Deer impacts in alpine grasslands of Fiordland National Park: A report on the measurement of alpine browse transects between 2006 and 2009.

Department of Conservation
Te Papa Atawhai

New Zealand Government

Deer impacts in alpine grasslands of Fiordland National Park: A report on the measurement of alpine browse transects between 2006 and 2009.

Cover: *Celmisia verbascifolia* browsed at Oho Saddle, Fiordland National Park, 2006.

Photo: Richard Ewans, Department of Conservation.

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Contents

Summary

This report describes the results of the first full re-measurement of a monitoring programme established in 2006 to quantify the impacts of deer in the alpine grasslands and herbfields of Fiordland National Park. The re-measurement took place in January and February in 2008 and 2009. The methodology used counted browsed and un-browsed plants of selected palatable alpine herbs (*Celmisia verbascifolia*, *C. holosericea*, *Dolichoglottis scorzoneroides*, and *Ranunculus lyallii*) on a group of transects at a number of sites. Forty-four of the original 52 sites were re-measured.

The overall pattern observed was of a strong reduction in browse levels, particularly in those areas and on those species where browse levels were relatively high to start with. The overall abundance of deer sign (measured by pellet group counts) halved during the same period. Browse levels and deer sign in the Murchison Mountains sites remained negligible, as would be expected in an area that has had long term deer control.

The re-measurement of the baseline monitoring recorded strong overall decreases in browse levels on the selected palatable alpine herbs measured since the resumption of widespread aerial venison recovery in Fiordland in 2006. Approximately 15,000 deer have been removed from Fiordland by non-recreational hunting (mostly via aerial venison recovery operations) between 2006 and 2009. Further improvement in the health of the alpine grassland ecosystem would be expected if aerial venison recovery continues at the current levels.

1. Introduction

Prior to 2007 the deer population in Fiordland National Park was increasing steadily since the cessation of widespread aerial venison recovery in 2001 - the main means by which deer have been controlled in Fiordland over the past forty years.

In response to concerns about increasing deer numbers in Fiordland, a new method of rapidly assessing the impacts of deer browse on palatable alpine herbs was developed and trialled during 2004 and 2005. Baseline monitoring using this method was established in 52 areas (sites) in 13 sub-regions of Fiordland in 2006 (Ewans & Lake, 2006). This provided an assessment of alpine vegetation condition in 2006 and a baseline against which future vegetation changes could be measured.

The method was based on the plot sampling methodology used by Lee (1990) as part of permanent transect monitoring of deer use of fertile alpine grasslands in three areas of Fiordland. Vegetation changes in the alpine zone are relatively slow but the presence of browsed leaves indicates recent deer use, probably within the two previous growing seasons, and provides an indication of current deer pressure on the habitat (Lee et al., 2003).

Since the baseline monitoring in 2006, widespread aerial venison recovery has resumed in Fiordland with approximately 15,000 deer harvested between July 2006 and June 2009. In order to assess the outcome of the upturn in deer control provided by the resumption of venison recovery on alpine vegetation, the original baseline sites were re-measured over January and February in 2008 and 2009.

The re-measurement of the alpine browse transects provided an opportunity to assess how quickly browse pressure was changing with decreasing deer numbers and is consistent with Munn (2006), who recommended the alpine browse transect method as the major outcome monitoring method for deer control in Fiordland.

This report summarises the results of the re-measurement of the alpine browse transects at all the original sites chosen as long term sites after 2006 (44 of the original 52 established) across Fiordland.

2. Objective

To assess deer browse pressure on selected palatable indicator species in different areas of Fiordland between 2006 and 2009.

3. Study Area

In the original baseline survey, thirteen sub-regions throughout Fiordland National Park (1.2 million ha.) were selected for monitoring to represent a range of geographical locations throughout Fiordland with a range of deer numbers. Four sites were monitored within each sub-region. Sites from the head of the Harrison River in the north, to the Long Burn in the south, and a range of locations from the western fiords to the eastern side of the park were monitored in the original survey (Ewans & Lake, 2006).

The re-measurement took in 11 of the original 13 sub-regions (44 sites). The Arthur and Princess sub-regions were not considered for re-measurement, as the cost was not considered prudent in terms of the extra information that would have been gained from re-measuring these sites. These sub-regions were less of a priority either because deer impacts were very low to start with (Arthur), or the sites generally lacked good numbers of quality indicator species (Princess).

Alpine grasslands in Fiordland are generally dominated by five species of snow tussock: *Chionochloa crassiuscula*, *C. pallens*, *C. flavescens*, *C. acicularis* and *C. oreophila*. Large herbs, along with snow tussocks, are major components of deer diet in alpine grasslands (Lavers et al., 1983). In particular in Fiordland, deer show a strong preference for grasslands characterised by *Chionochloa pallens* and large-leaved herbs (Rose & Platt, 1987).

Red deer (*Cervus elaphus scoticus*) and wapiti (*C. e. nelsoni*) were introduced to Fiordland in the early 1900's and by the 1960's high numbers of deer had strongly modified the composition and structure of alpine grassland habitat (e.g. Rose & Platt, 1987). Herbaceous species above timberline which appear to be particularly palatable to deer include; *Anisotome haastii*, *Celmisia verbascifolia*, *C. holosericea*, *Dolichoglottis scorzoneroides*, *D. lyallii*, *Ranunculus lyallii*, *Ourisia macrophylla*, *O. macrocarpa* and *Gentiana* spp. (Rose & Platt, 1987; Mark, 1989; Lee, 1990; Lee et al., 2003).

Deer numbers in Fiordland peaked in the mid-twentieth century and began declining quickly with the introduction of widespread aerial venison recovery in the late 1960's and early 1970's. Between 1969 and 1984, deer density was reduced to near zero above timberline in northern Fiordland, with an overall decline in density of 81% in this area (Nugent et al., 1987). Overall it is estimated that deer populations were reduced by around 90% from peak numbers and had been held at reduced levels for three decades, until the 2001 downturn of the export feral venison industry. This allowed for at least partial recovery of the vegetation in many alpine areas (Rose & Platt, 1987).

