# Assessment of the Recovery Index for Narrow-leaved Snow Tussock (*Chionochloa rigida*) in Otago

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Kristín Svavarsdóttir

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# Abstract

The Recovery Index for Narrow-leaved Snow Tussock (RINST) was developed to provide managers with a tool for assessing recovery of *Chionochloa rigida* tussock plants. The index consists of three variables: tussock cover, tiller length and tiller weight. The critical values for these tussock variables are 70%, 0.6 m and 1.2 g for cover, tiller length and tiller weight, respectively, for a site to be considered to have recovered. The current study assessed the index at different geographical locations, and its practicality for use by Department of Conservation staff.

Nineteen sites were selected in four Ecological Districts in Otago. Tussock cover, tiller length and weight were measured at each site. Results were compared with the data set that was used to develop the index. Regression analysis, similar to that used to develop the index, showed that the relationship between tiller weight and years since last fire did not differ between the two data sets.

It is concluded that the specific critical levels identified in the RINST are acceptable and that the index is a useful tool for managers to assess the recovery of narrow-leaved snow tussocks.

# 1. Introduction

Fires have been an important factor in the development and subsequent management of the snow tussock grasslands of central and eastern Otago (Molloy et al. 1963; Mark 1965). Deterioration of these grasslands has been attributed to the combined effects of burning and subsequent grazing (Connor 1964; Mark 1965). Although frequency of snow tussock grasslands fires has decreased in recent years, it is still practised in areas used for pastoral agriculture.

Some work has recently been done on various aspects of narrow-leaved snow tussock (*Chionochloa rigida*) growth in relation to fire and grazing in Otago (e.g. Gitay et al. 1991, 1992; Lee et al. 1993). As a part of that work, an index was developed for the Department of Conservation (DOC) to determine the relative recovery of this species after burning (The RINST: Recovery Index for Narrow-leaved Snow Tussock; Lee et al. 1995). In the index, three variables are used to assess the relative recovery of the tussock plants: tussock cover, tiller length and tiller weight. The critical levels for these variables are: tussock cover 50% or tussock linear cover 70% (measured); at least one tiller per tussock to exceed 0.6 m in length; mean tiller weight 1.2 g. All three criteria need to be met for a tussock site to be classified as adequately recovered.

This study tested how well the recovery index for narrow-leaved snow tussock, developed by Lee et al. (1995), applies to areas which were not included in the initial development of the index. The field work was carried out during the summer of 1996–97. The objectives were to assess whether the specific critical levels identified in the RINST as indicative of optimal snow tussock recovery from burning are consistent for a range of narrow-leaved snow tussock grassland sites, and to assess the practicality of the index for use by DOC staff.

# 2. Methods

## 2.1 SITES

Nineteen sites were sampled from four Ecological Districts within Otago: Waipori (4 sites), Dansey (6 sites), Old Man (3 sites) and Wanaka (6 sites). The sites sampled within the Waipori Ecological District were on the Lammerlaw Range within the general area sampled when the index was developed. Other sites were outside the areas sampled previously, both to the west and to the north, including the moister Wanaka area and the sub-humid Danseys Pass area. Three of the four sites on the Lammerlaw Range had hybrid tussock plants (*Chionochloa rigida* X *C. macra*) for which the index was not developed. The results from these sites are, however, included in this report. Analyses were done on both the full data set (n = 19) and the reduced data set after the sites containing hybrids had been removed (n=16). Since the regression models with and without these hybrid sites differed, the reduced data set was used for testing the index.

All sites (except two on the Lammerlaw Range (Waipori Ecological District)) were grazed by sheep. The ungrazed sites were relatively recently retired (in 1995). Sites were chosen where time since last fire was known, based on information from runholders. The most recently burnt site was burnt in September 1996; it was estimated to have last been burnt at least 30 years before that. The study included sites that had not been burnt for up to 50 years. The longer the time since the last burn, the more approximate was our estimate of the time since this burn. The number of years given was often the minimum time the area had not been burnt.

Altitude ranged from 800 m to 1210 m, with most sites above 900 m (Table 1). An attempt was made to sample different aspects for each area in order to test whether there was a difference in the index value between sunny and shady aspects. However, this was not achieved at all sites due to difficulties in finding both aspects within an area with the same burning history. There were eleven sites sampled on sunny faces (less than 90° deviance from 0/360°) and 8 sites on shady faces (more than 90° deviance) (Table 1). Slopes were usually under 20° (Table 1), this being consistent with the sites used for developing the index.

