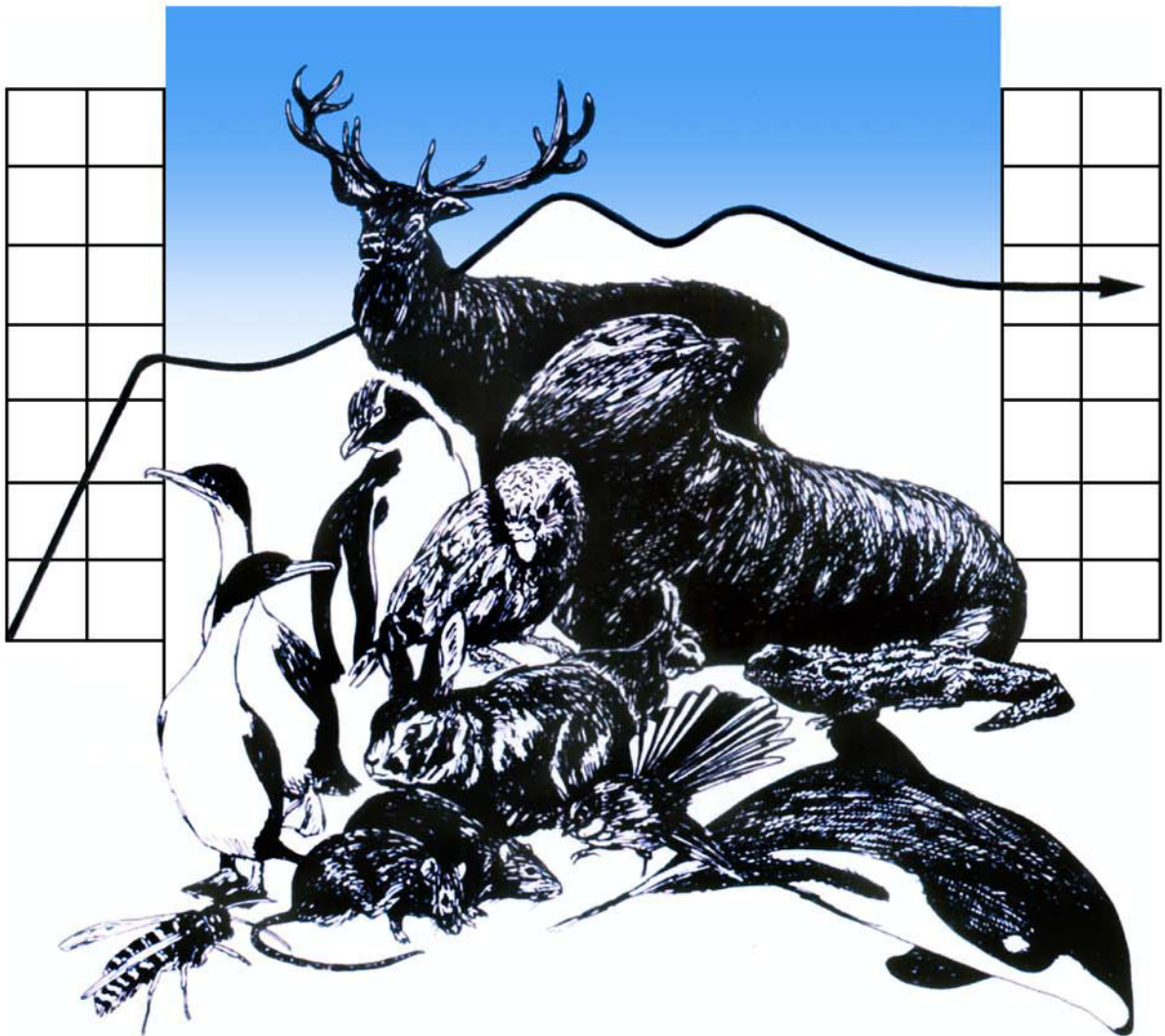




DEPARTMENT OF ZOOLOGY



WILDLIFE MANAGEMENT

Estimating red deer abundance using Fecal Pellet Indices and implications for management

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A report submitted in partial fulfilment of the
Post-graduate Diploma in Wildlife Management

University of Otago

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Abstract

Fecal pellet data was gathered on the red deer population at Mill Creek, a 683ha area of native New Zealand beech forest. Fecal pellet data was converted into 95% confidence intervals of deer density for three indices using estimates of the relationship between fecal pellet counts and deer density. The estimated 95% CI for the red deer population size from total pellet count (179-598) and pellet group count (104-400) appeared overly high, whereas the estimate from pellet frequency (27-85) appears to be more realistic. This indicates the use of estimates of the relationship between fecal pellets and absolute deer abundance from areas other than the study area is unreliable. More reliable methods of estimating deer abundance need to be found to effectively manage deer populations in New Zealand.

