

# Removal of red deer (*Cervus elaphus*) from Anchor and Secretary Islands, Fiordland, New Zealand

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**Abstract** Red deer (*Cervus elaphus*) have been successfully removed from Anchor Island (1130 ha), progress has been made toward removing them from Secretary Island (8100 ha), and a start has been made against the population on Resolution Island (21,000 ha) in Fiordland, New Zealand. The programme on Anchor Island ran from July 2002 until December 2007, and removed 29 deer. Team hunting combined with the use of tracking dogs was the key method. The Secretary Island programme began in 2006 and is continuing. This programme was planned in three phases. The first was to reduce the population within 2 years, and 542 deer (estimated to c. 80% of the population) were killed mostly by ground-based hunting with some helicopter hunting. The second was to remove the survivors, and 91 deer had been removed up to the end of June 2010, mostly by helicopter hunting. The final phase will attempt to detect and remove any immigrant deer. DNA extracted from hair samples was used in an attempt to calculate an initial population size, but the deer were too closely related for this method to be useful. However, the high level of relatedness indicates that there have been few female immigrants to Secretary Island, suggesting reinvasion may be a rare event. The removal of deer from Resolution Island began in November 2009.

**Keywords:** Helicopter hunting, eradication, ground hunting, indicator dogs

## INTRODUCTION

Islands are frequently used as sanctuaries for threatened species. There are approximately 90 islands over 1 ha in size within the Fiordland region of New Zealand, but almost all are sufficiently close to the mainland to be within swimming distances of stoats (*Mustela erminea*) and red deer (*Cervus elaphus scoticus*). Until relatively recently, these islands were not considered likely to provide safe sanctuaries for threatened species, but over the last ten years several pest populations have been eradicated from Fiordland's islands allowing native species to be translocated to them (Elliott *et al.* 2010). Although this ongoing programme focuses primarily on invasive predators, there is an increasing focus on removing all feasibly eradicable pests. For red deer, the long-running programme of sustained deer control in the Murchison Mountains of Fiordland, to protect the habitat of endangered takahe (*Porphyrio hochstetteri*), has helped develop and refine methods suited to the Fiordland environment (Fraser and Nugent 2003) and provided hope that removal of all deer from Fiordland's islands might be possible.

Here we document one completed (Anchor Island; 1130 ha) and one current (Secretary Island; 8100 ha) programme to remove red deer from progressively larger islands in Fiordland. We also note the start of a third attempt on Resolution Island (21,000ha) (Fig. 1).

## MAIN FINDINGS

### Study Area

The coastal Fiordland region has a wet, cool, temperate climate. Westerly or north-westerly winds bring most of the rainfall while southerly or south-westerly winds can bring snow to the higher altitudes, particularly in the winter months. Anchor and Secretary Islands (Fig. 1) lie at the entrance to glacial fiords and have been heavily modified by glacial erosion.

Anchor Island rises steeply on the eastern side to a high point of 417m, with low hills to the west. The highest ridges are capped with small areas of tussock and shrubland, while the lower ridges and hill slopes are covered with a mixed podocarp-broadleaved-beech forest, with coastal scrub, especially on the western shores. Secretary Island is much larger, steeper and more rugged. It has a greater diversity of forest and shrubland cover, with many open landslips. The island rises steeply to over 1100 m and has several areas of alpine vegetation.

### Anchor Island Campaign (2002-2007)

As in many parts of Fiordland, deer densities on Anchor Island were probably quite high before the 1970s, but were considerably reduced by commercial hunting during the 1970s and 1980s. Hunting by fishermen and recreational hunters probably helped keep numbers low after that. During an initial survey in 2001, the survey team noted well worn deer trails and estimated that about 20 deer were present, mostly on the western side.

Although hunting, as part of the eradication campaign, began July 2002, the control plan was not formalised until October 2003. That plan acknowledged the potential for deer to re-invade the island and a need for ongoing surveillance and control (M. Mawhinney pers. comm.).

Use of poisoned baits was not favoured because deer food was relatively abundant on the island. A programme based initially on the use of ground hunters and dogs was therefore developed. The waters around Anchor Island are generally sheltered, with landing possible on most shores, so hunting operations were based from a boat. Most hunting involved week-long trips by a team of 5-10 hunters, with a total of 24 trips being completed over the period 2002 to 2007. Although 34 different hunters were involved, most hunting was conducted by just three of them. Initially, hunters worked independently, but after two years there was a switch to team hunting. By then, areas favoured by the remaining deer and previously used escape routes had been identified. Hunters were placed at strategic spots to ambush escaping deer that were being hunted by others in the team. Communication by hand-held radio was crucial in repositioning hunters when hunted deer changed course or avoided ambush. Several smaller islands between Anchor Island and the nearest other deer populations were checked regularly for deer that might use these as "stepping-stones" to invade Anchor Island, or to escape from it.

