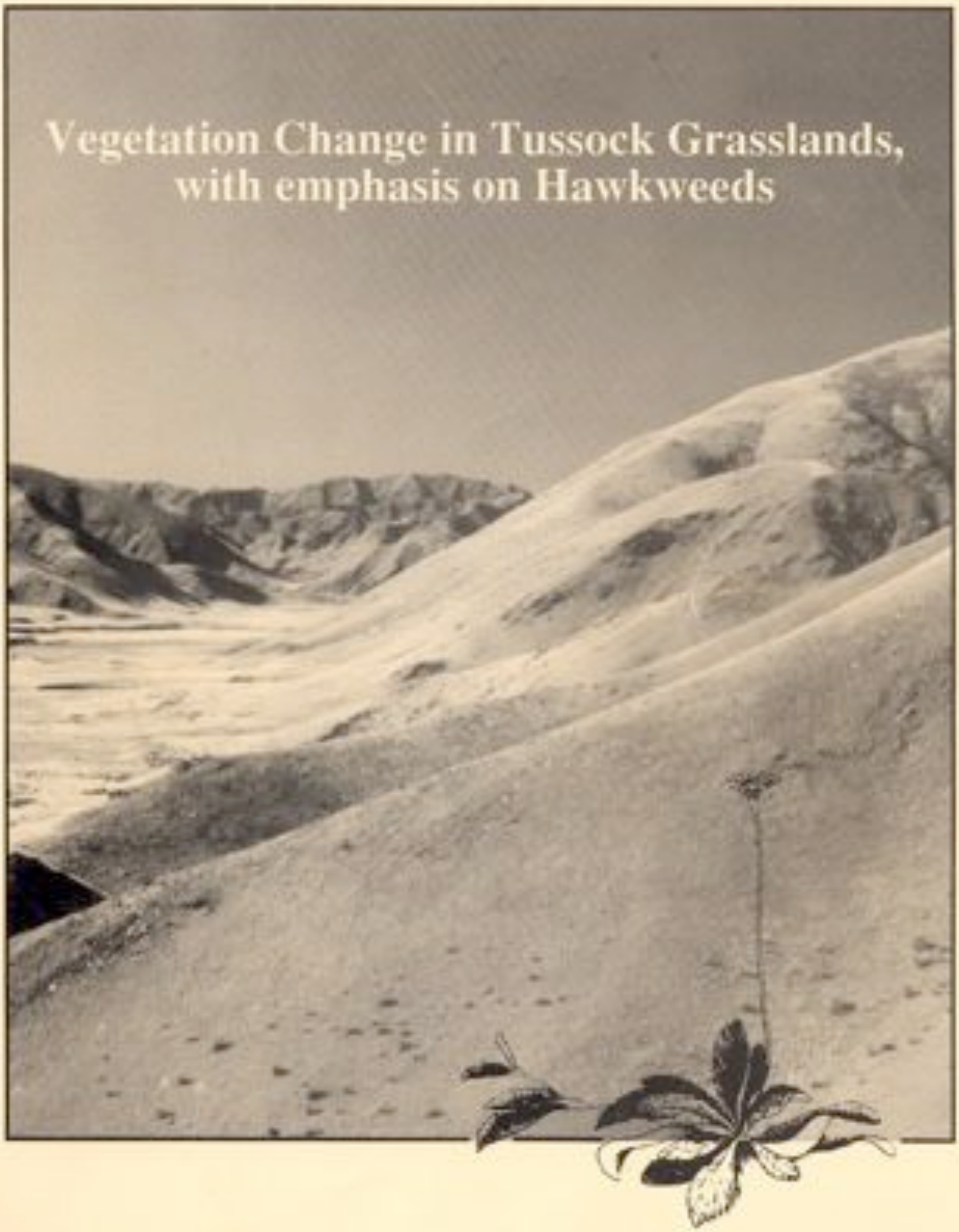
Vegetation Change in Tussock Grasslands, with emphasis on Hawkweeds



New Zealand Ecological Society Occasional Publication No. 2 1992

Electronic edition, 2005

This is the electronic edition of the 1992 publication of the same name. Both are published by the New Zealand Ecological Society, Inc. (http://www.nzes.org.nz). The electronic edition is a computer read then human proof-read reconstruction of the 1992 edition. The content of the 1992 publication has not been revised or updated.

The electronic conversion of this document was funded in part by the New Zealand Government's Terrestrial and Freshwater Biodiversity Information System (TFBIS). As a TFBIS project, the following conditions apply.

The electronic reconstruction of this document was made by Jon Sullivan, Chris Berry, and Lora Peacock (Lincoln University, Canterbury, New Zealand).

VEGETATION CHANGE IN TUSSOCK GRASSLANDS,

WITH EMPHASIS ON HAWKWEEDS

Record of a workshop
of the New Zealand Ecological Society,
Cass Field Station, Canterbury,
3-6 October 1991.

Edited by
G.G. Hunter, C.R. Mason and D.M. Robertson

New Zealand Ecological Society
Occasional Publication No.2
1992

ISSN 0114-8028

ISBN 0-9597949-2-1

Published by:
The New Zealand Ecological Society (Inc.)
P O Box 25178
Christchurch, New Zealand

First published 1992

Suggested reference to articles in this volume:

Author, 1992: Article title. *In,* Hunter, G.G.; C.R. Mason; D.M. Robertson (Editors), *Vegetation change in tussock grasslands, with emphasis on hawkweeds,* pp. xx-zz. Occasional Publication No.2, New Zealand Ecological Society, Christchurch.

CONTENTS

[1] *Paper not presented at workshop*

Session Three: Case studies from plant introduction, agronomic and grazing trials

Session Four: Development of simple models relating hawkweed performance to environmental and management conditions

[1] *Paper not presented at workshop*

PREFACE

Hawkweeds (*Hieracium* spp.) are associated with a widely-acknowledged concern about degradation of tussock grasslands in the South Island. Resource managers, affected communities and scientists share concern for the future sustainability of tussock grassland based production and conservation systems.

In 1990 a series of workshops and committees, convened by New Zealand Mountain Lands Institute, considered implications of the 'hawkweed problem' to land management and made recommendations for action. A clear outcome from these deliberations was that the status of hawkweeds was not widely understood in terms of the underlying interactions between vegetation, environment and management.

It was recognised, however, that the findings of a substantial pool of research effort relating to these grasslands, when integrated in a 'hawkweed context', would increase our understanding and provide a more objective basis on which to evaluate the status of the grasslands and hence to formulate management strategies. .

Accordingly, in October 1991, the New Zealand Ecological Society convened a workshop to bring together people with key scientific information and understanding of hill and high country tussock grassland ecosystems to provide this integration. Participants included scientists and resource managers from Department of Conservation, DSIR, Forest Research Institute, High Country Section of Federated Farmers, Land Corporation Ltd., MAFTech, regional councils, Mountain Lands Institute and universities.

Various scenarios regarding the role of hawkweeds have been put forward; the aggressive invader, the stress-tolerant indicator of long-term ecosystem decline, and the opportunist responding to shorter-term disturbances or stresses such as those related to climatic fluctuation (e.g., drought) and management effects (e.g., grazing). The challenge for this workshop was to critically evaluate available evidence and to advance best-bet explanations for the tussock grasslands change phenomenon. The measure of a successful workshop was seen as "what does available information tell us about what is happening in the tussock grasslands", rather than simply "what information do we have?"

Aims of the workshop were:

- To consider quantitative information on condition and trends in vegetation composition and cover in tussock grasslands, especially those containing hawkweeds.
- To develop, as far as possible, simple models of trends in tussock grasslands, with emphasis on causes of change and the role of hawkweeds.
- To improve understanding of the ecology of hawkweeds in tussock grasslands.
- To identify future research requirements.
- To identify management implications, from an ecological perspective.

The initial papers at the workshop set the scene by outlining plant sociological issues in the tussock grasslands. The biology of mouse-ear hawkweed (*Hieracium pilosella*) was reviewed. Case-studies set out the evidence of vegetation change and vegetation-environment-management relationships in tussock grasslands from ecological investigations, grassland monitoring programmes, plant introduction and management trials, and from investigations of grazing animal-vegetation interactions. The working groups were structured to integrate this evidence and to clarify current understanding. Emphasis was placed on reaching consensus on the processes of change where possible, and on the identification of areas of disagreement and on areas for which insufficient information is available.

The working groups also developed a broad schedule of priorities for research requirements for tussock grasslands.

The workshop recognised that timely and appropriate reporting from the workshop would include: a summary of the main findings for media release, a record of the material presented together with the associated discussions and working group reports, and specific submissions to appropriate agencies and Ministers of Government.

Contributors were encouraged to present even interim results, and to be speculative rather than conservative with their interpretations. Consequently interpretations in this record may be modified as more information becomes available, and as results are more fully evaluated within the wider body of evidence.

A feature of the workshop was the high level of cohesion and mutual understanding developed by the participants who were drawn from diverse production and conservation systems perspectives. We wish to record the willingness of the scientific and resource management community to contribute to this workshop. We believe that this attitude reflects their level of concern on this issue and their commitment to contributing to solutions.

We thank Barney Foran, Kath Dickinson and Alan Mark for directing the workshop sessions which integrated our understanding and for crystallising the outcomes of the workshop. We also thank Diana Robertson (Land Corporation Ltd.) and Graham Hickling and John Hunt (Forest Research Institute) for their contribution to the smooth running of the workshop.

Caroline Mason, Grant Hunter & Chris Kerr
Workshop Convenors

EDITORS' NOTE

This publication provides a record of papers presented at the workshop. Some papers are produced in full, while others have been summarised, and may be subsequently reported in full in formal scientific publications. Three papers were circulated but not verbally presented at the workshop. Discussions following presentation of the papers (sessions 1-3), and a summary of the workshop sessions on development of simple models (session 4) are reported. While every attempt has been made to accurately and fairly reflect discussions and conclusions arising from the workshop, we recognise the potential, and accept responsibility, for any misinterpretation and *I* or over-simplification of comments.

The report from session 4 also includes recommendations for future research requirements that arose from the workshop, and which have been circulated to workshop participants, appropriate Ministers of Government and agencies.

Many people have contributed to the production of this publication. We would particularly like to thank David Scott, Alan Mark, Kath Dickinson, Alan Rose, Pat Garden, Barney Foran and Chris Kerr for comments. Facilities for editing and page layout were kindly provided by Land Corporation Ltd.

Grant Hunter, Caroline Mason & Di Robertson
Editors

LIST OF PARTICIPANTS

Dr Bruce Allan[1]	MAFTech
Dr Ralph Allen[2]	DSIR Land Resources
Dr Les Basher[2]	DSIR Land Resources
Dr Peter Clinton[3]	FRI (Forest & Wildlands)
Ms Joy Comrie	Department of Conservation
Dr Gordon Cossens	MAFTech
Dr Nilo Covacevich	Chilean Government, Lincoln University
Mr Jeromy Cuff	Canterbury Regional Council
Dr Gavin Daly	Lincoln University
Dr Kath Dickinson	Victoria University of Wellington
Mr Kevin Duggan	Otago Regional Council
Dr Peter Espie	FRI (Forest & Wildlands)
Mr Barney Foran[2]	MAFTech
Mr Pat Garden	High Country Section, Federated Farmers
Mr Neil Harris	Otago University
Mr Grant Hunter[2]	DSIR Land Resources
Mr Tim Jenkins	DSIR Grasslands
Mr Chris Kerr	Mountain Lands Institute
Prof Alan Mark	Otago University
Ms Caroline Mason	Land Corporation Ltd.
Dr Colin Meurk[2]	DSIR Land Resources
Mr Jon Moen	University of Umea, Sweden
Mr Phil Murray	Land Corporation Ltd.
Mr Alan Nordmeyer[3]	FRI (Forest & Wildlands)
Prof Kevin O'Connor	Centre for Resource Management, Lincoln University
Mr Tony Perret	Department of Conservation
Mr Alan Rose[2]	Forest Research Institute (Forest & Wildlands)
Dr David Scott[1]	DSIR Grasslands
Mr Ron Sutherland	Nelson/Marlborough Regional Council
Ms Kristin Svavarsdottir	Plant Science Dept. Lincoln University
Dr Marta Treskonova	Centre for Resource Management, Lincoln University
Dr Morgan Williams	MAFTech
Dr Peter Williams[2]	DSIR Land Resources
Dr Barrie Wills[2]	DSIR Fruit & Trees
Mr Hugh Wilson	Freelance Botanist, Research Associate, DSIR Land Resources

[1] *NZ Pastoral Agriculture Research Institute Ltd (as of 1/7/92)*
[2] *Landcare Research New Zealand Ltd - Manaaki Whenua (as of 1/7/92)*
[3] *NZ Forest Research Institute (as of 1/7/92)*

SESSION ONE

PLANT SOCIOLOGICAL ISSUES

CONCEPTS AND METHODS IN ASSESSING VEGETATION TRENDS

D. Scott
NZ Pastoral Agriculture Research Institute Ltd.
P. O. Box 60, Lincoln, CANTERBURY

Summary
With the emphasis on vegetation as an indicator of ecosystem condition, a brief review is made of the concepts and methods used for vegetation assessment used by different groups, and the consequent assumptions they make in assessing the present trends of hawkweed species in New Zealand high country.

Introduction
It is often said that ecology is more a way of looking at things than an exact science. At the start of this symposium on hawkweeds *(Hieracium* spp.), it may be as well to have a quick look at the way different people view vegetation and its trends. Note the tenor of this opening comment. The most important paper at the recent International Rangeland Conference emphasized that there is probably no real world, only different people's perception of it, and the ideas and concepts that they use to try and share that experience (Russel and lson 1991).

Vegetation, environment and time
Using the theme of hawkweeds, there are at least three initial components or concepts - vegetation, environment and time. It is relatively well ingrained in the psyche of people at this meeting that vegetation is a good measure of the status or condition of a particular ecosystem, and I only need to point to the widespread habit in New Zealand of including vegetation surveys as part of land capability and other resource surveys. Here, and throughout the paper, these approaches and concepts will be given in their more extreme form to make the point that people do have different perceptions.

New Zealand probably inherited its emphasis on vegetation from USA rangeland and European phytosociology ethos. We have embraced it so well as a measure of ecosystem condition that I am going to assume its relevance for the rest of the paper in considering different concepts of vegetation. But there are many other ways of looking at ecosystem condition ego economic, landscape values, and natural conservation values.

In looking at landscapes or ecosystems our objective is to understand the vegetation changes in terms of environmental changes over time. The presumed intention is that we may be able to intervene to change the direction to some state considered more desirable. In such discussions it should be recognised that most attitudes are of the 'seat of the pants', 'wise men', or 'accumulated experience' type, with detailed measurement and analysis using the particular concepts often only secondary. In particular the treatment of the three components is very uneven. The major emphasis is given to the description of vegetation as it is at one point in time. Much less emphasis is given to the description of the environmental factors in any precise or detailed manner, and most of the measures used, come from extrapolation from some distant source. There are relatively few studies which measure either vegetation or environment over time, and almost none that measure both. Such lack of factual data means that discussion is very much influenced by the conceptual and analytical approaches used, and hence the need to briefly examine them. To keep the discussion relevant, a hypothetical site will be used which in its present state could either be beech forest, short tussock grassland, hawkweed mat, vegetation characteristic of bare soil, or a developed fertilised pasture.

Climate climax
The prevailing concept in North America is the climax concept of Clements (Weaver and Clements 1938) which sees vegetation developing towards the highest type that can be supported by the climate of the area. That climax is seen as a desirable state with range or ecosystem condition being measured by how close the particular vegetation is to the climax (Fig 1). There is a continuum of the intermediate states, either determined by insufficient time to reach the climax, or the presence of disturbance factors like

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.

grazing or fire. Associated concepts have developed like 'decreasers', 'increasers', and 'invaders' to describe the behaviour of vegetation components, and for identification of 'indicator' species and 'range condition'. This concept sees ecosystem condition as being defined by reference to the climax of the site, which may have to be extrapolated from geographic considerations. The climate is also seen to be stable over millennia. This concept had difficulty in accommodating subsequent work which indicated that American rangelands were as much determined by past grazing or fires as climate.

These concepts are moderately prevalent in New Zealand but probably never applied in their extreme form. The difference probably relates to the earlier recognition in New Zealand that vegetation is very dynamic, that environment varies greatly over short distance and time, and for tussock grasslands many of the dominant species are not agricultural species. In our hypothetical example, the short tussock, hawkweeds and bare ground communities would be seen as successively poorer 'range conditions' from the climax beech forest. In applying the concept, all the possible vegetation communities on a particular type of site would have to be arranged in a single continuum which would then define 'range condition'. Environmental factors and time would be an explanation of the sequence but not an integral part of the concept. The concept would have difficulty in accommodating improved pasture, unless it was seen as an earlier stage of some hypothetical fertilised forest.

Ball and cup

A recent development of the climax concept incorporates the observation that some vegetation communities in a supposed continuum of types are very stable, and if disturbed will tend to return to that type rather than another (Laycock 1991). In this, the even slide of the climax concept (where the actual position is seen as an equilibrium between competing forces as the climate factors drive the vegetation towards the climax and the competing disturbing factors drive it away), is replaced by a switch back in which there are depressions in which a vegetation will tend to stay until there is some major change to shift the vegetation over the hill into the next depression (Fig 1). I believe this concept has good support from the observed log *l* linear relationship between abundance and rank of species in a vegetation which results in species tending to form themselves into communities of relatively fixed composition across gradients of environmental factors or time. The other climax concepts and limitations probably translate across to the ball and cup concept.

The concept has not been used in New Zealand yet, though it does raise the possibility that hawkweeds may be a stable state, even if not desirable. The concept would have difficulty accommodating the improved pasture option along with other vegetation types.

Transition state

Partly to overcome limitations found in the previous concept, Laycock (1991) has made a further suggestion that the 'ball and cup' should not be seen as a single sequence but a range of associated hills and depressions where movement between depressions depends on particular combinations of environmental factors. The analysis technique of transition matrices would have particular relevance to this concept.

This concept could accommodate all the types in the example - the conversion of beech forest to short tussock due to the environmental combination of Polynesian fire and low intensity grazing, short tussock to improved pasture by fertiliser and species introduction, and hawkweed to bare ground by continued nutrient degradation, drought and grazing. The attraction of this approach is the inclusion of environmental factors to explain particular changes. The rate of change or time scale does not form part of these concepts.

Synusia

The dominant concept in early European ecology was to see landscape as a series of distinct vegetation types, synusia or associations, based on floral composition, each of constant composition. A synusia was conceived as tending to act as a unique organism at a hierarchical level above that of their constituent species (Braun-Blanquet 1932). Variation between samples or 'rei eves' of the same 'synusia' were probably regarded as experimental error even if they were initially used to help define them. Each synusia is regarded as unique and much effort is given to identifying unique or 'indicator' species as compared with those that are present in several communities. This concept has difficulty with ecotones. The unique organismic view of the synusia also implies that they could be defined by vegetation characteristic alone, and that environmental factors were descriptive rather than explanatory variables. There was also an implication that these synusia were stable over long periods so time trends were not important. Their uniqueness also implied that the relationship between them was not an important consideration.

Gradient analysis

The second concept originating from North America is based on the recognition of the close relationship between species and environment (for species Gleason 1917, Hanson 1958, and for vegetation Whittaker 1952, 1956). This concept sees the landscape as the response of individual species to individual environmental factors, with the particular vegetation being the sum of the response of the species that make up that vegetation. The implication is that there could be infinite environmental factors and gradients to consider and an infinite variation in vegetation composition. However the concept becomes practical where one or a few environmental factors dominate a particular situation (Fig 1). To accommodate situations where the vegetation is of different types, the species importance is generally given in relative rather than absolute terms. In this concept a vegetation type is seen as being a particular position on some environmental scalar rather than a value judgement of its condition relative to some desirable state. The gradients used can be those appropriate to the particular situation and need not have any universality. The gradient could be time as well as environmental factors.

The concept is moderately prevalent in New Zealand and may even have independently developed here from the early recognition of the relationship between soils; vegetation and environment because of our very steep Climate gradients. The attraction of the concept is the combination of both environmental and vegetation considerations. The hypothetical example could see beech forest, short tussock, hawkweed and bare ground communities as all part of some degradation gradient. The difficulty is to define the gradients in some objective way, or to include other gradients like fertility, to take account of the pasture option, or to include time so that the trends or rate of changes can be considered. There is also the need to include value judgement of what is desirable so that 'vegetation condition' can be assessed.

Environmental factorisation

While recognising the importance of plant / environment interactions there is a multitude of potential plant species and a multitude of potential environmental factors. This has led to the attempt to see plant species or environmental factors in terms of fewer attributes that may have a degree of universality. There is almost universal recognition that the environment must supply the light, temperature, water and nutrients required for plant growth and that species will differ in their ability to compete for these in particular situations.

One approach was to change Jenny's soil concept to an emphasis on vegetation (Major 1951), ie. that vegetation was a function of the general factors of rock parent material, soils, climate and time. It included the useful concept that to study the effect of one of the factors it was necessary to select or design situations where the other factors were constant.

C-S-R plant strategy

Grime in the UK has developed concepts which sees the environmental factors which affect vegetation in two broad categories with the species and vegetation response to these as three contrasting evolutionary strategies. These concepts are best explained by direct paraphrasing from Grime *et al.*(1989).

The first category (called 'stress' factors), consist of environmental factors which restrict production, such as shortage of light, water, mineral nutrient or suboptimal temperatures. The second category (referred to as 'disturbance~ factors) are factors associated with partial or total destruction of plant biomass from herbivores, pathogens, cultivation, drought, frosting, flooding, fire etc.. When the four permutations of high or low stress and high or low disturbance are examined it is apparent that only three are viable plant habitats. The extremes are 'competitors' exploiting conditions of low stress and low disturbance, the 'stress tolerators' associated with high stress and low disturbance, and the 'ruderals' characteristic of low stress and high disturbance. There are other combinations of plant characters suited to exploiting various intermediate conditions corresponding to particular equilibria between stress, disturbance and competition factors in the environment. These can be displayed in a triangular ordination diagram, which can also be used to indicate the strategic range of various life forms (Fig 1). The C-S-R model proposes that the vegetation which develops in a particular place and at a particular time is the result of an equilibrium which is established between the intensities of stress (constraints on production), disturbance (physical damage to the vegetation) and competition (the attempt by neighbouring species to capture the same unit resource).

The thesis of the concept is that there has been evolutionary specialisation in different taxa towards similar physiological and morphological characters in the three different modes of plant response. Species suitable for competitive environments favour genotypes in which high morphological plasticity facilitates escape from resource depletion zones, in order to sustain resource capture and maintain reproductive fitness. In stress environments, both survival and reproduction depend crucially upon the capacity of the plant to remain viable through long periods during which little growth occurs. This may confer selective advantages upon species which uncouple growth from resource intake. In disturbance environments, selection is likely to favour those genotypes in which rapid growth and early reproduction increase the probability that sufficient offspring will be produced, mostly in a dormant stage like seed, to allow the survival and re-establishment of the population.

Environmental gradients

Another concept, principally developed to accommodate the range of both natural and modified (oversown and fertilised) New Zealand tussock grasslands, gives emphasis to the plant / environment interactions and sees them in terms of four composite factors (Scott 1979). These are temperature, moisture, soil fertility, and a fourth related to the interaction of growing points and animal management. The concept is akin to the other species gradient concepts. It has no time component and would have difficulty accommodating disturbance or stress factors.

In the hypothetical example, this concept would see beech forest, short tussock and the bare ground communities as being three different environments differing in moisture regime, and would have difficulty if they were time phases on the same site. The example might also suggest that hawkweed is a moderate fertility phase of the others. It easily accommodates improved pasture as being a high fertility phase.

Physiological modelling

The alternative to trying to condense plant responses and/or environment into a few universal factors is to go the other way using the power of modern computers to model all the components in terms of their known complexity. The attraction is that it can potentially synthesize all the known interactions, either determined directly, or from extrapolation from other studies. The other main attraction is that it can simulate the dynamics of processes and hence give a time frame of potential changes. An example of this is White's (1984) transcription of the USA prairie biome programme to the New Zealand tussock grassland situation.

To date this approach has not lived up to expectation (Hansen *et al1985).* In my view this is because of the complexity of detail, with different emphasis in different research groups, with only a few people knowing the full details of any particular model. Probably the main limitation has been because the details are not available for most real life range land problems. The degree to which parameters have to be estimated or 'guessed at' does not engender confidence among those not directly involved in the model. It would be doubtful if there were enough base data to attempt this approach for the examples given.

Probably more progress could be made if models were only used to do preliminary estimates of the 'what in' type questions. Thus the trend has been towards simpler models of the 'expert' type which are different from the concept of physiological models as used here. As has been remarked, it seems we may have become involved with large complex systems, but have not learned to use some of the universal properties of complex systems ego for vegetation, the possible universal application of the 3/2 thinning law or the log / linear relationship between abundance and rank.

In the subsequent sections of the paper the emphasis is as much on techniques as the concepts they imply.

Cluster analysis
For vegetation, this is a general term for analytical techniques which attempt to group samples of field data into like kinds (Fig 2). There can be considerable debate about whether there are real groups in which variability in field data can be regarded as experimental error, or whether clustering is just a utilitarian grouping of a continuum for the purpose of showing relationships or summary. A wide variety of techniques have been developed for this purpose applicable to nominal, ordinal and quantitative vegetation data.

However clustering only looks at vegetation in one time frame and implies nothing about its dynamic or environmental relationships, though these may be appended as descriptive information. Thus in the present context, cluster analysis methods may only serve as a prelude to further analysis.

Component analysis
If the concept of vegetation is as a continuum and if the vegetation data are quantitative, then alternative concepts and analytical techniques are to seek the major trends between two classes of data. Principal component and factor analysis are two such statistical techniques, and there has been development of several non statistical techniques within plant ecology.

These methods make no prior assumption as to what the trend may be, and leave the data to speak for themselves. This can be regarded as a fault or virtue depending on whether the observer has a prior concept as to what the trends are. The techniques only work well for unimodal species data and have difficulty with multi-modal species data or multi-species in different domains. Like cluster analysis, component analysis only deals with vegetation in one time frame without reference to time or environment, and would only be useful,as a prelude to other analyses. As the diagram indicates, there are many similarities between cluster and component analysis, especially if one regards the clustering tree as a 'mobile' which can be variously rotated in space to correspond with the component diagram.

Correspondence analysis
One method of considering vegetation / environment interactions is by doing component like analyses separately on both the vegetation and environmental factors and to then superimpose them and note their correspondence. Canonical correlations and twinspan analysis are two such analysis methods. These, and similar techniques, are probably just more sophisticated approaches to the 'eye balling' or 'seat of pants' approach implied when environmental descriptors are added to vegetation data.

Transition matrix
One method of considering vegetation / time interaction is that of transition matrix or life table analysis. In this, vegetation data from permanent quadrats monitored at regular intervals is first classified into nominal vegetation types, and then into tables giving the empirical probabilities of a particular vegetation type changing to another within a certain time period (Van Hulst 1989). In the hypothetical example, hawkweed dominated quadrats have an 80 % chance of remaining hawkweed dominant for one year, 12 % chance of changing to bare ground types, 6 % to pasture, 1.9 % to short tussock, and 0.1 % to beech forest. Actual tussock grassland examples are given in Scott *et al* (1990). The main features of the matrix can also be shown in diagrammatic form.

The method is probably the most useful and powerful technique currently available for studying vegetation time trends. It depends on regular repeated measurement on permanent quadrats, and vegetation defined in qualitative terms. It does require a large database to get reliable estimates of probabilities. There can be some debate on whether there is an implied concept that dynamics of the vegetation are determined by the vegetation itself, or whether they represent a response to environmental changes. If the former, then environmental effects are essentially disregarded. If the latter, then the transition matrix needs to be developed for each set of environmental conditions, or the matrix derived from several years data, as being the general trend after year to year variation has been removed. The approach can be used for extrapolation. Application of the method to some developed and undeveloped tussock grasslands data has given the clear impression that vegetation adjusts to new environmental conditions much more rapidly than commonly supposed - usually within a decade.

Black box correlation

This tenn is introduced to cover the wide range of approaches that seek correlation between variables without implying, or being unable to clearly prove, causality. This applies to all of the vegetation *I* environment *I* time interactions. A good example is the wide spread use of altitude, aspect and slope descriptors to vegetation data — these are factors which *per se* have no physiological basis for effect on plants. Again as the example shows this is not to decry their usefulness - only that it must be realised that they are only correlations. The approach is justifiable if it works and gives realistic results, but must be dumped when a more mechanistic *I* physiological approach is available.

The concept, virtues and criticisms are more widespread than the simple example. It is inherent in most measurement of environmental factors appended to vegetation data, to most statistical analysis and many of the simpler, more robust models. There is seldom sufficient experimental justification or proof of the variables we choose to measure and probably most are in the category of 'it is well known that..'.

There may even be virtue in this approach in that it may allow extrapolation from a well based concept, or direct application of principles established in other situations. Also in the computer analysis or modelling sense it may allow application of 'unifonn subjectivity' across large data sets.

Regression analysis

Where species, vegetation, environment and time variables have been measured in quantitative terms, then multiple regression is the most common form of analysis for determining empirical quantitative relationships between the variables. If the requirement is only a quantitative empirical relationship of the 'black box' type, then there is considerable latitude in choice of variables, selection procedure for variables, curvilinear relationships, and determination of relative significance or importance of explanatory variables.

However, in light of the previous section, if the analysis is also intended to imply causal mechanistic / physiological relationships then much care is needed in the initial selection of variables, the transformation of these variables and the form of the assumed function. The commonly assumed linear additive relationship between vegetation and environmental variables is unlikely to reflect biological reality. Also, multiple regression is a two stage process (Fig 2), with the response or dependent variable on one group and the various independent or explanatory variables in the other; again unlikely to reflect biological reality.

There are a number of difficulties in dealing with time, of which only two will be mentioned at this stage. The first is that in the study of vegetation trends, one will invariably be trying to predict outside the range of the data. One would need to be very sure of the variables and the form of the function to make this extrapolation with any degree of certainty. A second difficulty is that the base of data usually come from repeated measurement of permanent quadrats which violates the statistical requirement of independence of samples.

Path analysis

The multi-stage interactions between variables characteristic of ecosystems is more realistically mimicked in the statistical technique of path analysis or simultaneous regression analysis. I have described this technique using New Zealand examples (Scott 1973, 1977). While the technique is conceptually useful in its diagrammatic form in showing the expected relationships between variables, it is seldom applicable in its statistical analytical form in that it requires simultaneous quantitative measurement of all variables of interest. The technique would have difficulty in dealing with time.

Time series analysis

It has been suggested that time trends in vegetation should be suited to the econometric statistical technique of time series analysis. The basic assumption in time series is that the response in the-current period is partly dependent on the response in the previous period (unlike regression analysis) as well as other cyclical or general trends and random effects. The analysis attempts to determine that magnitude of different components and make prediction about future values. Vegetation changes are likely to have the same features.

However there are some major limitations to the technique for analysing vegetation trends. The most likely is that it requires a series of at least thirty measurements, preferably at equal time intervals. Probably the most successful application of time series to vegetation data has been in tree ring research. There is also the concept in several of the aspects of time series analysis, that the behaviour is determined by intrinsic properties of the series, and not external factors, and would thus have difficulty in interpreting time trends in vegetation in terms of environmental factors.

Segment analysis

The final concept is my as yet unpublished analysis technique for determining time trends in vegetation data that are normally available. These data tend to be quantitative measurements from permanent quadrats at irregular time intervals; where there is marked variation between quadrats, where the response at each quadrat is reasonably well defined, and the time scale of the measurements is short (relative to the total vegetation change). It is suggested that these small changes within individual quadrats can be conceived as being possible segments of a much longer 'mean trend' and the only requirement is to place them in their correct sequence. It was found that a scattergram of the mean and gradient of these individual segments formed a distinctive pattern according to the likely long term pattern and could be used to show that pattern. In an example from the long term Waimakariri data (Scott *et alI988),* segment analysis showed that once hawkweed appeared on a plot an exponential increase followed.

Discussion

This brief review paper has tried to make several points.

- Where factual information is limited, as in the role of hawkweed in New Zealand tussock grasslands, decisions are going to be swayed by concepts. Therefore there is a clear need to examine these concepts and their background, and to be aware how much they influence our attitudes. You are reminded that each of the concepts was given in their more extreme form to illustrate the diversity.

- The objective is to determine the condition and trend of a particular group of ecosystems that make up the New Zealand tussock grasslands. My impression is that we do not have very good criteria for assessing condition, but that major emphasis is being given to the state of the vegetation.

- Using the above approach there are three main components — vegetation, environment and time. My impression is that we are reasonably well endowed with concepts and analysis techniques to describe variation in vegetation in a status quo, one off time frame. There are some concepts and analytical techniques for considering environmental factors and their correspondence with species or vegetation, however the clearest deficiency is in the treatment of the time concept. While it is almost universally recognised as being the dimension in which the interaction of the other two components must be seen, there is a lack of specific concepts and analysis techniques to include time.

- Finally while concepts may provide useful guidelines, they must only be a prelude to, and subservient to, detailed factual information on hawkweed and its dynamic, physiological interaction with other tussock grassland components.

Acknowledgements
To Mr. J. Poff for diagram preparation.

References

Braun-Blanquet, J. 1932. *Plant Sociology*. (translated by G.D. Fuller and H.S. Conard). McGraw Hill 439 pp.

