika deer and putting all deer at risk (i.e. criterion 3). If this access cannot be obtained, the model of sika deer management in Russell Forest is sustained control. Northland Regional Council and other stakeholders have kept sika deer and their impacts at low levels and have prevented the geographical spread of this species, and key assets in Russell Forest have already been protected from sika deer (but probably not pigs and goats) by annual sustained control. Although information yielded by faecal DNA may marginally improve control efficacy, it cannot currently help achieve eradication.

4.3.3 Judas deer

The use of 'Judas' deer for managing wild deer in Northland was discussed by Latham (2016). It has not yet been trialled in Northland, but is being considered as a potential tool for increasing detection and kill rates (Coulston 2019). Here I reiterate the discussion from Latham (2016).

Judas animals are used to track down and kill conspecific survivors of eradication or control operations and have most often been used for feral goats (e.g. Parkes 1993). The method uses one or more radio-marked individuals released into an area where conspecifics surviving initial knockdown programmes are suspected or known to be. The idea is that these individuals will seek out and group up with survivors (even if they are not related), allowing controllers to more readily locate and kill (mop up) survivors using either ground or aerial methods.

Very-high-frequency (VHF) or global-positioning-system (GPS) collars with a VHF beacon can be deployed on Judas animals. The advantage of GPS collars is that additional information about fine-scale spatiotemporal habitat use, range extent, and behaviour can be obtained (Latham, Latham et al. 2015), potentially improving future control efforts. The disadvantage of GPS collars is that they are expensive compared to VHF (Latham, Latham et al. 2015), and if the animal wearing the collar is shot by recreational hunters the collar may be stolen or purposely destroyed.

To my knowledge, the Judas method for deer has been trialled only on red deer in the Murchison Mountains and Anchor and Secretary Islands in the South Island. The results of those trials suggest that it might be a key tool for mop-up and maintenance phases of deer eradication programmes (Crouchley et al. 2007, 2011). The Judas method has also been recommended as having possible utility for deer control or eradication in the Northland region (Fraser et al. 2003; Latham 2016) and the Auckland region (Latham et al. 2012), but so far it has not been used in these regions.

The method is likely to have the greatest utility for deer species that are highly social, because they will be more likely to seek out conspecifics than solitary or 'barely social species' such as sambar deer (*Rusa unicolor*, Mattioli 2011). For example, the Judas approach might be useful for red deer because they tend to aggregate into matrilineal kin or stag groups (Nugent & Fraser 2005), and for fallow deer because they tend to be gregarious (Nugent & Asher 2005). Latham et al. (2012) have suggested that sterilised juvenile females are probably the best Judas candidates for social species because they will be less likely to make long-distance dispersals compared with males, or to remain independent of other groups, like mature females. These authors add that targeting surviving females will have a greater effect on population reduction than targeting males.

Sika deer in New Zealand and elsewhere within their native and introduced ranges are considered a moderately social species, showing (sometimes strong) sexual segregation (Fraser 2005a; Mattioli 2011; Latham, Herries et al. 2015). In New Zealand, intensive recreational and aerial hunting have markedly reduced historical larger mixed groups of sika deer (Davidson 1973) and most now live in small groups or alone (Fraser 2005a). Thus, it is debatable whether deploying Judas female sika deer would be as useful as it has proven to be on more social species (Parkes 1993; Crouchley et al. 2007, 2011). However, sika deer stags use a number of behavioural strategies to acquire mating opportunities during the rut that result in males and females being found together more often than at other times of the year (Bartos et al. 1998; Fraser 2005a). It may be possible to utilise the breeding behaviour of radio-collared male sika deer to betray the locations of females to the deer control team during the rut.

An advantage of using one or more males as the Judas animals (c.f. females) is that releasing them will not increase reproductive potential within the target population (assuming that survivors already comprise at least one male to fertilise females), although, as stated above, females can be sterilised prior to release (Latham et al. 2012). A potential disadvantage of using male sika deer as Judas animals is that they are prone to making long-distance dispersals (Fraser 2005a). This might not be important if they cannot find a sika deer hind to mate with, although they can hybridise with red deer.

Survivors detected with Judas deer in Russell Forest could be targeted using ground or aerial methods, the appropriateness of which will probably depend on forest canopy cover. Sika deer in dense forest are probably best targeted using ground-based control methods, whereas those in more open scrub and pasture margins may be better targeted using a helicopter-based TI camera and shooter (e.g. Munn 2019).

Using Judas deer will probably be expensive, and will possibly only achieve minor gains in terms of increased detection and kill rates. This method may have the greatest utility for mopping up survivors to achieve eradication (if criterion 3 can be met). However, assessing the efficacy of this method before using it as a mop-up tool may be beneficial.

4.3.4 Acoustic monitoring devices

Latham (2016) also discussed the potential utility of acoustic monitoring devices for sika deer management in Russell Forest.