Key Words: Deer; Fecal Pellet Index; Pellet count; Relative density; Wildlife management

Introduction

New Zealand's forests evolved in the absence of the mammalian herbivores (Husheer et al. 2003) which now occur across the majority of the mainland (Wardle et al. 2001). Deer were introduced to New Zealand in the nineteenth century and numbers rapidly increased, largely due to the quality of forage (Veblen & Stewart 1982). Populations of deer in New Zealand regularly reach high densities in many areas; the absence of predators commonly allowing higher survival of introduced animals (Forsyth & Duncan 2001). Red deer (*Cervus elaphus*) are particularly competitive, and are the most widespread species of deer in New Zealand (Nugent et al. 1997). After significant reductions from the implementation of government-funded culling operations red deer numbers again increased (Nugent et al. 1997), resulting in high densities in many forests of New Zealand (Nugent et al. 2001). Foraging from deer and other ungulates cause a dramatic reduction in the understory abundance and composition of palatable plant species (Coomes et al. 2003, Husheer et al. 2003). Red deer forage on particular plant species (Nugent, et al. 1997, Coomes et al. 2003) which commonly results in shifting of species composition (Husheer et al. 2003, Forsyth 2005). The degradation of forest habitat quality frequently has indirect impacts on many native animal species (e.g. Towns et al. 2002) as well as influencing the survival of deer (Coulson et al. 1997). Therefore, it is important for managers of areas of native forest (e.g. Department of Conservation) to maintain deer numbers at relatively low densities where possible. Because of limited economic resources (Joseph et al. 2009), deer will only be controlled when at levels where damage to vegetation is unacceptable; this level differs at various areas across New Zealand. For this reason, a method is required for determining animal densities at

selected locations. Estimating population size and relative density is important when attempting to monitor or control a population (Smart et al. 2004). Detailed research into population biology may aid in enhancing effectiveness of controlling widespread invasions, and can lead to the creation of new control methods (Simberloff 2003). The ability to accurately estimate population size/density from fecal pellet counts of ungulates in New Zealand would likely prove invaluable. Fecal pellet counts have been commonly used in New Zealand (Batcheler 1975, Forsyth et al. 2007) and other countries (Smith 1964) for determining the abundance or relative abundance (density/relative density) of deer in a given area. However, there are difficulties in attaining reliable estimates from fecal pellet counts. Habitats with different biotic and abiotic factors cause variations in pellet detectability. This may be caused by varying rates of pellet deposition with changing forage quality and quantity, and/or varying pellet decomposition rates due to dissimilar rainfall between areas (Nugent et al. 1997, Harestad & Bunnell 1987). Fecal pellet indices are commonly used to estimate relative density (the current density estimate in relation to previous density estimate). This estimation is relatively uncomplicated providing the relationship between pellet counts and density is linear. The methods which are most often used for finding relative abundance are fecal accumulation rate (FAR) and fecal standing crop (FSC) (Campbell et al. 2004), the latter being preferred due to increased accuracy (Smart et al. 2004). Three indices (or variants of FSC index) which have been used to attain relative abundance are total pellet count, pellet group count and pellet frequency (Forsyth et al. 2007). However, having an accurate estimate of density of animals in an area is superior to knowing relative density. Forsyth et al. (2007) used these three FSC indices to estimate the relationship between fecal pellets and deer density, with

a sample of 20 enclosures in New Zealand.

Study Area

The Mill Creek area, west of the city of Dunedin, is home to a population of red deer. There have been no documented studies on deer density in this 682.3 ha area of native forest. To gain an understanding of the deer population in this area a fecal pellet count was conducted through the Department of Conservation (Otago conservancy), using the methodology of Forsyth (2005). These methods were designed to give an estimate of relative density after two surveys had been completed. This report discusses the first survey undertaken at Mill Creek and its findings. To gain an estimate of deer density in this area, the relationship (95% confidence interval) between pellets and deer density from Forsyth et al. (2007) was extrapolated across the data from this study.

Methods

Deer pellet counts were undertaken at Mill Creek, an area of native forest west of the city of Dunedin (Fig. 1). Mill Creek is surrounded largely by open tussock grassland and has a relatively low deer density (L. Genever 2009, pers. comm., 9 June). The methodology in Protocol for estimating changes in the relative abundance of deer in New Zealand forests using the Faecal Pellet Index (FPI; Forsyth 2005), prepared for Department of Conservation (DoC) by Landcare Research, was used to count deer fecal pellets. This entailed counting deer fecal pellets within plots along randomly selected transects. The study area was defined using a topographical map of Mill Creek, and the survey restricted to forest habitat. The start point for each transect was randomly found by using random numbers and turning them into coordinates (a Global Positioning System is essential for accurately finding these points). A random bearing ($1-360^{\circ}$) was found for the starting point of each transect, which would travel 150m in this direction. If the transect struck a boundary (e.g. cliff or forest edge), the bearing was changed by 90° to avoid the obstacle. If a coordinate fell outside the forest area (e.g. in scrub), it was excluded and another coordinate found.