## 2.2 DATA SAMPLING

At each site, a 20 m transect line was laid down parallel to the slope. The three variables used in the index were measured as follows. Tussock cover was recorded by measuring the proportion of the 20 m length of the tape intercepted by tussock canopy. Then at 2 m intervals along the tape four tillers were broken off a tussock (i.e. each of 10 plants):

- length of the four tillers was measured in the field and then
- the four tillers were stored in a paper bag, oven-dried at 75°C for 48 hours and weighed. The individual tiller weight was calculated.

TABLE 1. SITE CHARACTERISTICS FOR THE 19 SITES USED FOR THE TESTING OF THE RINST.

| SITE | ECOLOGICAL DISTRICT | ALTITUDE (m) | ASPECT (°) | SLOPE (°) | YEARS SINCE LAST BURNT |
|---|---|---|---|---|---|
| 1 | Wanaka | 1150 | 50 | 15 | 30 |
| 2 | Wanaka | 1120 | 60 | | < 1 |
| 3 | Wanaka | 910 | 250 | 30 | 29 |
| 4 | Wanaka | 930 | 270 | 30 | 29 |
| 5 | Wanaka | 1020 | 120 | 22 | 40 |
| 6 | Wanaka | 1080 | 190 | 12 | 40 |
| 7 | Dansey | 800 | 330 | 8 | 10 |
| 8 | Dansey | 940 | 220 | 10 | 10 |
| 9 | Dansey | 920 | 330 | 8 | 1 |
| 10 | Dansey | 1160 | 30 | 6 | 20 |
| 11 | Dansey | 1160 | 170 | 7 | 20 |
| 12 | Dansey | 1010 | 190 | 10 | 1 |
| 13 | Old Man | 1090 | 290 | 18 | 13 |
| 14 | Old Man | 1210 | 270 | 18 | 13 |
| 15 | Old Man | 1170 | 350 | 8 | 50 |
| 16[1] | Waipori | 950 | 350 | 8 | 15 |
| 17 | Waipori | 970 | 260 | 18 | 15 |
| 18[1] | Waipori | 810 | 230 | 10 | 7 |
| 19[1] | Waipori | 810 | 60 | 4 | 7 |

[1]Sites which had hybrids between narrow-leaved snow tussock and slim snow tussock (*Chionochloa macra*).

Notes were made on each site, including amount of bare ground and litter, and presence of some exotic species, such as *Hieracium* spp. and *Hypochoeris radicata*.

One or two people carried out the work on each site, with the measuring time varying from 30 to 60 minutes. The shortest time it took one person was 40 minutes; with two people the time required did not ever exceed 45 minutes. The measuring time for the first two sites took a little longer as we were becoming familiar with the field methods. After the first trip, tillers were chopped up before being put into the paper bags. This added some time to the fieldwork for one person, but made the weighing process in the laboratory quicker.

## 2.3 DATA ANALYSIS

Tiller weight and tiller length values were logarithmically transformed prior to analysis. Site details, tussock and tiller variables were tested for cross-correlation. T-tests were used to determine whether tiller parameters differed between sunny and shady sites.

The regression analyses used in Lee et al. (1995) when the RINST was developed were repeated on the test data set. Firstly, regression analysis was used to determine the relationship between tiller weight and time since last fire. T-tests were used to test whether the relationship was the same as the one found by Lee et al. (1995). The differences of the regression coefficients for the line intercept and the slope between the two data sets were tested. Secondly, regression analysis using time since last fire to predict tiller weight was used to determine which sites had optimal tussock recovery using the same criteria as Lee et al. (1995) employed when they developed the index. The sites that had recovered according to these criteria in this new analysis (above the 95% confidence limit for sites burnt in the last two decades and above the estimated values for sites that had not been burnt for at least 20 years) were compared to the sites that passed the original index of Lee et al. (1995).

# 3. Results

## 3.1 RELATIONSHIPS BETWEEN MEASURED VARIABLES

The three variables that the index uses were all positively correlated ($p<0.001$; Table 2). None of the topographical variables were significantly correlated to the tussock factors. Tiller weight and tiller length increased with time from last fire ($p<0.05$), whereas cover did not have a significant relationship with time.

Neither tiller weight nor tiller length differed between sunny and shady aspects ($t=0.217$ for tiller weight and $t=-0.308$ for tiller length, $n=16$, $p>0.5$ for both variables).