Between 2001 and 2006/7, when widespread aerial recovery had ceased in Fiordland, it is estimated that the deer population in remote areas such as Fiordland was potentially recruiting at a rate between 0.25-0.3 per year, which would result in a doubling of the population every three to four years. If sustained, the recent resumption of aerial recovery in 2006/7 should lead to a reduction of deer and their impacts on alpine vegetation above the tree-line in Fiordland.

4. Method

In 2008 and 2009, at each of 44 sites, five transects were re-measured using the method described below (see Figure 1 and Appendix 1). There was one minor change from the original 2006 methodology described in Ewans & Lake (2006), which was to use two size classes for *Ranunculus lyallii* (3-8cm and >8cm).

Each transect was re-measured by first re-locating the original start point using GPS and detailed location photographs taken in the original survey. Then the 50 x 2m belt transect was laid out on the original bearing and re-measured. Three main indicator species were used, *Celmisia verbascifolia*, *Dolichoglottis scorzoneroides* and *Ranunculus lyallii*. *Celmisia holosericea* was also recorded at some sites when present.

On each transect the number of browsed or un-browsed individual rosettes (=plants) of indicator species rooted within the transect area was recorded for rosettes equal to or greater than a certain minimum size (8cm leaf length for *Celmisia verbascifolia*, *C. holosericea*, and *Dolichoglottis scorzoneroides*; 3-8cm and >8cm leaf width for *Ranunculus lyallii*). The number of deer pellet groups per transect was also recorded. The definition of a pellet group followed Section 3.3.3 in Forsyth (2005) i.e. 'intact pellets voided in the same defecation' except that all groups were counted regardless of whether pellets were intact or not.

Most sites are located away from the main chamois populations identified in Fiordland, however on the rare occasion where both deer and chamois sign was present at a site, all ungulate browse on indicator species was recorded. Insect browse was mostly easily distinguished from deer browse by experienced observers and where plant damage could not be confidently attributed to ungulates then no browse was recorded.

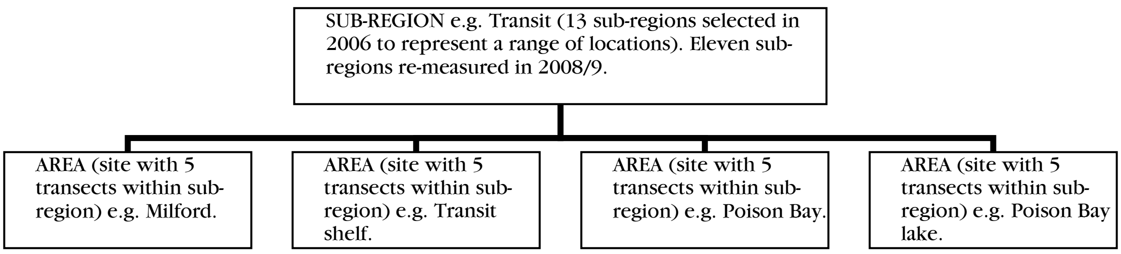

FIGURE 1. STUDY DESIGN (SEE MAP IN APPENDIX 1 FOR LOCATIONS OF SUB-REGIONS AND AREAS).

4.1 DATA ANALYSIS

For each indicator species in each area (site), the percentage of browsed plants was calculated using the total number of plants browsed and the total number of plants counted on the five transects. The area (rather than transect) was considered the independent sample unit. The combined total plants counted and browsed and the percentage browsed was calculated for each indicator species for all sites re-measured. For each sub-region, the mean percentage browse was calculated from the four areas for the three main indicator species (*Celmisia verbascifolia*, *Dolichoglottis scorzoneroides* and *Ranunculus lyallii*). The total number of deer pellet groups per sub-region, area, and for all sites combined was also calculated. All graphs were produced using R version 2.9.2 (R Development Core Team, 2009).

4.2 DATA STORAGE

Information on transects and sites (maps and transect location photographs), species sampled and transect data are filed in hardcopy form in the Biodiversity (Monitoring) section of the Department of Conservation Te Anau Area Office. Copies of all information, except hardcopies of location photographs, are also held by Department of Conservation Southland Conservancy in Invercargill. All data, GPS waypoints, maps and transect location photographs are in electronic form on the DOC Te Anau Area S drive or in the DOCDM system. The master data spreadsheet and document links are in DOCDM-409914.

5. Results

Figures 2 and 3 below use the six letter species codes of the species monitored. They are as follows;

celver=*Celmisia verbascifolia*, celhol=*C. holosericea*, dolsco=*Dolichoglottis scorzoneroides*, and ranlya=*Ranunculus lyallii*.

5.1 CHANGE IN PERCENTAGE OF PLANTS BROWSED BETWEEN 2006 AND 2008/9

The percentage of indicator plants counted browsed by deer was lower overall in 2008/9 than in 2006 for all species (Table 1).

TABLE 1. RESULTS FOR ALL SITES COMBINED.

	TOTAL NUMBER OF PLANTS		NUMBER OF PLANTS BROWSED		% PLANTS BROWSED	
	2006	2008-2009	2006	2008-2009	2006	2008-2009
Dolichoglottis scorzoneroides	20142	22951	6188	3385	30.7	14.7
Celmisia verbascifolia	28889	26671	2546	997	8.8	3.7
Ranunculus lyallii	9207	10425	724	394	7.9	3.8
Celmisia holosericea	1266	858	434	74	34.2	8.6

Of the three main indicator species at the sub-region level, the largest decreases were on *Dolichoglottis scorzoneroides* in the Transit and Nancy-Thompson sub-regions where mean percentage browse fell from 42.2% and 59.1% in 2006 to 3.1% and 21% respectively in 2008 (Figure 2). Large decreases were also recorded on *Celmisia verbascifolia* in the Dusky sub-region between 2006 (43%) and 2009 (9.3%) and Nancy-Thompson sub-region between 2006 (31.4%) and 2008 (8.4%).