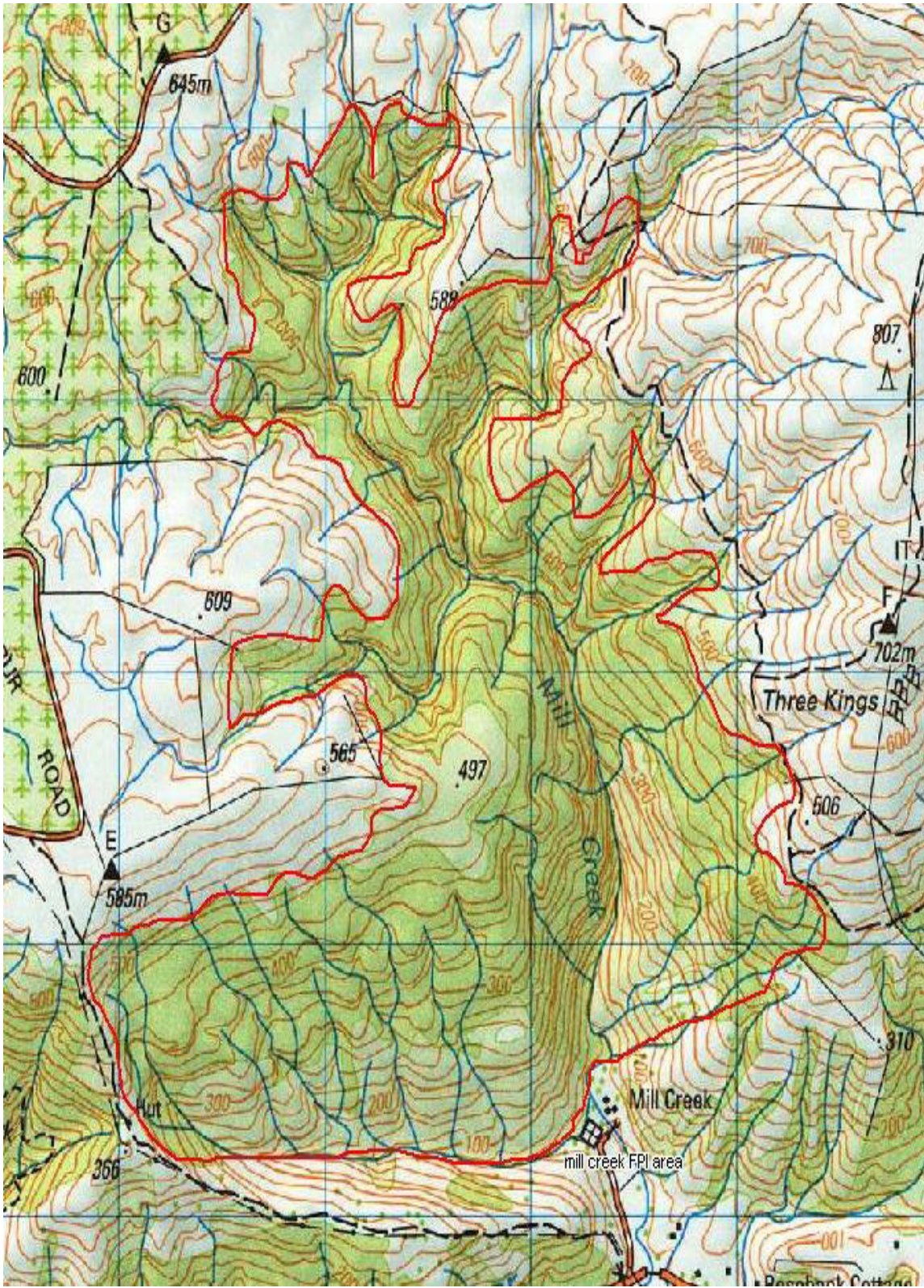


Figure 1. Map of Mill Creek. The survey site is within red line and has an area of 682.3 ha.

A total of 30, 150m transects were used, with plots every 5m. The first plot began at 5m, resulting in 30 plots per transect. All pellets within a 3.14m² circular plot (1m radius) were counted. This was achieved with a 5m non-stretch rope with a peg at each end. A knot 1m from each peg gave the radius for each plot. One peg was placed in the ground and the other peg was taken on the required bearing until the rope was taut. After the first peg was removed from the ground the 1m knot was used to determine the outer limits of the plot area, moving vegetation (e.g. ferns fronds) but not disturbing leaf litter. Pellets were counted when they were judged to be intact, that is, having no loss of material (following Baddeley 1985; see Appendix 1 of Protocol). Those searching for pellets were instructed on which pellets to count before commencing research. Pellet number was recorded when voided in the same defecation. If multiple groups were found within the same plot, they were recorded as separate counts. Deer pellets can be distinguished from pigs, possums and lagomorphs, but not goats. Surveys were only conducted in good visibility. The information recorded includes: Name of study area; Date; Observer name; Plot and transect number; Number of intact pellets in each pellet group. Data was later entered into an excel spreadsheet for analysis.