Gleason, H.A. 1917. The structure and development of the plant association. *Bulletin of the Torrey Botanical Club* 43: 463481.

Grime, J.P.; Hodgson, J.G.; Hunt, R. 1989. *Comparative plant ecology — a functional approach to common British species*. Unwin Hyman, London 742 pp.

Hanson, J.D.; Parton, W.J.; Innis, G.S. 1985. Plant growth and production of grassland ecosystems: a comparison of modelling approaches. *Ecological Modelling* 29: 131–144.

Hanson, H.C. 1958. Principles concerned in the formation and classification of communities. *Botanical Review* 24: 75126.

Laycock, W.A. 1991. Stable states and threshold of range condition on North American rangelands - A viewpoint. *Journal of Range Management* 44: 427–433.

Major, J. 1951. A functional, factorial approach to plant ecology. *Ecology* 32: 392412.

Russel, D.B.; Ison, R.L. 1991 (in press). The research — development relationship in rangelands: An opportunity for contextual science. *IVth International Rangeland Congress.*

Scott, D. 1973. Path analysis: a statistical method suited to ecological data. *Proceedings of the New Zealand Ecological Society 20:* 79–95.

Scott, D. 1977. Plant ecology above timberline on Mt Ruapehu, North Island, New Zealand. I. Site factors and plant frequency; II. .Climate and monthly growth of five species. *New Zealand Journal of Botany* 15: 255–310.

Scott, D. 1979. Potential pasture production in the hill and high country. *Tussock. Grasslands and Mountain Lands Institute Special Publication No.* 16: 171–193.

Scott, D.; Dick, R.D.; Hunter, G.G. 1988. Changes in the tussock grasslands in the central Waimakariri River basin, Canterbury, New Zealand, 1947–1981. *New Zealand Journal of Botany* 26: 197–222.

Scott, D.; Robertson, J.S.; Archie, W.J. 1990. Plant dynamics of New Zealand tussock grassland infested with *Hieracium pilosella* II. Transition matrices of vegetation change. *Journal of Applied Ecology* 27: 235–241.

Van Hulst, R. 1989. On the dynamics of vegetation: Markov chains as models of succession. *Vegetatio 40:* 3–14.

Weaver, J.E.; Clements, F.E. 1938. *Plant ecology* (2nd edition) McGraw Hill, London 601 pp.

White, E.G. 1984. A multi species simulation model of grassland producers and consumers. *Ecological Modelling* 24: 241-–262.

Whittaker, R.H. 1952. A consideration of climax theory: the climax as a population and pattern. *Ecological Monographs* 23: 41–78.

Whittaker, R.H. 1956. Vegetation of the Great Smoky Mountains. *Ecological Monographs* 26: 1–80.

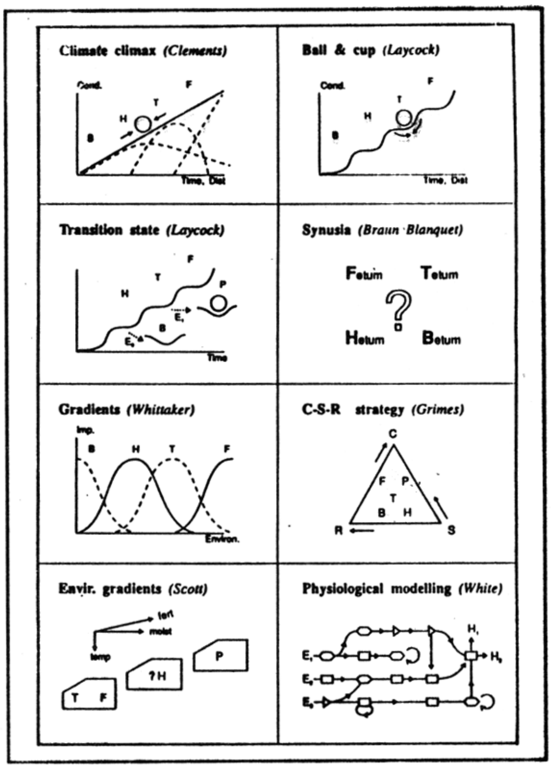


Figure 1: *Concepts in assessing ecosystem condition from vegetation characteristics. F=beech forest, T=short tussock, H=hawlcweed, B=species associated with bare ground, P=oversown developed pasture.*

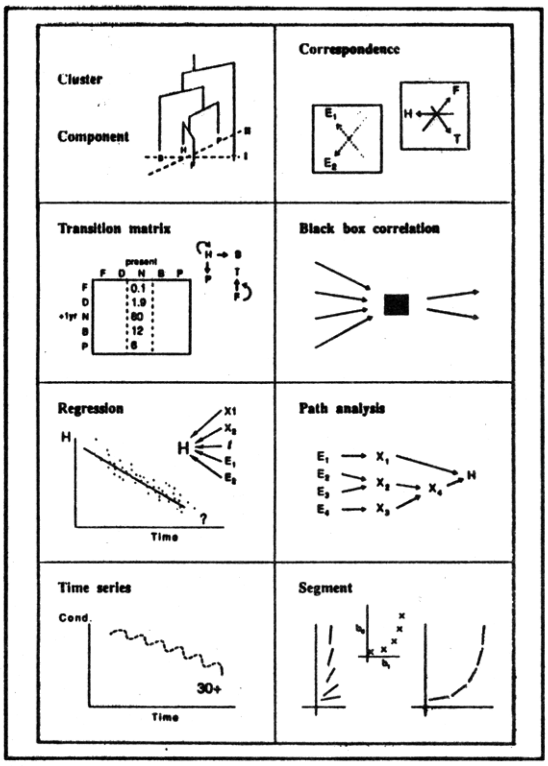


Figure 2: *Vegetation analysis techniques used in assessing ecosystem condition and trends.*

INCONSISTENCIES BETWEEN THE SCALE OF THE HAWKWEED *(HIERACIUM)* PROBLEM AND THE METHODS USED FOR INVESTIGATING IT.

Marta Treskonova
P. O. Box 56
Lincoln University, CANTERBURY

The problem of hawkweeds *(Hieracium* spp.) has reached ecosystem dimensions. It needs to be understood at an ecosystem scale. Usually, small scale empirical experiments have been used to investigate the large scale and complex problem of infestation by hawkweeds. Contemporary vegetation science offers an ecosystem approach with techniques which are able to detect causes underlying complex processes.

Depending on the approach used, aspects of the hawkweed problem can be interpreted in different ways. From a species-centred perspective, the distribution of hawkweeds appears to be chaotic. Patterns can only be recognised when observing the wider grassland ecosystem. Within a wider perspective the patterns of human-induced and natural disturbances, both of which facilitate distribution of species of hawkweeds, become clearer.

From a small scale experimental approach, hawkweed-dominated vegetation may appear to be a relatively stable stage. On a larger scale, considering grassland succession, hawkweed dominant stages are relatively short-term and unstable. Under the prevailing environmental and management conditions, hese stages are subject to further degradation.

Measurements in a permanent trial may appear to be the only reliable method to determine temporal relationships. However, the sequence of stages can only be established from ecosystem data, representing larger areas and longer time spans. It then becomes evident that a space for spread of hawkweeds has been pre-empted before hawkweeds occupy it.

Even detailed measurements of vegetation change on a small scale would be insufficient to determine the composition of grasslands which are resilient to invasion by hawkweeds. That determination needs to come from successional trends in grasslands in a variety of conditions.

Hawkweed species, from a non-ecosystem perspective, are unwanted alien plants. Within an ecosystem context they fulfil a role of soil conservation in depleted grasslands, as well as a role of initiation of natural revegetation. No satisfactory management decision can be made without understanding the role of hawkweeds in grassland ecosystems. Categorical proclaiming of hawkweeds as a pest, similar to rabbits, is misleading. Whereas rabbits and sheep are removing biomass, hawkweeds are restoring the damage at faster rate than indigenous species and current management is able to achieve.

An understanding of these complex relationships is essential if application of biological control of hawkweeds is to be considered.

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.

CHANGES IN GRAZED AND RETIRED FESCUE TUSSOCK GRASSLANDS, HARPER-AVOCA CATCHMENT, CANTERBURY, 1965 -1990

A.B. Rose[1], K.H. Platt, C. Frampton
Landcare Research New Zealand Ltd - Manaaki Whenua
P.O. Box 31-011, CHRISTCHURCH
[1]Present address: Marlborough Research Centre
Private Bag 1007, BLENHEIM

On permanent transects in the Harper-Avoca catchment, vegetation changes over the last 25 years indicate a widespread and continuing trend away from fescue tussock grassland towards vegetation dominated by exotic grasses and hawkweeds. This period was characterised by marked expansion of mouse-ear hawkweed *(Hieracium pilosella)*. tussock hawkweed *(H. lepidulum)* and browntop *(Agrostis capillaris),* with associated declines in hard tussock *(Festuca novae-zelandiae),* other native species, and previously abundant exotic species.

Such change was most advanced in the relatively dry lower-valleys (1200 - 1300 mm annual rainfall). However, a slow increase in exotic species further up-valley (1300 - 1500 mm) suggests this process is spreading. Fluctuations in spring-early summer rainfall did not appear to trigger periods of rapid hawkweed spread, but may be more important in drier areas.

On north-aspect, lower valley slopes the rate and extent of invasion by mouse-ear hawkweed was similar in grasslands still extensively grazed by sheep and in those retired from grazing in 1968. This may be interpreted as indicating that the two contrasting grazing histories had no influence on the susceptibility of the grasslands. It could equally be argued that by 1965 all lower-valley grasslands were predisposed by the effects of c. 100 years of extensive grazing. Although prolonged sheep-grazing appeared to predispose the tussock grasslands to early invasion by browntop and tussock hawkweed, these species are now also increasing in retired grasslands.

Exotic species are also becoming increasingly dominant on grazed and retired south-facing lower valley slopes, where the main hawkweed involved is tussock hawkweed.

Even in the absence of exotics, the grasslands would continue to change as woody vegetation and snow tussocks *(Chionochloa* spp.) invade.

The essentially seral, culturally induced fescue tussock grasslands are predisposed to ongoing vegetation change and eventual demise over much of their range. Researchers and land managers must:

- accept the inevitability of such decline in order to develop appropriate and sustainable goals for nature conservation or production
- apply appropriate management to achieve these goals
- monitor management outcomes to gauge their success
- be prepared to revise management goals as new information becomes available.

TIIE INFLUENCE OF GROUND COVER ON HAWKWEED ESTABLISHMENT IN FESCUE TUSSOCK GRASSLAND

P.R. Espie
Forest Research Institute
Present address: 29 *Woodford Tce, CHRISTCHURCH* 5

How ground cover affects hawkweed *(Hieracium* spp.) establishment in tussock grasslands is poorly understood, but has important implications for land management. This study investigated the influence of ground cover, site preparation and soil fertility on hawkweed establishment and flowering from 1982 to 1990.

The trial site is located in the mid-Waimakariri basin on a fluvioglacial outwash terrace with an infertile Craigiebum high-country yeIlow-brown earth soil. Vegetation is undeveloped fescue tussock grassland. Mean annual precipitation varies between 850 and 900 mm (Espie 1987).

Three site treatments; cultivation, oversowing after glyphosate herbicide pre-treatment, and oversowing alone were applied factoriaIly with three legumes; Maku lotus *(Lotus pedunculatus* cv. Maku), birdsfoot trefoil *(L. corniculatus* cv. Maitland), white clover *(Trifolium repens* cv. Huia). Two phosphate (P) levels (12.5 and 50.0 kg P/ha) were applied once at sowing. Calcium, magnesium, potassium, molybdenum, and sulphur were supplied as basal fertiliser. Control plots were undeveloped fescue tussock grassland. Plot size was 2 m^2 with five replicates per treatment in a randomised block design. Hawkweed percentage cover and flowering were measured in February 1990.

Mouse-ear hawkweed *(Hieracium pilosella)* was the only hawkweed present in the grasslands in 1982, occurring at low density (less than one plant per 64 m^2). By 1990 king devil *(H. praealtum)* and tussock hawkweed *(H. lepidulum)* had colonised by seed from populations outside the study area and hawkweed cover increased to 3%, almost entirely comprised of king devil. Establishment of mouse-ear establishment in the trial was minimal.

Establishment of king devil was greater in herbicide-treated grassland than in cultivated soil or intact grassland ($P<0.07$). Legumes and P had no significant effect on king devil cover or flowering.

There was a linear relationship between king devil rosette area and number of flowering culms ($P<0.0001$; R^2 0.985), biologically indicative of an early stage of population expansion and little density stress (Bishop and Davy 1985).

The implications for management are that seed is important in establishment of new hawkweed populations and that spring and early summer grazing may reduce hawkweed expansion rate by removing flowering culms and limiting seeding. King devil appears to establish better with some ground cover than on bare soil, so removing undeveloped grasslands from grazing is unlikely to prevent or decrease spread.

References

Bishop, G.F.; Davy, A.J. 1985. Density and the commitment of apical meristems to clonal growth and reproduction in *Hieracium pilosella. Oecologia 66*: 417-422.

Espie, P.R. 1987 (unpublished). *Edaphic ecology of Festuca novae-zelandiae, Lotus pedunculatus and Trifolium repens on Craigieburn high-country yellow-brown earth and related soils.* Ph.D. thesis, Lincoln College, University of Canterbury. 313 pp.

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in *tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.*

A REVIEW OF CHARACTERISTICS OF MOUSE-EAR HAWKWEED *(HIERACIUM PILOSELLA)*

T. A. Jenkins
c/o *David Scott, NZ Pastoral Agriculture Research Institute Ltd.*
P.O. Box 60, CHRISTCHURCH

Introduction

Mouse-ear hawkweed *(Hieracium pilosella* L.) is a weed of increasing abundance throughout the New Zealand high country, sometimes forming a continuous mat. This species is a problem weed in several countries, particularly in cool climates (Bingham, 1965; Hay and Ouellette, 1959; Healy, 1976; Stevens and Hughes, 1973). The species has ecological and physiological adaptations that allow it success over other species present, and this review outlines the literature on some of these adaptations.

Taxonomy

Hieracium is a large and complex genus. The genus comprises two subgenera, *Hieracium (sensu stricto)* containing several thousand species and *Pilosella* Hill containing 136 species originally confined to Europe. The *Hieracium* section prepared by Sell and West in the Flora Europaea (Tutin *et al.* 1976), lists 111 of the 136 species of subgenus *Pilosella* as originating from interspecific hybrids, 67 of these are widespread and 44 are limited in distribution. 33 of the hybrid origin species are noted as having *H. pilosella* as a possible ancestral parent. A revision was carried out suggesting that *Pilosella* be made a separate genus (see Makepeace, 1985a). Some New Zealand authors followed this suggestion for a period but a revision of NZ material prepared by Garnock-Jones (Webb *et al.,* 1988) kept *Pilosella* as a subgenus of *Hieracium*. The two subgenera are morphologically distinct. Species of the *Pilosella* subgenus produce stolons from a basal rosette, whereas species of the subgenus *Hieracium* are not stoloniferous.

There are five species of the subgenus *Pilosella* present in New Zealand including *H. aurantiacum, H. caespitosum, H. pilosella, H. praealtum,* and *H.* X *stoloniflorum*. There are five members of the *Hieracium* subgenus present, *H. argillaceum, H. lepidulum, H. murorum, H. pollichiae* and *H. sabaudum*.

Mouse-ear hawkweed is distinguished from the other species by having a single stemmed, leafless flower stalk bearing solitary capitula with yellow ligules. The leaves have stellate hairs on the underside forming a dense tomentum.

Mouse-ear hawkweed is likely to have been introduced into New Zealand as a contaminant of pasture seed or grain from the United Kingdom. Only three of the eight morphological subspecies described by Tutin *et al.* (1976) have been reported in New Zealand; ssp. *micradenium* (the most common), ssp. *pilosella* and ssp. *Trichosoma* (Webb *et al.,* 1988). Although Tutin *et al.*(1976) list only eight subspecies, Turesson (1972) identifies those eight plus seventy two other subspecies in Sweden alone. This demonstrates the difficulty encountered with the taxonomy of subspecies in such a partly apomictic species with a large variety of stable morphological forms. Garnock-Jones states that occasional New Zealand specimens approach other subspecies (Webb *et al.,* 1988). The subspecies are differentiated on the basis of the indumentum of the involucral bracts, which probably have no ecological significance. The subspecies are all found in a wide range of New Zealand high country regions.

Cytology and Chromosome Numbers

The diploid number of chromosomes for mouse-ear hawkweed is 18. The species bas been recorded with a wide range of ploidy levels including diploid (2x; 20= 18), 4x (20=36), 5x (2n=45), 6x (2n=54) and 7x (20=63) noted by Sell and West (1976). Gadella (1987) also records the presence of 8x (2n=72), 9x (2n=81) and decaploids (l0x ; 20=90). In a study of 31 New Zealand mouse-ear hawkweed populations, Makepeace (1981) found evidence only of pentaploid (2n=45) chromosome numbers. Makepeace found variation in forms of mouse-ear hawkweed populations that remained distinct in a transplant experiment. This is characteristic of the pentaploid chromosomal race (Turesson &

Turesson, 1960). No relationship however was found between ecological distribution and the morphological form. It is interesting to note that *H. pilosella* subsp. *pilosella* is not recorded by Sell and West (1976) as having a pentaploid form in Europe; they only describe the tetraploid form.

In Europe mouse-ear hawkweed is a well studied species (Turesson and Turesson, 1960, Turesson, 1972; Gadella, 1972, 1987). There is little relationship between cytology and morphological subspecies. Four of the eight subspecies described by Sell and West (1976) have two or more possible chromosome numbers recorded e.g subsp. *trichosoma* can be 2n=36,45,54 or 63. The three subspecies occurring in New Zealand have wide geographical distributions in Europe according to Sell and West (1976). *H. pilosella* subsp. *micradenium* is noted for presence in pastures and sandy ground through most of Europe, the subsp. *pilosella* is noted as mainly lowland throughout most of Europe, and the subsp. *trichosoma* is noted as mainly present in North and East Europe. However Gadella (1972, 1987) describes distribution according to sexual or apomictic biotypes and ploidy levels generally. Gadella *(loc cit)* states the pentaploids occur in Western, Eastern and Northern Europe and particularly in areas which were glaciated during the Pleistocene era. The pentaploids also occur in the montane and subalpine zone. Makepeace (1981) believed that this could explain why the New Zealand mouse-ear hawkweed grows so well in the high country rather than the lowlands. Grime *et al*. (1988) make the point that cytological and historical components are important for perspective of the autecology of a species.

Breeding Systems

Garnock-Jones (Webb *et al*. 1988) describes the subgenus *Pilosella* as being sexual or partly apomictic whereas the subgenus *Hieracium* is described as being mostly obligately apomictic. However the polyploidal race of mouse-ear hawkweed, such as is present in New Zealand, is reported to be usually facultatively apomictic (Turesson & Turesson, 1960; Gadella, 1972). Gadella (1987) states that pentaploid mouse-ear hawkweed plants mostly reproduce agamospermously (by apomixis). In fact Gadella stated that it was .highly probable that all seedlings of 5x plants are formed apomictically. (Gadella, 1987 p. 234). This was based on the findings that all seedlings had the same chromosome number as the mother plant even when potentially cross pollinated (no addition hybrids were found), and that approximately equal numbers of viable achenes were produced after both isolation and cross pollination (43.6% and 43.7% respectively). Some populations of New Zealand material of mouse-ear hawkweed and tussock hawkweed *(H. lepidulum)* have been confirmed as being apomictic. (R. Bicknell *-pers comm).*

If mouse-ear hawkweed is reproducing apomictically, then floral reproduction is simply another form of clonal reproduction, and the variability within a population is potentially very small. If apomixis is the sole or dominant form of seed production, then it does raise difficulties in explaining the present variability in subspecies and forms within New Zealand, and the suggestion that there may have been evolutionary adaption of the species to more suit the New Zealand environment. Either there have been multiple entry of different types into New Zealand, or there has been more sexual cross breeding occurring than would be indicated by the ploidy level and apomixis.

H. X stoloniflorum, a hybrid between *H. pilosella* and *H. aurantiacum,* is present in New Zealand. It is not known when the hybridisation occurred, whether in the Northern Hemisphere or locally. In New Zealand populations of *H. X stoloniflorum* are isolated from populations of *H. aurantiacum* indicating that the crossing is unlikely to have occurred in those areas.

Morphology

Mouse-ear hawkweed is a prostrate perennial herb with a rosette of small, setose, entire leaves and a single terminal shoot apex. Leaves are lanceolate, often less than 1000 mm^2 in area, lacking petioles and are usually appressed to the ground. Stomata are present on the top as well as on the underside of the leaves. Field observations in the Mackenzie country indicate that on average a new leaf is produced every two weeks in mid to late summer. The scape is erect and bears glandular hairs. Each leaf base has a single axillary bud which is initially dormant. Axillary buds can remain dormant for four years or longer. The axillary buds give rise to either flowers or stolons. Only after an inflorescence has been initiated, can stolons be produced from other axillary buds, even if the floral parts subsequently abort (Grime *et al.,* 1988; Makepeace, 1985a).

Stolons generally remain appressed to the ground and can be observed within surrounding vegetation. Stolons generally have the potential to produce a new daughter from the terminal bud. However stolons can branch in some cases from a bud at each leaf axis, with daughters potentially being formed at the end. of each branch. The stolons produce adventitious roots from root initials, located mostly at the nodes. Daughter rosettes are then formed, take root and can become functionally distinct with the breakdown of the stolon or the senescence of the mother plant (Grime *et al.,* 1988). The stolons root in about February after rainy periods and stolon elongation has stopped (Makepeace, 1985a). It is not known whether there is a direct metabolic link between daughter rosettes and parents which are still attached i.e. when the stolon is intact. Makepeace (1985a) said the transport of photosynthates, water and minerals would probably be negligible based on findings for other species. However I have observed in a glasshouse culture, that stolons may form rosettes which can proceed all the way to seed set without taking root. This indicates a some degree of translocation for distances of greater than 30cm.

Rosettes are monocarpic (semelparous), and therefore after the completion of flowering a rosette will die. If a new daughter rosette survives the winter Makepeace (1980) suggests it be defined as a new individual plant. Overwintering leaves are characteristically reddened. In the Mackenzie country (Scott, 1984) new leaves start appearing in August. Field observations indicate that over four leaves per rosette remain viable over winter. Initiation of inflorescences and stolons begins around November and scape development and flowering is evident 1 to 3 weeks later. The development of the inflorescence is more or less completed near ground level, and the scape development and actual flowering can occur within one day (Makepeace, 1985a). Seeds are fully ripened on the capitula around December to January and are wind dispersed usually within a few days.

Each flower produces approximately 20-40 seeds. Estimates from five contrasting sites give total seed production in the range of 30-1340 million per hectare (Makepeace 1985).

Mouse-ear hawkweed characteristically forms mats. In the centre of dense patches it is found that flowering, stolon formation and the general production of new daughters are reduced (Makepeace, 1980, 1985a; Bishop & Davy, 1985). This could be partly due to auto-inhibition through allelopathy which is discussed in a later section. However it is probably related to a lack of resources in the densely populated zone, Makepeace (1980) mentions the lack of phosphorous in particular. There is an observable gradient of flowering and stolon production from the centre of a patch to the edge, where activity is greatest.

In Table 1 a comparison of population dynamics between several different sites is given. Makepeace (1980, 1985a) found that five new rosettes resulted from stolon growth in one season in a dense mature mouse-ear hawkweed stand (Sawdon). This was only sufficient to offset the death of rosettes that senesced after flowering, and therefore there was no net increment for the year. This compares to a net increment of 64% in the Wolds site where mouse-ear hawkweed was rapidly colonising.

Mouse-ear hawkweed has been described in NZ as having a deep root system. However Grime *et al.* (1988) and Anderson (1927) in their description of the species in the UK, state that the root system is shallow. The UK authors suggest that the shallow root system is the reason why mouse-ear hawkweed patches can be seen to suffer from drought. Drought stress is apparent in New Zealand also (personal observation). Mouse-ear hawkweed is reported by Grime (pers. comm.) to have roots to the depth of 50cm. Thus the species has the potential to have deep roots if soil conditions permit. There are high numbers

Table 1: *Population dynamics of H. pilosella in five unfertilised high country sites of increasing rainfall in 1978/79 (Makepeace 1980, 1985a).*

Site	Ben Ohau	Ruataniwha	Wolds	Sawdon	Glentanner
Rainfall (mm)	475	600	675	800	1300
Soil	s+v	s+v	m	m	m
H. pilosella density	m	m	c	d	m
Plant flowering(%)	46	49	79	5	34
Abort (%)	3	2	27	3	1
Seedling estab.(%)		0.9	1.0		
New daughters(%)	68	102	173	5	53
Autumn mort. (%)	9	25	30	0	1
% survival	87	75	83	100	98
Net increment(%)	13	28	64	0	18
Half-life (years)	1.1	1.0	0.4	13.5	1.7

Soil: s= shallow; v= variable, m= moderate.
Density of *H. pilosella:* m= moderate; c= newly colonising; d= dense.
Plant flowering: individual plants which flower and subsequently die.
Abort: inflorescences which aborted before seed production.
New daughters: plants produced in mid summer.
Autumn mort.: mortality of new daughter plants in the autumn.
% survival: % of daughters surviving into autumn.
Net increment: nett change from late winter to autumn.
Half-life: = ln 2 / (10 n_2 - 10 n_1) [where n_1 = 100 and n_2 = l00-reproductive].

of wiry primary roots with relatively sparse lateral roots, which are apparently long lived. The roots generally have a very heavy vesicular-arbuscular mycorrhizal colonisation, which can increase seedling growth by 9 times (Grime *et al.* , 1988).

Although the form of mouse-ear hawkweed is generally appressed, the leaves can be held more upright by surrounding vegetation, according to Grime *et al.* (1988). However in experiments involving the shading of mouse-ear hawkweed with shade cloth in pots, there was very little effect on form, though leaf size was approximately doubled with 10% shade conditions compared to open light (Makepeace 1980).

Mouse-ear hawkweed may be relatively unusual in having a relatively fixed relationship between leaf position (numbered from apex) and dry weight of the leaf, over five sites (Makepeace 1980, 1985a). This contrasts with the considerable variability between these sites in the king devil hawkweed *(H. praealtum)* leaf dry weight relationship to leaf position.

Population Dynamics

Because rosettes are monocarpic, thus dying after setting seed, there can be a high turnover of rosettes within mouse-ear hawkweed populations. Table 1 (from Makepeace, 1985a) shows how this turnover is less in the dense established stands than the newly colonising patches. The Wolds site (newly colonising) showed 79 % flowering, and therefore death of rosettes, whereas the Sawdon site showed only 5 % flowering. The different sites also showed differences in new daughter production from stolons, with 5 new rosettes per 100 existing ones at Sawdon, and 173 new rosettes per 100 existing at Wolds. Overall there was a large difference in turnover between the five sites in Table 1, and there was a wide range of net increases of stolons from 0 at Sawdon, to 64 per 100 existing rosettes at Wolds.

Makepeace (1985a) (see Table 1) found that the half life of individual mouse-ear hawkweed plants varied from 0.4 years at Wolds to 13.5 years at Sawdon. Bishop and Davy (1984) found that the turnover of rosettes was less in the presence of rabbit grazing, mainly due to the removal of flower heads resulting in the longer life of rosettes. An older age structure was also noted in the rabbit grazed swards.

Establishment

Originally the spread of mouse-ear hawkweed into the New Zealand high country would have been by seed. However more recently the spread appears to be mainly by vegetative means i.e. stolon production. Makepeace (1985a) found that rosettes originating from seed accounted for only 1 % of total new rosettes in plots in the Mackenzie Country. Scott (1984) concluded that emphasis for control should be placed on the vegetative spread rather than floral reproduction. In the UK, mouse-ear hawkweed plants arising from seed are uncommon compared to plants arising from vegetative spread (Grime *et al.* 1988).

No persistent seed bank is evident for mouse-ear hawkweed either in the UK (Roberts 1986) or in New Zealand (Makepeace 1980), but Roberts (1986) stated that there can be a delay between dispersal and germination. Fungal contamination resulting in seedling death is common in laboratory studies.

Seedling establishment in the UK was found by Watt (1962) to occur mostly during a wet spring and more where grazing was limited. Makepeace (1985b) found that in the Mackenzie country seedling establishment was mostly in warm wet summers immediately following seed shed, the seed needing no post dispersa1 ripening. Seedlings that establish successfully, quickly reach adult size in 8 to 10 weeks (Makepeace, 1985b).

Table 2 shows the effect of temperature and osmotic stress levels on germination of mouse-ear hawkweed, as measured by Makepeace (1985b). At 2∞C no germination was evident. Optimum germination was at 22∞C, with regard both to the total number of germinated seeds, and to the number of days taken till 50% had germinated. At 32∞C, there was reduced germination. The level of osmotic stress had a profound effect on germination, with 85 % of seeds germinated in the moist conditions of 1 bar.

The removal of inflorescences prior to seed-set is reported to increase stolon activity and therefore

Table 2: The *effect of temperature and osmotic stress on the germination of mouse-ear hawkweed (Makepeace, 1985b).*

Treatment	% germination
(a) Temperature (∞C)	
2	0
17	62
22	66
27	50
32	11
(b) Osmotic Stress (bars)	
1	85
3	62
7	20
11	0
15	0

vegetative spread (Makepeace, 1985b). This can occur through grazing. However Mason (1987), in glasshouse pot experiments, found that although there was some increased stolon production following an initial removal of inflorescences, there was no obvious response following subsequent removals of inflorescences.

Allelopathy

Mouse-ear hawkweed has been demonstrated to contain allelopathic chemicals. Most literature is focused on the presence of allelochemicals in the leaves. The phenol compounds identified include umbelliferon which is the major allelochemical according to Makepeace *et al.* (1985), as well as caffeic acid and chlorogenic acid (Adams, 1987; Makepeace *et al.,* 1985; Duquenois, 1956). These chemicals are retained in living tissue and only released into the soil upon senescence and subsequent leaching. Henn *et al.* (1988) found the allelochemicals umbelliferon and apigenin-glucoside also in the roots of mouse-ear hawkweed. These chemicals are secondary metabolites not directly involved in metabolic pathways. It is not known whether they serve a distinct role such as anti-herbivory or allelopathy.

Water extracts from the leaves of mouse-ear hawkweed were shown to slow the rate of germination in some pasture species (Makepeace *et al.* 1985). Abnormalities in root growth of pasture species were noted in glasshouse grown plants which had soil amended by the water leachates of mouse-ear hawkweed. Symptoms included the absence of root hairs, damage to root tissue and the browning of apical meristems. Species affected included mouse-ear hawkweed itself, king devil hawkwed, perennial ryegrass, white clover, sheeps sorrel and two annual grasses. Alsike clover was not affected. Scott (1984) pointed out that any negative effect on plant roots would exacerbate difficulties in obtaining moisture and mineral nutrients. This would particularly affect the establishment of pasture species.

Henn *et al.* (1988) concluded that allelopathy was not significant for mouse-ear hawkweed in Northern France in maintaining a stage of succession. Makepeace *et al.* (1985) demonstrated allelopathic effects of mouse-ear hawkweed in both the laboratory and the glasshouse. Leaf extracts inhibited root production and activity. However in the field Makepeace *et al.* (1985) could not find measurable levels of umbelliferon in the soil. They suggested that the effect would be transitory in the field with levels only being significant at certain times eg after summer drought killing of leaves followed by autumn rain leaching of chemicals into the soil. Adams (1987) found that the levels of allelochemicals produced by mouse-ear hawkweed were greater in the harsh field conditions than in a glasshouse regime.

Auto-inhibition by allelopathy was purported by Makepeace *et al.* (1985) to be responsible for the mouse-ear hawkweed patches often having bare spaces in the centre. Observational evidence of interspecific allelopathy could be confounded by the effect of competition particularly for phosphorous (Makepeace *et al.,* 1985).

Herbivory and Animal Selection

Because of the generally slow and appressed growth of mouse-ear hawkweed and its possible exclusion of other species the total stock feed available is limited in much run country. However the species is not unpalatable to stock. In fact Hughes (1975) found that mouse-ear hawkweed was one of the herb species that was actively selected for on undeveloped run country near Lake Ohau. Through cuticle analysis of the sheep faeces mouse-ear hawkweed was identified by Hughes (1975) as the seventeenth to twentieth most selected species in developed and undeveloped land. However in later work on the Harper-Avoca area with dense mouse-ear hawkweed, the proportion of the species in the diet was less than in the vegetation composition (Harris and O'Connor 1980). The mineral content of mouse-ear hawkweed is good (Scott & Maunsell, 1974; Grace and Scott, 1974). Field observation indicates that sheep will preferentially select flowering heads when available.

Grazing by rabbits is thought to promote mouse-ear hawkweed infestation through the grazing of surrounding vegetation. Rabbits evidently have a preference for resting on mouse-ear hawkweed patches - probably due to the low, dry vegetation - as indicated by a high frequency of rabbit faeces on the patches possibly leading to a mineral nutrition advantage for mouse-ear hawkweed patches over the surrounding vegetation.

Changes in pasture vegetation can infer low acceptability of species which become dominant (Hughes, 1975; Scott & Maunsell, 1974). However this is generally the result of greater preference for other species.

Diseases and Pests

In New Zealand mouse-ear hawkweed appears to be relatively free of pests and diseases. There are no confirmed reports of plant diseases and only polyphagous insect herbivores such as porina and a common seed eater have been noted on the species. No host specific insects have been recorded in New Zealand. Scott (1984) summarised the presence of pests and diseases in Europe and the UK.