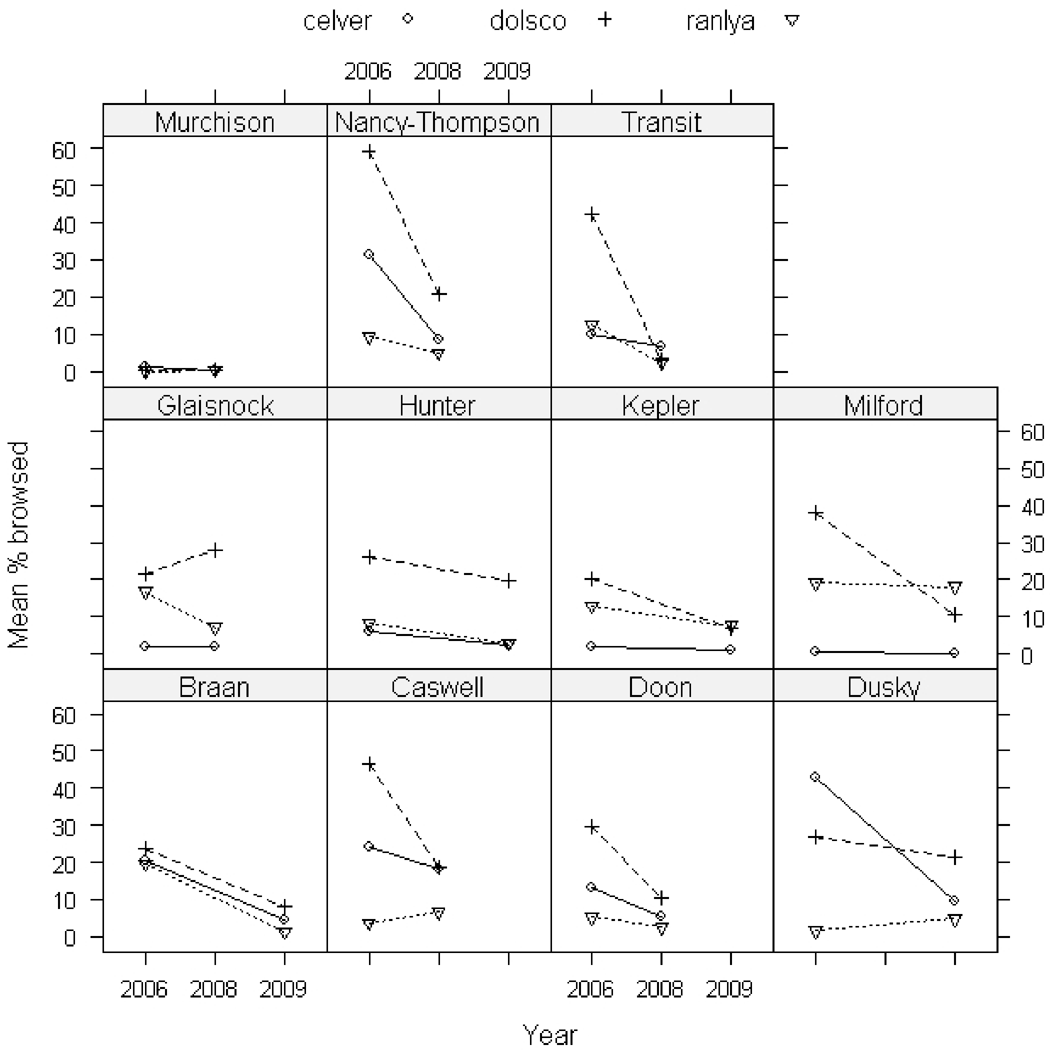

FIGURE 2. MEAN PERCENT BROWSE IN EACH SUB-REGION ON THE THREE MAIN SPECIES MONITORED.

In the Murchison sub-region, where deer numbers have been managed to low levels for many years, browse levels on all species were at negligible levels in both years. In the other ten sub-regions browse levels generally declined the most on species and in sub-regions that had recorded the higher browse levels in 2006 e.g. *Dolichoglottis scorzoneroides* in the Transit and Nancy-Thompson sub-regions.

Mean percent browse decreased on *Ranunculus lyallii* in eight sub-regions with the decreases ranging between 1.1-18.3 percentage points. This species recorded the lowest overall initial browse levels in 2006 (see Section 6.4.3 for discussion of the influence of the method on this pattern).

Increases in sub-region mean percentage browse were few and small, being recorded on *Dolichoglottis scorzoneroides* in the Glaisnock sub-region and *Ranunculus lyallii* in the Caswell, Murchison and Dusky sub-regions (up 6.5, 3.1, 0.3 and 3.2 percentage points respectively). The increase in mean percentage browse on *Dolichoglottis scorzoneroides* in the Glaisnock sub-region was strongly influenced by one area (Edith River basin), where percentage browse increased by 53 percentage points.