As this was the first study using these methods in this area, predictions resulting from this survey are limited. A study by Forsyth et al. (2007) was used to determine estimates, based on 95% confidence intervals of the relationship between fecal pellet counts and known deer densities. Although total pellet, pellet group and pellet frequency are variants of the same index they will be referred to as three separate indices for simplicity.

The average total pellets, pellet group and pellet frequency were found by averaging the results of all transects. The 95% CI from Forsyth et al. (2007) were used to find 95% CI

estimates for total pellet, pellet group and pellet frequency for Mill Creek (Table 1). The estimates for each of the three indices were used without added Mill Creek error rates, which would further confound the error and further increase the size of the confidence interval.

Microsoft Excel was used to model 95% CI from Forsyth et al. (2007) against Mill Creek means for each index (Fig. 2, 3, 4).

Results

There was much variation between the 95% confidence intervals for total pellet, pellet group and pellet frequency (Table 1). Estimates were expected to be similar in all three indices if each index gave accurate results.

The difference between pellet groups and pellet frequency was greatest for Mill Creek (Table 2), whereas there was usually little difference in the enclosures from Forsyth et al. (2007).

Pellet frequency shows the lowest 95% confidence interval for deer density (Fig. 2), whereas the 95% confidence intervals for total pellet and pellet group are relatively high (Fig. 3; Fig. 4).

Table 1. The average total pellet, pellet group and pellet frequency for Mill Creek, and the 95% CI for deer density and total deer using estimates from Forsyth et al. (2007).

	Average	Deer/ha for Mill Creek		Deer estimate for Mill Creek	
		Lower 95% CI	Upper 95% CI	Lower 95% CI	Upper 95% CI
Total Pellet	59.567	0.262	0.876	179.277	598.470
Pellet group	2.167	0.152	0.586	103.517	400.078
Pellet frequency	0.072	0.039	0.124	26.955	85.047

Table 2. Comparison of total pellets, pellet groups and pellet frequency of three South Island and three North Island enclosures (Forsyth et al. 2007) and Mill Creek.

Enclosure	Island	Area (ha)	N		Total pellets		Pellet groups		Pellet frequency	
			x	SD	x	SD	x	SD	x	SD
3	South	2,491.50	410	21.9	50.9	84.7	2.1	3.8	1.8	2.8
8	South	511.7	995	6.4	198.7	141.9	12	6.9	9.5	5.1
10	South	815.7	434	4.3	188.3	179.6	9.8	7.5	8.1	5.7
13	North	273.9	100	20	76.7	135	3.1	3.9	2.6	2.4
17	North	975.8	125	33.4	77.9	97.8	3.1	3.1	2.9	2.8
19	North	607.1	300	86.6	144.3	143.8	7	6	5.6	4.4
Mill Creek	South	683.2	-	-	59.567	69.15	2.167	1.6	0.072	0.05