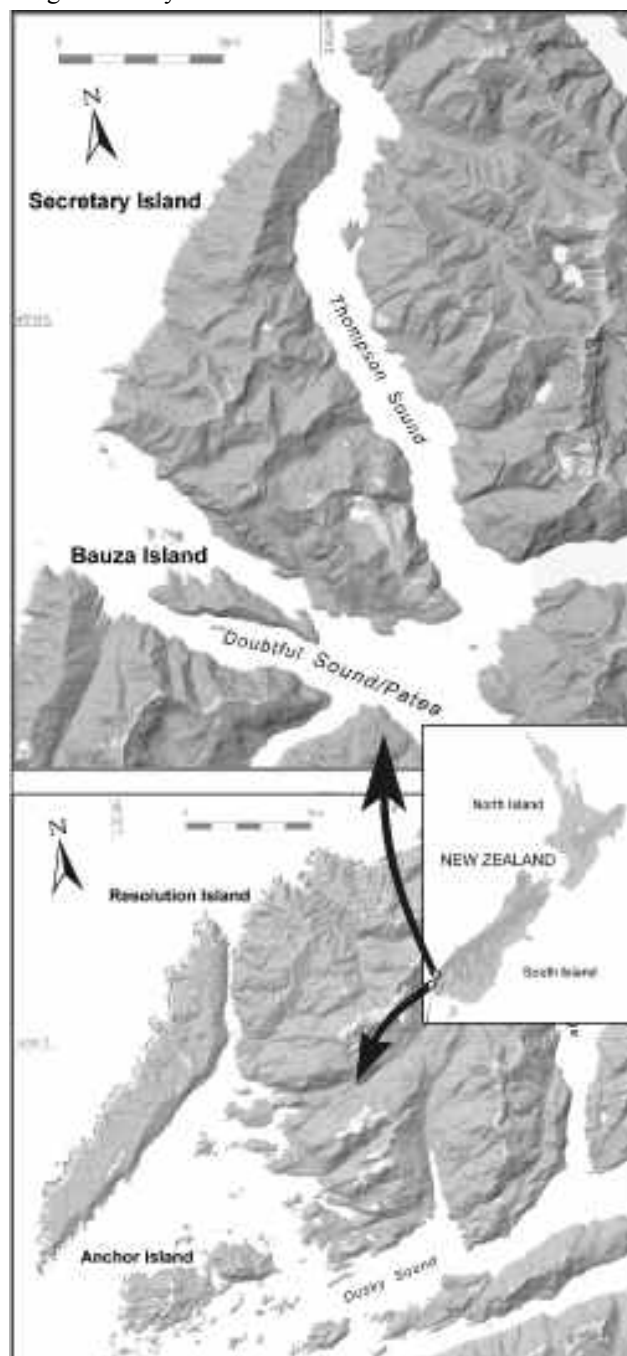
Helicopter-based hunting was used on several occasions. However, deer made little use of the larger open areas so helicopter hunting was ineffective, although the second last deer killed was shot from a helicopter in the highly favoured western coastal scrub/forest habitat.

Ten self-attaching snare collars (Taylor 1969) that incorporated a radio transmitter were set from December 2003, in an attempt to collar deer so they could be radio-tracked and shot. Deer did pass through and knocked down some radio-collar sets, and some interference by seals was also recorded. Two collars disappeared from where they were set: one was recovered c. 250 m away with the clip

not fastened, while the other was found 800 m away with the clip fastened but on the ground by an antler-thrashed tree, suggesting it had become tangled in a stag's antlers but later came free.

From 2004, barrier fences were used in an attempt to confine deer to trails (and to provide improved sites for setting self-attaching snare collars). Initially, portable electric fence tape was used as a visual guide. This changed to the use of posts and wire netting to establish permanent barrier fences on key trails, where topographical features already channelled deer movement. Gateways were also established as sites for setting self-attaching collars or placing ambush hunters. Deer were recorded using the gateways of all five barrier fences late in the programme, and a barrier fence was pivotal in the shooting of the last deer.