5.2 CHANGES IN BROWSE LEVELS IN EACH AREA

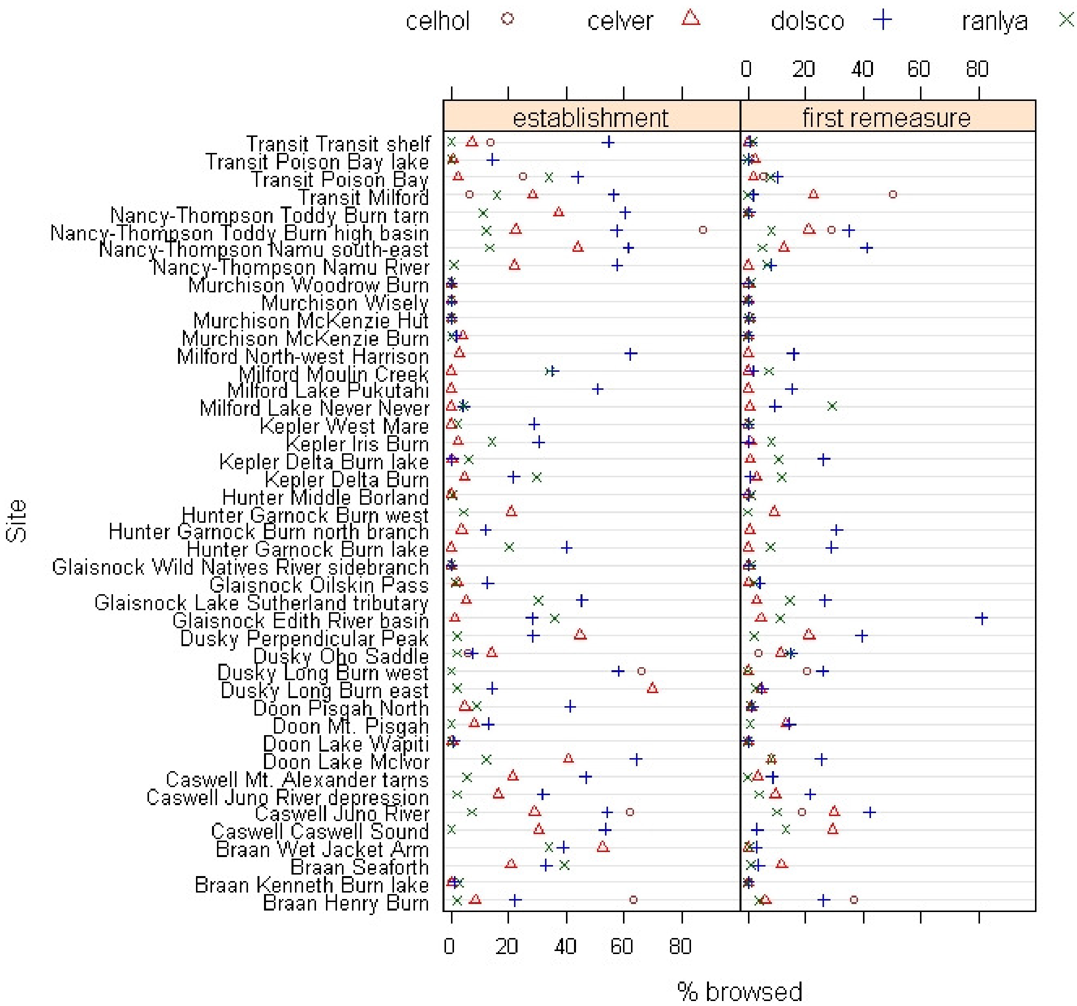

FIGURE 3. PERCENT BROWSE ON THE FOUR SPECIES OF ALPINE HERB MONITORED AT ALL SITES AT MONITORING ESTABLISHMENT (2006) AND FIRST RE-MEASUREMENT (2008/9).

Of the 135 species/area combinations available where a species was recorded in both years (e.g. *Celmisia verbascifolia* at the Namu River site), decreases were recorded in 85 with 15 recording no change. Increases were recorded in 35. Thirty-six of the decreases were of 20 percentage points or more (mostly on *Dolichoglottis scorzoneroides*), whereas only 4 of the increases were of this scale. All of the no change results recorded no browse in either year. This illustrates well the main trend in the data which was for overall decreases in browse levels between 2006 and 2008/9 at the sites monitored, with the exception of the Murchison sub-region, where browse levels were already extremely low in 2006. The percentage browse in 2006 and 2008/9 in each area re-measured is shown in Figure 3, and a table of all data for the species monitored is in Appendix 2.

5.3 CHANGE IN ABUNDANCE OF DEER SIGN BETWEEN 2006 AND 2008/9

The total number of deer pellet groups recorded for all sites decreased from 232 in 2006 to 109 in 2008/9. The largest decreases were recorded in the Nancy-Thompson, Transit and Braan sub-regions, in which the number of deer pellet groups decreased by 55, 30 and 15 respectively. An increase was recorded in the Dusky sub-region, where deer pellet groups increased from 8 in 2006 to 11 in 2009. No deer sign was recorded in the Murchison sub-region in either 2006 or 2008 and counts remained low in the Doon and Kepler sub-regions.

TABLE 2. DEER PELLET GROUP TOTALS FOR EACH SUB-REGION IN EACH YEAR.

SUBREGION	2006	2008/9
Braan	26	11
Caswell	44	36
Doon	6	6
Dusky	8	11
Glaisnock	13	11
Hunter	7	0
Kepler	5	4
Milford	8	0
Murchison	0	0
Nancy-Thompson	77	22
Transit	38	8

6. Discussion

6.1 CHANGES BETWEEN 2006 AND 2008/9

The original baseline survey was carried out in 2006 partly in response to concern over increasing deer numbers after the cessation of commercial venison recovery in 2001. Since 2006 commercial recovery has resumed, with the numbers of animals harvested comparable to the period from 1985-2001, when an average of around 5000 deer per annum were being removed (Table 3). The cost to DOC of replacing this level of control provided by the commercial recovery of deer in Fiordland has been estimated at between $500K and $1M per annum (Murray Willans, pers. comm., August 2009).

TABLE 3. SUMMARY OF ANNUAL NON-RECREATIONAL DEER HARVEST IN FIORDLAND SINCE 1985.

TIME PERIOD	NUMBER OF ANIMALS HARVESTED PER YEAR	NOTES
1985 to 2001	5000	An approximate average figure for this time period. Actual numbers harvested per year reflected price levels and costs (Munn, 2006).
2002 to mid 2005	0	Does not include DOC deer control in Murchison Mountains.
2005/6	1537	From Munn (2006).
2006/7	3910	From Harper (2007). Includes DOC deer control in the Murchison Mountains and helicopter hunting and recovery in the Wapiti Area.
2007/8	6622	From DOC (2009). Includes DOC deer control in the Murchison Mountains and helicopter hunting and recovery in the Wapiti Area.
2008/9	5261	Approximate figure to June 2009 from DOC unpublished data.