Plant Strategies

There appears to be a difference of opinion over whether mouse-ear hawkweed takes advantage of bare ground in the inter-tussock zone, or whether it can grow and displace existing vegetation. An examination of actual processes involved is needed. Makepeace (1985a, 1985b) published a comprehensive study of establishment characteristics of mouse-ear and king devil hawkweed which are relevant to the "bare ground question".

Darkness reduced the germination of mouse-ear hawkweed, from 64 % in the light to 49 %. This was a minor change compared to king devil hawkweed seed germination which dropped from 55 % to 12 %. Mouse-ear places more reserves in its seed than king devil hawkweed. Mouse-ear hawkweed has a resource allocation resulting in a higher root to shoot ratio. High allocation to roots and also to seed are characteristic of species adapted to survival in competition with other species e.g. in a stable pasture (Makepeace, 1985b).

Makepeace (1980) showed that mouse-ear hawkweed leaves remained essentially horizontal even under shading. Scott (1984) noted that this characteristic was one of the few which indicated less adaptation for growing in a sward than king devil.

Discussion

It is too early to attempt a synthesis of what the genetic and physiological characters of mouse-ear hawkweed are which have allowed it to so effectively exploit the New Zealand high country environment. What the review has given is the known facts which will have to be included in that synthesis along with other investigations still to be done.

It is probably easier to highlight the major areas which have not been investigated in any detail. These areas require study before any synthesis and decision on whether the current land degradation is better interpreted as being the result of hawkweed invasion or whether hawkweed is just a symptom of other degradation processes. The major aspects needing investigation are the mineral nutrition and water relationships of mouse-ear hawkweed, particularly as they relate to its drought susceptibility in the low rainfall areas. There is also the whole field of pest and disease interactions which are not apparent in New Zealand, but which the literature indicate are present in its home territory and could be the basis of a biological control programme. The perspective of such features will be obtained by comparing the characteristics of mouse-ear hawkweed with resident native species, other adventive species, and also those species which have similar ecology to mouse-ear hawkweed in its home territory but do not appear to have become important in New Zealand. However even within the aspects covered in this review, some require further work.

Present' indications are that only a small proportion of morphological and cytological diversity of the species has entered New Zealand, and yet it has dominated the high country to a level rare in its home territory. The confirmed apomictic status of the material in New Zealand influences the consideration of; whether there has been evolutionary adaptation to New Zealand conditions, its likely further diversification, and the possible impact of control options.

Further work is needed on the role of seed in the life history of mouse-ear hawkweed. The magnitude of the seed production is at variance with the very low observed frequency of seedlings. This may be explained by the very rapid reported growth of seedlings - but this needs to be checked. There is also debate on the type of micro-site in which mouse-ear hawkweed can successfully establish. The physiological characters of king devil hawkweed would seem to indicate bare soil and open sites, while those of mouse-ear hawkweed would indicate adaptation to low vegetation.

Acknowledgement

The financial support of the Miss E.L. Hellaby Indigenous Grassland Trust is appreciated.

References

Adams, J.A. 1987. Studies on *Pilosella officinarum* Hill. (mouse ear hawkweed): changes in nitrogen balance and phenolic chemical levels under varying soil fertility conditions. Unpublished BSc(Hons) Thesis, Lincoln College, Canterbury.

Anderson, V.L. 1927. Studies of the vegetation of the English chalk 5. The water economy of the chalk flora. *Journal of Ecology 15*: 72-129.

Bingham, S.W. 1965. Hawkweed control with turf herbicides. *Northeastern Weed Control Conference 19*: 486-489.

Bishop, G.F.; Davy, A.J. 1984. Significance of rabbits for the population regulation of *Hieracium pilosella* in Breckland. *Journal of Ecology 72*: 273-284.

Bishop, G.F.; Davy, A.J. 1985. Density and the commitment of apical meristems to clonal growth and reproduction in *Hieracium pilosella*. *Oecologia (Berlin) 66*: 417-422.

Gadella, T.W.J. 1972. Biosystematic studies in *Hieracium pilosella* L. and some related species of the subgenus *Pilosella*. *Botaniska Notiser 125*: 361-369.

Gadella, T.W.J., 1987. Sexual tetraploid and apomictic pentaploid populations of *Hieracium pilosella (Compositae)*. *Plant Systematics and Evolution 157*: 219-245.

Grace, N.D.; Scott, D. 1974. Diet and mineral nutrition of sheep on undeveloped and developed tussock grasslands. I. The macro- and micro-element composition of blood plasma and herbage. *New Zealand Journal of Agricultural Research 17*: 165-175.

Grime, J.P.; Hodgson, J.G.; Hunt, R. 1988. *Comparitive Plant Ecology. A functional approach to common British species*. Unwin Hyman, London. 742 pp.

Harris, P.S.; O'Connor, K.F. 1980. The grazing behaviour of sheep *(Ovis aries)* on a high country summer range in Canterbury. *New Zealand Journal of Ecology 3*:85-96

Hay, J.R.; Ouellettee, G.J. 1959. The role of fertilizer and 2,4-D in control of pasture weeds. *Canadian Journal of Plant Science 39*: 278-283.

Healy, A.J. 1976. *Identification of Weeds and Clovers*. Editorial Services, Wellington. 271 pp.

Henn, H.; Petit, D.; Vernet, P. 1988. Interference between *Hieracium pilosella* and *Arrhenatherum elatius* in colliery soils of North of France: allelopathy or competition. *Oecologia (Berl) 76(2):* 268-272.

Hughes, J.G. 1975. *A study of the grazing preferences of sheep on developed and undeveloped grassland at a high-country site*. M.Agr.Sc. Thesis, Lincoln College, Canterbury .

Makepeace, W. 1980. *Ecological studies of* Hieracium pilosella *and* H. praealtum. Ph.D. Thesis, University of Canterbury, Christchurch, New Zealand.

Makepeace, W. 1981. Polymorphism and the chromosomal number of *Hieracium pilosella* L. in New Zealand. *New Zealand Journal of Botany* 19: 255-257.

Makepeace, W. 1985a. Growth, reproduction, and production biology of mouse-ear and king devil hawkweed in eastern South Island, New Zealand. *New Zealand Journal of Botany 23*: 65-78.

Makepeace, W. 1985b. Some establishment characteristics of mouse-ear and king devil hawkweeds. *New Zealand Journal of Botany 23*: 91-100.

Makepeace, W.; Dobson, A.T.; Scott, D. 1985. Interference phenomena due to mouse-ear and king devil hawkweed. *New Zealand Journal of Botany 23*: 79-90.

Mason, C.R. 1987 (unpublished). *Rhizomatous legumes for hawkweed dominated grasslandr*. M.Applied.Sc. Thesis, Lincoln College, Canterbury .

Roberts, H.A. 1986. Seed persistence in the soil and seasonal emergence of some plant species from different habitats. *Journal of Applied Ecology 23*: 639-656.

Scott, D. 1984. Hawkweeds in run country. *Tussock Grasslands and Mountain Lands Institute Review 42*: 33-48.

Scott, D.; Maunsell, L.A. 1974. Diet and mineral nutrition of sheep on undeveloped and developed tussock grassland. II. Vegetation composition and availability. *New Zealand Journal of Agriculture 17*: 117-189.

Scott, D.; Keoghan, J.; Cossens, G.C.; Maunsell, L.A.; Floate, M.J.S.; Wills, B.J.; Douglas, G. 1985. Limitations to pasture production and choice of species. *In:* Burgess, R.E; Brock J.L. (Editors) *Using Herbage Cultivars. Grasslands Research and Practice Series No.3*. New Zealand Grassland Association, Palmerston North.

Scott, D.; Sutherland, B.L. 1992 (in submission). Competition between some pasture species and mouse-ear and king devil hawkweed. *New Zealand Journal of Ecology*.

Sell, P.D.; West, C. 1976. *Hieracium. In:* Tutin, T.G.; Heywood, V.H.; Burgees, N.A.; Moore, D.A.; Valentine, D.H.; Walters, S.M.; Webb, D.A. (Editors), *Flora Europaea Vol 4*. Cambridge University Press. Cambridge University Press. pp. 358-410.

Stevens, E.J.; Hughes, J. 1973. Distribution of sweet briar, broom and ragwort on Molesworth Station. *Tussock Grasslands and Mountain Lands Institute Special Publication No.9*.

Turesson, B. 1972. Experimental studies in *Hieracium pilosella* L. II. Taxonomy and differentiation. *Botaniska Notiser 125*: 223-240.

Turesson, G.; Turesson, B. 1960. Experimental studies in *Hieracium pilosella* L. I. Reproduction, chromosome number and distribution. *Hereditas 46*: 717-736.

Tutin, T.G.; Heywood, V.H.; Burgees, N.A.; Moore, D.A.; Valentine, D.H.; Walters, S.M.; Webb, D.A. 1976: *Flora Europaea Vol 4*. Cambridge University Press

Voss, E.G.; Bohlke M.W. 1978. Tbe status of certain Hawkweeds *(Hieracium* subgenus *Pilosella)* in Michigan. *The Michigan Botanist 17*: 35-47.

Watt, A.S. 1962. Tbe effect of excluding rabbits from grassland "A" (xerobrometum) in Breckland. *Journal of Ecology 50:* 181-198

Webb, C.J.; Sykes, W.R.; Garnock-Jones, P.J. 1988. *Flora of New Zealand. Vol IV, Naturalised pteridophytes" gymnosperms, dicotyledons*. DSIR Botany Division, Cbristchurch. 1365 pp.

SESSION ONE DISCUSSION: PLANT SOCIOLOGICAL ISSUES

It was observed that scientists are having difficulty getting the message across to the community that hawkweed dominance could be symptomatic of degraded grassland ecosystems as well as of invasion by weeds.

A need was identified to explicity define concepts of degradation as different researchers, resource management officers and the community may assume different meanings. A particular issue was whether or not concepts of vegetation degradation also included elements of soil degradation, in physical, chemical or biological terms.

M. Treskonova clarified her use of the term degradation, which is based most strongly on native plant species records, with loss of species or decline in species abundance being indicators of degradation. However, soil physical properties, (e.g., thickness of the A horizon) were also implicated.

It was noted that degradation in a vegetation sense was open to interpretation. Alternative measures of vegetation degradation, including replacement of nutritionally rich species by poor species and declining species diversity, may lead to different interpretations.

A. Rose reiterated that in the Harper-Avoca catchment, loss of beech forest had led to the induction of a range of unstable plant communities. Changes back from short tussock to tall tussock grassland, to scrub and to beech forest could be checked, at least in the short term, by intervention such as by grazing management, pasture improvement and by the invasion of well-adapted species (e.g., hawkweeds). Instability of plant communities, induced since deforestation, was an underlying feature.

The farming community also has had difficulty with concepts of degradation. In particular farmers who are involved with application of fertiliser to improve land had difficulty accepting concepts of soil degradation/depletion.

It was asked if we could recognise the reverse of vegetation degradation, in the field, where degraded plant communities are entering a stage of recovery beyond hawkweed. M. Treskonova had recognised such plant communities in her published models for vegetation change in Waitaki basin. Sites in the Awatere Valley, where native species had become established in hawkweed vegetation have also been interpreted in this way. In the Harper-Avoca, snow tussock seedlings have established in tussock hawkweed-dominant vegetation. A light infestation of mouse-ear hawkweed in tall tussock grassland in Black Rock Scientific Reserve has been virtually eliminated since grazing exclusion in 1972. However, no clear trends of widespread change from hawkweed dominance to other vegetation had been identified.

Questioned about the influence of climate on vegetation change, A. Rose clarified that he had found no significant climatic effect in the Harper-Avoca. Climate had fluctuated over time, but hawkweeds had increased linearly with time. Specific weather factors may trigger change, but probably won't alter the direction of vegetation change.

The ability of hawkweeds to lock up nutrients was questioned. It was considered that the 'halo effect' of hawkweed mats, having vigorous, flowering rosettes surrounding a dead centre, may relate to the uptake of P and N by the younger, outer rosettes.

Clarification was sought on the low contribution of seed establishment in hawkweed populations (especially mouse-ear hawkweed). The understanding was that although wind-dispersed seed has made the main contribution to the geographic dispersal of hawkweeds, vegetative spread has been the main mechanism for subsequent increases in local abundance and has therefore accounted for most plants. As seed is viable only for a short time, the rate, pattern and timing of widespread establishment may have been influenced by climatic triggers, including wind patterns and soil moisture levels in summer following seed release.

Field observations suggest a range of mechanisms of spread, and differences between species. Observations interpreted as supporting the importance of wind dispersed seed in the early phases of invasion included:

> The Nevis Valley, where the down-valley edge of significant mouse-ear hawkweed in grassland was abrupt, and not obviously related to management and site factors. Beyond the 'edge', scattered plants in grassland were initiating new sites for spread.

> The Central Otago farm survey, which identified extensive areas of grassland containing small, localised mats of mouse-ear hawkweed.

> Humid western Otago where individual tussock hawkweed plants have established throughout vigorous valley floor grassland. Tussock hawkweed may be non-stoloniferous and seed may be the predominant mechanism for establishment of new plants.

The need to re-evaluate allelopathy was stressed. Although no allelopathic effects have been confirmed in the field, recent work has shown that a range of plant communities produce large amounts of phenols. Umbelliferone production by hawkweeds could be very significant.

SESSION TWO

CASE STUDIES FROM
VEGETATION MONITORING PROGRAMMES

TRENDS OF MOUSE-EAR HAWKWEED *(HIERACIUM PILOSELLA)* IN THE SOUTH OPUHA CATCHMENT

J. Cuff
Canlerbury Regional Council, P. O. Box 550, TIMARU

The South Canterbury Catchment Board established four line transects in the South Opuha catchment in April 1963. The transects have been re-surveyed annually in the autumn (with the exception of occasional years) to provide an indication of annual variation in condition. The record for mouse-ear hawkweed *(Hieracium pilosella)* bas been extracted from these data and is presented in this paper.

The four sites are located in the headwaters of the South Opuha catchment about 20 km north-west of Fairlie in South Canterbury. The sites are on steep west-facing slopes at 1070-1460 m altitude and are estimated to receive about 1250 mm mean annual rainfall.

At each site eight 30 m lines were established in a radiating pattern. Each line was sampled at 0.6 m intervals using a weighted 6.3 mm diameter ring.

The occurrence of mouse-ear hawkweed varied between sites and over time (Fig 1). Mouse-ear was abundant at site A in the early 1960's, plentiful at site B and erratic to absent at sites C and D. There has been an increase in mouse-ear at all sites to the extent that it now has an occurrence of approximately 30 % at site A. Mouse-ear hawkweed occurrence was correlated with time (Table 1).

Gradient values from the regression equations show that the rate of increase in mouse-ear reduces with increasing altitude. Regressing these gradient values against altitude gives an equation of:

Gradient value = 11.5 - 0.0075 Altitude (m) ($r=0.89$ $p<0.05$)

The relative abundance of mouse-ear hawkweed for any given year is inversely proportional to altitude (Fig 2).

The variation in mouse-ear occurrence may be due in part to three measured variables of time, altitude and rainfall. There was a relatively consistent increase in mouse-ear at sites A and B from 1963 up to the 1980's (Fig 1). This trend bas stabilised or possibly slightly reversed during the 1980's. At these two sites, it is possible that the most suitable and available areas for colonisation have been taken up. Mouse-ear establishes best on decaying plant litter. Future expansion may occur as present vegetation dies. Mouse-ear began establishing and increasing at the higher elevation sites C and D about 1980. This increase bas continued to the present. Variation in altitude or rainfall does not explain the overall trend of mouse-ear hawkweed increase, although between year variability may be influenced by rainfall. It appears that the increase in mouse-ear over time is a measure of natural expansion on sites of this condition in this

Table 1: *Regression between mouse-ear hawkweed occurrence* and *time, at four sites in South Opuha catchment.*

Site	Altitude (metres)	Regression *	Correlation r^2	Years
A	1070	H = 3.1Y - 149	0.74 ($p<0.01$)	1963-88
B	1250	H = 2.7Y - 159	0.8 ($p<0.01$)	1963-88
C	1460	H = 0.3Y - 22	0.3 (ns)	1982-91
D	1370	H = l.02Y - 81	0.75 ($p < .01$)	1981-91

* H - mouse-ear hawkweed
Y - years

Record of a workshop of the *New Zealand Ecological Society on "Vegetation change* in *tussock grasslands,* with *emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.*

environment once mouse-ear hawkweed has colonised and become established. Past land use may have influenced this initial site condition. The virtual lack of grazing during the study period indicates that current grazing is not a cause of the subsequent increase in mouse-ear at these sites.

There is little evidence that growing season rainfall, based on records of adjacent rainfall stations, is a useful predictor of either short-term or long-term trends in mouse-ear hawkweed abundance.

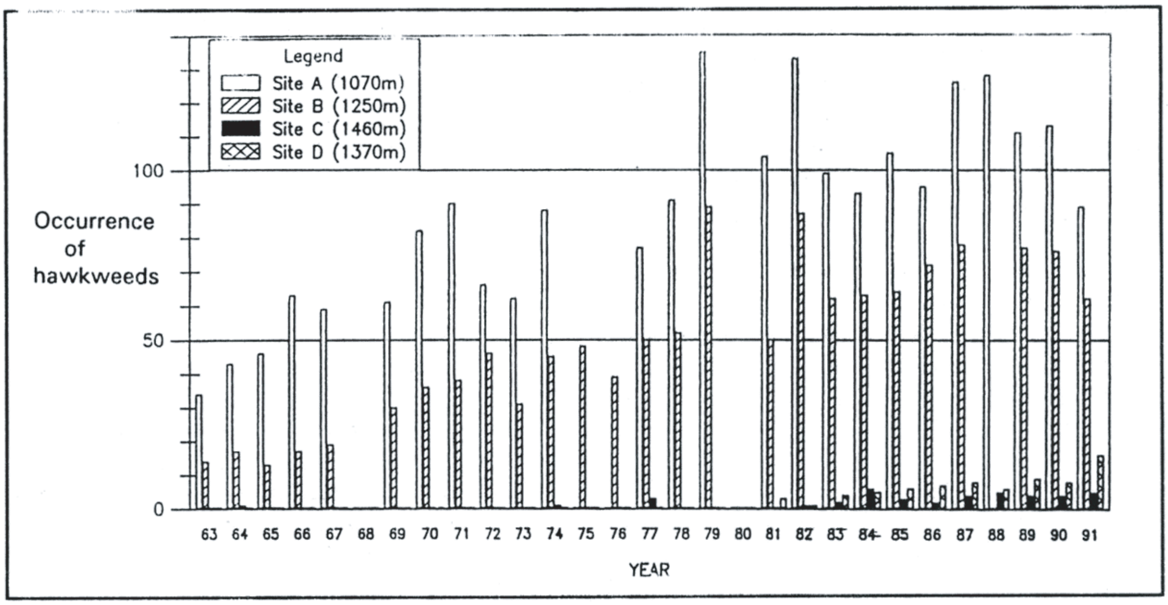


Figure 1: *Occurrence of mouse-ear hawkweed at 4 sites in the South Opuha Catchment, Canterbury, 1963-1991.*

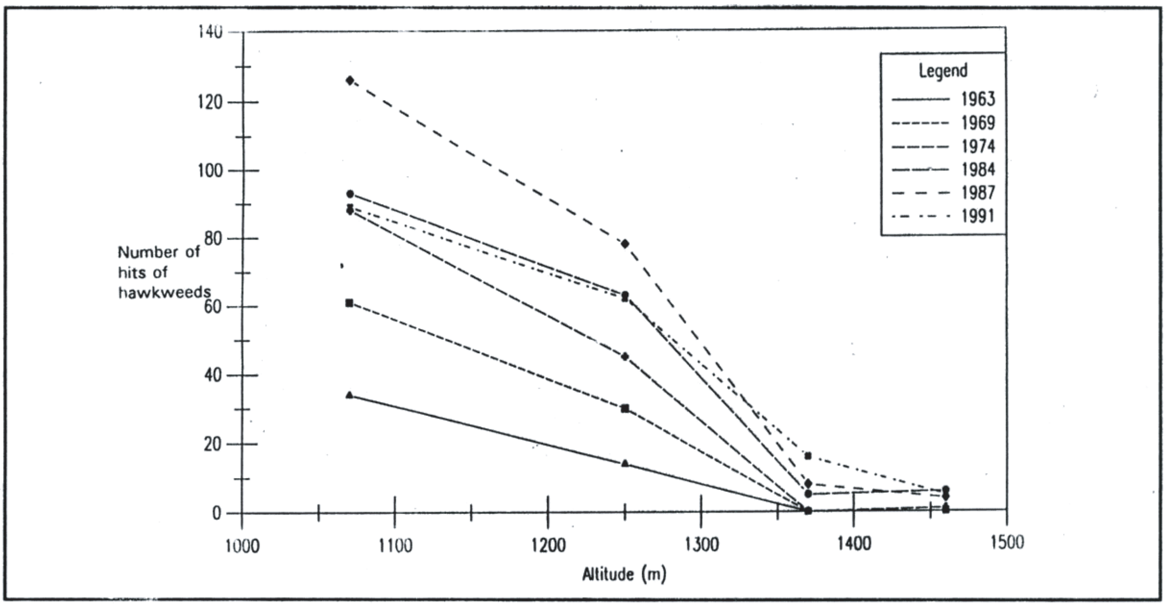


Figure 2: *Effect of altitude and time on occurrence of mouse-ear hawkweed in the South Opuha Catchment, Canterbury.*

EFFECTS OF BURNING ON OTAGO TUSSOCK GRASSLANDS - GLENSHEE STATION

K. B. Duggan
c/o Otago Regional Council, Private Bag, *DUNEDIN*

The Otago Regional Council is concerned with the impacts of burning and grazing and the introduction of exotic plant species in the tussock grasslands. It has established and maintained networks of sites for the collection of data about changes in ground cover in response *to* environmental and management factors. Results are used to assist with the identification and promotion of sustainable grasslands management.

In 1957, eight line transects were established in Timber Creek catchment on Glenshee Station, located on the Ida Range north of the Maniototo Plain, to monitor vegetation responses to burning snow tussock grassland. The sites were burned in 1959 and have subsequently carried at least two more fires. The transects have been resurveyed nine times, most recently in 1986. Ground cover at points along the transect were recorded as 'living vegetation' (subdivided *into* 'tussock', 'mat plants', 'shrubs', 'herbs', 'exotics' (clover and sward grasses)), 'dead plant material' and three categories of 'bare ground'. The transects are on steep slopes in the elevation range 820 to 1050m. Soils are mapped as Tengawai Hill and Kaikoura steeplands. Annual rainfall ranges from 700 to 1200mm, generally increasing with altitude.

Immediately after burning, total 'living vegetation' declined from between 28 % and 85 % of the pre-bum levels. Initial recovery was rapid, with the cover returning to pre-burn levels within one and a half to three years following fire. It continued to increase until peaking about five years after fire, at levels exceeding pre-bum values. Changes in 'bare ground' and 'dead vegetation' were the inverse of living vegetation, although the levels of 'dead vegetation' were affected by the intensity of the burns.

Although resurvey intervals in recent years have been insufficient to monitor long-term trends in relation to the full fire history, results indicate that 'living vegetation' has increased at most sites from 1957 to 1986. There has been a corresponding decrease in 'dead vegetation', and 'bare ground' has remained at relatively stable levels.

The pre-bum 'living vegetation' cover was dominated by 'tussocks'. 'Herbs' was an important subdominant category at many sites whereas 'shrub' and 'exotic' categories combined usually accounted for <10% of the cover. Following the fire, the 'tussock' category responded quickly and increased for up to five years to peak at pre-bum levels. At some sites 'tussock' cover then declined. The responses of 'herb' cover was more pronounced and these species peaked three to five years after a fire, at levels which exceeded pre-bum values by up to 300%. Values for herbs then declined in relation to other cover categories. Although the levels of tussock cover have not changed overall, this category is now subdominant to either 'herbs' or 'exotic' cover categories according to site.

Within the 'herb' category, hawkweeds had not been recorded prior to 1980. In that year hawkweeds were recorded at low levels in four transects and in 1986 were recorded on five transects and contributed from 8 to 11 % of the total cover on four of them. Hawkweeds were recorded on a wide range of altitudes, slopes and aspects.

Following the implementation of a soil and water conservation plan in the early 1980's, there has been a major development programme on Glenshee, involving subdivision fencing, erosion control fencing and aerial oversowing and top dressing. The 590ha blocks containing the transects are now set stocked with 2000 ewes prior to lambing until weaning (6 months) and with 2000 wethers (2 months) and 1000 hoggets (1 month) over late autumn and winter. There is concern that hawkweeds have spread over a range of sites contained within this development programme.

HAWKWEEDS IN OTAGO - DISTRIBUTION, ECOLOGY, MANAGEMENT

N. S. Harris and A. F. Mark
Botany Department, University of Otago, P. O. Box 56, DUNEDIN

Serious infestations of hawkweeds *(Hieracium* spp.) in the tussock grasslands of Otago appear to be anomalous in their distribution, particularly in relation to climatic regimes and patterns elsewhere in the South Island high country (G Hunter, 1991).

Two hawkweed species predominate: mouse-ear *(Hieracium pilosella)* and tussock hawkweed *(H. lepidulum)*. Tussock hawkweed is limited in distribution to Wanaka, Lindis, Pisa and Dunstan Ecological Districts (E.D.). It dominates several sites - Pisa Station and Luggate Creek on the Pisa Range, Thompson's Creek on the Dunstan Mountains and the upper Rob Roy Valley, Wanaka - and appears to be actively invading westward into Mt. Aspiring National Park. Mouse-ear is more widespread, with a major infestation throughout much of the Manorburn E.D., and smaller areas on lower slopes in the Nevis Valley (Remarkables and Old Man E.Ds.) and on the western slopes of the Rock and Pillar Range (Rock and Pillar E.D.).

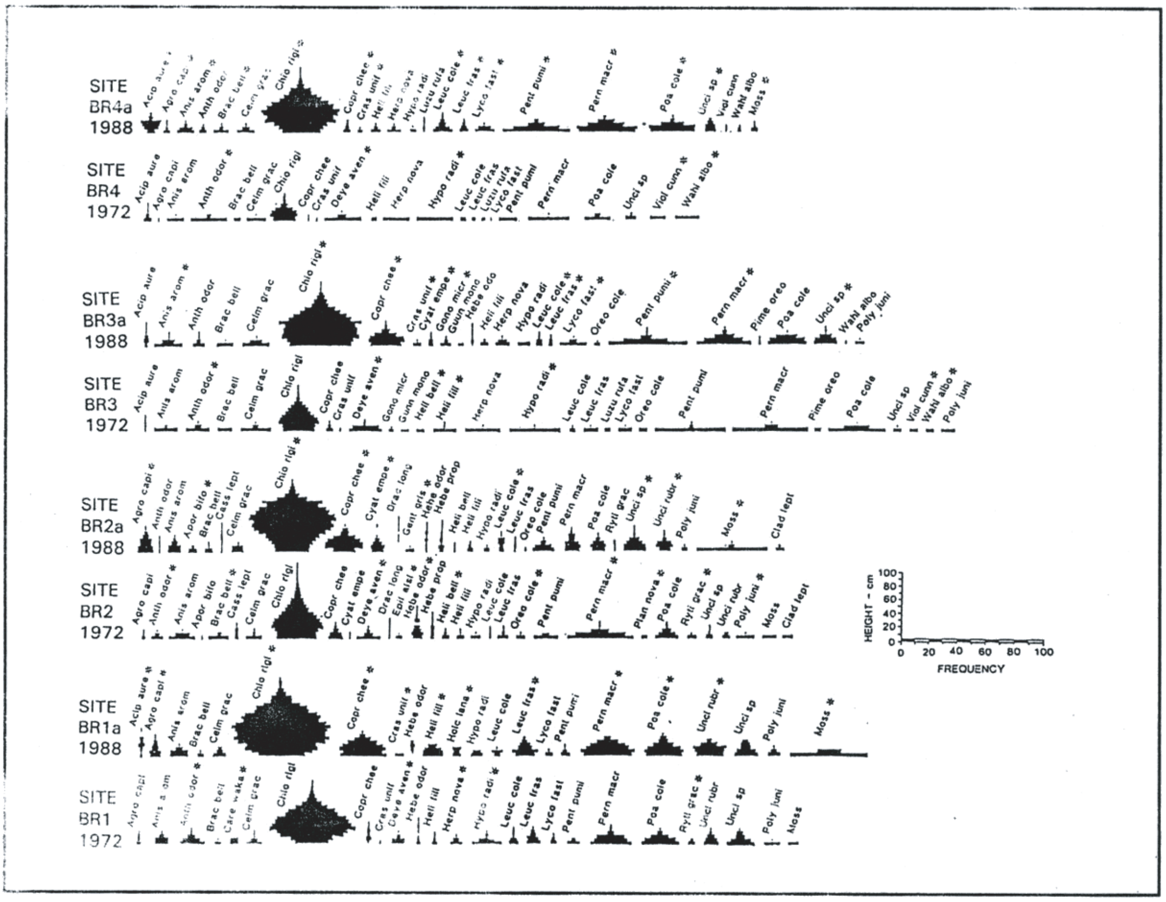


Figure 1: *Height/frequency values for four sites in Black Rock Scientific Reserve (c.700m), Waipori E.D. for 1972 (adapted from Bulloch 1973) and 1988. Vie more important vascular species (biomass index >4 for at least one site) are arranged alphabetically. * indicates species with biomass index values significantly higher than in comparative samples. The first four letters of binomials have been used.*

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.

The Lindis Valley and Dansey E. D. apparently have serious infestations but were not covered in our survey.

Most other areas in Otago appear to be largely devoid of serious hawkweed infestations, notably the eastern slopes of the Old Man Range adjacent to the severely infested Knobby Range (Manorburn E.D.) to the east of the Clutha Valley. King devil *(H. praealtum)* is locally common, usually with one or both of the other two species, particularly in the Manorburn E.D.

A series of long-term monitoring sites, using the height frequency method of sampling, have been established in Otago-northern Southland to follow future trends in vegetation, including hawkweed infestation.

Monitoring of snow tussock grassland at Black Rock Scientific Reserve (Waipori E. D.; 700m), hom its inception in 1972, has revealed the virtual elimination of a relatively light infestation of mouse-ear over the ensuing 16 years as the snow tussock has recovered in both height and cover (Fig. 1). Similar monitoring, initiated in 1988, on conservation tussockland and associated mountainlands in Otago and northern Southland / southern Old Man Range (Old Man-Umbrella E.Ds.); Maungatua Scientific Reserve (Waipori E.D); Nardoo Scientific Reserve (Waipori E.D); Lammermoor Range (Waipori E.D); Eyre Mountains stewardship land (Eyre E.D) (Dickinson *et al* 1992) revealed negligible amounts of hawkweed, with king devil at two sites on Old Man Range and mouse-ear at Nardoo and Lammermoor Range.

Over the 1990-91 summer, similar monitoring was established at *S2* sites throughout much of the Otago high country (Waipori, Rock and Pillar, Manorburn, Old Man, Dunstan, Pisa, Remarkables E.D.s), specifically to assess and monitor hawkweed infestation. Topsoil (0-10cm) was collected at each site for bioassay using browntop *(Agrostis capillaris)* (Harris, 1991).

General distribution, together with an apparent preference for disturbed sites, indicates that tussock hawkweed (and king devil) has higher requirements for moisture and fertility than mouse-ear. Even though its rosettes are erect and diffuse, tussock hawkweed is still able to form extensive areas of virtually pure stands (Fig. 2).

Tussock hawkweed and king devil do not appear to represent a serious threat to pastoral activities in Otago by virtue of their erect habit and present distribution. However, the presence of tussock hawkweed in the upper Rob Roy Valley on the eastern edge of Mount Aspiring National Park, on sites with no recent history of ungulate grazing, represents a major threat to conservation values in these areas. King devil occupies equivalent sites in western parts of south and mid-Canterbury, e.g., North Temple Stream and Hopkins Valley.