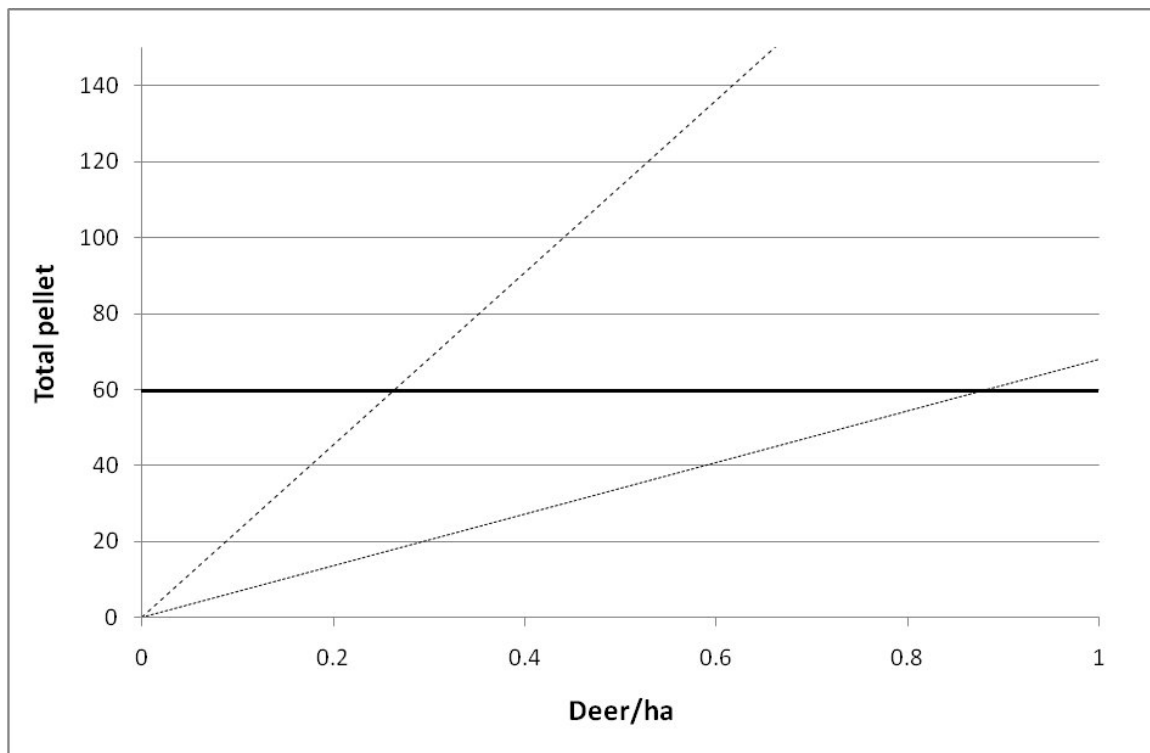


Figure 2. Line graph indicating 95% Confidence Interval for deer density using total pellet index. Upper (dashed line) and lower (dotted line) 95% confidence intervals of deer density (deer/ha) from Forsyth et al. (2007) and total pellet estimate for Mill creek (solid line). The values along total pellet estimate between 95% CI indicates 95% CI estimate for Mill Creek using this index.

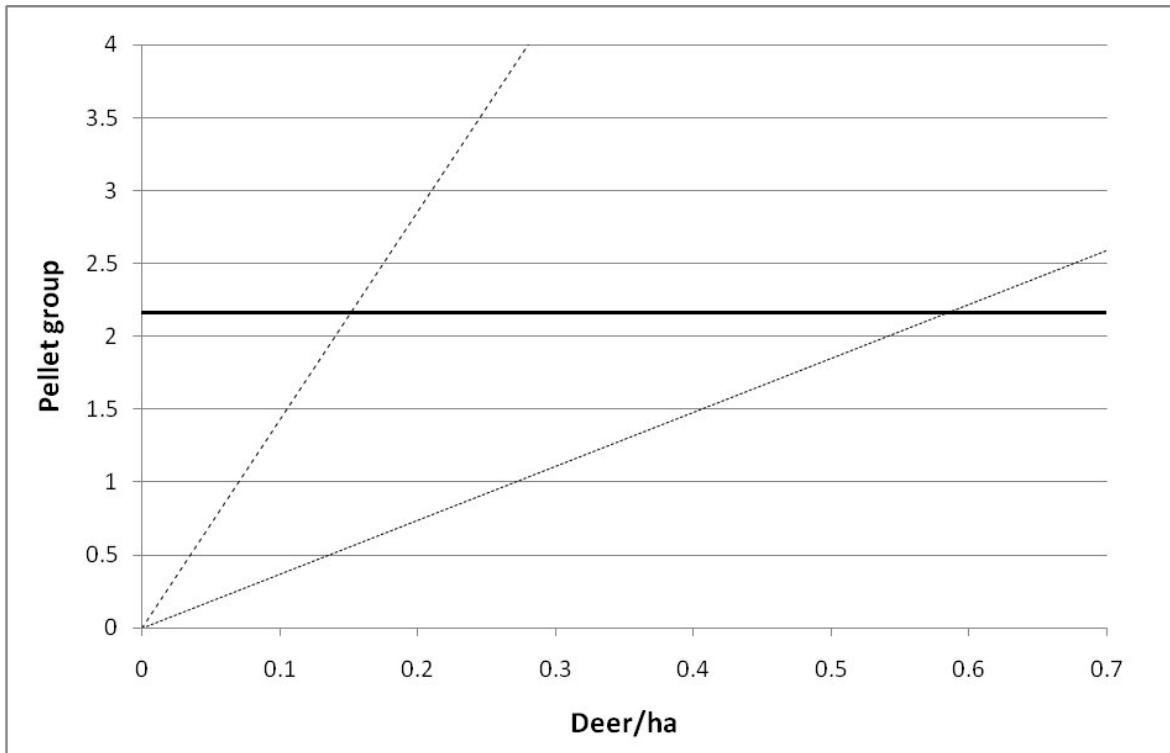


Figure 3. Line graph indicating 95% Confidence Interval for deer density using pellet group index. Upper (dashed line) and lower (dotted line) 95% confidence intervals of deer density (deer/ha) from Forsyth et al. (2007) and pellet group estimate for Mill creek (solid line). The values along pellet group estimate between 95% CI indicates 95% CI estimate for Mill Creek using this index.