While it is uncertain what effect the resumption of harvesting is having on the overall direction of the deer population in Fiordland, the removal of this many animals from alpine areas would be expected to have a positive effect on the alpine flora. The results in this report show such a benefit, with the main trend in the data being for overall decreases in browse levels between 2006 and 2008/9 at the sites monitored, with the exception of the Murchison sub-region where browse levels were already negligible in 2006.

6.2 CHANGES IN BROWSE LEVELS RELATED TO DEER PELLET GROUP ABUNDANCE

The overall changes in deer browse levels on each of the three main species monitored and in the number of deer pellet groups were of a similar magnitude in that all of these declined by about half. This suggests that the expected relationship between the two variables is present. More sophisticated analysis of this data using statistical modelling techniques is beyond the scope of this report, but would be valuable in examining the strength and predictability of the effect of reducing deer numbers on indicator species condition.

6.3 CHANGES IN DIFFERENT MANAGEMENT AREAS

In terms of deer management in mainland Fiordland there are currently three main areas:

- The Murchison Mountains where deer numbers have been managed to low levels over a number of years by the Department of Conservation (50,000ha.).
- The Wapiti Area (190,000ha.), which is not open to WARO (Wild Animal Recovery Operations) concession holders (i.e. commercial deer recovery) but is managed by a separate deer management plan. This includes wild animal recovery as well as search and destroy, in recognition of the recreational hunting values of wapiti.
- The rest of Fiordland (c. 900,000ha.) which is open to commercial deer recovery (WARO).

The main difference between management areas shown by the 2008/9 re-measure is the continuation of browse levels of virtually nil in the Murchison Mountains compared to the rest of Fiordland including the Wapiti Area. Outside of the Murchison Mountains browse levels mostly declined overall, but not down to the levels seen in the Murchison sub-region, which has had long term deer control.

In the Wapiti Area browse declined on most or all species at each site from a range of baseline levels, which appears to be broadly in line with the pattern observed at the sites throughout the rest of Fiordland with the exception of the Murchison Mountains.

The amount of deer sign recorded fell sharply in two of the sub-regions outside the Wapiti Area (Nancy-Thompson and Transit), whereas it declined only slightly or remained steady at low levels in the Wapiti Area sub-regions (Caswell, Doon, Glaisnock) and remained at nil in the Murchison sub-region.

6.4 METHODOLOGICAL CONSIDERATIONS

6.4.1 Success of the method

As noted in earlier reports (e.g. Ewans, 2008), the indicator species browse method used here appears to be sensitive to short-term changes in deer numbers and impacts on vegetation in the alpine zone. The presence of browsed leaves indicates recent deer use, probably within the two previous growing seasons for *Celmisia* spp. and within the current season for the annual *Ranunculus lyallii* and *Dolichoglottis scorzoneroides*, and provides an indication of current deer pressure on the habitat (Lee et al., 2003). The results of the first re-measurement of the data suggest the method has been successful and is appropriate for short to medium term assessment of alpine vegetation condition at the large scale reported on here.

6.4.2 Interpretation of results

The mobility of deer and the location of each transect can mean that browse levels recorded on some transects, and even over some areas, may be greater or lower than would be observed generally in the locality. However, having five transects per area and using the area totals as the independent sample unit should help reduce this potential variability and still gives 44 sites sampled across Fiordland.

Trends seen at the sub-region level are most vulnerable to site variability as the means are derived from only 4 samples (e.g. *Dolichoglottis scorzoneroides* in the Glaisnock sub-region, where a large increase in browse at one site caused an increase in mean browse for the sub-region despite the other three sites recording steady or declining browse).

The variable of percent browsed should be interpreted alongside the number of plants counted to gain a more complete picture of the trends, as some percentages are derived from low numbers of plants e.g. *Celmisia holosericea* at the Transit-Milford site recorded 50% browse in 2008 but this is from only 2 plants (see Appendix 2). There were only five occasions where the number of plants counted was less than 10 for a species in an area in any given year (from 270 species/area/year combinations).

6.4.3 Notes on field re-measurement

The addition of another size class for *Ranunculus lyallii* produced no additional burden for the collection of the data and is likely to be useful in the longer term as browsed areas recover. This change to the method was recommended in Ewans & Lake (2006) to differentiate between seedling size plants (rarely browsed as they are too small) and more mature plants which are highly palatable. In the baseline survey, this species was found to be present often in high numbers as un-browsed seedlings in areas of high deer use, so the data was not accurately reflecting the deer impacts at some sites for this species.

Although the transects are not permanently marked, relocation of the transect start points was relatively straight forward with GPS taking the observers to within around 2-5m and detailed relocation photographs allowing accurate relocation of the transect starts. This is reflected in the similar numbers of plants counted in each area each year (see Appendix 2).

6.4.4 Further development and application of the method

A suggested future use of this monitoring could be for setting browse trigger levels for management. This may be particularly useful if there is a cessation of commercial deer recovery in Fiordland at any stage. It appears that the method would be an appropriate tool for this scenario, but there are several issues that should be addressed in order to gain more confidence in using the method this way.

Firstly, if a management block scenario was envisaged at any stage then it is likely that additional sites would be required for more robust monitoring within blocks, as has been recommended for the Wapiti Area (Ledgard, 2007). The amount of additional sites required would be dependant on the block boundaries.

Secondly, another full re-measurement of the sites should be undertaken. Thirdly, statistical analysis of the relationship between altitude and deer browse should be undertaken for the baseline survey (2006). Lastly, the relationship between deer browse and deer pellet group abundance should be examined more closely, most likely using statistical modelling techniques.