## 3.2 APPLYING THE INDEX TO THE SURVEY SITES

Results for tussock cover, tiller length, and tiller weight for each site are summarised in Table 3. According to the index, tussocks at ten out of the 19 sites have recovered after burning. These sites were number 1, 5 (Wanaka Ecological District), 7, 8, 11 (Dansey Ecological District), 13, 14, 15 (Old Man Ecological District), 16 and 17 (Waipori Ecological District).

The ten sites whose values passed the index were spread between all four Ecological Districts. At these sites time since the last fire varied, from 10 years (Dansey) to 50 years (Old Man). There were a further three sites, of which one had hybrid plants, that

TABLE 2. PEARSON CORRELATION COEFFICIENT BETWEEN TUSSOCK COVER (%, TAPE INTERCEPT), TILLER WEIGHT (g), TILLER LENGTH (m) AND YEARS SINCE LAST FIRE ON THE 16 SITES. TILLER VARIABLES WERE LOGARITMICALLY TRANSFORMED. STARS SHOW THE PROBABILITY, * $P<0.05$, *** $P<0.001$.

| | COVER | TILLER LENGTH (ln) | TILLER WEIGHT (ln) |
|---|---|---|---|
| Tiller length (ln) | 0.78*** | | |
| Tiller weight(ln) | 0.73*** | 0.98*** | |
| Last burn | 0.40 | 0.52* | 0.58* |

TABLE 3. RESULTS FOR THE THREE MEASURED VARIABLES FOR EACH SITE. TUSSOCK COVER IS THE INTERCEPT COVER (%) WITH THE CRITICAL INDEX VALUE 70%. THE RANGE OF THE MAXIMUM TILLER LENGTH (m) OF THE 10 MEASURED TUSSOCKS ARE SHOWN; THE CRITICAL INDEX VALUE FOR THE TILLER LENGTH IS 0.6 m. THE MEAN TILLER WEIGHT (g) (n = 10) IS SHOWN WITH THE STANDARD DEVIATION IN BRACKETS. THE CRITICAL INDEX VALUE FOR TILLER WEIGHT IS 1.2 g. SITES THAT HAVE RECOVERED AFTER A FIRE ACCORDING TO THE RINST ARE TICKED.

| SITE | ECOLOGICAL DISTRICT | TUSSOCK COVER(%) | MAX TILLER LENGTH(m) | TILLER WEIGHT(g) | INDEX PASSED |
|---|---|---|---|---|---|
| 1 | Wanaka | 82 | 0.6 - 1.0 | 1.2 (0.61) | ✓ |
| 2 | Wanaka | 12 | 0.1 - 0.3 | 0.2 (0.08) | |
| 3 | Wanaka | 55 | 0.7 - 1.2 | 1.6 (0.68) | |
| 4 | Wanaka | 68 | 0.5 - 1.1 | 1.0 (0.47) | |
| 5 | Wanaka | 72 | 0.7 - 1.3 | 1.8 (0.98) | ✓ |
| 6 | Wanaka | 79 | 0.6 - 0.9 | 1.1 (0.24) | |
| 7 | Dansey | 83 | 0.6 - 0.8 | 1.2 (0.30) | ✓ |
| 8 | Dansey | 80 | 0.7 - 1.0 | 1.4 (0.34) | ✓ |
| 9 | Dansey | 69 | 0.4 - 0.6 | 0.5 (0.15) | |
| 10 | Dansey | 100 | 0.4 - 1.0 | 1.3 (0.51) | |
| 11 | Dansey | 84 | 0.6 - 0.9 | 1.4 (0.48) | ✓ |
| 12 | Dansey | 58 | 0.3 - 0.5 | 0.3 (0.04) | |
| 13 | Old Man | 75 | 0.9 - 1.3 | 2.5 (0.67) | ✓ |
| 14 | Old Man | 74 | 0.8 - 1.4 | 2.0 (0.44) | ✓ |
| 15 | Old Man | 92 | 0.6 - 1.4 | 2.4 (0.79) | ✓ |
| 16[1] | Waipori | 82 | 0.6 - 1.1 | 1.3 (0.64) | ✓ |
| 17 | Waipori | 92 | 0.7 - 1.3 | 1.9 (0.86) | ✓ |
| 18[1] | Waipori | 69 | 0.6 - 0.9 | 1.2 (0.32) | |
| 19[1] | Waipori | 68 | 0.5 - 0.8 | 0.8 (0.33) | |

[1]These sites had hybrid plants of *Chionochloa rigida* and *C. macra*.

had sufficient tiller weight ( ≥1.2 g) but failed to fulfil the other two criteria—two sites had less than 70% cover, and one site had one tussock with no tiller exceeding 0.6 m in length. The remaining six sites failed on at least two criteria. Most of these sites had been burnt within the last 10 years, with the exception of two sites burnt 29 and 40 years ago, both in the Wanaka Ecological District.