On a few occasions, nets were suspended across deer trails or barrier fence gateways in the hope that deer fleeing the hunting team would be caught in them, but none were caught this way.



**Fig. 1** Location of Secretary, Anchor and Resolution Islands.

In total, 29 deer were removed from Anchor Island and two neighbouring small islands between July 2002 and December 2007 (Table 1). Checks of the island in December 2008 and December 2009, where hunters (with dogs) familiar with the island checked all areas of known preferred habitat, found no deer.

**Table 1** Numbers of deer shot (by method) and effort; Anchor Island 2002-2007.

	Kills by Hunting Method			Effort (hrs)	Hours/Deer
	Individual	Team	Helicopter		
2002	8	0	0	324	41
2003	5	0	0	774	155
2004	3	2	0	824	165
2005	0	9	1	1244	124
2006-07	0	1	0	456	456
<b>Total</b>	<b>16</b>	<b>12</b>	<b>1</b>		

### Secretary Island Campaign (2006-ongoing)

In 2006, a second campaign began on Secretary Island. Mark and Baylis (1975) had confirmed the presence of a small resident population of red deer there in 1970, prompting an effort between 1970 and 1989 to remove the deer and prevent re-invasion. That effort was neither intensive nor widespread enough to eliminate the population (Brown 2005). In contrast, the new extirpation programme begun in November 2006 was better planned, with adequate resourcing of an intensive control effort that delivered comprehensive coverage of the island. A four year programme of work aimed to completely remove deer within that time, but annual reviews of progress were scheduled to allow regular reassessment of the feasibility of the goals and objectives.

As with Anchor Island, the Secretary Island campaign was conducted in conjunction with a stoat eradication campaign (see McMurtrie *et al.* 2011). The greater scale, complexity and difficulty of the Secretary Island campaign required a different mix of techniques to those used on Anchor Island.

As a first step, a hut and track network and radio repeater were established in 2005, prior to the stoat eradication programme (see McMurtrie *et al.* 2011). At the same time, an analysis of the likely issues and potential methods were presented in a scoping document (Brown 2005). Based on responses to that, an operational plan was developed in 2006 (Crouchley *et al.* 2007). Because re-invasion from the mainland was considered likely, the goal was the complete removal of the resident deer population (which we now term 'extirpation'; see Edge *et al.* 2011) followed by an ongoing monitoring and control programme to manage re-invasion. Because Secretary Island was larger than any other forested island from which deer had previously been eradicated, the programme was necessarily experimental in nature, with a key subsidiary aim being the development or refinement of methods for the proposed eradication of deer from the almost three-times larger Resolution Island.

For Secretary Island, three phases were planned, as follows:

1. A 'knock-down' phase, aimed at reducing the population by 80% within two years
2. A 'mop-up' phase, aimed at removing all surviving residents in Years 3-4
3. A 'maintenance' phase, aimed at detecting and removing new arrivals in perpetuity

The plan included reviews at the end of each phase, as there was some expectation that objectives would need to be revised or mop-up work extended beyond Year Four.

Ground and helicopter hunting were the main methods used to achieve initial 'knock down'. Additional methods such as capture pens, baits and lures, self-attaching transmitter collars and Judas animals have been introduced during the mop-up phase.

*Ground Hunting:* Priority was given to contracted ground hunters during 'knock-down' so that observations and data collected by the hunters could be used to assess progress and plan tactics. These hunters recorded the GPS locations of any deer shot or seen, and of any fresh deer sign. They used rifles and indicator dogs and worked separately from huts located near the centre of nine ground hunting 'blocks', usually for 4-5 days per block. They were rotated around the blocks to ensure that each hunter gained a good knowledge of the whole island and that each block was hunted by multiple hunters. The programme was designed to pulse hunting effort, with individual blocks being rested, to allow deer to return to preferred areas, for at least two weeks between each hunting session. Blocks on the western side of the island were known to hold the highest densities of deer so were hunted more often.

Unlike Anchor Island, team hunting was not often practical because of the more rugged terrain and larger size of the areas, but this technique may still be used during 'mop-up'.

*Helicopter Hunting:* Helicopter hunting is very effective in open unforested areas, so the alpine grasslands, scrub areas, numerous slips, open coastal fringe, and areas of open canopy forest on Secretary Island were more suited to this method than on Anchor Island.