6.5 OTHER CURRENT DEPARTMENT OF CONSERVATION STUDIES OF DEER IMPACTS IN FIORDLAND NATIONAL PARK

This study sits alongside several other ongoing monitoring programmes based around different deer management regimes in Fiordland. They include:

- Vegetation outcomes in response to long-term deer control in the Murchison Mountains (Scott height-frequency grassland transects, 20x20m forest plots including exclosures, Ecotone exclosure plots, and shrubland plots).
- Vegetation outcomes in response to deer eradication on islands (20x20m forest plots on Anchor Island; 20x20m forest plots, Wraight grassland transects and Seedling Ratio Index transects on Secretary Island; and Seedling Ratio Index transects on Resolution Island).
- Assessment of forest under-storey condition in the Wapiti Area and central Fiordland (Seedling Ratio Index transects).

7. Conclusions and recommendations

Since widespread aerial venison recovery resumed in 2006/7, overall deer browse levels have halved on the three main species monitored, along with deer sign (number of deer pellet groups). This reduction in deer browse is consistent across most sites except in the Murchison sub-region where browse was negligible in both years.

The following recommendations are made:

- All transects re-measured over 2008/9 are re-measured again during 2011/12.
- A statistical modelling approach is investigated to analyse the strength of the deer browse/pellet group relationship and the results assessed for potential publication.
- Aerial recovery records continue to be collected from helicopter operators and details mapped to show numbers of deer removed from all areas in Fiordland National Park.

8. References

Department of Conservation. (2009). Non-recreational hunting harvest of deer from Fiordland National Park. July 2007-June 2008. Unpublished internal report, Department of Conservation Te Anau Area Office.

Ewans, R. (2008). Deer impacts in alpine grasslands of Fiordland National Park: A report on re-measurement of alpine browse transects in January and February 2008. Unpublished internal report, Department of Conservation Te Anau Area Office.

Ewans, R.; Lake, S. (2006). Deer Impacts in Alpine Grasslands Fiordland National Park: A report on baseline monitoring using a rapid assessment method of monitoring deer impacts in alpine grasslands and herbfields, January to March 2006. Unpublished internal report, Department of Conservation Te Anau Area Office.

Fenner, M.; Lee, W. G.; Duncan, S. J. (1993). Chemical features of Chionochloa species in relation to grazing by ruminants in South Island, New Zealand. *New Zealand Journal of Ecology 17(1)*: 35-40.

Forsyth, D. (2005). Protocol for estimating changes in the relative abundance of deer in New Zealand forests using the Faecal Pellet Index (FPI). Landcare Research Contract Report: LC0506/027 (unpublished). 24 p.

Forsyth, D.; Coomes, D. A.; Nugent, N. (2003). Framework for assessing the susceptibility of management areas to deer impacts. *Science for Conservation 213*. 39 p.

Harper, G. (2007). Non-recreational hunting harvest of deer from Fiordland National Park. July 2006-June 2007. Unpublished internal report, Department of Conservation Te Anau Area Office.

Lake, S.; Ewans, R. (2005). Deer impacts in alpine grasslands in Fiordland National Park: a report on the trial of a new monitoring method for the rapid assessment of deer browse in alpine grassland habitats in Fiordland National Park, summer 2005. Unpublished internal report, Department of Conservation Te Anau Area Office.

Lavers, R. B.; Lee, W. G.; Wilson, J. B.; Mills, J. A. (1983). Foods of red deer in the Murchison Mountains, Fiordland, New Zealand. *New Zealand Journal of Ecology 6*: 151-152.

Ledgard, G. (2007). Fiordland Wapiti Area. A review of past vegetation monitoring within the Wapiti Area and recommendations for the future. Unpublished internal report, Department of Conservation Southland Conservancy.

Lee, W. G. (1990). Permanent transects to monitor deer usage of Chionochloa pallens grassland in three areas of Fiordland National Park important for the conservation of takahe (*Notornis mantelli*). DSIR Land Resources contract report (unpublished). 72 p.

Lee, W. G.; Wilson, J. B.; Rance, B. D. (1994). Reassessment (1989-1994) of permanent transects to monitor vegetation change and use by deer of Chionochloa pallens grassland in the Murchison and Stuart Mountains, Fiordland. Landcare Research Contract Report: LC9495/44 (unpublished). 17 p.

Lee, W. G.; Wilson, J. B.; Maxwell, J.; Walker, S.; Rance, B. D.; Allan, C. (2003). Vegetation change (1989-2000) and use by deer of *Chionochloa pallens* subsp. *cadens* grassland in the Murchison and Stuart mountains, Fiordland. Landcare Research Contract Report: LC0203/132 (unpublished). 13 p.

Mark, A. F. (1989), Responses of indigenous vegetation to contrasting trends in utilization by red deer in two south-western New Zealand national parks. *New Zealand Journal of Ecology 12 (Supplement)*: 103-114.

Munn, A. (2006). Fiordland National Park Deer Management: Feral Deer in Fiordland, Current Commercial, Recreational and Environmental Status and options for Management. Unpublished report, Department of Conservation Te Anau Area Office.

Nugent, G.; Parkes, J. P.; Tustin, K. G. (1987). Changes in the density and distribution of red deer and wapiti in Northern Fiordland. *New Zealand Journal of Ecology 10*: 11-21.

R Development Core Team (2009). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Rose, A. B.; Platt, K. H. (1987). Recovery of Northern Fiordland alpine grasslands after reduction in the deer population. *New Zealand Journal of Ecology 10*: 23-33.

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Appendix 1

MAP OF SUB-REGION AND AREA LOCATIONS

KEY TO APPENDIX 1 MAP: LIST OF ALL LOCATIONS WHERE DEER BROWSE MONITORING RE-MEASUREMENT TOOK PLACE DURING 2008/9.