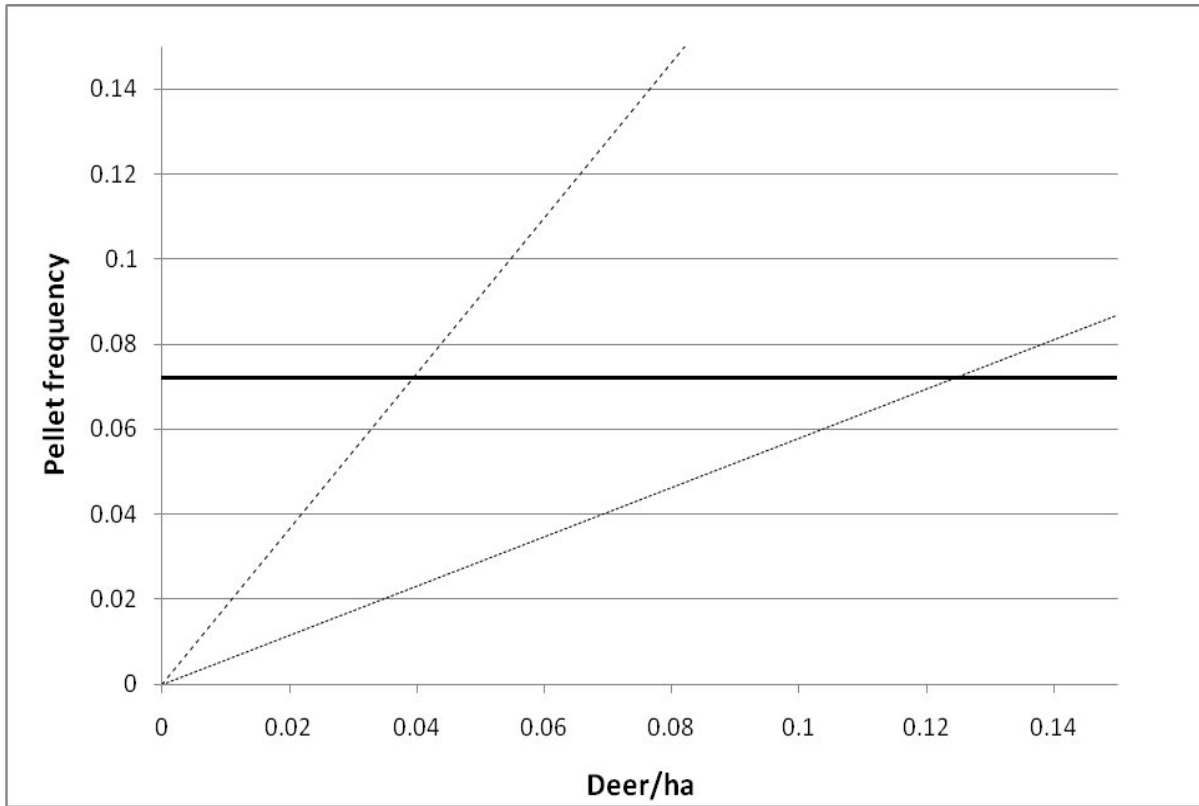


Figure 4. Line graph indicating 95% Confidence Interval for deer density using pellet frequency index. Upper (dashed line) and lower (dotted line) 95% confidence intervals of deer density (deer/ha) from Forsyth et al. (2007) and pellet frequency estimate for Mill creek (solid line). The values along pellet frequency estimate between 95% CI indicates 95% CI estimate for Mill Creek using this index.

Discussion

For the 682.3 ha area of forest at Mill Creek, a density which gives a population exceeding 100 appears to be unrealistic (L. Genever 2009, pers. comm., 9 June). The estimated 95% CI for pellet frequency gave a density and population size closer to the expected estimate than total pellet or pellet group indices (Table 1). However, there was much variation in the results from different enclosures from Forsyth et al. (2007; Table 2) which would inevitably lead to inaccuracies in the 95% CI in that study. The relative difference between pellet group and pellet frequency was greatest for Mill Creek (Table 2). The values for these two indices were usually close for the data in Forsyth et al. (2007). The methodology in the FPI protocol by Forsyth (2005) was used in Forsyth et al. (2007), the latter advising against extrapolating the pellet count-density relationship across new data, because of the variation in pellet detectability in different areas. However, to attain an estimate of density, this study appeared to have a more reliable estimate of the relationship between pellet count and deer density than other studies. Previous studies which have attempted to model the relationship between pellet counts and deer density have had problems with the methodology employed (Forsyth et al. 2007). This included particularly small sample sizes (Eberhardt and Van Etten 1956, Ryel 1971) and not accounting for error in deer estimates, even when attaining an estimate from aerial surveys (Fuller 1991). Forsyth et al. (2007) had a large sample size ($n=20$) and known deer population sizes within enclosures (not exact numbers), and allowed for the small error involved. Using fenced enclosures could influence estimates on deer density-pellet count relationship. There is variation in the spatiotemporal distribution of red deer at different times of day, season and year (Godvik et al. 2009). Red deer will

often use pasture habitat in hours of darkness where forage quality may exceed that of forests (Godvik et al. 2009). For this reason, red deer may behave abnormally in an enclosure (depending on enclosure size and available forage), potentially spending more time moving along fenced edges. There is also migration of individuals between habitats and between red deer populations where fences are not present (Clutton-Brock et al. 1985, Schmidt 1993). Red deer are also less territorial than some other deer species, and will travel further and avoid areas where fallow deer (*Dama dama*) are at high densities (Carranza & Valencia 1999), probably to prevent competition. Fallow deer were present in one sample area from the Forsyth et al. (2007) study. Although these factors may contribute to slight inaccuracies in the data, fenced areas with known deer numbers appears to be the most reliable method available for this type of study.