Anomalies with the distribution of mouse-ear in Otago are more difficult to explain. It does not appear to be related to climate patterns but its

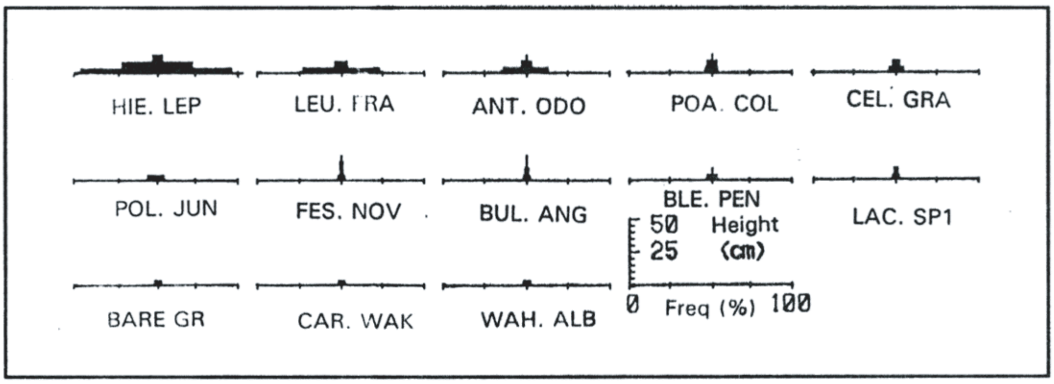


Figure 2: *Height/frequency values for the more important species (biomass index >4) arranged* in *order of importance for a sue on Pisa Station (885m), Pisa E.D., with severe infestation of tussock hawkweed* (H. lepidulum), *23.1.91.*

association with present or relict red tussock grassland and relatively stable mature soils with a high loessial content in the Manorburn district

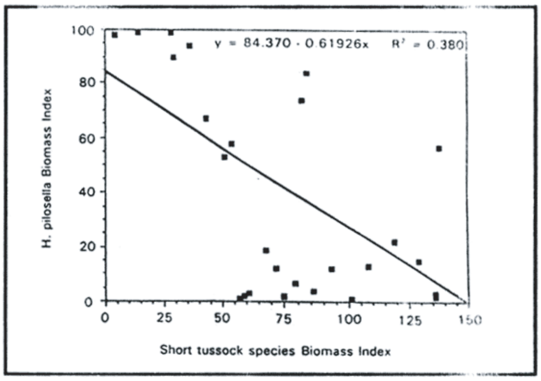


Figure 3: *Changes in mouse-ear hawkweed (H. pilosella) biomass index in relation to short tussock species cover.*

may be relevant. General nutrient deficiency, but particularly of nitrogen, phosphorus and/or boron in soils of this district may also be significant (G Cossens, *pers. comm.)*. Analysis of sample sites (Fig. 3) showed a negative relationship between tussock cover and mouse-ear dominance, despite the very wide environmental gradients present, and implicates pastoral management in mouse-ear dominance.

Results of the bioassay did not indicate any allelopathie effects of mouse-ear dominated soils (Harris 1991).

Conclusions

Continued monitoring and additional research is needed before conclusions and recommendations can be offered on future management. Retention of a healthy tussock cover through lenient grazing and reduction in the frequency of burning, with adequate post-fire spelling (at least one year) are implied from the evidence for tall tussock grasslands in Otago. Maintenance of canopy cover also appears important in short tussock grasslands and continued oversowing and topdressing is supported as a preventive measure in areas least affected by mouse-ear (Fig. 4). Few options for areas already heavily infested with mouse-ear are available and successful replacement with more favoured species appears unlikely

References

Dickinson, K.J.M.; Mark, A.F.; Lee, W.G. 1992. Long-term monitoring of non-forest communities for biological conservation purposes. *New Zealand Journal of Botany 30:* 163-179.

Hunter, G.G. 1991. Distribution of hawkweeds *(Hieracium* spp.) in the South Island, indicating problem status. *Review. Journal of the N.Z. Mountain Lands Institute 48*: 21-31.

Harris, N.S. 1991 (unpublished) *Aspects of the ecology and distribution of hawkweeds (Hieracium spp.) in Central Otago, New Zealand.* B.Sc.Hons. thesis, Univ. of Otago.

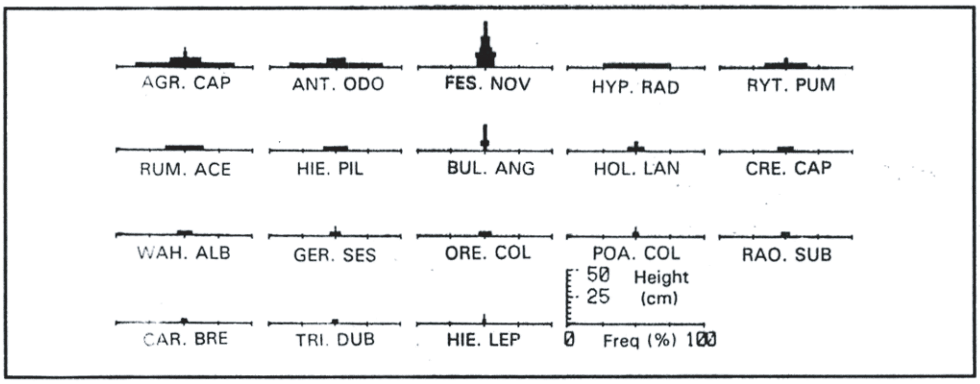


Fig. 4: *Height/frequency values for the more important species (biomass index >4) arranged in order of importance for a site in the Remarkables (950m), Remarkables E.D. with a potential problem involving two species, mouse-ear hawkweed* (H. pilosella) *and tussock hawkweed* (H. lepidulum). *15.1.91*

HAWKWEEDS AND VEGETATION MONITORING IN THE RABBIT AND LAND MANAGEMENT PROGRAMME

K. Colhoun, B.D. Foran and W.D. Ross
Landcare Research New Zealand Ltd - Manaaki Whenua
P. O. Box 276, *ALEXANDRA*

Abstract
Data from 240 vegetation monitoring sites in the core Rabbit and Land Management problem area give a snapshot of the hawkweed problem from the 1990/91 sampling period. Hawkweeds *(Hieracium* spp.) cover 16% and 4% of the sampling sites in Canterbury and Otago respectively. Species frequency (% presence in metre square quadrats) data confirm the widespread nature of mouse-ear *(H. pilosella)* (Cant. >60%; Otago >20%) king devil *(H. praealtum)* (Cant. >30%; Otago> 10%) and tussock hawkweed *(H. lepidulum)* (Otago 20%). No site characteristic analysed so far showed a major causative effect on hawkweed dominance. The difference between Canterbury and Otago is probably as much a time one as a site one. Our monitoring efforts will not solve the hawkweed problem, but might give early warning of the next major landscape change. We discuss whether monitoring activities might have broken the inactivity cycle that seems to have characterised this major landscape change. If landscape monitoring does have a part to play we suggest that all institutions accept a minimum data set of species frequency on high country landscapes. This will enable the landscape records from different institutions and generations to be tied together more effectively, and stimulate government to develop vision in its land management policies.

Introduction

This paper reports on the baseline data collected in the 1990/91 summer in the core rabbit prone landscapes of Canterbury and Otago. While the real aim of monitoring is to measure vegetation change away from the baseline as rabbit control takes effect, the relevance of the data for this workshop on hawkweeds, is the recent sampling within the core hawkweed area defined by Hunter (1991). This paper reports mainly on a regional view of the hawkweed problem within the Rabbit and Land Management Programme area, with some analysis of site factors which might enable a more detailed risk of hawkweed dominance to be assessed.

Methods

Sites of 4-6 ha in area were selected at regular intervals of 3-6 km along rabbit counting transects. Ground cover was measured with the wheel point apparatus and 500 points per site. Species frequency was measured by the presence of species in 50 placements of a metre square quadrats. Scrub cover was measured by Bitterlich gauge at 25 points. A wide range of site data was collected including soil type, aspect, altitude, proneness to erosion etc. A total of 241 sites were surveyed with 129 in Canterbury and 112 in Otago.

Results

Hawkweeds and Ground Cover

Comparisons of the average regional cover values show that the two regions, Canterbury and Otago have equivalent readings for most of the components of ground cover e.g. bare ground, grasses, tussocks etc. However the sites sampled in Canterbury have a higher coverage of hawkweeds (16%) than those in Otago (4%). This can probably be explained by a mixture of the history of the problem, difference in soil type and soil fertility, and rainfall. However it could also be judged that the trends in both regions are the same, Canterbury having the advantage of years, and a more advanced problem.

The hawkweed cover situation becomes clearer when we look at data from districts within the regions. Sites from the Tekapo and Pukaki regions had an average of 30% and 20% cover respectively. The other districts are close to 10% or lower. No district average for sites in the Otago region was greater than about 5 % hawkweed cover, although there were individual sites with values greater than 30 % .

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.

The average bare ground was about 37 % for both regions. Site averages for the Mackenzie and Maniototo districts were both considerably greater than the regional average, and this is probably a combination of rainfall, rabbits, stock grazing and long term site potential. It does however emphasise that the opportunity for the encroachment of bare ground colonisers such as mouse-ear hawkweed, are frequently present in some areas. Tussock cover was mostly below 5 % in the districts, while other grasses were mostly in excess of 20% except in the Tekapo and Alexandra districts.

Hawkweeds and Species Frequency

Mouse-ear had a higher frequency in Canterbury (>60%) compared to Otago (>20%), while king devil (30% in Canterbury, 10% in Otago) was also sufficiently present to become a focus for spread in the future. Tussock hawkweed (20 % frequency) mainly featured in the Otago sites, and was never sufficiently frequent to rate in the Canterbury sites. .

Tekapo, Pukaki and Mackenzie districts are the major problem areas for mouse-ear hawkweed with a greater than 60 % frequency. The higher rainfall Ahuriri district by comparison had less than 20 % frequency. Sites from the Alexandra district had the highest mouse-ear frequency (>40%) in Otago, with Hawkdun and Lindis/Hawea being next with greater then 20% frequency.

King devil hawkweed had a frequency of greater than 40 % in the Pukaki district, and greater than 20% in the Ahuriri, Omarama and Tekapo districts in Canterbury. In Otago it appeared to be mainly a problem in sites in the Lindis/Hawea district. Tussock hawkweed was most obvious on sites in the Alexandra (40% frequency) and Upper Clutha (32%) districts.

Hard tussock *(Festuca novae-zealandiae)* had a frequency of greater than 30 % across the regions and was greater than 50 % in the Tekapo region where mouse-ear hawkweed had its highest frequency. Many of these hard tussock plants were small and not readily apparent at a general landscape view, but their continued presence offers some opportunity for tussock recovery.

Silver tussock *(Poa cita)* and blue tussock *(Poa colensoi)* did not show much difference on a regional basis, but there were large differences between districts. Both species have much lower frequencies where mouse-ear hawkweed is dominant. Snow tussock *(Chionochloa rigida)* is generally absent from our sites in Otago compared to Canterbury where it has a frequency of greater than 40 %. This may reflect a rainfall/altitude interaction with different numbers of sites located in the montane zone (> 600 m) in the two regions (Canterbury 48; Otago 34). It may also suggest that the impact of burning and pastoral use have been greater or longer in Otago, within the rabbit problem areas where our sampling sites are located.

Site Factors Correlated to Hawkweed Dominance

i) Altitude and Aspect

Site selection was biased towards the drier end of the high country environment, where rabbits continue to be a problem. The sites in both regions range in altitude from 200 to 1100 m. Within these limits some trends have emerged. While all three species appear to be able to dominate at any altitude, frequencies of > 50% can be found at altitudes greater than 400m in Canterbury and 600m in Otago. In Canterbury aspect did not appear to have an effect on the frequency of any of the hawkweed species. In Otago mouse-ear hawkweed was similarly frequent on northerly, easterly and southerly aspects, but tussock hawkweed may have been confined to more easterly and southerly aspects.

ii) Soil Type

Soil type was a little more obvious in its effect. In Otago the sites with the higher mouse-ear hawkweed frequencies (>50%) were almost entirely Yellow Grey Earths (Fig. 1). In Canterbury Upland Yellow Brown Earths were more important (Fig. 2). In functional terms, the YGE and UYBE of Otago and Canterbury are fairly similar especially in measures of soil resilience (Allan Hewitt, *pers. comm.)*. In both regions the lower resilience soils seem to trip easier into hawkweed dominance.
When these broad soil types were subdivided into soil sets, and selected on the basis of those soil

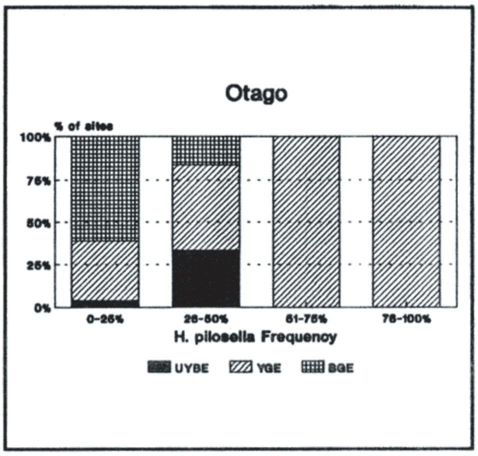


Figure 1: *Frequency. classes of mouse-ear hawkweed (0-25%, 26-50%, 51-75%, 76-100%) in relation to soil types* in *Otago.*

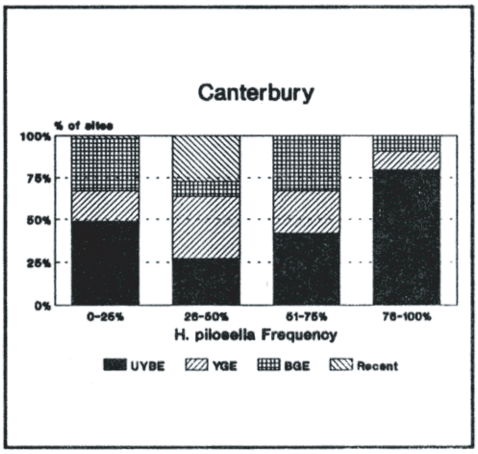


Figure 2: *Frequency classes of mouse-ear hawkweed (0-25%, 26-50%, 51-75%, 76-100%) in relation to soil types in Canterbury.*

sets where a particular hawkweed species was greater than 50 % frequency, further detail emerged. From the 17 soil sets represented by our Otago sites, the Arrow and Linnburn favoured both mouse-ear and tussock hawkweeds. The Naseby and Linnburn favoured mouse-ear alone, while the Alexandra favoured tussock hawkweed alone. From the 14 soil sets represented by our Canterbury sites, Acheron, Tekapo, Omarama, Pukaki and Benmore favoured both mouse-ear and king devil hawkweed. The others (Mackenzie, Grampians, Waitaki, Meyer, Otematata, Benmore) favoured mouse-ear predominately. From this frequency data, it is obvious that hawkweeds find many soil sets to their liking. On our Canterbury sites, soil set would almost seem to be the least important factor influencing hawkweed distribution. In Otago there still appears to be some soil characteristic (or a time factor 1) preventing the levels of mouse-ear hawkweed problem found in Canterbury.

iii) Rabbits

The simple correlation and regression analyses testing the relationships over all the sites between rabbit spotlight counts and hawkweed cover or species frequency gave no indication of any relationship. When these data were bulked up into district averages, some significant correlations were obtained. Using independent variables of pre- and post-kill rabbit numbers, total plant cover (R^2 0.86), grass cover (R^2 0.68), herb cover (R^2 0.66), tussock cover (R^2 0.48), hawkweed cover (R^2 0.72) and bare ground (R^2 0.79) all had a reasonable proportion of their variation explained. These results probably integrate the difference between districts, rather than the short and long term effect of rabbits *per ser*. For example, the rabbit/total plant cover relationship is mainly due to the Tekapo district, where reductions of high rabbit populations (80 down to 5 per spotlight km), and reasonable summer rains saw the total plant cover rise to around 80 %.

iv) Other Factors

Many other site factors (> 50) and species (> 130) are held within this data set awaiting analysis. Seasonal rainfall is an obvious one which will be the major driving factor in determining the response of the whole plant community, both its composition as well as its productivity.

Discussion

Monitoring and Hawkweeds

From some of New Zealand's more media rich pastoral lands, we have presented data from our vegetation monitoring program. We have not been able to add clarity to either the cause, or the solution of the hawkweed problem. Rather we have presented some baseline data for cover and frequency of the main hawkweed species. Changes for the better or worse can be measured against these baselines.

A cursory examination of the literature over the last few decades shows that some causes and some solutions have been around for a long time (Scott, 1984). Intensive agronomic work (Makepeace, 1985; Lambrechtsen and Sheppard, 1979; Trought and Morgan, undated; Cossens and Brash, 1980) has been well underway for 15 years or more. These same 15 years have seen profound changes in scientific institutions, generous farm subsidies in the core problem area (rabbit killing, land development and destruction, 'skinny sheep' schemes), some years of excellent fine wool prices, a drought or two, and many other influences. As well as immersing ourselves in the biological detail, should we also be asking ourselves why we haven't progressed in the last 15 years. Is it a lack of scientists talking out, an incorrect research emphasis, or is it a lack of an audience listening in ?

Would Monitoring Have Helped ?

Casual conversations over morning tea at any meeting seem to liberate filing cabinets full of data that are relevant to the high country. The expectation is always that "someone" should write it up. It is good to see some of the important longer term data liberated at this workshop. The difficult decision as a scientific manager is whether to "put good money after bad" (old data sets are always messy and time consuming), whether to start monitoring now for the future (the next wave of problems), and whether to prove the cause, or develop the solution.

Would we have had this workshop in 1985 if we could have had a constant stream of data rolling in which said that the hawkweed problem (defined at the Lincoln College workshop, 30/6/1975, cited in Lambrechtsen and Sheppard, 1979) was then 50 % worse. It is difficult to say, because we as a scientific group have not confronted the hawkweed problem with a sense of mission or urgency (Mountain Lands Institute, a notable exception to this). We continue to tack the word Hieraciwn onto all our research bids, in the hope it might liberate the extra $100k that we needed to pursue our major career interest. The major themes of this workshop (the cause; restricting the spread; fixing it up) probably coincide with the major institutions that will do the work during the next decade. Little projects won't solve the problem. A couple more integrated projects that are 100% committed might do a little better.

And If Monitoring Might Have Helped !

The Minimwn Data Set

Most monitoring on rangelands throughout the world (USA, South Africa, parts of Australia) have come back to **species frequency in metre square quadrats** (or nested sizes if you need them) as being a robust standard that can tie institutions and generations together. Frequency methodology is good for showing change in species composition and can also be presented in the broader biodiversity context. Institutions can then add their own requirements to this minimum data set. The R&LM team also measure herbage layer plant cover, scrub cover and describe site characteristics.

Who Does It and For Whom?

A small team of players is obvious. Farmers, Landcorp, Regional Councils, Lincoln and Otago Universities, Department of Conservation, National Institute of Land Environments (DSIR, FRI, MAF) and the Forest and Bird Society. Before we all rush out to collect the data, there has to be a team who is competent to analyse and report on the data probably on a yearly basis. Our filing cabinets jammed packed with data sheets and photos are a stunning comment on this lack of management direction in the past. The Rabbit and Land Management team has the following yearly labour commitment to maintaining 300 sites: 12 scientist, 9 student, and 6 technician months per year. Cooperation with other like minded landscape measurers is the only way that we might expand our high country vision into a more national view, which farmers land managers and government might listen to.

References

Hunter, G.G. 1991. The distribution of hawkweeds *(Hieracium* spp.) in the South Island, indicating problem status. *Review. Journal of the New Zealand Mountain Lands Institute 48*: 21-31.

MONITORING CHANGES IN NON-FOREST ECOSYSTEMS: CASE STUDIES FROM MOLESWORTH STATION AND THE MACKENZIE (WAITAKI) BASIN

K.J.M. Dickinson
School of Biological Sciences. Victoria University, P. O. Box 600, WELLINGTON

Introduction

Existing protected natural areas, and areas recommended for protection (RAPs) as part of the Protected Natural Areas (PNA) Programme, have been targeted for long term monitoring of changes in non-forest ecosystems. Against this background, a network of 50-metre permanent transects using a modified height-frequency (h-f) method (cf. Scott 1965; Dickinson *et al* 1992; Harris and Mark, Allen *et al* this workshop) has been established: North Island Central Plateau (9), Nelson Red Hills (6), Molesworth Station (19), Mackenzie (Waitaki) Basin (18) and Central Otago / Southland (Harris and Mark this workshop).

Case study one: Molesworth Station

Thirty six RAPs were identified in a PNA survey on Molesworth Station in 1987/1988.
Negotiation in 1988/89, resulted in some RAPs being recognised for their conservation value by intended exclusion of cattle by fencing. Consequently, monitoring has been initiated in both fenced and unfenced areas to follow changes as a result of cessation of grazing (Table 1).
Hawkweeds were recorded in all transects (except five transects in wetland communities). Mouse-ear hawkweed *(H. pilosella)* was present in ten transects and king devil *(H. praealtum)* in five. Both species were particularly abundant in the short - tussockland communities in Sedgemere (Figs 1 & 2). The majority of highly modified *Festuca* short-tussock land communities have been excluded from the fenced off areas because of perceived grazing value. With high abundance of pasture species these communities harbour hawkweeds but at relatively low frequencies.

Areas with high natural value have been included in the reserved areas. Thus, in many cases, an adjacent equivalent area outside of the fence was not present. Consequently, change will be followed in these communities without an unfenced control.

Hawkweeds appear widespread, are most abundant in, but not exclusive to short - tussockland communities. The impact of cattle removal will need to be monitored closely, following fencing.

Case study two: Mackenzie (Waitaki) Basin

Results of the PNA survey of the Mackenzie Ecological Region are described by Espie *et al* (1984). To date, five RAPs in the region have been legally protected, out of a total of 103 which were identified during the survey. Noticeable deterioration in the natural values of several RAPs through rabbit and introduced plant invasion prompted calls for monitoring in late 1989. Ten RAPs, covering a range of tussockland and shrubland communities representative of the climatic range occurring in the Basin, were chosen for study (refer also Espie and Meurk this workshop). Of these ten, six are being monitored using the modified height-frequency (h-f) method (underlined Table 2).

Table 1: *Vegetation types on transects* in *the Molesworth Station RAPs chosen for study.*

Location	No. of transects	Altitude (metres)	Vegetation types
Sedgemere RAP	10	940 - 1030	*Chionochloa rubra* tall-tussockland, *Festuca* short-tussockland, modified *Festuca* short-tussockland, sedgeland. *Halocarpus bidwillii* - *Phyllocladus alpinus* shrubland/short tussockland.
Tennyson / Island Pass RAPs	3	1020 - 1120	modified short-tussockland, sedgeland.
Oyster RAP	5	1220 - 1460	*Festuca* - *Chionochloa pallens* tussockland, *Festuca* - *Rvtidosperma* tussockland, modified *Festuca* tussockland.

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.

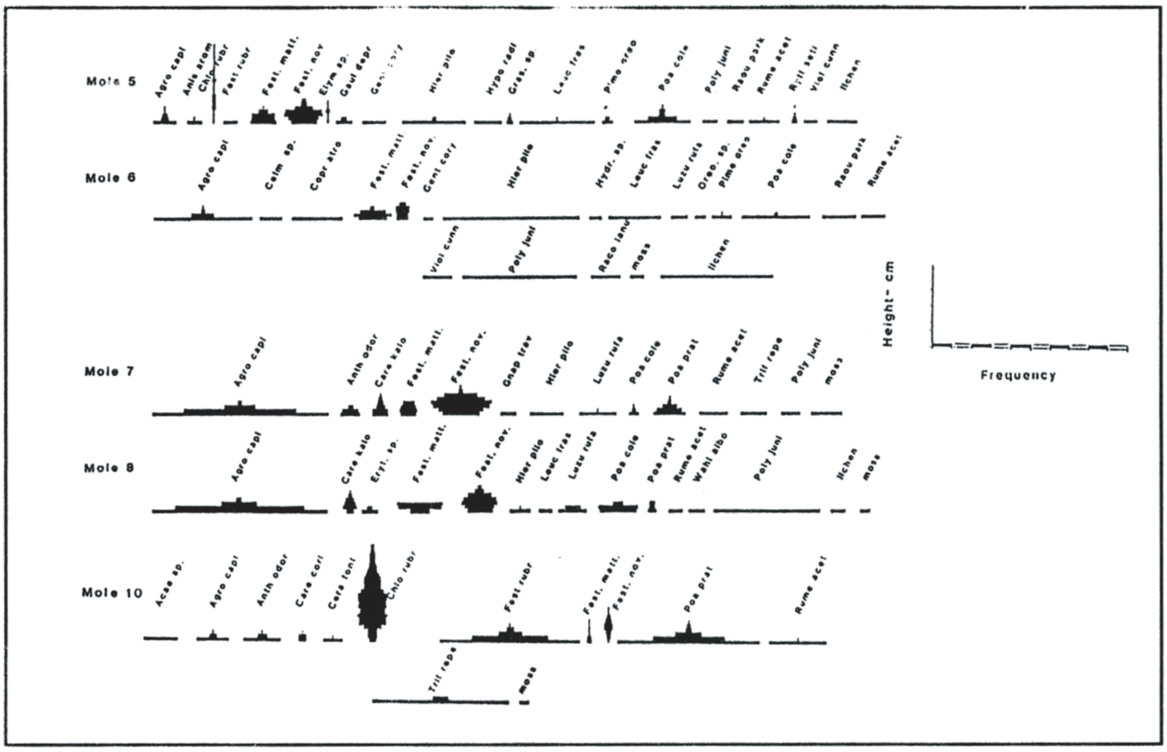


Figure 1: *Diagrammatic representation of the dominant species recorded using the height-frequency (h-j) method (Dickinson* et al *1992) along 50 metre transects at five sites on Molesworth Station.*

Mole 5	short *Festuca* tussockland,	1030 m. 8.11.89.
Mole 6	short *Festuca* tussockland,	1000 m. 9.11.89.
Mole 7	short *Festuca* tussockland,	1000 m. 9.11.89.
Mole 8	short *Festuca* tussockland,	1000 m. 9.11.89.
Mole 10	short *Festuca* tussockland / pasture,	1120 m 10.11.89.

Species frequency is given in 5 cm height classes and labelled alphabetically by the first four letters of their binomials. Bryophytes and lichens are offset to the right.

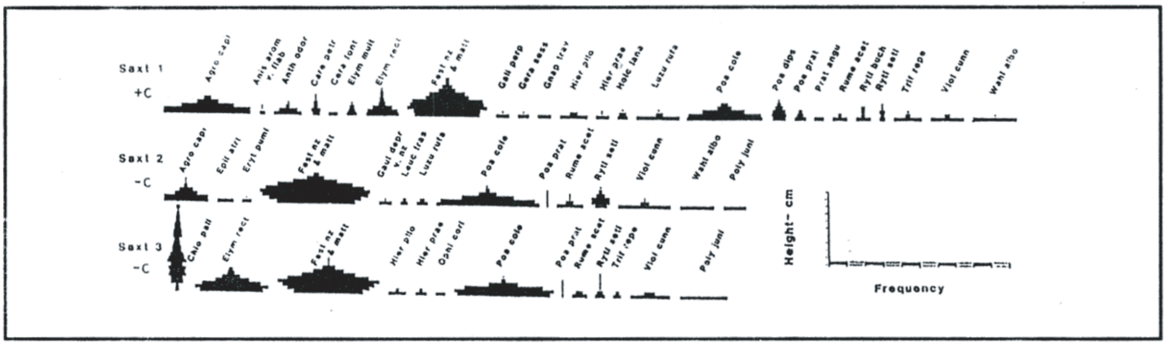


Figure 2: *Diagrammatic representation of the dominant species recorded using the h-f method along 50 m transects at three sites, Oyster RAP, Molesworth Station.*

Saxt 1	short *Festuca* tussockland,	1245 m. With cattle grazing.	2.2.90.
Saxt 2	short *Festuca* tussockland,	1245 m. Excluding cattle.	2.2.90.
Saxt 3	short *Festuca* tussockland,	1460 m. Excluding cattle.	2.2.90.

Species frequency is given in 5 cm height classes and labelled alphabetically by the first four letters of their binomials.

Table 2: *Vegetation types on transects in the Mackenzie Ecological District RAPs chosen for study.*

Location	RAP no.	Vegetation type
Ben Ohau	Pukaki 8	*Festuca* tussockland (moist)
Maryburn	Pukaki 14	*Festuca* tussockland / low shrubland (moist)
Richmond	Tekapo 30	*Festuca* tussockland (wet)
Sawdon	Pukaki 16	*Festuca* tussockland (very depleted, moist)
Simons Hill	Pukaki 9	*Festuca* tussockland (dry)
Rostrievor	Benmore 9	*Poa cita* tussockland (dry)
Balmoral	Tekapo 11	*Chionochloa rubra* / *Festuca* tussockland (moist)
Pukaki Downs	Pukaki 3	*Chionochloa rubra* / *Festuca* tussockland (dry)
Lindis	Lindis Pass S.R.	*Chionochloa rigida* tussockland
Omahau	Pukaki 7	*Chionochloa rigida* tussockland / shrubland (moist)

The study aims to differentiate the effects of rabbits and sheep through the monitoring of two c. 60 x 60 metre exclosures (one rabbit-proofed using wire netting, the other fenced with posts and wire only to exclude sheep) and a similar unfenced control at each site. First recording was undertaken in early 1990 prior to fence erection in August 1990. Various methods have been employed at each site which will fulfil the further aim of comparing the aptitudes of each approach in the monitoring of non-forest ecosystems (refer also Espie and Meurk this workshop).

Unfortunately, the rabbit-proof fencing is only now (October 1991) being brought up to an acceptable standard. Consequently, no interpretation of results for the first 18 months, in relation to sheep: rabbit impact is possible. The quality of the data in relation to the treatments, the timing and standard of fencing, together with the rabbit poisoning activities at each site, has to be very carefully assessed. Furthermore, damage by those doing the monitoring must dictate the frequency of recording. Annual monitoring, proposed for, at least, the first three years of the trial may be excessive.

One h-f transect was established in each treatment at each of the six sites in January / March 1990. Each was revisited in January 1991, rephotographed and three sites rescored. Only one, Omahau, showed an appreciable change in vegetation structure and composition, directly attributable to successful rabbit poisoning activities in the area. Thus, a similar reduction in rabbit browsing occurred across all treatments here. Generally, the woody species manuka *(Leptospermum scoparium)* and matagouri *(Discaria toumatou)* increased in frequency values (biomass index). Likewise, the grasses narrow-leaved snow tussock *(Chionochloa rigida),* hard tussock *(Festuca novae-zelandiae), Deyeuxia avenoides,* and brown top *(Agrostis capillaris)* also increased their biomass index. Hawkweed species showed no change in the unfenced control, but a decline in the exclosures. Because of the fencing problems no definite conclusions can be drawn (Fig. 3).

Mouse-ear hawkweed has high biomass indices on four of the six sites (Balmoral; Omahau; Richmond; Sawdon). King devil hawkweed is present but its frequencies vary between sites, being absent from Sawdon. Hawkweeds are present on both Ben Ohau and Rostrievor but at low frequencies in comparison to the other sites. The Ben Ohau community is species-rich with swales dominated by *Festuca* and ridges occupied by a close sward of herb species. Although hawkweeds are less prominent than on other sites, another introduced species, sheeps sorrel *(Rumex acetosella)* is abundant (Figs 4 and 5).

Rostrievor was complicated by the vagaries of response to rainfall by ephemeral species in these dryland areas. Recording even in early January is too late for ready identification of some of the herbs.

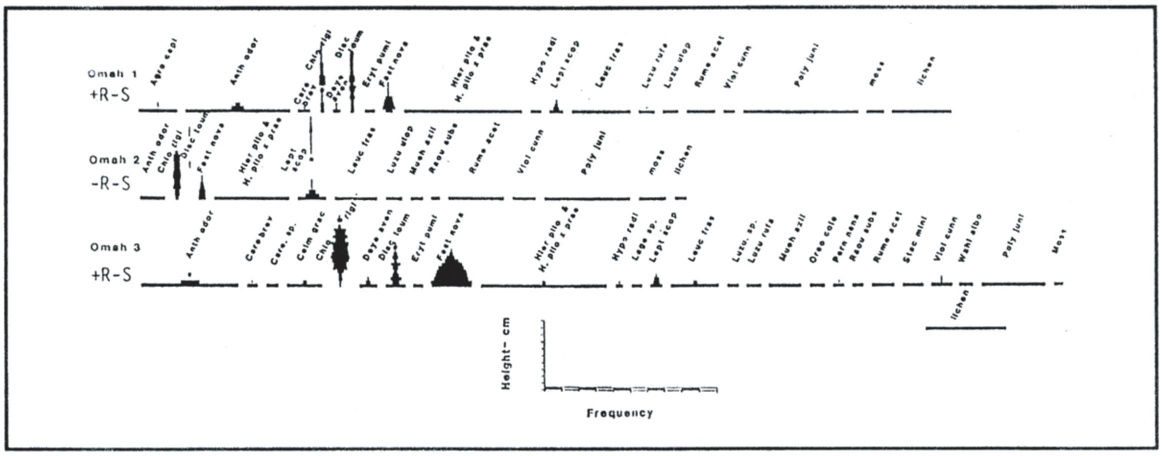


Figure 3: *Diagrammatic representation of the dominant species recorded using the h-f method along 50 m transects in each of the three treatments on Omahau Station (Omah).*

Omah 1 +R +S = control, ie unfenced plot.
Omah 2 -R-S = rabbit-proofed exclosure.
Omah 3 +R -S = sheep exclosure.
Species frequency is given in *5* cm height intervals and labelled alphabetically by the first four letters of their binomials.