AREA CODE	SUB-REGION	AREA NAME
DWAP	Doon	Lake Wapiti
DPIS	Doon	Pisgah North
DMTP	Doon	Mt. Pisgah
DLMC	Doon	Lake McIvor
MMCK	Murchison	McKenzie Burn
MWBN	Murchison	Woodrow Burn
MWIS	Murchison	Wisely
MMHT	Murchison	McKenzie Hut
CDEP	Caswell	Juno River depression
CSOU	Caswell	Caswell Sound
CMAT	Caswell	Mt. Alexander tarns
CJUR	Caswell	Juno River
GLKS	Glaisnock	Lake Sutherland
GWNR	Glaisnock	Wild Natives River
GOIL	Glaisnock	Oilskin Pass
GEDT	Glaisnock	Edith River basin
NTOD	Nancy-Thompson	Toddy Burn high
NTTR	Nancy-Thompson	Toddy Burn tarn
NRIV	Nancy-Thompson	Namu River
NNAS	Nancy-Thompson	Namu south-east
TMIL	Transit	Milford
TSHL	Transit	Transit shelf
TPOI	Transit	Poison Bay
TPBL	Transit	Poison Bay lake
KDBN	Kepler	Delta Burn north
KDBL	Kepler	Delta Burn lake
KIRB	Kepler	Iris Burn
KWES	Kepler	West Mere
DUPP	Dusky	Perpendicular Peak
DUOH	Dusky	Oho Saddle
DULE	Dusky	Long Burn east
DULW	Dusky	Long Burn west
BWJA	Braan	Wet Jacket Arm
BHBN	Braan	Henry Burn
BKBL	Braan	Kenneth Burn lake
BSFT	Braan	Seaforth
MNVV	Milford	Lake Never Never
MMOU	Milford	Moulin Creek
MPUK	Milford	Lake Pukutahi
MNWH	Milford	North-west Harrison

HGBN	Hunter	Garnock Burn north
HBOR	Hunter	Middle Borland
HGTP	Hunter	Garnock Burn top
HGLK	Hunter	Garnock Burn lake


Department of Conservation
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Appendix 2

SUMMARY DATA TABLES FOR THE SPECIES MONITORED IN EACH AREA AND NUMBER OF DEER PELLET GROUPS IN EACH AREA

NR=not recorded

NUMBER OF DEER PELLET GROUPS IN EACH AREA IN EACH YEAR.

SUB-REGION	AREA	NUMBER OF DEER PELLET GROUPS	
		2006	2008/9
Caswell	Mt. Alexander tarns	14	4
Caswell	Juno River	10	21
Caswell	Juno River depression	13	9
Caswell	Caswell Sound	7	2
Nancy-Thompson	Namu River	15	4
Nancy-Thompson	Toddy Burn tarn	14	1
Nancy-Thompson	Toddy Burn high basin	22	9
Nancy-Thompson	Namu south-east	26	8
Transit	Milford	15	0
Transit	Transit shelf	8	1
Transit	Poison Bay	11	2
Transit	Poison Bay lake	4	5
Doon	Lake Wapiti	0	0
Doon	Pisgah North	2	0
Doon	Mt. Pisgah	2	3
Doon	Lake McIvor	2	3
Glaisnock	Lake Sutherland tributary	4	4
Glaisnock	Wild Natives River sidebranch	0	1
Glaisnock	Oilskin Pass	7	2
Glaisnock	Edith River basin	2	4
Murchison	McKenzie Burn	0	0
Murchison	Woodrow Burn	0	0
Murchison	Wisely	0	0
Murchison	McKenzie Hut	0	0
Dusky	Oho Saddle	1	1
Dusky	Perpendicular Peak	5	7
Dusky	Long Burn east	2	3
Dusky	Long Burn west	0	0
Kepler	West Mare	4	1
Kepler	Iris Burn	1	0
Kepler	Delta Burn	0	0
Kepler	Delta Burn lake	0	3
Braan	Kenneth Burn lake	0	0

Braan	Seaforth	15	2
Braan	Henry Burn	9	9
Braan	Wet Jacket Arm	2	0
Hunter	Garnock Burn north branch	2	0
Hunter	Middle Borland	0	0
Hunter	Garnock Burn west	1	0
Hunter	Garnock Burn lake	4	0
Milford	North-west Harrison	3	0
Milford	Lake Never Never	0	0
Milford	Lake Pukutahi	5	0
Milford	Moulin Creek	0	0

NUMBER OF PLANTS COUNTED AND PERCENT BROWSED FOR *Celmisia holosericea* 2006 TO 2008 AT ALL SITES WHERE PRESENT.

SUBREGION	AREA	NUMBER OF PLANTS		% BROWSED	
		2006	2008/9	2006	2008/9
Dusky	Oho Saddle	427	371	5.4	3.2
Dusky	Long Burn west	363	147	65.8	20.4
Braan	Kenneth Burn lake	48	77	0	0
Braan	Henry Burn	60	38	63.4	36.8
Caswell	Juno River	108	32	62.1	18.8
Nancy-Thompson	Toddy Burn high basin	24	7	87.5	28.6
Transit	Milford	46	2	6.6	50
Transit	Transit shelf	44	36	13.7	0
Transit	Poison Bay	138	113	24.7	5.3

NUMBER OF PLANTS COUNTED AND PERCENT BROWSED FOR THE THREE MAIN SPECIES MONITORED AT ALL SITES 2006 TO 2008.