Four different pilots and three models of helicopter were used (Hughes 500, Robinson R44 and R22) to vary the hunting style and helicopter attributes (such as noise level) that might influence effectiveness. All pilots were experienced aerial hunters. Two shooters were used with the larger machines (Hughes 500 and Robinson R44) with a shotgun being used from the front door and a high-powered rifle from the rear door. The smaller R22 helicopter, with a single shooter using high-power rifle, was utilised more during Years 3 and 4 when fewer animals were being shot. Helicopter hunting was carried out periodically throughout each year as weather conditions permitted, with at least two weeks between hunts, and a total of 9-15 hunts per year. The GPS location of each deer seen or shot was recorded, plus track logs for hunting flights.

*Barrier Fences:* While barrier fences might enhance the effectiveness of ambush team hunting, few sites suited to fencing were found, and only one fence was built (in conjunction with a capture pen).

*Capture Pens:* A total of 17 capture pens were built in the first two years, using 150 x 1900 mm wire mesh netting with wooden posts for gateways and corners, and steel standards between. Each had two drop-down gates, with a thin copper trip wire. Limited areas of flat terrain meant that the finished pens are generally small (100-200 m<sup>2</sup>). Each pen contained a water container and some natural food. Pens were remotely monitored using a VHF radio repeater to deliver a number code via e-mail. The status of the gates was monitored and there was an additional trip wire on the pen fence.

*Self-attaching Radio Collars:* A self-sizing design, different to that used on Anchor Island, using a sliding loop that moves over a series of 'barbs' (Kirchoff and White 2002) was used for seven collars set during Year 2. Several different methods of setting were used. Some deer passed through these sets but none were collared. Work is continuing on design and setting techniques.

*Judas Deer:* After 'knock-down', the use of the 'Judas' technique was explored. This method uses radio-collared animals to guide hunters and enable them to find and kill

the uncollared animals they associate with. To enhance the 'finding' power of the Judas deer, the concept of prolonging oestrus was investigated. This method has been applied to Judas goats to help eradicate goats from several Galapagos islands (Campbell *et al.* 2007). Two hinds were captured from the nearby Murchison Mountains and held in captivity for a period to be sterilised (through tubal ligation), fitted with a 400-day hormone implant, and tagged prior to release on Secretary Island in April 2009. This process was too late to be useful in the autumn 2009 rut, but should be effective during the 2010 rut. In addition, in 2009, a stag from the Murchison Mountains was fitted with a satellite linked GPS tracking collar and released on the island. The objective was to monitor his activity in relation to open habitats over the 2009/10 summer and 2010 autumn and to assist in planning the timing of helicopter hunting. Data collected on favoured sites will identify sites to check for remnant animals on the island. These data should be of particular value during the rut period when this animal will be searching for hinds.

*Other Methods:* A variety of food, scent and salt lures were trialed on wild red deer in accessible mainland forest sites. These trials did not identify any lure or bait that would attract wild deer any better than natural food baits. Deer did show interest in some of the baits and there was some indication that time of year or seasonal factors may have had some influence in bait attractiveness.

Trail monitoring cameras were trialed in conjunction with bait and lure trials. From Year Two, a small number of cameras were used on the island to help identify the presence of deer at key hunting or capture pen sites, and they provided some useful information on the presence (or absence) of deer at several sites of interest, especially during the 'mop-up' phase.

FLIR (Forward Looking Infra-Red) equipment has not been used because field inspection identified limited potential for its useful application in this project (P. McClelland pers. comm.), but may be re considered for use later in the programme.

*Monitoring:* An attempt was made to estimate the pre-campaign population size, using a DNA-genotyping mark-recapture approach in which fawns are effectively used as recaptures of their parents (Crouchley *et al.* 2007). The technique had been developed and successfully pilot tested on red deer in the Murchison Mountains in eastern Fiordland (Nugent *et al.* 2005). Hair samples were collected from all ground-shot animals, and in Year 1 useful genotypes were successfully obtained for each of 72 adult female and 13 fawns. However there was very little variation within the standard panel of 14 genetic markers used. As a result there were a number of instances in which the set of alleles for a fawn matched those from two of more adult females (i.e. some fawns could have been assigned to more than one potential mother). That rendered the approach invalid. The solution of analysing a much larger set of markers was not explored because of cost. However, an important upside is that the data show only a low level of genetic diversity on Secretary Island population, with many of the rarer alleles found in mainland deer not detected. A key implication is that the founding stock for the population must have been small, indicating that the reinvasion (immigration) rate is likely to be low.