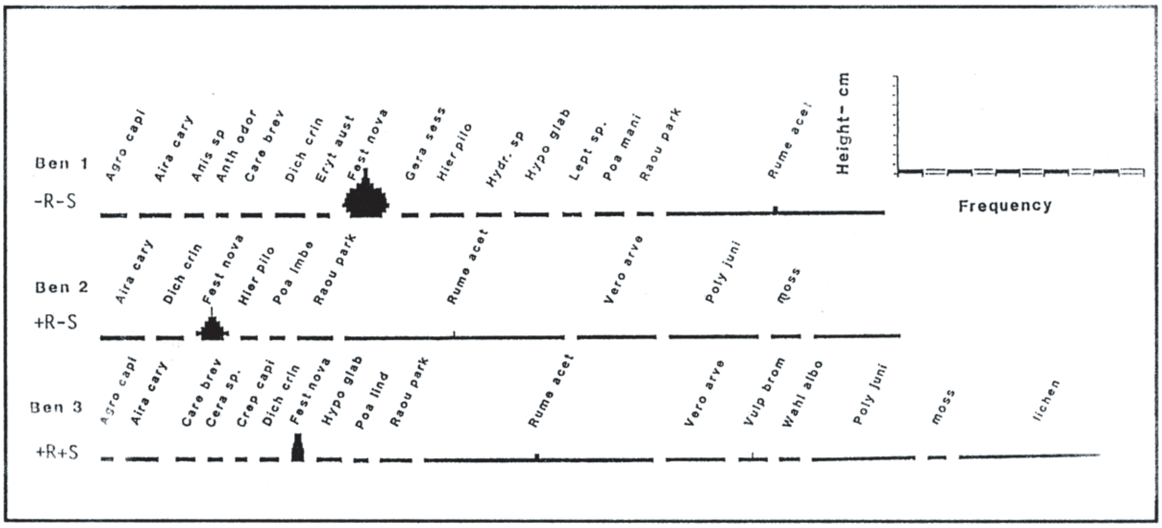


Figure 4: *Diagrammatic representation of the dominant species recorded using the h-f method along 5Om transects in each of the three treatments on Ben Ohau Station (Ben).*

Ben 1 -R-S = rabbit-proofed exclosure.
Ben 2 +R-S = sheep exclosure.
Ben 3 +R +S = control, ie unfenced plot.
Species frequency is given in *5* cm height intervals and labelled alphabetically by the first four letters of their binomials.

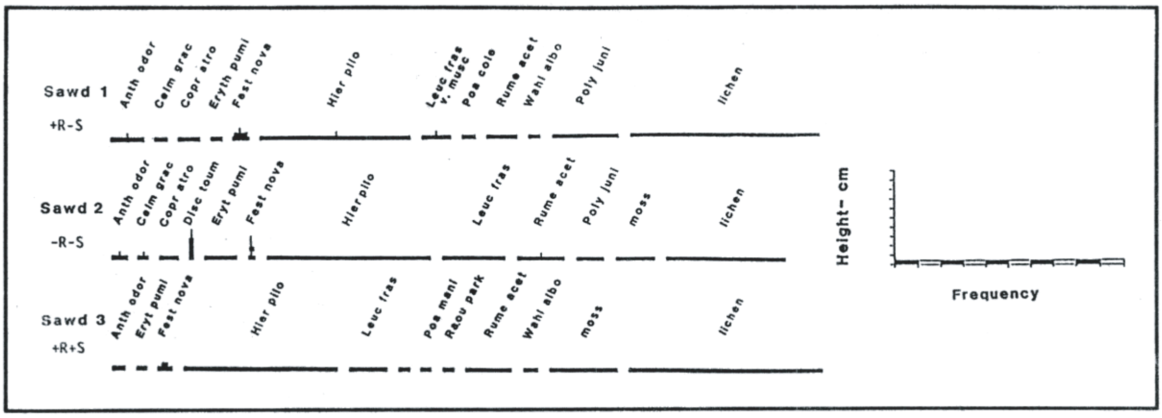


Figure 5: *Diagrammatic representation of the dominant species recorded using the h-f method along 5Om transects in each of the three treatments on Sawdon Station (Sawd).*

Sawd 1	+R-S	= sheep exclosure.
Sawd 2	-R-S	= rabbit-proofed exclosure.
Sawd 3	+R +S	= control, ie unfenced plot.

Species frequency is given in 5 cm height intervals and labelled alphabetically by the first four letters of their binomials.

Since presentation of this paper all sites have been resurveyed in December 1991.

Acknowledgements

This research has been supported by the Miss E.L. Hellaby Indigenous Grasslands Research Trust. The monitoring programme forms a part of a larger network established in association with Alan Mark (Otago University) and Bill Lee (DSIR Land Resources). I wish to thank Shannel Courtney, Susan Scobie and Mark Davis for their help during the Molesworth and Mackenzie field work. The Mackenzie Grazing Trial is a co-operative venture with Peter Espie (FRI) and Colin Meurk (DSIR Land Resources). The Department of Conservation provided logistical, and some financial, support. Susan Scobie and Phillippa Spackman helped with the drafting.

References

Dickinson, K.J.M.; Mark, A.F.; Lee, W.G. 1992. Long-term monitoring of non-forest communities for biological conservation purposes. *New Zealand Journal of Botany 30:* 163-179.

Espie, P.R.; Hunt, J.E.; Butts, C.A.; Cooper, P.J.; Harrington, W.M.A. 1984. Mackenzie Ecological Region. New Zealand Protected Natural Areas Programme. Department of Lands and Survey, Wellington.

Scott, D. 1965. A height frequency method for sampling tussock and shrub vegetation, *New Zealand Journal of Botany 3*: 253-260.

REGENERATION AFTER FIRE ON THE LEIDIG RANGE, MOUNT COOK NATIONAL PARK; THE ROLE OF HAWKWEEDS *(HIERACIUM* SPP.) DURING THE FIRST 20 YEARS.

Hugh Wilson
160 Salisbury St, CHRISTCHURCH

A major accidental fire on 28-30 March 1970 burned about 1200ha of forest, scrub, shrubland and snow tussockland between about 850 m and, the upper limit of alpine grassland, about 1900m, on the Leibig Range, Mount Cook National Park. About 200 ha of this land had been burned some 50 years previously; these carried fire-induced shrublands which recovered more quickly that remaining areas which had probably not been burnt for centuries.

Ten 6m x 6m quadrats, charted in 1971, 1973, 1975, 1980, 1985 and 1990, recorded the regeneration of vegetation across the burn and monitored species and individual plants involved in this process.

Mean annual rainfall in the study area is estimated between 2000 and 3000 mm. The ten plots range from 900 to 1800 m, on well-drained subalpine and alpine yellow-brown earth soils. Hares exerted moderate browsing pressure throughout the 20 year study, while the larger mammals (thar, chamois and red deer) were at low levels except at the beginning of the study period and again in recent years.

Recovery of vegetation was faster on the area that had been previously burnt because of the greatly increased proportion of fire-resilient species able to resprout after burning.

King devil hawkweed *(Hieracium praealtum)* occurred in only two of the plots in 1971, but by 1990 was present throughout.

King devil cover varied from 1 %, in mid altitude, vigorous, regenerated shrubland, to 8 % in high altitude degraded snow tussockland, to 97% (a nearly pure king devil sward) on land that had been under subalpine tall scrub with large mountain celery pine *(Phyllocladus alpinus),* mountain ribbonwood *(Hoheria lyalii)* and Hall's totara *(Podocarpus hallii)* before the fire. The increase of king devil hawkweed in this latter plot was spectacular. It first appeared in 1975 when it represented less than 1 % cover. At the same time Yorkshire fog *(Holcus lanatus)* represented 26 %, catsear *(Hypochoeris radicata)* 20%, hawksbeard *(Crepis capillaris)* 16 % and sheep's sorrel *(Rumex acetosella)* 8 % with only 4 % bare ground. Yorkshire fog and catsear continued to increase until 1980 when king devil hawkweed had also increased to 10%. By 1985, however, king devil had increased to 97 %, Yorkshire fog, catsear and hawksbeard were all absent and sheep's sorrel formed < 1 % of the cover. Throughout the study native woody species formed < 1 % cover.

In this climate and on these soils, king devil hawkweed shows a high degree of competitiveness and invasiveness on disturbed sites, but appears to be kept at a much lower level where shrubland, scrub and tall tussock recovered quickly after the bum. Mouse-ear hawkweed *(Hieracium pilosella),* on the other hand, has so far proved to be only a minor element in the post fire vegetation changes. It had appeared only in one lower-altitude plot by 1975, and although by 1990 it occurred throughout the whole altitude range, it was present only in three plots, and in none of them formed> 1 % of the cover.

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.

A PRELIMINARY ASSESSMENT OF THE EFFECTS OF MANAGEMENT ON MOUSE-EAR HAWKWEED *(HIERACIUM PILOSELLA)* ESTABLISHMENT IN NARROW-LEAVED SNOW TUSSOCK *(CHIONOCHLOA RIGIDA)* GRASSLAND, LAMMERMOOR RANGE, EAST OTAGO.

R.B. Allen[1], W.G. Lee[1] and A.F. Mark[2]
[1]*Landcare Research New Zealand Ltd - Manaaki Whenua, Private Bag 1930, DUNEDIN*
[2]*Botany Dept., University of Otago, Private Bag, DUNEDIN*

Summary
The frequency of mouse-ear hawkweed *(Hieracium pilosella)* was measured annually on paired 50 m transects in narrow-leaved snow tussock *(Chionochloa rigida)* grassland subject to three management regimes: unburnt for > 30 years, burnt in 1988 but not grazed, and burnt in 1988 and subsequently grazed by cattle. Mouse-ear hawkweed is present at low densities on tracks and firebreaks in the area. No establishment of mouse-ear hawkweed was recorded on the unburnt transects. Mouse-ear hawkweed was recorded at 2-3 % frequency on one burnt/ungrazed transect from 1989-1991, and at 2% on one burnt/grazed transect in 1990. These transects had the lowest litter frequencies recorded. Mouse-ear hawkweed probably established at low frequency from chance germination of wind-borne seed on suitable sites created as a 'window of opportunity' by burning and grazing the previously dense tussock grassland. Monitoring will continue to assess the persistence of mouse-ear hawkweed.

Introduction
As part of a study of the recovery of narrow-leaved snow tussock grassland from fire, with and without grazing, three topographically similar sites unburnt for at least 30 years were selected in narrow-leaved tussock grassland at c. 1070 m on the Lammermoor Range, east Otago. One site remained unburnt, the second was burnt in September 1988 but not subsequently grazed, and the third was similarly burnt but subsequently heavily grazed by cattle.

Mouse-ear hawkweed was present within a hundred metres of each site as scattered plants on bulldozed firebreaks and vehicle access tracks.
Data obtained from the sites present an opportunity to make a preliminary assessment of the effects of management on mouse-ear hawkweed distribution and establishment.

Methods
Two 50 m permanent transects were established on opposing aspects (NE and SW) at each site following burning (Table 1), and height/frequency data (presence in vertically contiguous 100cm^3 samples) at 0.5 m intervals were collected annually on each.

Table 1: *Site Descriptions, Transects T1-T6.*

Aspect	unburnt	burnt	burnt /grazed
NE	T1	T3	T5
SW	T2	T4	T6

Results
Three years' data for narrow-leaved snow tussock (including intact tussock bases), mouse-ear hawkweed, litter (excluding intact tussock bases but not recorded on T1 and T2 at any time, on T3 in May 1991, and on T4 in November 1988 and May 1991), and bare ground, are presented in Fig. 1.

Narrow-leaved snow tussock height/frequency values (biomass indices) changed little on the unburnt transects (T1 and T2), where no bare ground or hawkweeds were recorded.

On the burnt/ungrazed transects (T3 and T4), narrow-leaved snow tussock biomass indices increased rapidly in the first growing season (November 1988-April 1989), but changed little thereafter. No bare ground was recorded except in April 1990 on T4 (4%). Litter values remained more or less constant on T3 at 76-85 %, but were

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.

considerably lower (50-63%) on T4. Mouse-ear hawkweed was recorded at 2 % frequency on T4 at the end of the first growing season after burning, again a year later, and at 3 % frequency at the end of the third season.

On the burnt/grazed transects (T5 and T6), narrow-leaved snow tussock biomass indices increased slightly over the three growing seasons but remained markedly lower than that on the burnt only transects. Bare ground was present on T5 (10%) and T6 (12%) at the end of the first growing season following burning, declined to 1 % in May 1991 on T5, but increased on T6 to 19% in May 1991. Litter values were consistently higher on T5 (65-74%) than T6 (54-56%). Mouse-ear hawkweed appeared on T6 in April 1990 (2%), but was not recorded there in May 1991.

Discussion and Conclusions

The transects on the Lammermoor Range are at least 500m higher than the nearest major infestation of mouse-ear hawkweed in the adjacent Manorburn Ecological District (Report on Hawkweeds Workshop, Lincoln University, March 1990), 40-50 km to the north-west. Annual rainfall on the Lammermoor Range is 1050mm (DSIR Water Resources Survey, Dunedin; unpublished), compared with about 500 mm at 750 m elevation in the Manorburn area.

Vegetation differs markedly, with more or less intact narrow-leaved snow tussock grassland on the Lammermoor Range, and highly modified grassland with generally sparse silver tussock *(Poa cita),* red tussock *(Chionochloa rubra)* and narrow-leaved snow tussock in the Manorburn district.

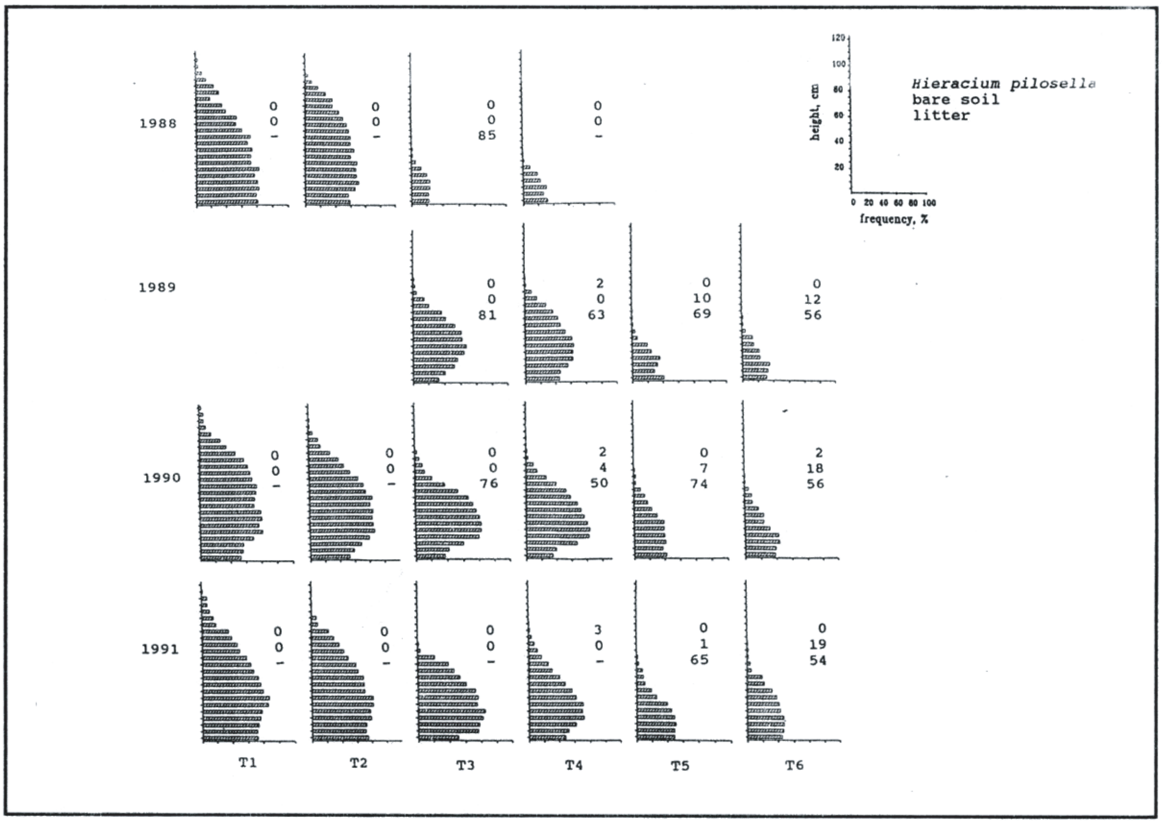


Figure 1: *Height / frequency diagrams for* Chionochloa rigida *and frequency values (%) for* Hieracium pilosella, *bare ground and litter, Lammermoor Range. Dashes indicate where litter frequency was not measured.*

The Lammermoor Range thus provides a different environment from that of the Manorburn district, and, except for altitude, from that considered to be optimal for mouse-ear hawkweed, namely intermontane basins, valley floors and adjacent footslopes, annual rainfall 650-800mm, altitude up to 1200m, and low vegetation such as hard tussock *(Festuca novae-zelandiae)* grassland (Report on Hawkweeds Workshop, Lincoln University, March 1990; McKendry & O'Connor 1990).

Nevertheless, mouse-ear hawkweed is established on disturbed ground on the Lammermoor Range, as elsewhere in tall tussock grasslands (Report on Hawkweed Workshop, Lincoln University, March 1990). The results to date of this study suggest that it can spread from these sites to enter and persist for at least three years ill tall tussock grassland where narrow-leaved snow tussock and associated litter biomass indices have been substantially reduced by fire.

The low frequency of mouse-ear hawkweed recorded in this study may reflect its intrinsic low rate of establishment from seed (McKendry & O'Connor 1990) and little vegetative spread in the time since establishment.

Although there was a tendency for mouse-ear hawkweed to establish on transects with the lowest litter frequencies, differences in mouse-ear hawkweed frequency between transects are probably a chance effect of establishment rather than the result of differences in habitat suitability.

The burning of narrow-leaved snow tussock grassland, with or without subsequent grazing, has evidently provided a 'window of opportunity' for mouse-ear hawkweed establishment at the study site. Further monitoring is required to determine the invasive ability and ultimate place of mouse-ear hawkweed on narrow-leaved snow tussock grassland on the Lammermoor Range in relation to the level of modification caused by fire, with and without subsequent grazing.

References

McKendry, P.J.; O'Connor, K.F. 1990. *The ecology of tussock grasslands for production and protection*. Unpublished report for the Department of Conservation, Centre for Resource Management, Lincoln University.

TIME SEGMENT ANALYSIS OF PERMANENT QUADRAT DATA: CHANGES IN HAWKWEEDS (*HIERACIUM* SPP.) IN THE WAIMAKARIRI IN 24 YEARS

D. Scott
NZ Pastoral Agriculture Research Institute Ltd.
P.O. Box 60, Lincoln, CANTERBURY

Summary
The data in Scott *et al* (1988) is re-examined with respect to hawkweeds. A new technique is described for determining time trends from permanent quadrats using a scattergram of means and rates of change from individual quadrats. While the mean cover of hawkweeds were low during the period, the analysis indicates that there is an exponential increase once they appear in a quadrat. .

Introduction
One of the longest and most accurate records of ground cover is from central Waimakariri for 1947-63, 1980 and 1981. Species cover were also recorded for 1956, 1959, 1962 and 1980. Permanent quadrats give precise changes at one point, but often differ greatly in mean level and rate of change from those at other points. These differences merge ecological variability with experimental variability and are not strictly independent for statistical analysis.

Time segment analysis
To overcome the non-independence of successive measurements the data for each species (eg hawkweed cover) in each quadrat is combined to determine the mean and rate of change from that quadrat. Long term vegetation trends appear as distinctive scattergram patterns of these ml".aDS and rates of change. Long term trends can be extrapolated from fitted parameters.

Methods
A full description of the sites and the field sampling methods is given in Scott *et al* (1988). In summary, permanent transects were established in 1947 at seven locations in the Porter River/Broken River area of the central Waimakariri Basin on steep slopes, in the 780-1300m altitudinal range and on various aspects. Each transect extended 200 or 300m up slope. Approximately 400 point samples at 50mm intervals were taken per 20m. Ground cover at each point was recorded as either living vegetation, dead material or bare ground. Measurements were taken annually in January or February from 1947 to 1963 and also in 1980 and 1981. In 1956, 1959, 1962 and 1980 the species touched by a third of the needles was also recorded.

The basic unit used for the present analysis was a 5m interval along a transect for a particular year, comprising approximately 100 ground cover and 30 composition records and converted to percentages. The same 5m intervals were used for samples in different years. There were 38-60 such samples per transect.

Results
Hawkweeds were only common on two transects (Cloudy Knoll South and Middle). Scattergram for Cloudy Knoll Middle showed a linear relationship between rate of change of hawkweeds and mean level for the 58 quadrats. When integrated this implied an exponential increase in hawkweed cover. The fitted relationship gave:-

% hawkweed cover = 0.0076*exp(0.0945*year)

This extrapolation estimated that there would be at least 50 % cover of hawkweeds in the present era. Extrapolation estimates were similar for Cloudy Knoll South.

Association analysis between species made a distinction between "mutual occurrence of species using all data, and interaction when hawkweeds were present in the quadrat. Hawkweeds were associated with good ground cover and were most closely associated with brown top *(Agrostis capillaris)* and patotara *(Leucopogon fraseri)*. There was an initial association with golden spaniard *(Aciphylla aurea)*.

Discussion

The exponential increase in hawkweeds observed in these transects is more consistent with the view of an invasive weed into a new environment with few environmental restraints, than that of a species exploiting a patchy degrading environment. Comparison is made with similar association analysis of Mackenzie Country data (Treskonova 1991).

References

Scott, D.; Dick, R.D.; Hunter G.G. 1988. Changes in the tussock grasslands in the central Waimakariri River basin, Canterbury, New Zealand, 1947-1981. *New Zealand Journal of Botany 26*: 197-222.

Treskonova, M. 1991. Changes in the structure of tall-tussock grasslands and infestation by species of *Hieracium* in the Mackenzie Country, New Zealand. *New Zealand Journal of Ecology 15 (1):* 65-78.

KING DEVIL HAWKWEED *(HIERACIUM PRAEALTUM)* IN WET, ALPINE, TALL TUSSOCK GRASSLAND, HOPKINS VALLEY, SOUTH CANTERBURY.

G.G. Hunter
Landcare Research New Zealand Ltd - Manaaki Whenua
P. O. Box 69, *Lincoln, CANTERBURY*

Introduction

In 1991 the main species present in midribbed snow tussock *(Chionochloa pallens)* grasslands and associated short tussock grasslands in the upper Hopkins Valley were assessed at a number of sites using a height frequency sampler. The distribution of hawkweed species at three sites, which differed in sheep grazing histories, is outlined. The sites were in a lower alpine (1380-1580 m), superhumid (annual rainfall 4000 mm/year) environment. They were located on moderately steep slopes having northerly to north-easterly aspects. Soils at sites 1 and 2 were yellow-brown earths and site 3 was on a recent soil on landslide debris.

All sites have carried moderate to high numbers of red deer, Himalayan thar and chamois, although populations have been relatively low over the last decade. Sheep have been grazed in the area since 1965. Grazing levels were nil (site 1), extensive, light summer grazing (site 2), and concentrated summer grazing within an extensive grazing regime (site 3) (Table 1). There have been no recent fires in the area.

Results and Discussion

King devil *(Hieracium praealtum)* and mouse-ear hawkweed *(H. pilosella)* were recorded at low frequencies in the study area. King devil hawkweed had become established within what are now relatively intact tall tussock grasslands (and associated subalpine scrub), in which living vegetation and litter provide a nearly complete ground cover (Table 1). It typically occurred as an inter-tussock species having a frequency of < 1 %, but it reached 16% at site 1 and was locally dominant nearby on areas disturbed by landslide.

Results do not indicate any positive relationship between impacts of past or present grazing by sheep and the distribution of hawkweeds. King devil reached highest frequencies at and near the site which had no history of grazing by sheep. This species is preferentially grazed in unimproved rangelands (Hughes 1975) and grazing may have suppressed its frequency. However, the ungrazed area had the highest rainfall and was surrounded by the most broken and bluffy terrain. Consequently it may have been prone to natural disturbances (e.g. snow avalanche, landslide) which may also favour the establishment of hawkweeds. This natural disturbance effect is corroborated by the dominance of king devil hawkweed on colluvial footslopes below high rock bluffs and on floodways in the nearby Temple Stream. (A.F. Mark *pers. comm.)* and on a landslide near site 1. Past grazing by wild animals, especially concentrated feeding by thar, may have depleted the cover and predisposed some areas to invasion by hawkweed.

Conversion of the most heavily grazed site (site 3) from tall tussock to short tussock grassland would have pre-dated the arrival of a local hawkweed parent source. Hawkweeds have not subsequently extended in cover, even in local bare areas within the overall dense grass sward. This lack of success may be related to a combination of plant competition and grazing effects.

Although king devil hawkweed was occupying sites which would otherwise have been occupied by other species, it is unknown whether or not it has directly displaced other species or colonised bare ground. It is also unclear if it will be displaced, over time, by other species, but photographs show that king devil has been dominant in naturally disturbed areas in Temple Stream for at least 10 years. Its dominance in these areas may be preserved by periodic disturbance.

Conclusions

King devil hawkweed is a significant species in tussock grasslands in superhumid, alpine and subalpine environments immediately east of the main divide. It is generally an intertussock species but is locally dominant. It is unlikely that a reduction in grazing intensity in these grasslands would induce extensive hawkweed dominance, because of the well developed plant canopy and ground cover, but its frequency as an intertussock species may increase.

Although mouse-ear hawkweed is locally present at very low frequencies in the grasslands, there was no evidence, in the study area, of its increasing.

Acknowledgements

The Department of Conservation supported this investigation.

References

Hughes, J.G. 1975. What sheep eat on developed and undeveloped high country. *Tussock Grasslands and Mountain Lands Institute Review 31* : 20-30.

Rose, A.B. 1983. Succession in fescue *(Festuca novae-zelandiae)* grasslands of the Harper - Avoca catchment, Canterbury, New Zealand. *FRI Bulletin No. 16*. New Zealand Forest Service. .

Scott, D. 1985. Hawkweeds in run country. *Tussock Grasslands and Mountain Lands Institute Review 42*: 33-48.

Table 1: *Site description for three grassland transects* in *Hopkins Valley.*

	Site 1	Site 2	Site 3
Grassland	midribbed snow tussock	Midribbed snow tussock/false spaniard	blue tussock/sweet vernal/Matthew's tussock
Sheep grazing	nil	light, extensive summer grazing (<0.1su/ha/yr)	heavy, concentrated grazing within Extensive grazing system (1.2 su/h/yr)
Ground cover %			
living vegetation	44	44	84
dead	53	52	10
bare around	3	4	6
Hawkweed frequency	moderate (1)	low (2)	low (2)

(1) King devil 16% frequency, and higher in some adjacent areas. Locally dominant on landslide scars and intertussock areas. Mouse-ear hawkweed a minor species, with frequency < 1 % and absent in many areas.

(2) King devil and mouse-ear hawkweed were minor and localised species, with frequency < 1 %. Species absent from much of the area.

SESSION TWO DISCUSSION: VEGETATION MONITORING CASE STUDIES

Time-sequential photographs of vegetation change on the South Opuha plots demonstrated that mouse-ear hawkweed plants often established and disappeared on a year-by-year basis, unrelated to longer-term trends. Such variations are important for interpretation of field records that are taken at infrequent intervals of time.

Relationships between hawkweed distribution, environment, disturbance factors, and time were discussed for specific sites:

> On the Knobby Range, patchiness in the distribution of mouse-ear hawkweed vegetation appears unrelated to environmental conditions. Some observers interpreted its distribution as being related to historic degradation of the vegetative cover, a management effect. An alternative hypothesis was that the distribution is related to chance establishment from seed, and subsequent thickening up by vegetative spread. D. Scott considered this phenomenon to be consistent with his observations of hawkweeds at the dry end of their habitat range.
>
> Tussock hawkweed and king devil are locally dominant species in rank, humid, valley 'grasslands' which have not been grazed by farm stock. Many invaded sites are subject to periodic natural disturbance (i.e., land slide scars, colluvial cones). It was hypothesized that other invasions may be related to concentrated grazing by feral animals, but no conclusive evidence was presented.

It was suggested that we have failed to make most effective use of the available information from existing long-term monitoring programmes, including ecological studies and agricultural trials. A limitation at the land management level has been the lack of reporting of derived management implications and advice, from monitoring programmes back to the community.

Key findings could be identified from a series of major, long term monitoring programmes and be integrated. Initial management implications could be derived and disseminated. However it is unlikely that we are yet at the stage where we can confidently relate hawkweed species performance to environments and management factors, or to define the limits of hawkweed species potentials.

Some elements of a successful monitoring programme were identified:

- they should be initiated with a clear concept of what is required, especially in terms of ecological issues and management needs,
- they need to be of sufficient dimension to accommodate new ecological and management questions as new issues arise. (As hawkweeds are just one element of tussock grasslands management, it would be inappropriate to focus new programmes too narrowly.),
- sites should be representative of ecosystems, landscapes and management so that results can be widely applied,
- they require a long term commitment of resources,
- results must be carried through to management implications and advice which is available to the community,
- farmers should be involved at an early stage.

Consideration was given to the respective roles of the Crown and the farming community in grassland monitoring and research. Whereas the Crown has supported, and should continue to support, investigations, the community was in the strongest position to make many of the necessary management responses. Investigations should therefore address management needs, and research implications and management advice must be in community hands. This requires early consultation between researchers and farmers. Benefits from having the community actively involved with monitoring programmes, within a standardised framework, were suggested.

Ecological implications of evidence from the monitoring programmes were reviewed.

Experience to date has shown that it is difficult to generalise as the 'hawkweed story' varies according to species and to vegetation and environments. Short tussock grasslands are most strongly affected and most at risk. Short tussock grasslands have been relatively recently induced from deforestation or destruction of tall tussock grassland. They tend to be unstable communities which are transforming to forest and scrub (comprising exotic and indigenous species), tall tussock grassland, weedy communities (especially hawkweeds), improved agricultural pastures or to degraded, open grasslands. The nature and timing of changes at any site depend on factors such as management (historic and present), climate and local vegetation types. Whereas strongly degraded tussock grasslands are at greatest risk of invasion, pictorial evidence suggested that mouse-ear hawkweed established more successfully in plant litter and in association with other vegetation than into bare ground. A semi-open canopy with patchy litter and bare ground, characteristic of most dry, short tussock grasslands, puts many communities at risk. Future management options for short tussock grasslands need to recognise the inherent instability of the induced short tussock grasslands.

Tall tussock grasslands appear to be less susceptible to hawkweeds overall, particularly in the alpine zone. However, it is clear that subhumid to humid, subalpine tall tussock grasslands, most closely associated with the montane short tussock grasslands, have also been strongly degraded and invaded. There may be more opportunities for management to preserve tall tussock grasslands than for short tussock grasslands.

SESSION THREE

CASE STUDIES FROM PLANT INTRODUCTION, AGRONOMIC AND GRAZING TRIALS

HAWKWEED CONTROL AND RESIDUAL EFFECTS OF OVERSOWING, OVERDRILLING AND HERBICIDE IN OTAGO

G. G. Cossens
MAF, Invermay Agricultural Centre
Present address: 38 *Adamson Drive, Arrowtown*

Effects of oversowing, overdrilling and herbicide
In a series of 12 field trials, between Macraes Flat and Alexandra, from which grazing was generally excluded, mouse-ear hawkweed cover was reduced from 60 to 3 % ground cover within three years by topdressing with superphosphate and oversowing or overdrilling with legumes and grasses, and to 22 % by herbicide control with 2,4-D ester. There was a. corresponding increase in clover cover from 3 % to 60% with overdrilling or oversowing but none on the untopdressed herbicide treatments. The grass component over all trials increased from 17 to 39 % cover on treated plots.

In the fourth year following treatment application the treatments were again opened to stock and after nine years under light grazing with little or no further fertiliser, the residual effect of the initial treatments was still apparent. Mouse-ear hawkweed had increased on treated plots from 8 to 29% or 2.3% per year, but had declined on nil treatments from 62 to 38% or 2.7% per year. Cloven on the treated plots declined from 45 to 6% but increased slightly from 3 to 10% ground cover on controls. The grass component increased from 17 to 31 % and 43 % cover on nil and treated plots respectively. Bare ground (15 %) and other weeds (6-8%) showed no changes over the 12 to 15 year life of the trials.

When mouse-ear hawkweed populations dominated pasture cover to at least 60% they subsequently collapsed either naturally but slowly over 9 years, or rapidly under the influence of chemical, fertiliser or plant competition.

Herbage yield
Total herbage dry matter yield on oversown or overdrilled treatments in the presence of superphosphate at 250kg/ha/yr for three years was increased by 700% over nil fertiliser and by 1,210% with superphosphate plus nitrogen at 300 kgN/ha annually. Yield of nil fertiliser treatments was approximately 500 kgDM/ha and hawkweed generally made up 15 % of the herbage components irrespective of fertiliser treatment. The herbage yield response occurred within six months of the initial fertiliser application.

Trigger values
All mouse-ear hawkweed trial sites had 60 % or more of mouse-ear ground cover, the mouse-ear having already been at this level for a considerable number of years. One area between Middlemarch and Macraes Flat was known to have had a marked infestation for at least 25 years and indicated a modal area for mouse-ear invasion. This indicated that certain site parameters or trigger values might be used to highlight probable nucleus areas from which mouse-ear hawkweed might spread. The derived threshold trigger values were:

- A November to April warm season mean temperature of 11.8°C.
- A September to April growing season with a total rainfall of 350mm.
- A September to April growing season with 100 drought days.

Other functions which interact with these trigger values would be:

- The amount of bare ground: i.e., soil temperature rises with increase of bare ground.
- Aspect: e.g., northerly aspects have a mean warm season temperature gain of 5-20%, southerly a loss of 5-12%.
- Soil depth: critically affects the number of drought days.

Mouse-ear hawkweed invasion will occur outside these limits but more slowly.

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.

Table 1: *MAF "Quick Test" 0-8cm soil nutrient analyses for hawkweed trial sites*

	Ph	P	Mg	Ca	K	S
Mean	5.2	21.5	38.3	5.7	8.1	1.5
Range	4.8-5.9	9-38	19-81	4-17	6.7	1.7

Soil nutrient status

Typically, nucleus sites show mouse-ear hawkweed to have a predilection for soils with a pH of 5.2, medium phosphate and high magnesium levels, but sulphur appears non-limiting. The mean and range of values on hawkweed trial sites for the MAF "Quick Test" analyses are given in Table 1.