SUB-REGION	AREA	NUMBER OF PLANTS		% BROWSED		NUMBER OF PLANTS		% BROWSED		NUMBER OF PLANTS		% BROWSED	
		Celmisia verbascifolia				*Ranunculus lyallii*				*Dolichoglottis scorzoneroides*			
		2006	2008	2006	2008	2006	2008	2006	2008	2006	2008	2006	2008
Caswell	Mt. Alexander tarns	47	29	21.3	3.4	18	47	5.6	0.0	221	523	46.6	8.4
Caswell	Juno River	513	610	29.0	30.0	29	51	6.9	9.8	283	385	54.1	42.1
Caswell	Juno River depression	677	475	16.5	9.5	51	52	2.0	3.8	947	979	31.8	21.5
Caswell	Caswell Sound	379	204	30.3	29.4	82	108	0.0	13.0	45	132	53.3	3.0
Nancy-Thompson	Namu River	470	458	21.9	0.0	126	363	0.8	6.6	73	90	57.5	7.8
Nancy-Thompson	Toddy Burn tarn	959	604	37.2	0.0	9	20	11.1	0.0	229	324	60.3	0.3
Nancy-Thompson	Toddy Burn high basin	1107	1077	22.4	21.2	33	125	12.1	8.0	895	1373	57.3	34.8
Nancy-Thompson	Namu south-east	971	731	44.1	12.4	76	164	13.2	4.9	817	1120	61.4	41.0
Transit	Milford	92	110	28.3	22.7	19	12	15.8	0.0	117	129	56.4	1.6
Transit	Transit shelf	236	249	7.2	0.0	64	121	0.0	1.7	964	1064	54.6	0.8
Transit	Poison Bay	617	632	2.4	1.7	237	550	33.8	7.5	487	1074	43.7	10.2
Transit	Poison Bay lake	1297	1110	0.7	2.2	13	10	0.0	0.0	119	89	14.3	0.0
Doon	Lake Wapiti	1249	1334	0.2	0.0	184	165	0.0	0.0	900	741	0.8	0.0
Doon	Pisgah North	1223	1306	4.8	1.1	104	185	8.7	1.1	470	319	41.1	1.3
Doon	Mt. Pisgah	251	184	8.0	13.0	125	148	0.0	0.7	340	250	12.9	14.4
Doon	Lake McIvor	131	37	40.5	8.1	57	87	12.3	8.0	336	409	64.0	25.2
Glaisnock	Lake Sutherland tributary	1444	1361	5.1	2.9	180	192	30.0	14.6	488	569	45.3	26.7
Glaisnock	Wild Natives River sidebranch	957	894	0.0	0.3	776	801	0.0	0.9	273	345	0.0	0.3
Glaisnock	Oilskin Pass	1716	1494	2.1	0.1	158	101	1.3	2.0	423	368	12.5	3.8
Glaisnock	Edith River basin	1077	1007	1.3	4.4	297	218	35.7	11.0	546	427	28.0	81.0
Murchison	McKenzie Burn	647	469	4.0	0.0	829	857	0.0	0.0	804	749	1.6	0.0
Murchison	Woodrow Burn	677	690	0.0	0.0	629	584	0.0	0.9	635	709	0.0	0.0
Murchison	Wisely	415	408	0.0	0.0	632	609	0.0	0.0	700	1433	0.0	0.0
Murchison	McKenzie Hut	1796	1629	0.0	0.6	502	544	0.0	0.2	389	474	0.0	0.2

NUMBER OF PLANTS COUNTED AND PERCENT BROWSED FOR THE THREE MAIN SPECIES MONITORED AT ALL SITES 2006 TO 2009.

SUB-REGION	AREA	NUMBER OF PLANTS		% BROWSED		NUMBER OF PLANTS		% BROWSED		NUMBER OF PLANTS		% BROWSED	
		Celmisia verbascifolia				*Ranunculus lyallii*				*Dolichoglottis scorzoneroides*			
		2006	2009	2006	2009	2006	2009	2006	2009	2006	2009	2006	2009
Dusky	Oho Saddle	249	219	14.1	11.4	57	28	1.8	14.3	198	140	7.1	15.0
Dusky	Perpendicular Peak	852	331	44.8	21.1	146	244	2.1	2.0	633	579	28.3	39.4
Dusky	Long Burn east	70	65	70.0	4.6	285	234	2.1	2.6	516	708	14.1	4.8
Dusky	Long Burn west	NR	4	NR	0.0	14	14	0.0	0.0	230	54	57.8	25.9
Kepler	West Mare	507	524	0.0	0.0	353	354	2.3	0.6	212	173	28.8	0.0
Kepler	Iris Burn	472	445	2.3	0.9	532	450	14.1	8.0	192	88	30.2	0.0
Kepler	Delta Burn	659	661	4.4	2.9	141	148	29.8	11.5	801	707	21.6	0.7
Kepler	Delta Burn lake	665	606	0.3	0.7	361	253	5.8	10.3	680	531	0.3	26.2
Braan	Kenneth Burn lake	29	33	0.0	0.0	425	420	2.8	0.0	524	732	1.3	0.1
Braan	Seaforth	328	258	20.7	11.6	178	250	39.3	0.8	180	82	32.8	3.7
Braan	Henry Burn	12	17	8.3	5.9	233	293	2.1	3.8	171	195	22.2	26.2
Braan	Wet Jacket Arm	57	49	52.6	0.0	148	286	33.8	0.3	504	520	38.7	2.7
Hunter	Garnock Burn north branch	220	248	3.6	0.8	NR	NR	NR	NR	446	863	11.9	30.6
Hunter	Middle Borland	57	84	0.0	0.0	300	293	0.3	1.0	NR	5	NR	0.0
Hunter	Garnock Burn west	62	268	21.0	9.0	90	114	4.4	0.0	NR	NR	NR	NR
Hunter	Garnock Burn lake	4	5	0.0	0.0	498	679	19.9	7.7	105	55	40.0	29.1
Milford	North-west Harrison	1592	1438	2.7	0.0	NR	NR	NR	NR	1489	1120	62.2	15.8
Milford	Lake Never Never	1338	1302	0.0	0.7	93	128	4.3	28.9	378	236	4.2	9.3
Milford	Lake Pukutahi	1545	1517	0.1	0.0	NR	NR	NR	NR	1134	1640	50.7	15.1
Milford	Moulin Creek	1223	1495	0.0	0.0	123	123	34.1	7.3	248	448	35.1	1.6