*Overall results:* In the 'knock-down' phase, 67 hours of helicopter hunting and 664 days of ground hunting resulted in 542 deer kills. In the first year, almost two thirds were helicopter kills, but since then the balance has slightly favoured ground hunting (Fig. 2). However, the cost per deer kill has been substantially lower for helicopter hunting, and in the second year (for example) was only one third of that for ground hunting.

Kills per unit hunting effort have generally declined over the campaign, but changes in hunter skill, experience and hunting method (and also in the wariness of the remaining deer) mean that the data do not provide a robust estimate of changing deer abundance. However, the lower kills rates and a subjective assessment of the abundance of deer sign indicated a major reduction in deer density. By the end of the 'knock-down' phase the ground hunters were finding little or no sign of deer in previously favoured locations. It was estimated that less than 100 deer remained. A similarly subjective estimate of 20 deer on Anchor Island was approximately correct, when the total killed (29) is adjusted down for deer born during the campaign.

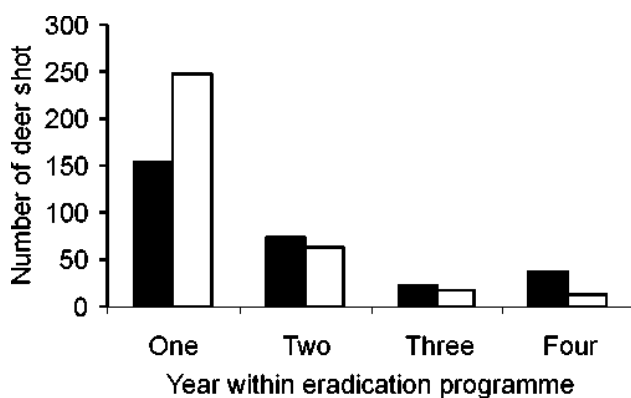
Of the 542 deer shot during 'knock-down', only 461 were present at the start of the campaign, the remainder having been born since 2006. If the estimate of 100 deer remaining at the end of that phase (including some born after campaign start) is accepted, the maximum size of the initial population was ~560, suggesting that the desired 80% reduction had been achieved.

The two year 'mop-up' phase was completed on 30 June 2010. A total of 91 deer were killed (57 helicopter, 32 ground hunting, and two captured in pens). Complete removal of the red deer population was not achieved by this date but field observations, records of deer sign suggested that fewer than 25 animals were likely to remain.

## DISCUSSION

Success on Anchor Island, coupled with success in managing other pests on other smaller islands where there is potential for pest animals to re-invade and the increased experience with managing successful deer control programmes at mainland sites, provided managers with the confidence to plan increasingly larger pest eradications and to cost those realistically.

The Anchor Island campaign demonstrated how continued refinement of methods and targeting effort based on experience could greatly increase efficiency, to the extent that the hunting effort per deer kill was lower in Year Four (when tactics changed to team hunting and the hunting effort targeted individual animals) than in Years Two and Three. Likewise, the use of hunting success rate data to target ground hunter effort at areas with highest kills rates (and presumably therefore the most deer) enabled hunters to maintain the same annual kill rates despite reducing deer numbers (Fraser and Nugent 2003). This approach of targeting effort and continuously modifying tactics is likely to be crucial in removing all deer from Secretary Island. In addition, the use of technological developments such as trail monitoring cameras, DNA monitoring, FLIR, and tracking collars will help to improve our knowledge of



**Fig. 2** Number of deer shot during the knock-down (years 1 – 2) and mop-up phases (years 3 – 4) of the Secretary Island deer eradication campaign (Filled bars = helicopter kills, open bars = ground hunter kills).

animal behaviour and how to target the last few deer. Thus, while deer have so far been extirpated only from Anchor Island, the success and progress as planned on Secretary Island, provides some confidence that all programmes will ultimately be successful.

Given that all three islands are within swimming distance of mainland deer populations, the ability to detect and deal with any immigrants is essential. It will be possible to use the results of the current extirpation campaigns to interpret future surveillance surveys that find no deer (e.g., Ramsey *et al.* 2009), but the question of how often such surveys should be conducted once the resident deer are removed remains unknown and depends in part on the frequency of invasion events. While the low genetic diversity of deer on Secretary Island precluded the planned use of genetic mark-recapture methods for density estimation, it indicated that few deer ever invaded this island. As these few invasions are most likely to have occurred in the 1960s when deer numbers on the mainland were much higher, it now appears that the likelihood of deer re-establishing on Secretary Island is very low. DNA genotyping is likely to be useful in identifying where any deer killed after the 'mop-up' phase is a survivor or a new invader.

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