Browntop decline - hawkweed invasion

The invasion of browntop *(Agrostis capillaris)* into the tussock grasslands between 1900 and 1950 has many similarities with the movement of mouse-ear hawkweed into the same areas between 1950 and 1990, with the modal site between Macraes Flat and Middlemarch being typical. Mouse-ear hawkweed thus becomes a successor to browntop which has been subject to any form of stress from insects and drought or from overgrazing by domestic or feral animals.

PLANT INTRODUCTION TRIALS IN HAWKWEED COMMUNITIES ON GALLOWAY STATION, UPPER MANORBURN

B.J. Wills, W.T. McDougall and J.S.C. Begg
Landcare Research New Zealand Ltd - Manaaki Whenua
P.O. Box 276, *ALEXANDRA*

Introduction

In the early 1980's, the Plant Materials Centre of Water and Soil Division (now DSIR Conservation Plants Section) was involved in setting up plant introduction trials on a site moderately affected by hawkweed at Galloway, near the Upper Manorburn Dam, Central Otago. Nearly 10 years -later, following dis-establishment of the trials in 1988, it is interesting to look at the situation now existing at Galloway and relate those observations to the current "explosion" of hawkweed (mainly mouse-ear hawkweed, *Hieracium pilosella)* in the tussock grasslands.

In this paper we discuss vegetation changes that have occurred in the oversown fertilised trials, large and small scale, in comparison with plant species survival in the non-fertilised "drilled" trials.

Methods

A Large Scale Oversowing trials

Trials were established in two seasons (Autumn and Spring) in each of two years (1982 and 1983). Control (non-oversown) areas were included for each year of sowing. Species used included *Lotus tenuis (corniculatus* not then being available in quantity), yellow sweet clover *(Melilotus officinalis),* lucerne *(Medicago sativa),* Alsike clover *(Trifolium hybridum),* cocksfoot *(Dactylis glomerata),* wheat grass *(Agropyron trichophorum)* and sheeps burnet *(Sanguisorba minor)*. Pertiliser (250 kg/ha sulphur super + Mo), was applied at time of sowing.

B Alternative Plant/Time of Sowing trials

These trials were established adjacent to the above trial in two seasons (Autumn and Spring) in each of three years (1983, 1984 and 1985). "Drill" lines were established in dense hawkweed with a small rotary hoe converted to cut slots (similar to the Hunter slot seeder) and a wide selection of plant species were seeded into these as 2 x 1 m lines, replicated (where seed quantity allowed) both within season of planting and over the three years of planting. No fertiliser was applied.

Table 1: *Site Details*

Soils	Matarae YGE's
Altitude	approximately 750 m a.s.l.
Mean annual rainfall	497 mm (1913-1977, Manorburn Dam) December (52 mm) and January (58 mm) receiving most rainfall.
Temperature Range	18.6°C to 34.
Mean annual	6.6°C (daily range 11°C)
Ground frosts	155 days/year.

Results and Discussion

The dominant features of the oversowing programme were the successful establishment of Alsike clover and a peak of haresfoot trefoil *(Trifolium arvense)* growth following fertiliser application. This was followed by a rapid regression of Alsike clover and subsequently a return to even higher ground-cover levels of hawkweed. The point analysis data indicates that hawkweed never really decreased in groundcover, but was simply overgrown for a couple of seasons by the Alsike and/or other species responding to the fertiliser.

Looking at both this trial and that set up by the MAF to investigate species/fertility level interactions (the latter having had total exclusion of animals for its duration), there are two notable features:

1) The rapid vegetation response which can be gained once fertility regimes are raised and productive plant species are introduced to these soils.

2) The equally rapid reversal in productivity and survival of such plant species once soil nutrients are depleted, in this case with a consequent increase in ground cover of hawkweed.

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.

In the main we believe this increase was due to the interim suppression of endemic, perennial plants by the competing biomass associated with the introduced Alsike clover and some annual species, something which the hawkweed could tolerate for a longer period and recover more quickly from. While taller statured tussocks should also be able to survive the additional biomass presence for some time, the rapid changes in soil fertility and hawkweed vigour may have sealed their fate.

On fertile soils where inputs can be maintained there is unlikely to be any problem with hawkweeds - these will remain productive as long as agronomic methods are feasible and fertiliser application remains economic. On areas less likely to be fertilised, however, we should be making much more effort to introduce "low" fertility species and allow these time, plus respite from rabbits, burning and stock, to gain a foothold in hawkweed affected country.

As regards the "low" fertility plant introductions, the situation in 1991 remains largely unchanged from the presented results, collected in 1988. *Lotus corniculatus* remains the dominant species over each of the three years x two seasons "drilling" with many of the original plots still very visible and vigorous. The other notable species is *Festuca ovina* which, while not a highly productive grass, does seem to be able to co-exist quite happily with hawkweed - it is also a very valuable soil conservation plant.

Tall oat grass *(Arrhenatherum elatius)* is establishing slowly but effectively and was actively growing when seen recently. These plants were superior selections made from material introduced from the USDA by the Soil Conservation Centre. Some red clover *(Trifolium pratense)* and *Dorycnium hirsutum* plants are still apparent and growing in the trial, but birdsfoot trefoil considerably out-produces them at this altitude.

It is interesting to note the survival of some native and other plant species in hawkweed swards of increasing density. Several of these plants appear more resistant to hawkweed competition and can, to a degree, provide an indicator of the state of pasture "degradation". For the drier, mid-altitude Otago tussock grasslands these plants are as follows: (Note that the list does not include improved pasture type plants which may only be present by virtue of OSTD programmes in the first place)

High susceptibility (to degrading soils /hawkweed)
Small intertussock dicots, ego *Celmisia gracilenta, Wahlenbergia albomarginata, Dichondra repens, Ranunculus lappaceus* and other plants like *Carex* spp., *Luzula rufa, Poa colensoi, P. lindsayii* , *P. maniototo,Agrostis muscosa, Agropyron (Elymus) scabrum* along with small annuals like *Aira caryophyllea, Bromus tectorum, Vulpia bromoides, Cerastium glomeratum, Geranium sessiliflorum,* haresfoot trefoil etc.

Moderate susceptibility
A broad grouping of many other tussock grassland plants, the mainstays among them being: *Festuca novae-zelandiae, F. matthewsii, Bromus spp., Dichelachne crinita, Rytidospenna spp., Acaena spp., Crepis capillaris, Hypericum gramineum, Hypochoeris radicata, Stellaria gracilenta, Taraxacum officinale, Vittadinia australis* etc.

Low susceptibility
Basically this group includes the taller tussocks *(Chionochloa* spp) and shrubby species - *Hymenanthera, Olearia, Coprosma, Muehlenbeckia, Pimelea, Rosa* etc. Other hardy plants which do persist include *Erythranthera pumila, Aciphylla* spp. and the scabweeds *(Raoulia* spp.). Also included in this group are the "low" fertility, introduced species mentioned above such as Chewing's fescue *(Festuca rubra)* tall oat grass and *Lotus corniculatus* which are very effective in growing with hawkweed, provided they are given time. Plants such as brown top *(Agrostis capillaris),* sweet vernal *(Anthoxanthum odoratum),* vipers bugloss *(Echium vulgare),* flannel weed *(Verbascum thapsus)* and sheeps sorrel *(Rumex acetosella)* probably should be included here, although they tend to overlap with the previous group.

Thus, although it is difficult to tie particular indicator plants into definitive stages of degradation or hawkweed invasion - the above list is by no means exhaustive and the plants listed by group will vary depending on which soil/altitude/climate combination affects them - trends are apparent.

Conclusion

What do we need for the future? We must make seed of appropriate plants, plus information on their management in hawkweed country, readily available to farmers at moderate cost. There are some who will opt for forestry/agro-forestry options, but we believe most hill and high country farmers would prefer to keep their pastoral systems alive. We may need some form of incentive to assist with the introduction of altered stock management systems and plant types for this to be successful. We believe there is enough information available to get change underway quickly. The problems lie with measures to ensure that time is available for biological remedies to take effect - we cannot afford to establish these plants only to return to grazing them within 1 - 2 years, or have rabbits eat them out in the interim. Grazing management systems must adjust accordingly - lower stocking rates, re-seeding periods, more cattle etc.

On the research side we see a need for more input into biological control methods and their optimisation, as well as into selection and breeding of improved and more diverse plant species adapted to conditions under which hawkweed currently thrives. We know much about plant introduction in tussock grasslands, but very little about the same in hawkweed deserts - this area needs attention, particularly with regard to low cost options suitable for the vastly differing landuse types and climatic regimes with which we are faced in New Zealand. A major problem facing plant introduction into hawkweed swards, with or without fertiliser, is increased susceptibility to drought-stress induced by mouse-ear hawkweed. Reduced litter content, faster water infiltration and more exposed soil surfaces combine to create a stressful environment for plant establishment even in moderately high rainfall regions.

LONG TERM CLIMATE RECORDS - CAN THEY ASSIST REAL-TIME MANAGEMENT DECISIONS IN OUR TUSSOCK GRASSLANDS?

B.J. Wills, W.T. McDougall and J.S.C. Begg
Landcare Research New Zealand Ltd - Manaaki Whenua
P. O. Box 276, *ALEXANDRA*

Introduction

Long term meteorological records along with data from corresponding. growing seasons can be used to identify rainfall periods critical to subsequent pasture growth in semi arid areas. Comparison of present rainfall figures, within the identified periods, with long term means allows some predictions of the upcoming growing season. Given sufficient warning this then allows implementation of appropriate grazing management.

Climate records for several sites in the Alexandra "region" have been accumulated with the aim of developing a reactive management system to aid farmers in managing grazing on drought prone land. The system described below aims to enable farmers to take precautionary measures to protect tussock grasslands in low or variable rainfall years when pasture growth may be detrimentally affected.

Methods

Monthly rainfall totals have been compiled from:
- Alexandra from 1922
- Earnscleugh from 1947
- Clyde Dam / DSIR from 1980.

Long term rainfall means, up until 1990, have been calculated for all sites. These were compared and combined to produce an overall long term (LT) mean monthly rainfall picture for the local "region" (Fig 1).

Monthly rainfall figures (including totals and deviations from the mean) for each of the past 11 years (1980-1990) inclusive were compared with this "regional" LT mean and with the success or failure of the corresponding growing seasons.

Results and Discussion

Two rainfall periods have been identified that affect availability of feed in late winter through spring, a critical time for feed availability.

i) Mid February to mid April. Long term monthly records indicate relatively high rainfall but also high variation from the mean during this period. Good rainfall at this period (above LT mean) may benefit early spring growth by increasing soil moisture levels prior to winter, provided good rainfall also occurs in late winter / early spring. Lack of rainfall during the autumn period is likely to result in poor vegetation responses during autumn and therefore affects utilisation in July / August.

ii) July to September. Long term monthly records indicate relatively low rainfall during this period and low variation from the mean. This indicates a reliance on steady but low moisture input during late winter / early spring to "kick off" late spring / early summer growth.

In 1991, February to April had a lower than mean rainfall. The above predictive model would suggest decreasing the grazing on low to mid altitude class 7 (and other critical land types) in spring in order to sustain vegetative cover. The two to three month warning period allows the manager to make alternative grazing arrangements.

Altitudinal and geographical differences of each site must be accounted for. The long term means are based on valley bottom records. These tend to be the driest sites in the area and should therefore provide conservative recommendations. What may appear to be a dry season at 100 m asl may be a reasonable growing season at 300 - 600 m asl.

By following rainfall closely during these critical periods, we hope to be able to build a picture of the likely situation for the autumn and spring growing periods, and have this information available in a form that can be clearly understood

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.

and acted on by runholders, with appropriate advice from Otago Regional Council officers.

In future, long term records of screen and ground temperatures may also be used to identify key trends. The model is being developed to make use of climate records from the many regional stations.

"Real time" comparison of key identified factors with long term means will allow for more accurate management decisions on land prone to drought and to depletion by inappropriate grazing.

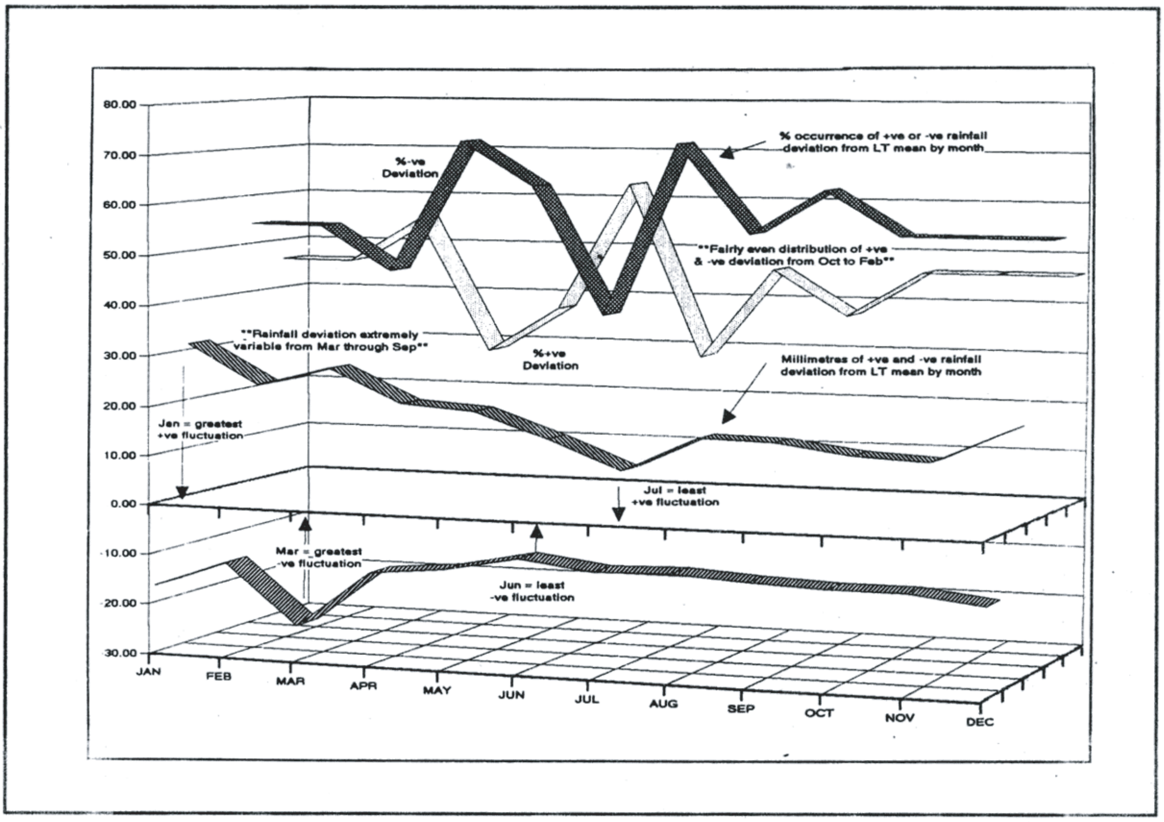


Figure 1: *Rainfall occurrence (%) and deviation (mm) 1980-1990 from long term mean for Alexandra / Clyde / Earnscleugh.*

A PADDOCK BASED SURVEY OF MANAGEMENT FACTORS RELATING TO MOUSE-EAR HAWKWEED (*HIERACIUM PILOSELLA*) DOMINANCE IN CENTRAL OTAGO

B. D. Foran[1], J. Bates[2], P. Murray[3], G. Heward[3] and D. Pickens[3]
[1]*Landcare Research New Zealand Ltd - Manaaki Whenua, P.O. Box 276, ALEXANDRA.*
[2] *MAF Farm Consultancy, P.O. Box 276, ALEXANDRA*
[3] *Landcorp, P.O.Box 27, ALEXANDRA*

Abstract
A paddock survey was conducted in the summer/autumn period of 1991 throughout the major pastoral districts of Central Otago to help in defining the extent and location of the hawkweed problem, and to generate possible hypotheses for its cause. A total of 107 paddocks were surveyed, many of them at a landscape size of 1000 ha or more. Data were collected (mostly estimates) on the cover dominance of the major hawkweed species *(Hieracium* spp.), and farm management factors that might have contributed to the problem. Multivariate analysis of the data showed that there were four main influences in the data that explained, in part, the mouse-ear hawkweed *(Hieracium pilosella)* problem. The first influence was related to the strength or resilience of the ecosystem, with weaker systems tending to trip over into mouse-ear hawkweed dominance easier than stronger systems. The second influence was related to grazing, and in particular spring grazing. The third influence was related mainly to climate, particularly the occurrence of droughts. The fourth influence was related to a number of management effects, the clearest of which was development by oversowing and topdressing during the "Land Devlopment and Encouragement Loans" period and then a failure to keep up maintenance fertiliser applications. The multivariate techniques used do not provide scientific proof of cause and effect, but rather give an overall framework within which new hypotheses can be developed and tested. From this wide ranging survey, we propose a number of management guidelines which might help hold mouse-ear hawkweed in check.

Introduction
Possible causes for the widespread dominance of high country landscapes by hawkweeds (particularly mouse-ear *(Hieracium pilosella)* and tussock hawkweed *(H. lepidulum)* in this study) have been hotly debated. Hypotheses include 'grazing/disturbance', 'invasive weed' and 'climate change' all have a place to play in the resolution of the hawkweed problem. These hypotheses need to be set in a framework with data to give initial leads to land managers, focus for research onto halting the hawkweed spread, and to find economic ways to rehabilitate those areas now dominated by hawkweeds.

In this paddock survey emphasis was placed on spatial scale of landscapes, and coverage of a range of locations along environmental gradients. To gain coverage with limited field time, data were mostly estimates along traverses within paddocks rather than measurements. Sample paddocks were selected on where hawkweed "was" and "wasn't", rather than random or regular sampling. The number of paddocks (107) and land units within paddocks (340) gave a widely drawn population, within which sampling was based on land unit, rainfall, altitude and management history.

Methods
A data collection sheet was developed with site characteristics (land unit makeup, soil, aspect, rainfall, altitude etc.), dominance of hawkweed species on a cover basis (mouse-ear, tussock, king devil hawkweed *(H. praealtum)* cover, and spatial patterning of cover and spread) and landscape management details (season and intensity of stocking, years since last burning, rabbits, porina infestation, development history and maintenance, experience of management etc.). Survey time was allocated to cover rainfall and management gradients within the different farming areas of the region. Eight primary landscape units were defined for data collection as follows, sunny faces, dark faces, dry flats, campsites, wet flats,

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in *tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.*

neutral hills, dry eroded ridges and gullies.

Data analysis went through three main phases. Correlation and multiple regression attempted to delineate simple relationships of site and management characteristics to hawkweed dominance. A suite of classification and ordination methods in the PATN multivariate analysis package (Belbin 1989) were used to locate major influences in the data. This produced a somewhat synthetic species composition array of 8 land units by 2 species giving the equivalent of a 16 species array. Vector values produced from the ordination were then regressed back to environmental descriptors to indicate "strength" of influence. Finally the data for individual land units were graphed in three dimensions with measures or ratings of site descriptors as the x and y values, and the cover of mouse-ear hawkeed as z values. When these data were incorporated into a smoothed surface, the peaks or valleys so displayed sometimes helped to suggest important influences that would not be shown with numeric analytical methods.

Results

Land Units and Mean Values
Most of the land units in the survey were sunny faces and dark faces, and most time in analysis was spent on them. Dry flats and sunny faces, and wet flats and dark faces were combined in some analyses on the basis that they provided similar opportunities for plant growth. Mouse-ear was the most important hawkweed on a ground cover basis, and most analysis concentrated on it. Tussock hawkweed was quite dominant on several sites, but replication was considered inadequate to explore in depth the possible causes of its dominance.

Maximum ground cover values of 65-75 % were found for mouse-ear hawkweed on sunny and dark faces, dry flats and dry eroded ridges. Mean ground cover values varied from 0% in campsites, to a range of 12-28 % in the major land units sampled. The survey sample of paddocks had many sites with zero or very little hawkweed cover. Tussock hawkweed reached a maximum value of 20% ground cover on a wet flat, and was important in cover terms in only 21 of the 340 land units surveyed.

Correlation Analysis
All correlation and regression analyses of hawkweed species ground cover against site and management descriptors gave disappointing results, with little variation accounted for. This was expected because of the many factors that appear to be operating in the hawkweed complex. Any attempt to define a relationship between mouse-ear hawkweed ground cover and an environmental descriptor was always confounded by a large number of zero hawkweed values.

Ordination and Pattern Analysis
The first four vectors of the ordination analysis accounted for 57 % of the variation in the hawkweed species by Land Unit matrix (Vector 1: 20%; Vector 2: 15%; Vector 3: 12%: Vector 4: 10%). Correlation of the vector values with the site and management values gave some indication of the possible contributing factors for each vector.

- <u>The First Influence</u>

The first influence (Vector 1) was correlated to the 'strength of the site' or 'site resilience'. Unfortunately this was not rated or measured directly in the site survey, but showed up in a 'site aridity/soil depth/water holding capacity' rating, and another one on 'tussock vigour'. There was also a negative correlation to the time back to last burn which might indicate a low system productivity, and a lack of need to burn. This strength/resilience vector as the dominant influence agrees well with the site notes and attitudes offered by the individual paddock surveyors. In lower rainfall areas, mouse-ear hawkweed did not dominate locations with very shallow soils or stone and rubble dominated areas. Dominance therefore seemed to be a feature of landscapes with intermediate to low landscape resilience, and it then petered out on locations which provide very poor opportunities for plant growth. Work proceeding in Central Otago (Allan Hewitt, *per. comm.*, DSIR Dunedin) aims to provide good estimates of landscape resilience and soil depth, based on a soil prediction model using slope, slope shape and aspect as the main inputs. The zones of intermediate resilience where we expect mouse-ear hawkweed to be most advantaged, are in the yellow grey or pallic soils at intermediate altitudes, the main development zone for oversowing and topdressing. Validating and testing these concepts of landscape resilience to other zones in the high country should be the first recommendation from this workshop.

- <u>The Second Influence</u>

Spring grazing and maximum yearly temperature, seem to be linked influences in this second vector. For both the sunny and dark faces these combine to apparently describe the spring grazing country (Fig. 1).

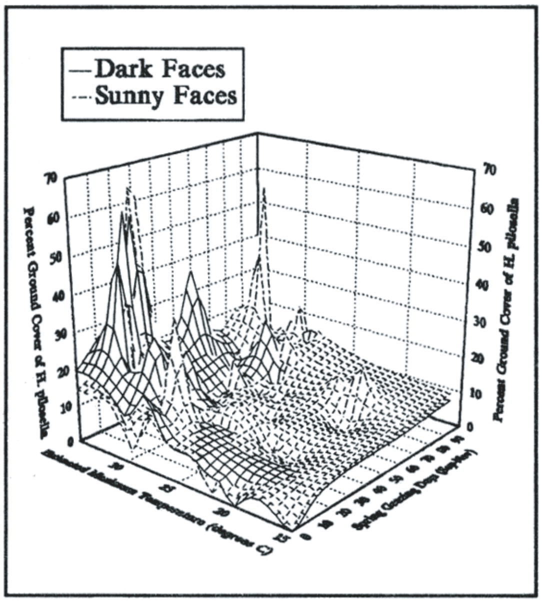


Figure 1: The *relationship between mouse-ear hawkweed ground cover (z), spring grazing days (x) and maximum yearly temperature (y).*

Parallel to this finding is the opinion gleaned from Rabbit and Land Management Program property plans in Canterbury, that mouse-ear hawkweed tends to be associated with spring grazing and ewe-lambing country. There are a number of contributing factors to this opinion. The allocation of flocks to the lambing blocks usually has very little flexibility, and has probably gone on since the start of extensive pastoralism. The same number of ewes go onto the same blocks whether there is drought or plenty. Sunny lower blocks such as these are often good habitat for rabbits as well. The feed requirements of the ewe flock increase by up to 300% after lambing. This increase, combined with a lack of availability of other country and a highly variable opening to the season, provide a scenario of how extreme grazing pressure could be exerted, year after year on the same block, even in well managed enterprises with land managers who are sympathetic to land conservation values. The key point to be addressed, is the lack of flexibility in the farming system, given that shearing and lambing are the key economic hinge on which the pastoral enterprise operates. They are essentially non moveable events in the mountain lands environment. The correlation of spring grazing days and mouse-ear hawkweed abundance does not prove the çgrazing/disturbanceé hypothesis, but rather it provides a tighter definition for the grazing hypothesis, which can be then proven or otherwise.

- <u>The Third Influence</u>

Climate was the main factor correlated with this vector, and in particular climate cycles (Fig. 2).

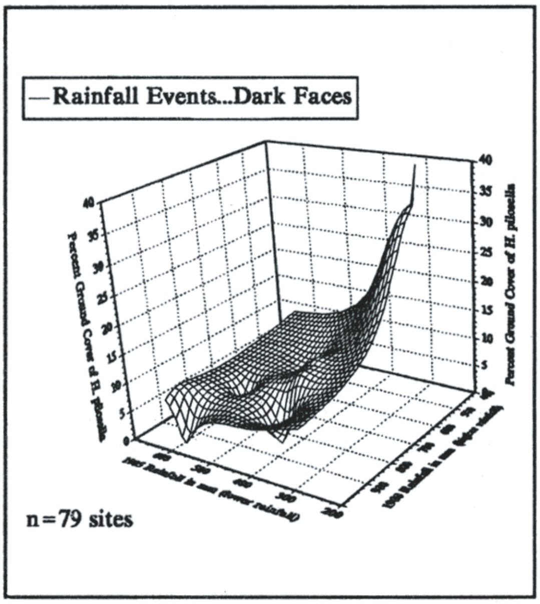


Figure 2: *A surface showing the relationship of the yearly rainfall in 1980 (x) and 1985 (y) on ground cover of mouse-ear hawkweed (z).*

From a somewhat sketchy rainfall database of the last 10 years, for 15 stations chosen to be as close as possible to our survey areas, the years 1980 and 1985 seemed to separate out some mouse-ear hawkweed dominant dark faces. 1980 was a year with rainfall 100 mm greater than average across the district, while 1985 was a drier year with 100 mm less than average. The blowouts of mouse-ear seems to have occurred in areas that bad drier than average years in both 1980 and 1985 i.e. twice the drought frequency.

To suggest cause and effect of droughts in themselves is a little risky, but drought in combination with several other factors such as high stock numbers etc. is a possible scenario. Opinions from farmers noted by the field surveyors point to drought being identified as a trigger in mouse-ear hawkweed increase, probably due to bare ground providing an opportunity for colonisation. There was also some correlation of this vector with a rating on Porina/grass grub infestation. This is some. support to a view that grass grub and/or porina are key agents in weakening tussock systems thereby allowing hawkweeds to gain a competitive advantage. The long term botanical studies presented at this workshop, should add more rigour to the view that rainfall cycles (wetter or drier) are important influences in the complex of factors which help hawkweeds assume dominance.

- <u>The Fourth Influence</u>

A mixed bag of management factors were related to the fourth vector or fourth influence. One was the influence of development (Fig. 3). There was a peak of mouse-ear hawkweed cover that related to a development phase about 10 years ago, which bad not received any subsequent maintenance fertiliser. This seems to correspond to the days of çLand Development and Encouragement Loansé where easy money encouraged capital expenditure on oversowing and topdressing, without a farmer commitment to proper maintenance and management of this technology. We can also assume that droughts and rabbits were playing a part in this complex of management factors.

A number of social ratings of farmer attitude and ability also correlated with this influence. Field officers were asked to rate the farmers managerial competence (1 =poor, 5 = good) and record keeping ability (1-5). A low rating on managerial ability and a medium rating on record keeping coincided with the major peak of mouse-ear hawkweed ground cover. It is difficult to know whether this says more about the attitude of the data collectors or the ability of farmers. The

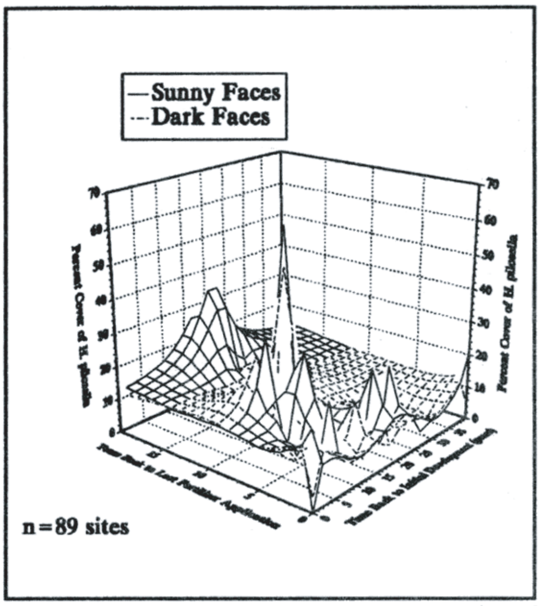


Figure 3: *A surface relating mouse-ear hawkweed ground cover (z) to time since pasture development (x) and time since last fertiliser (y).*

çWhite Fence Syndromeé whereby farm visitors assume a good relationship between neatness of homestead and land management ability is one that could be easily disproven. In addition there could have been an auto-correlation of 'high hawkweeds means poor management'. It does emphasise however, that practical descriptions of the people side of land management, are as important as the biological ones, in finding a way to trade our way out of the hawkweed problem.

Areas Most Prone To Mouse-Ear Hawkweed Dominance

This survey data for Central Otago shows that sunny faces can trip over into mouse-ear hawkweed dominance across the whole altitude and rainfall range. On the dark faces the risk areas seem to lie in a rainfall range from 300-500 mm and an altitude from 2500-4000 feet. These somewhat rough data tend to agree with the concept of landscape resilience, and suggest the need for a more rigorous data collection, as a precursor to the development of a çresilienceé field methodology. Ratings on tussock cover and tussock vigour, also show a threshold of around

20-30% tussock cover, below which mouse-ear hawkweed finds it easy to become dominant, especially where tussock vigour is low. This threshold is general across the other land unit types. These general landscape data, and the management effects highlighted in influences 1-4 (vectors 1-4 of the multivariate analysis), lead us to proposing a number of very shifty generalisations to help focus future management advice.

Management rules to avoid mouse-ear hawkweed dominance

Rule 1: Ecological strength or resilience of a landscape is a predisposing factor for proneness to mouse-ear hawkweed dominance. Therefore the ecological resilience of all paddocks on a farm should be assessed as part of the long term strategic management plan.

Rule 2: There appears to be a threshold of around 20-30% tussock cover below which mouse-ear hawkweed has a competitive advantage, especially where tussock vigour is low. Don't graze, bum or bugger up a paddock or site which is hovering around the cover/vigour threshold.

Rule 3: There seems to be an effect of spring grazing, ewe/lambing blocks and warm country. Buy or develop alternative spring grazing country , that allows flexibility of the grazing enterprise, particularly in drought years and dry springs.

Rule 4: Pasture development without the full commitment of regular fertiliser maintenance will probably tip over into mouse-ear hawkweed dominance with a little help from grazing pressure and drought years. Once you are on the development treadmill, you are committed to stay on it.

Rule 5: Climate cycles playa part in triggering mouse-ear hawkweed dominance, and they could playa part in getting rid of it. In times of drought and plenty, you must be prepared to destock and de-rabbit completely to either minimise system stress, or allow possible recovery.

References

Belbin, L. 1989 (unpublished). *PATH: Pattern analysis package*. CSIRO Division of Wildlife and Ecology. Canberra, Australia.

MANAGEMENT EFFECTS ON HAWKWEEDS - THE STONY CREEK EXPERIENCE

Caroline Mason
Landcorp Management Services Ltd., P. O. Box 142, CHRISTCHURCH

Introduction

In 1982, the former Department of Lands and Survey established a demonstration trial on the Stony Creek pastoral lease (eastern Mackenzie basin). The aim of this trial was to investigate some management options for pastures containing hawkweeds *(Hieracium* spp.) on a scale relevant to management of pastoral leases.

The trial site is 248 ha of hawkweed dominated hill country within the semi-arid rainfall zone. The altitudinal range is 640m to 850m and the aspect is predominantly north-east, south-west with a balance of half summer and half winter country. Soils are mapped as Omarama Steepland Yellow Grey Earths.

Three management strategies for control of hawkweeds were allocated to three farmlets of approximately equal size and balance of country;

(a) Attempt 'low-cost' control using low moisture and fertility demanding species, subdivision and stock management: **Farmlet A**.

(b) Attempt 'conventional' control using relatively high cost inputs of seed and fertiliser along with subdivision and intensive stock management: **Farmlet B.**

(c) Do nothing i.e. extensive management: **Farmlet C**.

The farmlets have been run as self-contained units, stocked with merino wethers and managed using the same constraints as would normally operate on this type of country. Vegetation composition has been monitored on permanent line transects, with ground cover estimates, biomass ranks and photos. Stock numbers and weight, wool weight and climate have also been monitored for the nine years the trial has been running.

Preliminary results from the trial are briefly summarised, concentrating on information collected on hawkweeds in relation to the three management options.

Summary

Cover of mouse-ear hawkweed *(Hieracium pilosella)* has tended to remain stable on both aspects of Farmlet B (at about 8% sunny and 30% shady) and on shady faces of Farmlet A (30% cover). A slight increase in cover has been noted on sunny faces of A (from 2 to 7 % approximately), while cover has increased on both aspects of C (from 15 to 30% on sunny, and 32 to 40% on shady).