Forsyth et al. (2007) recognises the risks involved with using the relationship between fecal pellet count and deer density to estimate deer density in areas other than where the relationship was found. This is largely due to differences in the deposition and decomposition of pellets, which ultimately influences pellet counts (Cochran & Stains 1961). Variation in quality and quantity of forage between habitats commonly affects the rate of pellet deposition (Rogers et al. 1958), whereas decay rates of pellets appear to vary in response to changes in rainfall (Nugent et al. 1997). In Columbian black-tailed deer (*Odocoileus hemionus columbianus*) pellet persistence was lowest in moist, vegetated forest and highest in dry, bare areas (Harestad & Bunnell 1987). Only 5-25% of pellet groups were visible after two years in moist areas, whereas 25-75% remained visible in dry areas (Harestad & Bunnell 1987). Because of variations in forage abundance, combined with varying levels of precipitation, pellet count studies should be

undertaken in the same area and at the same time of year (Nugent et al. 1997) to gain more reliable relative density estimates. To gain an accurate estimate of absolute density for an area, estimates of variables (such as pellet deposition rates) must be attained at the study location (Forsyth 2005). Estimations of these variables for each site are particularly difficult and expensive to attain (Forsyth 2005), where funding could instead be put towards controlling deer.

No less than two years should take place between studies on relative deer density from pellet counts because of the ineffectiveness of this methodology to detect small changes in density (Smart et al. 2004). Deer pellet counts have been shown to be incapable of reliably detecting a change in population size under approximately 30% (Smart et al. 2004). Because of the relatively low reproductive rate of deer (Clutton-Brock et al. 1982), it is unlikely that a population would increase by this much in one year.

Differences in terrain between two study areas have the potential to limit the accuracy of using the relationship between pellet count and density to estimate deer density. Deposition and decomposition of pellets could be virtually identical in two areas, yet accuracy could be decreased due to one study site being steep and another relatively flat. The Mill Creek area is relatively steep, and in some areas a 90° change in direction was needed to avoid this terrain or other obstacles. At times, this would cause a route to be taken which ran roughly parallel to the obstacle. Deer will also avoid difficult terrain and therefore some data may be biased towards higher pellet counts. This bias would also apply to 90° changes of direction at the boundary of the study area. The boundary for this study was also a boundary between forest and scrub/tussock grassland. Deer often walk along forest edges because of sufficient concealment and abundant forage from tussock

habitat nearby (Mills & Mark 1977). Caution is therefore advised when changing transect direction, especially when in steep terrain or where boundary edges are boundaries between different habitats. Conversely, it is possible that some areas would have terrain accessible for the study, yet steep enough to be generally avoided by deer. This could result in lower than normal estimates for pellet frequency and may be, at least partially, the reason for the trend observed in this study (Table 1). Recent research (e.g. Godvik et al. 2009) has been focused on spatiotemporal habitat use in deer. Research into habitat use in steep terrain would undoubtedly be advantageous in determining estimates of density in red deer. This would aid in understanding where deer are likely to avoid and may increase reliability of pellet estimates, particularly in pellet frequency. Saturation can also affect the reliability of pellet frequency results (Forsyth et al. 2007). This is unlikely to be a concern in the Mill Creek area because of the relatively low density of deer present. However, in areas with higher deer densities pellet frequency may be less reliable, and so should not be used.

Deer management

There are several reasons for concern over high deer densities. Deer are commonly controlled to reduce the effects of browsing on native vegetation. Browsing directly affects native plant species (Nugent et al. 1997) as well as causing indirect impacts on many species of indigenous birds (Martin & Possingham 2005). Shifts in the composition of New Zealand native forests have been shown in numerous studies (Husheer et al. 2003, Nugent et al. 1997, Forsyth et al. 2005). Palatable species are heavily selected by deer (Coomes et al. 2003) to the point at which these species fail to recruit to saplings