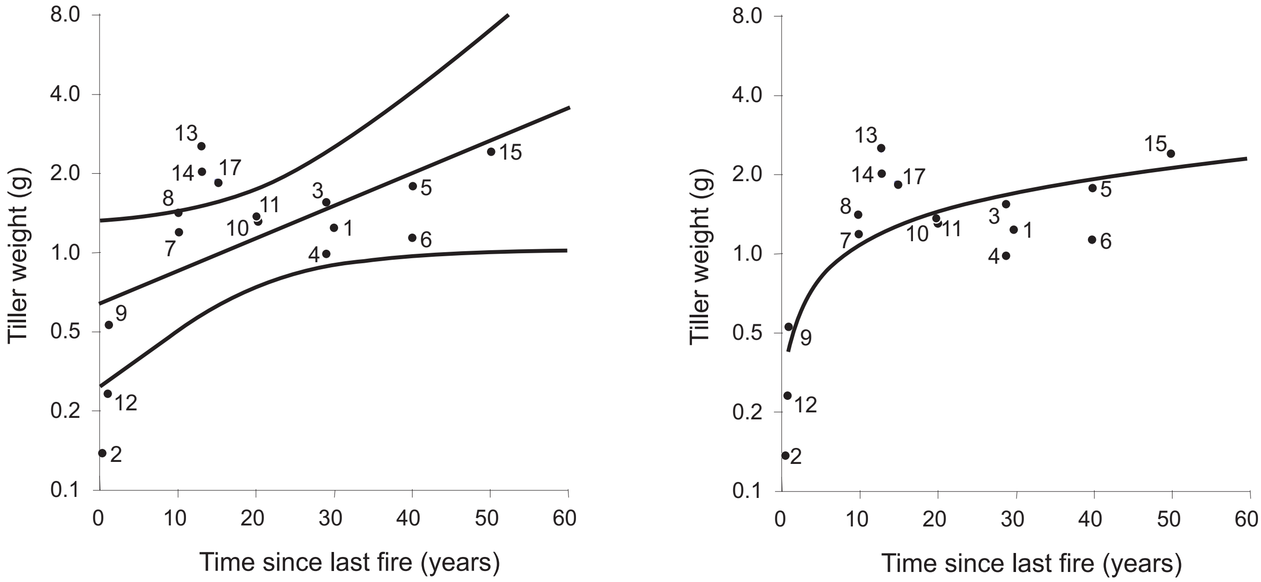
## 3.3 TESTING THE MODEL

Regression analysis was done using the reduced data set of 16 sites which excludes the three sites which had hybrid tussock plants. The model was significant ($p<0.05$), and explained 34% of the variation. The model did not differ from Lee et al.'s (1995) model (t-test: constant $t=0.98$ and slope $t=1.13$, $df=63$, $p>0.1$ in both cases). The two models are shown in Table 4.

Lee et al.'s (1995) analysis procedure for developing the tiller weight recovery criteria of the index was repeated for the test data set. Seven of 16 sites made it into the recovery group (Figure 1) using the statistical requirement of Lee et al. (1995), i.e. sites with sufficient recovery were those that (a) had tiller weights greater than the

TABLE 4. LINEAR REGRESSION MODELS FOR THE TWO DATA SETS, THE ONE THAT WAS USED WHEN THE INDEX WAS DEVELOPED (LEE et al. 1995; n=49) AND THE TEST DATA (n=16). FOR A COMPARISON OF THE TWO MODELS SEE THE TEXT.

| | INDEX DEVELOPMENT DATA | | | TEST DATA | | |
|---|---|---|---|---|---|---|
| | COEFFICIENT | SE | P (2 TAIL) | COEFFICIENT | SE | P (2 TAIL) |
| constant (intercept) | 22.09 | 1.489 | 0.000 | 18.61 | 3.222 | 0.000 |
| ln tiller weight (slope) | 17.15 | 2.209 | 0.000 | 11.77 | 4.429 | 0.019 |