This suggests that the application of fertiliser may have limited any increase in cover of mouse-ear on Farmlet B and shady faces of Farmlet A. In contrast, ferti1iser appears to have little impact on the sunny faces of Farmlet A. Introduction of more productive species on Farmlet B (where this has been successful) seems to have resulted in a decrease in cover of hawkweeds. However, it is difficult to generalise, due to the variability in response to oversowing and top dressing (OSTD) experienced throughout the trial.

King devil hawkweed (H. *praealtum)* was less abundant than mouse-ear hawkweed (initial cover ranged from 0 to 35 % compared with 0 to 80 %), but showed a similar distribution in relation to aspect. To date the cover of king devil has remained stable or declined along most transects.

Aspect (or more probably soil moisture) obviously has a major influence on distribution of both species of hawkweed, as well as on likely success of OSTD. The most successful OSTD was that undertaken in 1982 which was followed by a wet spring. In this climate of variable rainfall and high potential evaporation, spring rainfall appears to be a critical factor in determining success of OSTD. The variable seasons experienced over} the term of the trial probably explains much of the patchy success of oversowing to date. The disappointing results obtained from oversowing with 'non-traditional' species highlight the

problems associated with establishment of these species in country where aerial application is the only practical option.

While detailed analysis of grazing records in relation to changes in vegetation cover (particularly cover of hawkweeds) have not been undertaken to date, preliminary assessments show little obvious relationship. Stocking rates were substantially increased on Farmlet B, and this has some localised impact on vegetation cover. Estimates for bare ground and litter were noticeably higher in December 1985 for several paddocks grazed just prior to monitoring. At this stage, there is little evidence that this has had any impact on hawkweed cover, but this aspect needs further investigation.

Acknowledgements

Peter Innes (runholder, Black Forest Station) has been responsible for stock management and day to day running of the trial, and Ray Ward-Smith (Landcorp, Timaru) co-ordinated the oversowing and development programmes. Waitaki Catchment Commission (Canterbury Regional Council) established and maintained the climate station until 1990, when DSIR Water Resources, Tekapo took over. Numerous field workers have helped with the monitoring. Di Robertson helped with the preparation of this paper.

RESPONSE OF MOUSE-EAR HAWKWEED *(HIERACIUM PILOSELLA)* IN THREE LONG TERM MANIPULATIVE AGRICULTURAL TRIALS

D. Scott
NZ Pastoral Agriculture Research Institute Ltd
P. O. Box 60, Lincoln, CANTERBURY

Summary
The three trials related to fertiliser, seeding and grazing treatments on hawkweed dominated fescue tussock grassland communities. These were monitored for 6-9 years in terms of inputs required and sheep stocking rates and vegetation composition/cover achieved. Mouse-ear hawkweed decreased or disappeared under high fertiliser and sowing inputs but remained an increasingly important- component under successively lower fertiliser inputs. The approach of agricultural trials is contrasted with that of ecological surveys in determining management options for mouse-ear hawkweed control.

Methods
The first trial had 3 developments (undeveloped, fertiliser+simple general mix, fertiliser+species strips) x 4 times of set stocking (spring, summer, autumn, nil or mob stocking) x 2 sites (moderate soil + high mouse-ear hawkweed, shallow soil + low initial mouse-ear), (1975-82).

The second and third trials were a complex species mixture sown at the Mt John trial site with high initial mouse-ear hawkeed (1981 - present). The second trial had 27 combinations of P and S annual fertiliser rates. The third trial had 5 fertiliser rates (0, 50, 100, 250, 500 + irrigation superphosphate/yr) x 3 stocking rates (lax, moderate, hard) x 2 stocking methods (mob, sustained) x 2 replications. Vegetation composition was from spring rank scoring and converted to species composition by geometric series relationship of four classes:- mouse-ear hawkweed, tussock, legume sown grass and others. Anima1 grazing days per plot were recorded.

Results
The main response in vegetation composition and carrying capacity was to fertiliser. Stocking rate and method had relatively little effect on the proportions of the main vegetation classes. The carrying capacity increased 3-5 fold with development.

In the first trial, mouse-ear hawkweed remained dominant or increased on unfertilised treatments. Mouse-ear was suppressed on the moderate site with fertiliser and sowing but increased during the long legume establishment phase on shallow soil. In the second and third trials mouse-ear remained dominant at nil or low fertiliser inputs. Russel lupin *(Lupinus polyphyllus)* at low fertiliser inputs, and alsike *(Trifolium hybridum)* and white clover *(T. repens)* at high fertiliser input were dominant for six or more years. Sown grass only became dominant at high fertiliser input following the legume phase.

Discussion
Mouse-ear hawkweed control will depend on identifying those environmental factors that can be modified, and to which the hawkweeds are susceptible. The approach of the survey ecologist and experimental agriculturalist differ in the emphasis given to the two aspects. The ecologist tries to identify the environmental factors to which hawkweed is responding in the hope that some are manageable, while the experimentalist tries altering the environment in the hope that one of them will control hawkweeds. Both approaches will need to go through an experimental validation and costing phase.

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.

INTERACTION BETWEEN SOME PASTURE SPECIES AND TWO HAWKWEED *(HIERACIUM)* SPECIES

D. Scott and B.L. Sutherland
NZ Pastoral Agriculture Research Institute Ltd., P. O. Box 60, Lincoln, CANTERBURY

Summary
The input/output regression of harvest from binary mixtures was used to determine the competitive interaction between 13 pasture species, mouse-ear hawkweed *(Hieracium pilosella)* and king devil *(H. praealtum)* in a low fertility soil. Treatments included a factorial of presence or absence of compartments separating root and shoots of species. Species differed in their mean growth rate relative to hawkweed species, but the rate was not related to the proportion of hawkweeds in the combination indicating a general lack of specific competitive effects. Mean growth rates (relative to mouse-ear hawkweed) were; white clover *(Trifolium repens)* (best), smooth brome *(Bromus inermis),* sheep's burnet *(Sanguisorba minor),* fescue tussock *(Festuca novae-zelandiae),* chewings fescue *(Festuca rubra),* tall oat grass *(Arrhenatherum elatius),* sweet vernal *Anthoxanlhum odora/um),* birdsfoot trefoil *(Lotus corniculalus),* catsear *(Hypochoeris radicata),* alsike clover *(Trifolium hybridum),* and milk vetch *(Astralagus cicer).* Shoot partitions decreased interaction of white clover while root partitions increased interaction with smooth brome.

Introduction
The search for species which out-compete hawkweeds bas two components; identification of species which have greater growth rates than hawkweeds, and those that may have particular competitive abilities against hawkweeds. Most competition experiments should be called 'interaction' or 'interference' experiments because they do not differentiate between resource capture and other interactions.

Methods
The species were compared in binary combinations in two ratios; 4 plants of species A to 1 plant of species B (or vice versa). Species mixtures were grown in containers that were 200x200x200 mm in size, in high country yellow-brown mixed topsoil/subsoil of the Craigieburn set. Within containers, an additional treatment of an above ground or below ground partition around the central plant was imposed. Most species comparisions were made on unamended soil but a fertility treatment comparison (weekly addition of a nutrient solution) with unamended soil was added to 6 of the 19 species combinations tested. Each species pair, root/shoot partition and fertility treatments were replicated 3-6 times. Containers were grown in a field situation at DSIR Lincoln.

Shoots of each species pair were harvested 3-6 times per year depending on growth rates. Data (dry weights from shoot harvests) were analysed using a modified input/output ratio method. Ratios were rotationally transformed so that regression intercepts became direct tests of differences in mean growth rates, and gradients direct tests of competitive or interaction effects.

Results
Growth rates were generally low. There were significant difference between species in growth rates relative to the hawkweed component. No species showed significant gradients, indicating a general lack of specific competitive effects. The difference between species did not alter witb fertility.

Discussion
Competition is a simple concept, but difficult to define accurately. Mason (1987) similarly found no indication of specific competition effects. Continued search for species with specific competitive effect is probably not a useful allocation of research effort.

References
Mason, C.R. 1987 (unpublished). *Rhizomatous legumes for hawkweed dominated grasslands:* M.Applied Sc. thesis, Lincoln College, University of Canterbury.

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.

LONG TERM EFFECTS OF PASTORAL MANAGEMENT ON IMPROVED TUSSOCK GRASSLAND VEGETATION

B.E. Allan[1] and R.J. Doney[2]
[1]*MAF Technology, P.O. Box 24, LINCOLN*
[2]*Previously MAF Tara Hills, Private Bag, OMARAMA.*

Summary
The ecology of much of the South Island tussock grassland is under threat, particularly from hawkweed *(Hieracium spp.),* and present pastoral practices are perceived to be aggravating this threat. Eleven years of research evidence from a long term grazing trial at Tara Hill High Country Research Station near Omarama identifies effects pastoral management has on the botanical composition of improved tussock grasslands. Effects on native tussocks include:

- Fescue tussock *(Festuca novae-zelandiae)* cover can be maintained under careful grazing management (optimal from an animal production point of view) but will be lost at higher stocking rates.
- Blue tussock *(Poa colensoi)* cover can be enhanced by grazing, even at relatively high stocking rates. Blue tussock will respond to grazing by producing high quality stock feed. Its value as a pastoral and conservation species is under-rated.
- Tussock cover is generally stable and not influenced greatly by year to year climate variability .
- Changes in tussock cover are induced by stocking rate rather than grazing practice (ie continuous stocking versus rotational grazing)

In 1985 the management from the grazing trial that gave optimal, yet sustainable pasture utilisation was applied to the commercial hill farm at Tara Hills. Whole farm vegetative monitoring was started in 1986 to record the impact of management change. Transects were recorded in 1990 and results with particular reference to the occurrence of hawkweeds are presented.

- There was no occurrence of hawkweed on the low sunny BGE/YGE soils that are improved, carefully grazed and well maintained.
- Mouse-ear hawkweed *(H. pilosella)* was considered the greatest threat on the high (1200m asl) improved sunny YBE soils where it increased while clover and tussock cover decreased.
- King devil hawkweed *(H. praealtum)* was of highest occurrence on the high (1100 masl) improved shady YBE soils but appeared to be in balance with other pasture species.
- King devil hawkweed occurrence increased substantially on the high (1500 masl) unimproved YBE soils, reducing the amount of bare ground.

Responsible high country farming should be recognised as a manipulative tool that can enhance rather than deplete ecological values of the tussock grasslands, but for this to happen generally, there must be change in management and attitude amongst high country land managers.

RABBIT AND SHEEP GRAZING IN MACKENZIE TUSSOCK GRASSLANDS: VEGETATION CHANGE 1991

P.R. Espie[1] and C. Meurk[2]
[1]*Forest Research Institute. Present address:* 29 *Woodford Tce, CHRISTCHURCH* 5
[2]*Land Resources, D.S.I.R., Private Bag, LINCOLN*

Grazing and hawkweeds *(Hieracium* spp.) are two critical factors affecting management of montane tussock grasslands, for both pastoralism and nature conservation. The effect of rabbit and sheep grazing on the major short and tall tussock grassland communities in the Mackenzie Ecological Region is being assessed yearly in a long-term monitoring programme.

Ten study sites were chosen from the Mackenzie Protected Natural Areas Programme survey (Espie *et al* 1984) with representative red *(Chionochloa rubra)* , fescue *(Festuca novae-zelandiae),* silver *(Poa cita),* and snow tussock *(Chionochloa* spp.) grassland communities. The sites range from the top of Lake Tekapo to Benmore, and from Burke's Pass to Lindis Pass, spanning the major climatic gradients in the basin. At each site three grazing treatments (60 x 60 m or 75 x 75 m) were established:

a) Ungrazed (post and 2 cm mesh netting exclosure)
b) Grazed by rabbits (post and wire exclosure)
c) Grazed by rabbits and stock (unfenced)

Within each treatment a 20 x 20-m plot was randomly located and eight randomly selected stereo-pair photo-points were recorded (Allen *et al* 1983). A 50 x 50 cm quadrat at the centre of every photo-point was used to identify and visually estimate percentage cover of all species present, including bryophytes and lichens. Basal cover at ground level was also recorded for tall species. Two additional quadrats were randomly located outside the plot. Tussock density and size were measured on a variable area plot (Batcheler 1986), randomly located within the 20 x 20 m plot. The plots were measured in January 1990 and again in 1991. The exclosures were fenced between July and September 1990.

Preliminary results are that vegetation cover increased by 4 %, and litter cover declined 2 % between 1990 and 1991, attributable to overall reduction in grazing pressure and a favourable spring in 1990. Severely depleted grasslands recovered rapidly after release from grazing; vegetation cover increased by 23 % at one site. Shrub and grass recovery was conspicuous on the deeper moister soils.

Overall, the removal of grazing has not yet had a statistically detectable effect on extent of bare ground, total vegetation, tussock, grass, or hawkweed cover. Exclosures were fenced only 3-5 months before remeasurement, and rabbit exclusion was inadequate in some sites. The trend, however, is as expected: total grass cover increased 0.4% (on average) in the exclosures compared with only 0.2% in the grazed grasslands.

Hawkweeds are continuing to spread in the Mackenzie Basin. Cover increased an average of 1.5% across the Basin, varying from a 2.0% decline on an eroding site to a 6.2 % increase in mesic grassland. Mouse-ear hawkweed *(H. pilosella)* appears to be increasing faster than king devil *(H. praealtum)* although this varied according to site.. It is too early to see any differences that might be due to grazing.

References

Allen, R.B.; Rose, A.B.; Evans, G.R. 1983. *Grassland survey manual: a permanent plot method*. NZ Forest Service, FRI Bull. 43.

Batcheler, C.L. 1986. Rapid inventory and monitoring of vegetation and animals by variable area and pellet sampling. *In:* Stewart, G.H. and Orwin, I.(Eds.) *Indigenous Vegetation Surveys: Methods and Interpretation,* pp. 18-24. Forestry Research Centre, FRI, Christchurch.

Espie, P.R.; Hunt, J.E.; Butts, C.A.; Cooper, P.J.; Harrington, W.M.A. 1984. *Mackenzie Ecological Region, New Zealand Protected Natural Areas Programme*. Department of Lands & Survey, Wellington. 140pp.

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.

STUDIES OF HAWKWEEDS IN THE DIET OF SHEEP IN NEW ZEALAND TUSSOCK GRASSLANDS

K.F. O'Connor and N. Covacevich
Centre for Resource Management. P.O. Box 56. Lincoln University, CANTERBURY

Introduction

Comments are frequently made that hawkweeds such as mouse-ear *(Hieracium pilosella)* are not eaten by sheep because of their appressed growth habit. Such evasion of grazing is offered as a reason for their increase in the tussock grassland communities. Other comments have suggested that their acceptability to sheep is affected by grazing pressure or by topdressing. I have recently been reviewing a series of studies of sheep diets in tussock grasslands, mostly as part of a post-graduate programme of persons under my direction or supervision. The following summary notes are abstracted from this incomplete review, to supply referential information on the place of hawkweed species in sheep diets.

Methodology

All of the six studies examined have involved estimation of species rank abundance in herbage mass. Most of them have involved estimation of species rank abundance in the diet of sheep by determination of species composition of cuticle fragments in faecal samples. Some of them have involved estimation of species rank abundance in herbage mass before and after a grazing period. Large advance in rank from field to diet would indicate selection by animals; large declines in rank would indicate rejection. Only species in very high rank in diet (1-5) are likely to contribute appreciably to animal intake. Likewise, in many herbaceous communities only species of high abundance (ranks 1-10 or even ranks 1-5), contribute measurably to herbage mass.

Summary of results

Mouse-ear hawkweed has been at low field abundance (rank >30th) at Ribbonwood (J.G. Hughes 1975), Tara Hills (A.B. Edge 1979) and very low at Brooksdale (E.J. Stevens 1977). It was frequently evident in diet at Ribbonwood, but principally as stem material. It was rarely evident, even as flower stem material, at Tara Hills or Brooksdale. It was at high field abundance at Glenthorne (P.S. Harris 1978) and at Mt. John (N. Covacevich 1991). In both these locations it was selected against, even when no longer appressed (Covacevich 1991). Before partial area topdressing at Glenthorne, its rank declined from mean 5th in field abundance to mean 25th in diet (Harris 1978). After partial area topdressing it may have been consumed with clover in the oversown and topdressed sward (Abrahamson *et al 1982)*

King devil hawkweed *(H. praeallum)* was at moderate field abundance at Ribbonwood (ca. 7th rank in undeveloped, ca. 14th in developed area) and at Tara Hills (from 11th to 20th). It was at low field abundance at Glenthorne, but not found at Brooksdale. At all topdressed sites where it was present, it was selected positively in diet. It was clearly rejected or selected against where topdressing had not been done.

Summmary conclusions

These two species are different in their acceptability to sheep. This difference may not be dependent on growth habit. Acceptability may be affected by pasture topdressing, especially for king devil and possible for tussock hawkweed *(H. lepidulum)* which has been include with it at Glenthome.

References

Abrahamson, M.; O'Connor, K.F; Harris, P.S. 1982. Sheep distribution and herbage utilisation after oversowing and topdressing part of a high country summer range. *Proceedings N.Z. Society Animal Production 42*: 77-78.

Theses referred to are available for consultation at Lincoln University Library. The publication of the complete review of these diet studies is expected before 1994.

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in *tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.*

NUTRIENT MASS BALANCES IN PASTORAL HIGH COUNTRY

K.F. O'Connor and P.S. Harris
Centre for Resource Management, P.O. Box 56, Lincoln University, CANTERBURY

Mass balances of N,P,S and K have been calculated for different sectors of the high country as part of a larger study of historic and current pastoral uses. Models have been developed which are primarily driven by livestock numbers for defined areas. For three groups of runs in the Mackenzie Basin represented in Figure 1, livestock numbers are derived from sheep returns from earliest times to 1952, integrated with results of periodic surveys by TGMLI from 1965 to 1982. Rabbit numbers have been partitioned from the 'best estimates' of regional populations from 1870 to 1960. In Figure 1, consumption of herbage phosphorus is the nutrient depletive function of animal numbers. Returns from animals to the grazing areas, and, more recently, fertiliser topdressing are the nutrient repletive components.

A fuller account, illustrating sulphur balances, is presented by O'Connor and Harris in Proceedings of the Napier November 1991 Conference on Sustainable Land Management.

Important features of these mass balances are the significance of variation in time (and locality) in livestock numbers, the early role of fire affecting N and S loss, the importance of rabbits and the overall significance of nutrient non-return because of transfer by livestock away from grazing areas. Whether decline in vegetation condition or increase in hawkweeds can be related to such indicated trends as a matter for speculation. These models are also being applied to blocks of known stocking history.

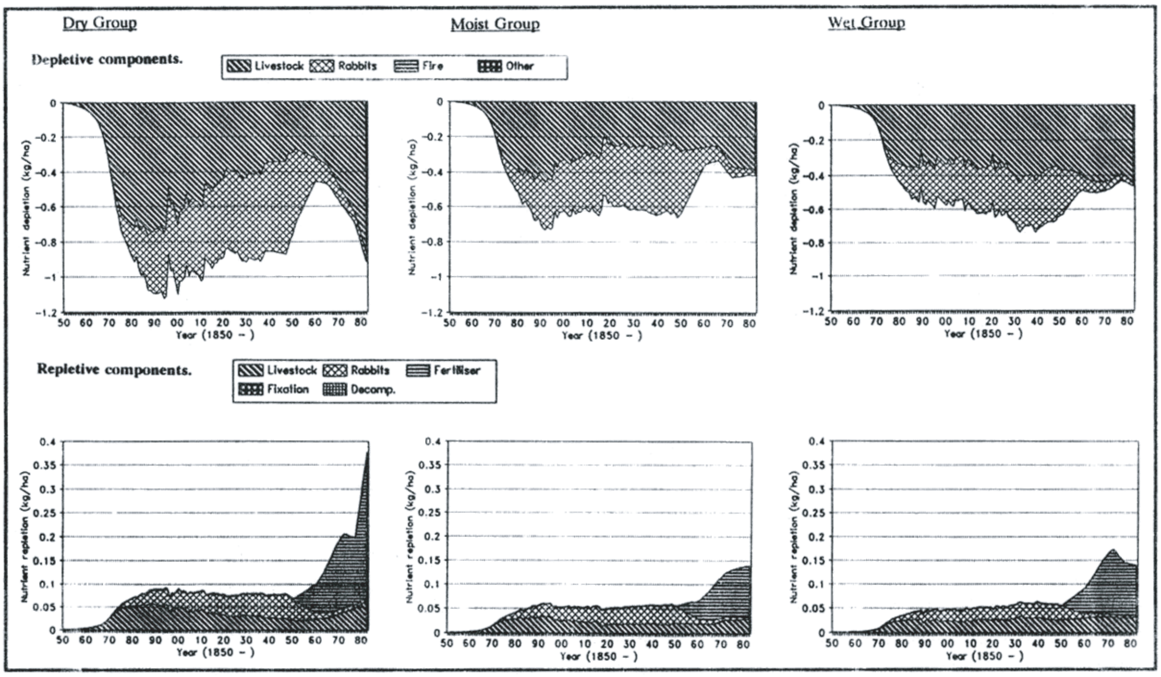


Figure 1: *Depletive and repletive components for phosphorus, within Dry, Moist and Wet Run Groups (1850 - 1982).*

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991 .

SESSION THREE DISCUSSION: PLANT INTRODUCTION, AGRONOMIC AND GRAZING TRIAL CASE STUDIES

The impact of pasture development (eg oversowing and topdressing) on hawkweeds was discussed in the light of results from a number of agronomic trials. It was clear from these trials that a reduction in cover of hawkweed species could be achieved, but questions remain as to whether these reductions could be maintained in the long term, without continued fertiliser input.

The difficulties of getting establishment of more agronomically productive species in areas of hawkweed dominance was highlighted particularly in relation to the so-called 'alternative species'. Climate, in particular. variability of spring rainfall, was identified as a major constraint to successful agronomic improvement in low-rainfall areas.

An observation was made (based on plant introduction trials in the Manorburn area) that an increase in cover of mouse-ear hawkweed appeared to coincide with an opening up of red tussock stands. There was some debate about the explanation of this phenomenon.

The role of grazing management was discussed. Results from a long-term grazing trial at Tara Hills suggest that maintenance of inputs and careful grazing management may 'exclude' hawkweed species from short tussock grasslands. However, concern was expressed about the low resilience of unimproved grasslands. The important role that stock play in distribution of nutrients within grazing systems was highlighted in discussion following Kevin O'Connor's paper on nutrient budgets.

The problem of hawkweed dominance in short tussock grasslands was discussed from the perspective of nature conservation. One view was that short tussock grasslands were especially vulnerable to hawkweed 'invasion'. The issue of the types of communities that were least vulnerable to hawkweed 'invasion' was debated with some opinions being expressed that wood/shrubland communities were relatively resilient.

It was generally accepted that maintaining nature conservation values in essentially seral communities (e.g short tussock grasslands) would require intensive manipulation and management. The lack of options for managing communities with a large hawkweed component for nature conservation was discussed. Agronomic options (e.g. altering fertility, adding new species, etc.) were not considered to be desirable because of the need to maintain 'naturalness'. Options were therefore limited to those that directly attack hawkweeds. Some of the options discussed included biological control, handweeding, herbicides and looking at the genetic structure of hawkweeds. It was recognised that some of these options were extremely labour intensive or expensive and therefore could only be applied in selected areas. The potential impact of biological control options (e.g rusts and mildews) was discussed. The point was made that the aim of biological control would not be to kill the plant, but rather to slow down growth rates.

The role of forestry as an alternative land use for hawkweed dominated areas was briefly discussed, D. Scott commented that the issues was not 'whether to have forestry or not' but rather what could be achieved for an investment of $100/ha or $200/ha or $500/ha. He suggested that sustainable agriculture could be achieved within 5 years for an investment of $200/ha.

The view was expressed that the fact that large areas of the high country are now becoming 'hawkweed environments' means that there is a need to look at the competence of natural systems to recover and at options for recovery. The suggestion of 'reconstruction' of communities (particularly tall tussock grasslands) was made. The need to identify where the various manipulative options were applicable was highlighted.

The comment was made that the manipulative approach was only likely to be successful to the degree to which the land would allow on a permanent basis. The role of economic restrictions was recognised.

SESSION FOUR

DEVELOPMENT OF SIMPLE MODELS RELATING HAWKWEED PERFORMANCE TO ENVIRONMENTAL AND MANAGEMENT CONDITIONS

To set the scene for the working group sessions, contributors were invited to present (at short notice) their models of vegetation change, with particular emphases on hawkweeds, based on their own data and their own data and other material presented or discussed in earlier sessions at the workshop. Models are presented here for two regions:

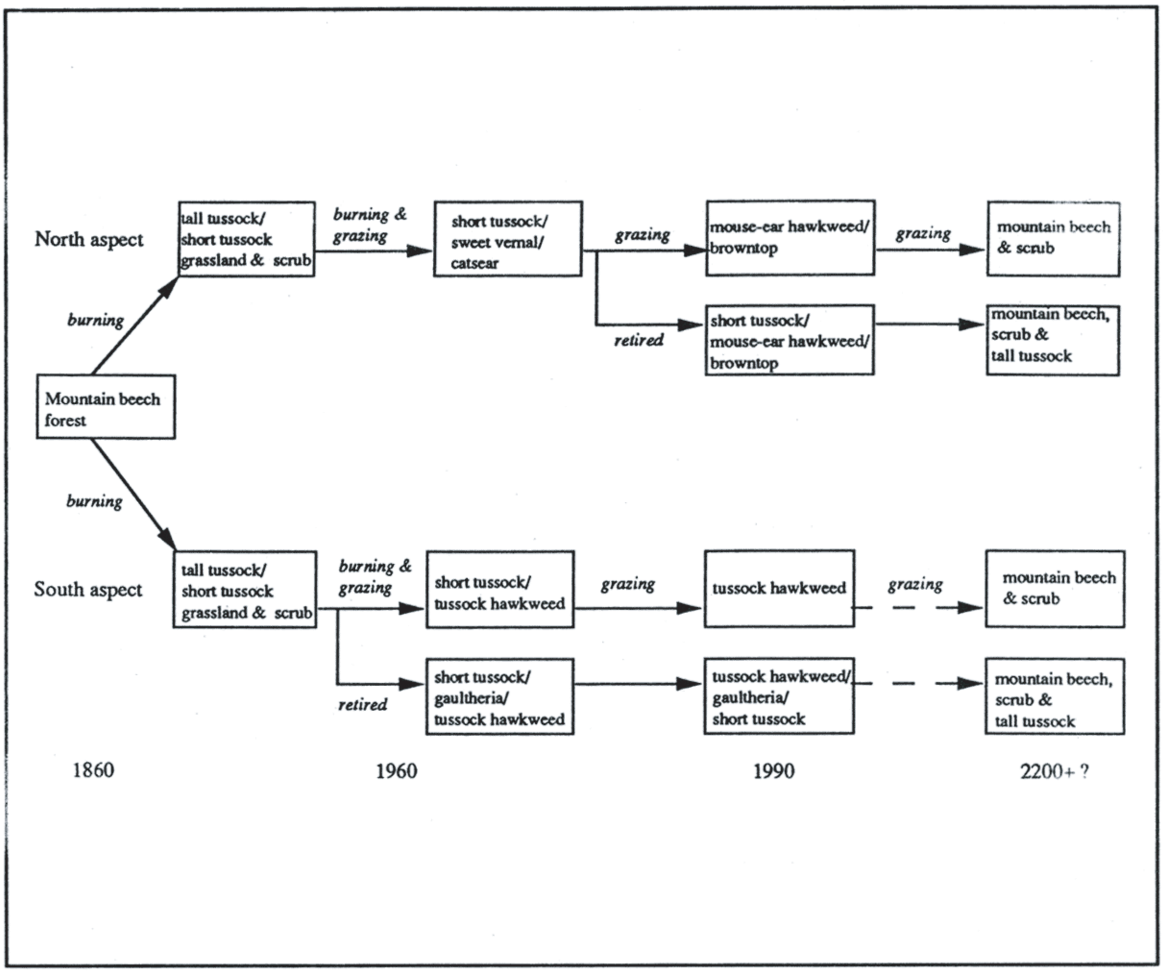
- The Harper - Avoca catchment, North Canterbury.
- Otago, east of the Lakes District.

Models of vegetation change for a third region, the Mackenzie country, have been published as:

Treskonova, M. 1991. Changes in the structure of tall-tussock grasslands and infestation by species of *Hieracium* in the Mackenzie country, New Zealand. *New Zealand Journal of Ecology 15 (1):* 65-78.

A GENERAL MODEL OF PAST AND LIKELY FUTURE VEGETATION CHANGES IN GRAZED AND RETIRED TUSSOCK GRASSLANDS OF THE HARPER-AVOCA CATCHMENT, 700-1400 M ALTITUDE, 1200-1500 MM ANNUAL RAINFALL

A.B. Rose
Landcare Research New Zealand Ltd - Manaaki Whenua
Marlborough Research Centre, Private Bag 1007, BLENHEIM.



Notes on the model

1. The model lists the dominant vegetation components and changes.

2. The main short tussock involved is fescue tussock *(Festuca novae-zelandiae),* with blue tussock *(Poa colensoi)* prominent at high elevations. The main tall tussocks are slim-leaved snow tussock *(Chionochloa macra* (south aspect) and broad-leaved snow tussock *(C. flavescens)* (north aspect).

3. The trend towards woody vegetation will probably be faster on retired sites and assumes a continued lack of burning.

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991 .

TEMPORAL CHANGES IN THE INDIGENOUS VEGETATION PATTERN OF OTAGO, EASfW ARDS FROM THE LAKES DISTRICT

A. F. Mark
Botany Department, University of Otago
P. O. Box 56, *DUNEDIN*

A request to produce, at short notice, a two dimensional model of indigenous vegetation of Otago eastward from the Lakes District (Fig. 1), is fraught with hazard. Nevertheless such a model will provide a basis for discussion and debate that hopefully will lead to further refinement.

The model uses major environmental factors (climate, edaphic) as one co-ordinate and time as the other co-ordinate. The time scale begins with the probable pattern immediately prior to human occupation.

The major influence of fire during the period of Polynesian occupation has been broadly documented on the basis of a range of evidence (charcoal, surface logs, forest dimples, soil, pollen; see Molloy *et al.* 1963; McGlone 1989; Mark *et al.* in prep.) for widespread forest over all but the driest parts of the intermontane valleys (as indicated by the brown-grey earth soils and a mean annual rainfall of < c. 400 mm), and above a treeline (associated with mean summer isotherm of 10 °C at c. 800-1200 m according to distance from the coast or increased continentality.

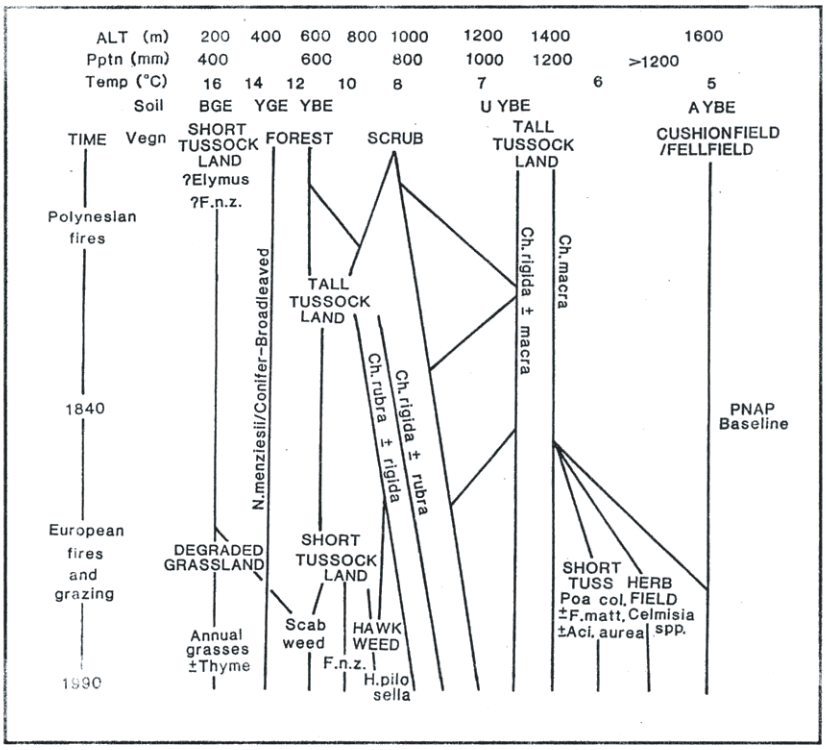


Figure 1: *Temporal trends in the indigenous vegetation pattern of Otago, eastwards from the Lakes District. Major climatic and edaphic factors are shown (mean annual precipitation, mean annual air temperature, and soil classification: brown-grey earths (BGE), yellow-grey earths (YGE), yellow-brown earths (YBE), upland yellow-brown earths (U YBE) and alpine yellow-brown earths (A YBE)) as they relate to the pre-I840 vegetation pattern. The generally accepted baseline for the Protected Natural Areas programme (PNAP) is also shown.*

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.