These devices are becoming increasingly used in wildlife ecology and management (e.g. Wall et al. 2014; Buxton et al. 2018). For example, they can provide 'real-time' directional tracking of animal sounds and gunshot detection (useful for anti-poaching programmes), both of which have immediate application for wildlife management (Wall et al. 2014), such as sika deer control in Russell Forest.

This method was briefly trialled in Northland in 2019 (Glen Coulston, Good Wood Aotearoa Ltd, pers. comm.). Five devices were deployed in Russell Forest for 2 weeks and these devices were able to detect calls emitted by sika deer. However, the utility of these devices was limited because data had to be downloaded from each device, rather than being retrieved remotely in real time. Although this study confirmed that sika deer calls could be detected using acoustic monitoring devices, the information was not received quickly enough to be useful for sika deer control. Receiving data in real time would mean that control staff could respond immediately to a sika deer call, thereby increasing the likelihood of locating and killing the individual detected by the device.

There is also the potential to link acoustic monitoring devices to artificial intelligence (AI) systems that can learn to recognise the target species and then alert an appropriate person in real time when a deer is heard. This AI approach is at an early stage of development and would need to be developed specifically for detecting sika deer.

Acoustic monitoring devices could be deployed in concert with camera traps (Buxton et al. 2018) to maximise information about sika deer presence and behaviour, especially if data from both methods were received in real time. Because acoustic monitoring devices are designed to monitor animal sounds, some thought would need to be given to when they should be deployed; e.g. for sika deer, it might be most useful to deploy them during the rut, when this species is most vocal (Fraser 2005a).

As with camera traps, acoustic monitoring devices are likely to be stolen or vandalised by some members of the public if they are seen.

5 Conclusions

Currently not all private land can be accessed to control sika deer in the Russell Forest area. If all deer in Russell Forest cannot be put at risk of being shot by the deer control team (criterion 3), eradication will not be achievable, even if new detection technologies are, or become, available. If Northland Regional Council chooses to maintain a strategy of eradication, access to private land must be obtained through the appropriate legislative framework. If access cannot be obtained, then the council needs to reconsider its strategic approach to sika management in Northland.

New liberations of sika deer in Russell Forest are also a threat to the programme, especially if eradication is achieved. However, if access to private land can be obtained through the appropriate legislative framework, individual deer originating from new liberations can be located and killed, and their eradication confirmed.

There are new or improved control and monitoring tools that may be useful for sika deer management in Russell Forest. In my opinion, however, these are of secondary importance to gaining access to all private land. Although they may marginally increase detection and kill rates of sika deer, they will probably not noticeably change the outcomes of current deer management, as deer are already at low densities (Speedy et al. 2016). If access to all private land can be obtained, these tools may contribute to mopping up surviving sika deer, and to declaring eradication with a high level of confidence.

6 Recommendations

- If Northland Regional Council and its stakeholders want to keep eradication as the preferred strategy for sika deer in Russell Forest, legal advice should be sought to determine how best to gain access to sika deer on all private land.
- Northland Regional Council and its stakeholders should continue to proactively educate the Northland community about why deer are not wanted in the region and to rapidly respond to any further illegal liberations of sika deer (as described in the Northland Region's wild deer response strategy, Speedy et al. 2016).
- Getting access to all private land through the appropriate legislative framework may be time consuming. In the interim, the deer control team should continue to shoot

deer on permissible land tenures. In addition to a ground hunter, indicator dogs and ground- or aerially based TI equipment may be useful for detecting deer.

- If feral pigs and feral goats are preventing the deer control team from effectively targeting sika deer, Northland Regional Council and its partners should consider reducing pig and goat numbers to low levels, thereby reducing the likelihood that they will alert deer to the presence of control staff.
- Faecal DNA may be useful for managing sika deer in Russell Forest. Unless access to all private land can be gained, I do not consider faecal DNA a priority. However, a pilot trial assessing the abundance of pellet groups, especially near the boundaries of private land, may provide insights into the feasibility of this tool.
- Sika deer abundance and impacts are qualitatively estimated to be low in Russell Forest. The deployment of Judas deer will be unlikely to substantially improve outcomes associated with annual sustained control. I suggest that this tool might have greater applicability if used to locate and kill the few individuals surviving an eradication attempt (if access to all private land can be gained). In the interim, a pilot trial determining whether released radio-collared deer pair up with conspecifics might be warranted.
- Acoustic monitoring devices also have the potential to increase detections and kill rates of sika deer, and are likely to be less expensive than using Judas deer. These devices might be particularly useful near the boundaries of private land to identify areas where animals might move in and out of refuges created by private land. I recommend that these devices be deployed, potentially in concert with camera traps, to assess their efficacy for increasing sika deer detections and kills.

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