(Husheer et al. 2003, Husheer 2007). Husheer (2007) found that regeneration in six hardwood species was suppressed predominantly by red deer browsing. These six species, which included *Coprosma grandifolia*, *Elaeocarpus dentatus*, and *Griselinia littoralis*, were only common as saplings in the absence of ungulate browsing (Husheer 2007). This over-browsing ultimately prevents regeneration of preferred species (Nugent et al. 2007) and shifts forest structure, potentially leading to the local extinction of seed sources (Coomes et al. 2003). This often generates long-term effects, even after deer densities have been reduced or populations removed. Red deer can also greatly reduce abundance of vegetation, especially when combined with browsing from possums (Nugent et al. 1997). This commonly leads to a decrease in available forage for other species through decreased forage abundance or the complete elimination of certain plant species (Husheer 2007). There is a decrease in many bird species with an increase in grazing pressure (Martin & Possingham 2005). A reduction in invertebrate abundance is also a common concurrence with increased foraging (Wardle et al. 2001). Grazing decreases both available invertebrate and plant forage and nesting sites for native bird species. With the ubiquitous pressure of introduced mammalian predators, the availability of sufficient forage quality and quantity could be the difference between a population recovering or declining. Impacts of deer browsing on vegetation can be difficult to determine due to the uncertainty of cause (e.g. other herbivores and/or other environmental variation). A method of accurately measuring deer density would enable deer control in areas with threatened native species to increase the chances of survival for those populations.

A considerable sum of New Zealand's economy comes from the export of beef and

venison (Fletcher 2001, Bisset 1994). Domestic cattle and deer are threatened by bovine tuberculosis (TB) which can spread through a herd once present (Menzies & Neill 2000). Although brushtail possums are known more widely as carriers of TB (Sauter & Morris 1995a), deer also carry it and can infect cattle (Schmitt et al. 1997, Lugton et al. 1998). It has been found that deer will more commonly carry TB when possums in the area are also infected; and presumably contract TB from possums (Lugton et al. 1998). Deer are widespread in New Zealand and it is not unlikely for wild deer to come into contact with domestic deer and cattle. More dominant and investigative deer also have a higher probability of becoming infected with tuberculosis (Sauter & Morris 1995b) and are likely to be those which come into close proximity with domestic animals. Higher densities of deer increase the probability that certain individuals will venture further to decrease competition for resources. For this reason it is paramount to control deer numbers to acceptable levels, especially in areas where they may come into contact with domestic animals. A method for accurately and economically measuring deer density would enable limits to be set across certain areas (e.g. national parks within 20km of farmland). With this in place, control operations could occur when densities are exceeded.

Estimating deer density for the management of healthy populations of deer may become more useful in the near future. The realisation of the importance of hunting tourism in New Zealand, and the economic gain that comes with it (Lovelock 2007), elucidates the importance of healthy ungulate populations in some areas. Many countries actively manage wild deer populations (Clutton-Brock et al. 2002), largely for the economic gain obtained through hunting tourism or for protecting native species. This is a recent

development in New Zealand, where the population of wapiti in Fiordland is currently being managed (www.fwf.net.nz) to maintain a healthy wapiti herd for hunting purposes. Many trophy hunters hunt for large antlered wapiti bulls in Fiordland, and as it is the only free-range wapiti herd outside America (www.fwf.net.nz), deer numbers should be kept below a certain threshold to ensure trophy potential. Pellet counts may aid in understanding population dynamics in areas where management of ungulate populations is needed. High calf/fawn mortality can result at high local densities (Coulson et al. 1997), and consequently, knowledge that an area is becoming overpopulated may explain why calf/fawn mortality is high in a certain year. Overpopulation is also a cause for decreased condition in deer (Sams et al. 1998) and can cause significant decreases in antler size through reduced forage (French et al. 1956). It is probable that managing healthy herds of wild ungulates will become more common across New Zealand in the future.

Conclusion

The estimates of deer density and population size for Mill Creek were in no way conclusive. The 95% confidence intervals from Forsyth et al. (2007) when extrapolated across Mill Creek data gave estimates that are higher than the expected number of deer present (L. Genever 2009, pers. comm., 9 June). The pellet frequency estimate likely gave the most realistic estimate, yet this index has previously been declared to give the least reliable results (Forsyth et al. 2007). The methodology in this study should be repeated at Mill Creek at the same time of year. No less than two years should pass between surveys to allow the population size to change by a detectable amount. This will give an indication of density relative to the density at the time this research was

undertaken. There is concern over using pellet counts as a method to estimate absolute size of deer populations (Fuller 1992). If doubt exists about any variables involved the methodology should not be used. The use of a 90° change in direction (Forsyth 2005) should also be employed with caution, due to the inconsistencies which can arise with this method.

It appears deer have greater effects on vegetation than previously thought and, therefore, priorities of DoC should be reassessed with greater consideration of ungulate impacts (Nugent et al. 1997). More recent studies show that deer clearly suppress the growth of many plant species and increased ungulate control is justified to allow the regeneration of native forest in many areas (Husheer et al. 2003, Husheer 2007). A method of reliably gaining estimates of deer density from pellet counts would greatly enhance the ability to control deer below certain thresholds. This would be beneficial for reducing the damage to native forests, minimising the risk of spreading bovine tuberculosis and managing healthy populations for recreational purposes.

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