A. B.

Figure 1. Tiller weight plotted against time since last fire (n=16). A. The linear relationship between tiller weight and time. B. log fit curve showing the relationship between the two variables.

upper limit of the 95% confidence if they had been burnt in the last two decades or (b) had tiller weight greater than the mean if it was longer since they had been burnt. These seven sites were numbered 3, 8, 10, 11, 13, 14 and 17 (Figure 1). Tussocks at two of these seven sites did not pass the index, at site 3 due to the cover value, and site 10 because one of the 10 tussocks did not have a tiller longer than 0.6 m (Table 3). On the other hand, two sites where values passed the index (sites 5 and 15) were not in the recovery group, both being burnt over forty years ago. Thus there was some inconsistency between the data sets, probably due to larger variance in the test data than the initial data set. The lower confidence limit which was used to determine the threshold value of the tiller weight for the index was 1.3 g for the test data, a little higher than when the index was developed (i.e. 1.2 g, Lee et al. 1995)). The lower confidence value for tiller length of the same group of sites (n=7) was 0.7 m and the cover value was 67%. The former being higher than the threshold in the index (0.6 m) and the latter being lower (70% in the index).

# 4. Discussion

Development of an index such as the one discussed in this report is an important contribution to the management of tussock grasslands. For managers it is essential to have clear criteria on which to base their decisions, and in order to allow consistency over time and between areas. For the index to be useful it needs to be applicable in different conditions of geography and historical management. The RINST provides a tool by which to assess tussock conditions without needing to know the exact time the grassland was last burnt. This is beneficial, not least for the reason that frequency and the interval between fires affect regrowth (Mark 1965).

The work described in this report shows that the index will hold reasonably well at different geographical locations and that aspect did not affect the outcome. The relationship between tussock weight and years since last fire did not differ between the two data sets, implying that the relationship described in Lee et al. (1995) applies to wider conditions than examined within their study. However, because of larger variance in the test data, the threshold values for tiller weight and length were a little higher than in the original data. Although this may that indicate the index is too liberal, I believe that when the noise of the test data is taken into consideration the index values are acceptable.

Both data sets have a similar pattern when tiller weight is plotted against time since last fire (Figure 1 and Figure 4 in Lee et al. 1995). As the figures show, the increase in tiller weight is greatest over the first two decades and after that the growth appears to slow down. Similar recovery times have also been shown in other studies (e.g. Payton et al. 1986; Gitay et al. 1992). The good fit of the logarithmic curve for both data sets suggests that a non-linear model may be more appropriate than a linear relationship. After fitting such a model, a threshold value could be determined based on a fixed deviation from the asymptote. An alternative method of identifying threshold values would be to use sites that had not been burnt for the last 20 years as a benchmark. The justification for this would be the consistency in many studies that tussocks grow fastest during the first two decades after being burnt (Payton et al. 1986; Gitay et al. 1992; Lee et al. 1995). The sites in the test data that had not been burnt for at least two decades were used to find the lower limits of the standard error of the mean of tiller weight and length. This resulted in 1.0 g and 0.6 m for tiller weight and length respectively, giving more liberal values than the other method.

The index justifiably focuses on narrow-leaved snow tussock, which is the dominant species of these grasslands. Many variables (e.g. bare ground) that may be of concern are likely to be related to the tussock variables in such a way that they would be detected indirectly through the index. In future, the relationship between the tussock variables as identified in the RINST and other variables that may be of concern, e.g. *Hieracium* spp. and the native component of the vegetation, could be studied to strengthen the use of the index.

Lee et al. (1995) emphasised that the RINST had been developed for narrow-leaved snow tussock only. The results obtained here from the three hybrids sites support this, i.e. that its use should be restricted to *Chionochloa rigida*. Establishment of the relationship between the different tussock species to the variables used in the index may enable the index to be more widely applied. Currently, the index should only be used on narrow-leaved snow tussocks.

The work involved in measuring tussocks to derive the recovery index is straightforward and should be easily manageable by any conservation officer or field manager. Of the three components of the index, two can be completed in the field, i.e. tussock cover and tiller length. If these values do not pass the threshold values for the index, time could be saved as there would be no need to collect and dry tillers, and obtain their weights.

In conclusion, the index is a useful and easy-to-use tool for managers to assess recovery of narrow-leaved snow tussocks. It appears to be applicable to a wider geographical area than that where it was initially developed.

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