Descriptions of the vegetation during the early period of European settlement (Buchanan 1868) contain limited relevant information while that from the first half of the present century is invaluable (Petrie 1912; Poppelwell 1914; Cockayne 1919, 1921, 1922, 1928; Bathgate 1922; Zotov 1938; Gibbs and Raeside 1945). Information from the second half of this century, relevant to the present pattern of vegetation, while more abundant, (Wardle and Mark 1956; Mark 1955, 1965; McCraw 1962; Mark and Bliss 1970; Wells 1972; McIntosh et al. 1983; Brumley et al. 1986; Ward et al. 1987; Dickinson 1988, Molloy 1988; Fagan 1989; Comrie in prep.) is still deficient in detail for many areas and/or vegetation types.

References

Bathgate, A. 1922. Some changes in the fauna and flora of Otago in the last sixty years. *New Zealand Journal of Science and Technology 4*: 273-283.

Brumley, C.F.; Stirling, M.W.; Manning, M.S. 1986. *Old Man Ecological District Survey Report for the Protected Natural Areas Programme*. Department of Lands and Survey, Wellington.

Buchanan, J. 1868. Sketch of the botany of Otago. *Transactions of the New Zealand Institute 1* (part III): 22-53.

Cockayne, L. 1919. An economic investigation of the montane tussock-grassland of New Zealand. No. XI. Notes on depletion of the grassland. *New Zealand Journal of Agriculture 19*: 129-138.

Cockayne, L. 1921. An economic investigation of the montane tussock-grassland of New Zealand. No. XI. The grassland of the Humboldt Mountains established since the burning of their covering. *New Zealand Journal of Agriculture 23*: 137-147.

Cockayne, L. 1922. An economic investigation of the montane tussock grassland of New Zealand No. XU. The regrassing experiments in Central Otago, Part 1. An account of the depleted area in relation to the experiments. *New Zealand Journal of Agriculture 24*: 321-324.

Cockayne, L. 1928. *the Vegetation of New Zealand*. (2nd ed.) Leipzig, Enge1mann. (De Vegetation der Erde XIV)

Comrie, J. (in prep). *Dansey Ecological District: survey report for the New Zealand Protected Natural Areas Programme*.

Dickinson, K.J.M. 1988. *Umbrella Ecological District. Survey report for the New Zealand Protected Natural Areas Programme*. Department of Conservation, Wellington.

Fagan, B. 1989. *Protected Natural Areas Survey of the Manorburn Ecological District*. Unpub. MSc. Thesis, University of Otago.

Gibbs, H.S.; Raeside, J.D. 1945. Soil erosion in the high country of the South Island. *Department of Scientific and Industrial Research Bulletin No*. 82.

McCraw, J.D. 1962. Sequences in the mountain soil pattern of Central and western Otago. *New Zealand Society of Soil Science Proceedings 5*: 16-18.

McGlone, M.S. 1989. The Polynesian settlement of New Zealand in relation to environmental and biotic changes. *New Zealand Journal of Ecology 12* (Supp.): 115-129.

McIntosh; P.D.; Lee, W.G.; Berks, T. 1983. Soil development and vegetation trends along a rainfall gradient on the east Otago uplands. *New Zealand Journal of Science 26*: 379-401.

Mark, A.F. 1955. Shrubland and grassland on Maungatua, Otago. *New Zealand Journal of Science and Technology .A37*: 349-366.

Mark, A.F. 1965. Vegetation and mountain climate. In: R. G. Lister and R. P. Hargreaves (eds.) Central Otago: *New Zealand Geographical Society Special Publication. Miscellaneous Series 5*: 69-91.

Mark, A.F.; Bliss, L.C. 1970. The high-alpine vegetation of Central Otago, New Zealand. *New Zealand Journal of Botany 8*: 381-451.

Mark, A.F.; Johnson, P.N.; McGlone, M.S.; Dickinson, K.J.M. (in prep). *Alpine patterned mires in southern New Zealand.*

Molloy, B.P.J.; Burrows, C.J.; Cox, J.E.; Johnson, J.A.; Wardle, P. 1963. Distribution of subfossil forest remains, eastern South Island, New Zealand. *New Zealand Journal of Botany 1:* 68-77.

Molloy, L.F. 1988. *The Living Mantle: Soils in the Living Landscape*. Mallinson Rendel, Wellington. 239 pp. .

Petrie, D. 1912. Report on the grass-denuded lands of Central Otago. *New Zealand Department of Agriculture, Industries and Commerce Bulletin 23* (i.e., 28). Wellington, Government Printer.

Poppelwell, D.L 1914. Notes on the plant covering of the Garvie Mountains with a list of species. *Transactions of the New Zealand Institute 47*: 120-142.

Ward, C.M.; Bruce, D.L; Rance, B.D.; Roozen, D.A. 1987 (unpublished). *Lindis, Pisa and Dunstan Ecological Districts. Draft survey report for the Protected Natural Areas Programme*. Department of Lands and Survey, Wellington.

Wardle, P.; Mark, A.F. 1956. Vegetation and climate of the Dunedin District. *Transactions of the Royal Society of New Zealand 84*: 33-44.

Wells, J.A. 1972. Ecology of *Podocarpus hallii* in Central Otago. New Zealand. *New Zealand Journal of Botany 10:* 399-426.

Zotov, V.D. 1938. Survey of the tussock-grasslands of the South Island, New Zealand; preliminary report. *New Zealand Journal of Science and Technology A20:* 212-244.

WORKING GROUP REPORT: DEVELOPMENT OF SIMPLE MODELS OF HAWKWEED PERFORMANCE IN TUSSOCK GRASSLANDS.

Compiled by: G.G. Hunter
Landcare Research New Zealand Ltd - Manaaki Wheua
P. O. Box 69, *Lincoln, CANTERBURY*

Introduction

Working groups convenor Barney Foran introduced the sessions by expressing concern about unresolved issues of hawkweeds in tussock grasslands, despite recognition of, and research into, the phenomenon for at least 15 years. There was a need to evaluate the range of hypotheses which have been put forward to explain the success of hawkweeds and to present some generalisations, based on present understanding, which c8n be used to guide management.

The working groups were presented with a framework, based on the relationships and patterns that had emerged from the workshop, within which to consider the hawkweeds phenomenon. The question posed was: 'to what degree do environmental and management factors help to explain the performance of hawkweeds in tussock grasslands, based on our collective knowledge?' There was provision in the framework to consider regional effects, time sequences, and different ecosystems and climate zones.

Five working groups each included, as far as possible, ecological, production and conservation interests as well as a regional spread of knowledge between Otago, Canterbury and Marlborough. Working groups responded to the framework and reported back to the workshop. Group leaders subsequently integrated the group responses and presented a single overall outcome which is presented in this report (Fig. 1).

The session was a pragmatic attempt to indicate the relative importance of a number of environmental and management factors on hawkweed success. Each factor was subjectively ranked as having a negligible (0), weak (I), moderate (2) or strong (3) effect. The quality of the outcome from the working group is limited by such factors as: the difficulty for a large and diverse group, with limited time, to systematically evaluate the information; the requirement to derive a ranking on a best-estimate basis, irrespective of the amount and quality of the evidence; and the different interpretations that could be placed on information. A more thorough, systematic and critical evaluation of the evidence still needs to be undertaken.

The categories 'semi-arid', 'short tussock' and 'tall tussock' used in Fig. 1 are generalised groupings covering contrasting combinations of vegetation and environment. They were used by the working groups to simplify the number of vegetation and environmental situations that needed to be accommodated (Table 1). Ony three species of hawkweeds were considered; mouse-ear *(Hieracium pilosella),* tussock *(H. lepidulum)* and king devil *(H. praealtum).*

Table 1: *Vegetation environments used in the consideration of hawkweed performance*

Vegetation environment	Typical vegetation	Typical climate	Typical soil groups
èsemi-aridê (1)	dry herbfield annual grasses	semi-arid (<400mm) & subhumid (400-600mm)	BGE dry subhygrous YGE
èshort tussockê	short tussock browntop, sweet vernal oversown pasture	subhumid to humid (600-1200mm) montane (<950m)	YGE dry-hygrous U&HC YBE
ètall tussockê	tall tussock	humid (>1200mm) subalpine & alpine (>950m)	hygrous U&HC YBE

1. category covers two contrasting rainfall ranges: hawkweeds are poorly adapted) to the driest areas (<400mm) but well adapted towards the 600mm end of the range. Unless specified, comments in this report relate to interactions at the wet en of the range.

Record of a workshop *of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury,* 1991.

Hawkweed-environment-management relationships

Environmental effects

1) Climatic trigger *i.e., have short term weather or climate conditions or long term climate trends triggered hawkweed success?*

- A moderate to strong climatic trigger effect on mouse-ear hawkweed and a slight to moderate effect for king devil in montane semi-arid and short tussock grassland environments was hypothesized.
- As seed viability is short lived, a wet summer may enhance establishment by seed.
- Droughts have stressed pre-existing plant communities and pre-disposed them to invasion.
- No trigger effect was registered in tall tussock grasslands, which were thought to be less prone to climatic fluctuations.
- Climatic triggers may affect the rate of change rather than the direction of change.
- Effects of longer term climate change were not considered and require further evaluation.

2) **Soil state** *i.e. does the success of hawkweeds relate to soil properties, including fertility, depth and texture, but excluding soil moisture?*

- Overall, soil conditions were considered to be of slight to moderate importance. However, relationships are poorly understood.
- Hawkweeds were regarded as moderate fertility species which are particularly competitive when plant communities are stressed.
- Evidence that the present distribution of hawkweeds is related to the spatial or temporal distribution of soils of low fertility is inconclusive. However, enhancement of soil fertility by the application of fertiliser has enhanced the success of improved pasture species.
- Possible relationships between hawkweed success and soil degradation, including decline in nutrient status and soil organic matter, require investigation.

3) **Site conditions** *i.e., are there other conditions associated with particular sites which influence hawkweed success, e.g., soil moisture, vegetation structure/depletion, topoclimate?*

- Conditions of low soil moisture in semi-arid and short tussock environments, especially at sites with shallow, stony soils, have enhanced the success of mouse-ear hawkweed and king devil.
- Aspect differences modify these relationship in the driest, (< 400 mm) semi arid areas: on northerly aspects, soil water levels tend to be too low for hawkweeds. At the wet end of the range, the reverse may occur, with moist aspects supporting a vegetative cover able to resist hawkweeds.
- Hawkweeds extend over wide temperature ranges, from the lowland into the alpine zones up to at least 1500 m. Low temperatures may limit vigour in the alpine zone.
- Mouse-ear hawkweed and king devil have been more successful in depleted, degraded plant communities, often related to management history and drought stress.
- Although site effects were generally weaker for tall tussock grasslands, degraded tall tussock grasslands in subhumid to humid areas, especially those gradational to short tussock grasslands were highly prone to hawkweeds.

4) **Natural disturbance** *i.e., have natural disturbance regimes, including snow avalanche, landslides and overland flows/jloods influenced hawkweed success?*

- Natural disturbance was a weak influence in semi-arid and short tussock environments. Greater effects in tall tussock grasslands reflected a higher rate of disturbance in these environments. Generally, effects were local.
- The distribution of king devil and tussock hawkweed in western, wet tall tussock grasslands appeared to be strongly associated with naturally-disturbed sites.

5) **Dispersal** *i.e., is the present distribution of hawkweeds related to the process and timing of dispersal and spread by seed and stolons?*

- Plant dispersal mechanisms and timing may have been a moderate to strong factor in explaining the present rather confusing distribution of all species across all environments. Although vegetative spread by stolons was considered. To be the major mode of spread for mouse-ear and king devil hawkweeds, initial colonisation over extensive areas was by dispersal of seed. *As* seed viability is short lived, critical combinations of seed production and favourable weather conditions may have influenced initial dispersal of new plants. This may help to explain the apparently different stages of spread in Waitaki basin (the earliest) and in Otago and Marlborough (the more recent).

- Spread of tussock hawkweed has probably been only by seed, as it is non-stoloniferous.
- There is an implication that it may still be 'early days' and that the geographic range of all species will increase.

Management & vegetation effects

1) Grazing and rare history

- Previous grazing and fire history has strongly predisposed all vegetation environments to mouse-ear and king devil hawkweed establishment. This has been in terms of reducing the biomass, structure and productivity of the vegetation in the general progression from forest and scrub to tall tussock to short tussock and degraded, semi arid grasslands. Depleted short tussock grasslands and semi-arid lands, and open tall tussock grasslands are competitively disadvantaged and hence prone to hawkweeds. .
- The situation for tussock hawkweed is less clear. Some circumstances indicate a strong management response whereas it has also been successful in other areas with no significant grazing by domestic stock or fire history.

2) Current grazing

- Evidence along fencelines and at sheep camps indicated an ongoing moderate grazing effect, which may have differed between species. In general, present grazing may have continued the patterns set historically, but at reduced levels due to improved stock control and pasture improvement. The relative roles of historic and current grazing impacts need investigation.
- Evidence of recent hawkweed invasion into 'marginal' grasslands, once improved but no longer being maintained, have provided a warning for future land development strategies.
- King devil may increase in response to a reduction in grazing pressure, especially where there is bare ground. This response was not regarded as a further stage in the degradation of the plant communities as there is evidence that other species also become established.

3) Current fire

- As fire is seldom used as a management tool in semi arid and short tussock grassland environments, it has had only a local, low to moderate effect. Burning of short tussock grassland for scrub control was of ongoing concern however. Oversowing and top dressing after fire has helped to reduce the competitive advantage of hawkweeds in burned areas, but such management inputs must be maintained.
- Fire has had a moderate to locally strong influence for all species in tall tussock environments, where burning is still practiced to control the rank tussock canopy, especially in Otago. Hawkweeds have colonised and established parent plant sources on burned areas and along access tracks.

4) Competition *i.e., has the ability of other grassland species to withstand hawkweed invasion influenced distribution?*

- Opportunity and life form interactions between hawkweeds and other grassland species have had a moderate to strong effect, increasing from semi arid to short tussock to tall tussock environments. Intact tall tussock grassland was relatively resistant to invasion by hawkweeds, whereas hawkweeds have had an advantage in depleted short tussock grasslands. Degraded tall tussock grasslands with inter-tussock bare ground have also been invaded by hawkweeds.
- Reduced hawkweed success has also been observed in improved pastures and in rank vegetation such as that on shady aspects, free of disturbance.
- Exceptions to this competition effect have included the local success of king devil and tussock hawkweed in apparently intact tall tussock and scrub communities in wet environments.
- The competitive ability or 'resilience' of some tall tussock grasslands may explain the lower abundance of hawkweeds observed in these communities. However, hawkweeds have become widely established and are likely to increase in abundance if conditions become favourable to them.

5) Invasion

- All species have demonstrated strong invasion in most vegetation environments. They have established most effectively in depleted or disturbed vegetation and bare ground, although individual plants have also established in relatively intact plant communities. Mouse-ear hawkweed has been particularly invasive in the short tussock grasslands. King devil and tussock hawkweed have been invasive in short and tall tussock grasslands, especially those which have been depleted or disturbed.

Regional distribution of hawkweeds

Hawkweeds affect both production and conservation in tussock grassland environments in Marlborough, Canterbury, Otago, and Southland. Mouse-ear hawkweed occurs extensively in all regions. It is present in all vegetation environments, with major concentrations in dry montane areas. King devil has a wide distribution in Marlborough and Canterbury, where it is most common in short and tall tussock grasslands. It has been observed only locally in Otago. Tussock hawkweed is most abundant in the western lakes area of Otago and occurs sporadically throughout all regions, especially in humid environments but possibly also in subhumid ones. It is often associated with the margins between short or tall tussock grassland and forest or scrubland. It has seldom been observed in semi arid landscapes. A fourth species, field hawkweed *(H. caespitosum),* is only common in Marlborough and locally in other regions. Individual plants are present in many areas. It has often been mis-identified as king devil.

All species appear to have been extending their geographic range, and extensive areas of apparently suitable vegetation-environments are available for this process to continue. The least affected environments at present appear to be the semi-arid (rainfall < 400 mm) brown grey earth soils, and humid alpine tall tussock grasslands. The Waitaki basin has supported the oldest extensive areas of hawkweeds and the distribution in Otago and Marlborough appears to have represented earlier stages of invasion. Reasons for these regional differences are unclear, but they may be related to historic patterns of plant dispersal as well as regional differences in environmental and management conditions.

Summary of environmental and management effects

- Hawkweeds are highly invasive species, particularly in depleted or disturbed tussock grasslands. Invasion appears to be initiated by establishment of wind dispersed seed into depleted grassland. Depending on the species, this may be into open plant cover or bare soil. The second phase of invasion involves an increase in ground cover by vegetative spread.

- The competitive advantage of hawkweeds tends to increase from tall tussock to short tussock to non-tussock semi arid grasslands. However, the degree of hawkweed invasion varies according to local environmental and management factors and for each hawkweed species.

- Past management has predisposed many grasslands to hawkweed invasion. Heavy grazing by stock and rabbits, and burning, are major factors in this process. Lower biomass and productivity, reduction in canopy cover and increase in bare ground resulting from these management impacts have reduced the competitive advantage of the grasslands and predisposed them to invasion.

- The present distribution and abundance of hawkweeds is strongly related to seed dispersal and vegetative spread, and possibly to associated climatic triggers. Establishment from seed may be enhanced by a wet summer. The subsequent increase in hawkweed cover by vegetative spread may be favoured by a reduction in the competitive advantage of the vegetation either by environmental (e.g., drought stress) or management (e.g., heavy grazing) factors.

- There is insufficient evidence to confirm or discard the hypothesis that the recent increase in hawkweed success is associated with a long term decline in soil fertility or levels of soil organic matter. The temporal and spatial distribution of soil properties, especially nutrient status, organic matter and water holding capacity, in relation to hawkweed distribution, require further investigation.

- Natural disturbance regimes including snow avalanche, floods, landslides and drift regimes appear to locally predispose grasslands to hawkweeds. Effects are most noticeable in moist, tall tussock environments.

MANAGEMENT IMPLICATIONS

Although it was not a main aim of the workshop, the opportunity was taken to identify some key management implications of hawkweeds in tussock grasslands.

- All degraded or disturbed tussock grassland communities are likely to be invaded by hawkweeds, to the extent that they affect production and/or conservation values. The short tussock grasslands in the semi-arid to humid montane environments (rainfall 500 to 1200 mm) are at greatest risk. Low abundance of hawkweeds in some areas may be related to delays in establishment rather than to a resistance to invasion.

- The cumulative effects of past management in predisposing tussock grassland ecosystems to hawkweeds underlines the need for the development and implementation of sustainable management practices to minimise further degradation.

- Maintenance of a vigorous, competitive, vegetative cover and associated resilient soils is the best-available general measure to minimise hawkweed establishment and spread. Attributes of a competitive vegetative cover include tall stature, high levels of biomass and productivity, and low levels of bare ground.

- A vigorous, competitive vegetative cover can be promoted by reduction or elimination of grazing, burning and other disturbances (for conservation and extensive grazing systems) and by programmes of pasture improvement and management (for agricultural areas). The incidence and extent of the use of fire should be minimised and emphasis placed on post-bum treatments including oversowing and topdressing. Baring of ground along fencelines and tracks, by over-grazing, high rabbit numbers and drought stress must be minimised.

- Particular attention must be paid to the ongoing management of pasture improvement programmes, which reduce the vigour of species present in the 'unimproved' grasslands. Where competition from improved pasture species or other disturbance has displaced tussocks and other relatively enduring species, pasture management programmes must be maintained to prevent subsequent 'reversion' to hawkweed communities.

- However, application of sound management practices now will not guarantee a decline in hawkweeds. Even when stock and rabbits have been excluded, or where maintenance topdressing has been consistently applied, hawkweeds may continue to be abundant.

- Climatic cycles may playa part in triggering hawkweed dominance, and they may playa part in hawkweed control. In times of stress and also in times of plenty, managers should be prepared to minimise impacts (e.g., stock reduction and rabbit control) for stress-reduction and to promote possible recovery.

- Hawkweeds will continue to be present in indigenous grasslands managed for nature conservation. Management efforts in montane-subalpine grasslands may need to be directed toward minimising the risk of hawkweed dominance which could arise through management-related disturbance, rather than to preventing initial establishment or to reducing existing distributions. Hawkweeds are less widely distributed and less abundant in alpine grasslands and they may be further contained by promotion of a vigorous grassland canopy.

- Notwithstanding these generalities, the resilience of grassland ecosystems, and hence their susceptibility to hawkweeds, varies according to interactions between environmental and management factors. Long-term management plans must take into account this variability on a block-by-block, site-by-site basis.

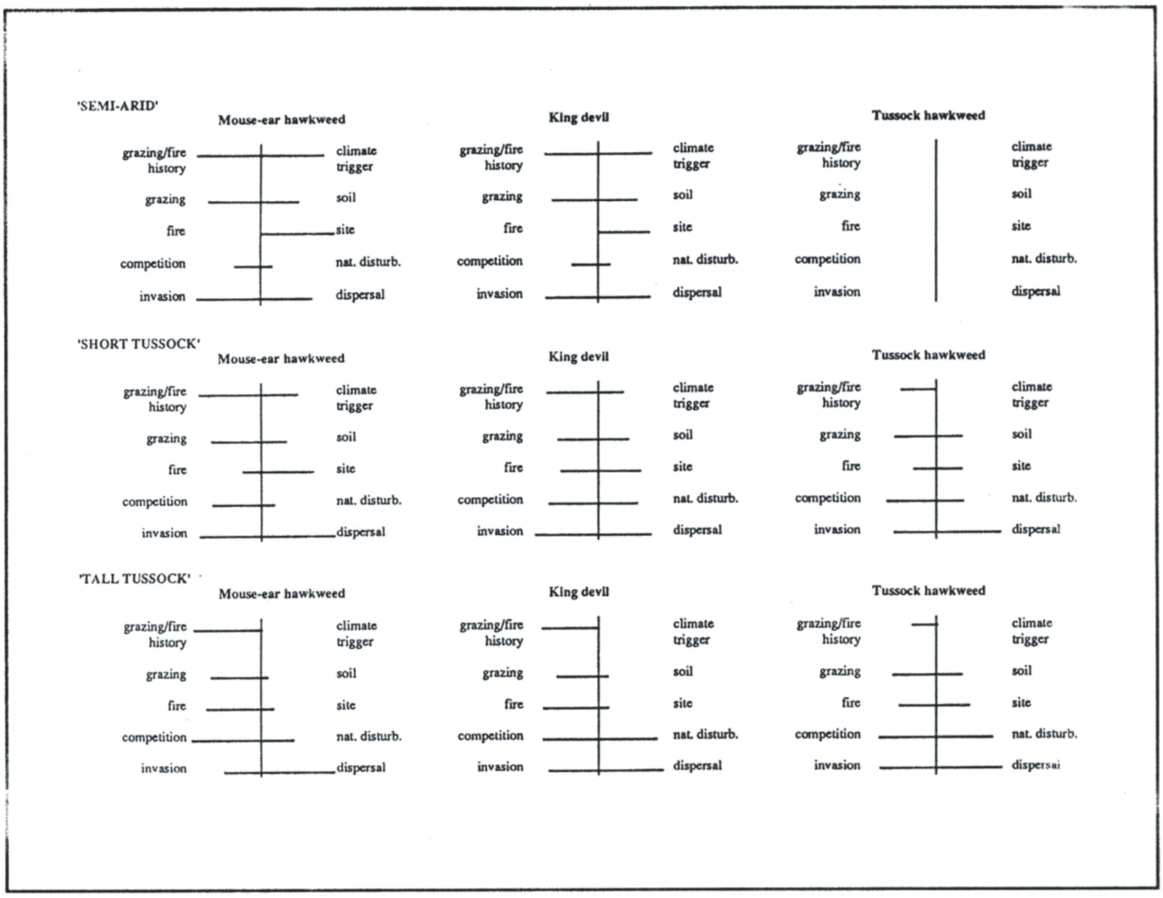


Figure 1: *An assessment of the influence of environmental and management factors on the performance of three hawkweed species* in *the tussock grasslands* in *the eastern South Island hill and high country*. The *line length represents the relative strength of interactions, based on the mean responses from individual working groups. For each species, management/vegetation effects are listed on the left and environmental effects on the right.*

REQUIREMENTS FOR URGENT RESEARCH INTO HAWKWEED *(HIERACIUM* SPP.)

Compiled by: A.F. Mark
University of Otago, Private Bag, DUNEDIN

In considering relationships between vegetation change and environmental and management factors, major gaps in knowledge were identified that are seriously inhibiting the management and containment of hawkweed impact in tussock grasslands. Four major areas of research that are in need of urgent action and funding were identified. Working groups were asked to allocate research funding on the basis that it was to be made available purely for hawkweed research. The collated values are given as percentages, of total research effort dedicated to this topic, for each of the four main research areas identified. Funds allocated within these research areas should be additional to resources allocated to the wider issues of tussock grasslands management, even though proposed and existing research programme should be integrated.

Recommended allocation (%)

I IDENTIFICATION OF SUSTAINABLE LAND MANAGEMENT OPTIONS — 35%

Research should embrace the following components:

(a) **Land use planning studies at a regional level**, to propose, test and identify the most suitable land use options, given the present state of the land and its ecological potential (i.e. pastoralism and conservation/recreation/tourism alternatives).

(b) Within "land uses" and "land use zones" so delineated, **develop and test adaptive management strategies** (i.e. ones that attempt to use more ecologically sensitive ways of doing things, and react to what is going on) to achieve stabilisation and/or rehabilitation of land.

(c) To work within present management structures with the aim of **enabling new land uses and adaptive management strategies to be implemented** by pastoral, conservation, recreation and other types of managers. A free exchange of information between researchers and managers, including the land managers/occupiers, is essential.

II GENERAL ECOLOGY OF HAWKWEEDS IN TUSSOCK GRASSLAND ECOSYSTEMS - defining the cause(s) — 30%

(a) **Plant competition** - comparative studies of the three hawkweeds with associated indigenous/exotic species.

(b) **Plant demography** - recruitment, extension, survival and turnover of individual plants and clones in a population.

(c) **Burning** - the role of fire (timing, frequency, intensity, post-fire spelling) in hawkweed invasion and extension.

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.

(d) **Grazing** - its role in hawkweed invasion and extension, in relation to the type (animal), intensity (stocking rate), method (mob vs set stocking at particular densities) and time (season).

(e) **Entomology** - the role of invertebrates in invasion and extension (through weakening of native grassland species) as well as control of hawkweeds within their ranges.

(f) **Climatic factors** - role of trigger factor(s) facilitating invasion/extension of hawkweeds, and in defining the limits of each hawkweed species to determine potential geographic ranges.

(g) **Soil factors** - the role of soil physical, chemical and microbiological factors in facilitating invasion/extension and limitation of hawkweeds. This includes determining the role of long-term soil degradation.

(h) **Systems analysis and modelling** - development of mathematical models (environmental, demographic, etc.) to simulate invasive conditions for particular species of hawkweed and to predict future changes for a range of scenarios.

III GRASSLAND REHABILITATION TECHNOLOGIES **20%**

Long term, low input technologies/strategies - their development and assessment in relation to hawkweed invasion/control for sustainable production and conservation purposes.

IV BIOLOGICAL CONTROL **15%**

(a) **Fungal** - assessment of exotic fungal pathogens for control/inhibition purposes.

(b) **Entomological** - assessment of invertebrates for control/inhibition purposes.

V MONITORING **--**

Generally applicable to I-IV above and financed within them.

(a) Basic monitoring

(b Research by management

The New Zealand Ecological Society stresses the need for adequate funding of urgently required research and for research funding agencies, scientists and land managers/occupiers alike, to adopt a collaborative attitude and a fully integrative approach to researching the serious and complex issues associated with hawkweeds in tussock grasslands.

Record of a workshop of the New Zealand Ecological Society on "Vegetation change in tussock grasslands, with emphasis on hawkweeds", Cass Field Station, Canterbury, 1991.

ANNOTATED BIBLIOGRAPHY ON HAWKWEEDS (*HIERACIUM* SPP.)

Compiled by: D. Scott[1], T.A. Jenkins[1] and P.R. Espie[2]
[1] *NZ Pastoral Agriculture Research Ltd., P. O. Box 60, Lincoln, CANTERBURY*
[2] *Forest Research Institute. Present address:* 29 *Woodford Tce, CHRISTCHURCH 5*

Adams, J.A. 1987. Studies on *Pilosella officinarum* Hill. (mouse ear hawkweed): changes in nitrogen balance and phenolic chemical levels under varying soil fertility conditions. Unpublished B.Sc(Hons) thesis, Lincoln College, Canterbury.

Allan, B.E. 1985. Grazing effects on pasture and animal production from oversown tussock grassland. *Proceedings of the New Zealand Grassland Association 46*: 119-125.
- hawkweeds not mentioned on developed dry hill site

Allan, H.H. 1920. A note on weeds. *The Magazine of the Agricultural and Pastoral Association* 1: 39-40.
- noting the invasion of king devil and mouse ear into the South Canterbury foothills

Allan, H.H. 1940. A handbook of the naturalised flora of New Zealand. *DSIR Research Bulletin* 82.

Anderson, V.L. 1927. Studies of the vegetation of the English chalk 5. The water economy of the chalk flora. *Journal of Ecology 15*: 72-129.

Anonymous 1976. *Hieracium* - good or bad? *Tussock Grasslands and Mountain Lands Institute Review* 32: 38-54.
- Popular article, good overview

Anonymous 1983. Hawkweeds. Annual report of Committee of Management 1982/83. Tussock Grasslands and Mountain Lands Institute.

Anonymous 1990. Action on hawkweeds. *Journal of the New Zealand Mountain Lands Institute Review* 47: 1-13.
- report on meeting at Lake Tekapo

Archer, A.C.; Cutler, 'E.l.B. 1983. Pedogenesis and vegetation trends in the alpine and subalpine zones of the northeast Ben Qhau Range, New Zealand. *New Zealand journal of science 26*: 127-150.
- hawkweeds uncommon

Ashdown, M. Lucas, D. 1987. Tussock grasslands: landscape value and wlnerability. *New Zealand Environmental Council, Wellington*. 122 pp.
- hawkweeds threat noted

Barabashova, V.N. 1979. Karyotypes of stem eelworms of wild plants. *Parazitologiya 13(3):* 257-261.
- .stem eel worm in hawkweeds

Barker, A.P. 1953. An ecological study of tussock grasslands, Hunter Hills, South Canterbury. *Department of Scientific and Industrial Research Bulletin 107:* 58.
- only occasional occurrence of hawkweeds

Bascand, L.D. 1979. Hawkweed occurrence and importance in South Island agriculture and pastoral land. Unpublished report.
- based on postal survey

Bate-Smith, E.C.; Sell. P.D.; West. C. 1968. Chemistry and taxonomy of *Hieracium* L. and *Pilosella* Hill. *Phytochemistry* 7: 1165-1169.
- biochemical case for separation of stoloniferous hawkweeds into separate genes

Bill, F. 1976. Study of the distribution of the genus *Hieracium* in the Department Pur de Dome, France. *Revue des Sciences Naturelles d'Auvergne 42 (1-4):* 23-38.

Bingham, S.W. 1965. Hawkweed control with turf herbicides. *Northeastern Weed Control Conference 19* 486-489.

Bishop, G.F.; Davy, A.J. 1984. Significance of rabbits for the population regulation of *Hieracium pilosella* in Breckland. *Journal of Ecology 72*: 273-284.

- age structure and population turnover of hawkweeds greater in presence of rabbits

Bishop, G.F.; Davy, A.J. 1985. Density and the commitment of apical meristems to clonal growth and reproduction in *Hieracium pilosella. Oecologia 66*: 417-422.

- UK study on resource allocation within species, density affects resource partitioning

Bishop G.F.; Davey, A.J.; Jefferies, R.L. 1978. Demography of *Hieracium pilosella* in a Breckland grassland. *Journal of Ecology 66*: 615-29.

- increase of hawkweeds principally vegetative, susceptibility to drought.

Blumer, S. 1967. Echte mehltaupilze (Erysiphaceae) ein bestimmungsbuch fur die in Europa vorkommenden arten veb. Gustav Fischer berlag. Jena.

- powdery mildew on hawkweeds

Bobbink, R.; Willems, J.H. 1987. Increasing dominance of *Brachypodium pinnatum* (L.) Beauv. in chalk grasslands: a threat to a species-rich ecosystem. *Biological Conservation 40:* 4, 301-314.

- hawkweeds decreasing under brachypodium invasion

Boesewinkel, H.J. 1979. Erysiphaceae of New Zealand. *Sydowia, Annales Mycologicia Ser II* 52: 13-56.

- powdery mildews in NZ - no record on hawkweeds

Brandenburger, W. 1985. Parasitische pilze an gesfasspflanzen Europa. Gustav Fischer verlag. Jena.

- fungi species recorded on hawkweeds

Burrows, C.J. 1962. Flora of Waimakariri Basin. *Transactions of Royal Society of New Zealand 15*: 196-215.

Burrows, C.J. (Ed.) 1977. Cass History and Science of the Cass district Canterbury, New Zealand (List of fungi prepared by W.H. Lintott), Botany Dept, University of Canterbury .

- General account of vegetation in area. Hawkweeds not prominent, rust recorded on hawkweeds but no voucher specimen

Carson, W.P.; Picket, S.T.A. 1990. Role of resources and disturbance in the organisation of an old field plant community. *Ecology* 17: 226-238.

- *Hieracium pratense* responded more to moisture than nutrient enhancement

Chevassut, G. 1987. Parasitic microfungi recorded on spontaneously growing plants in the Nantes region. *Bulletin Trimestriel de la Societe Mycologique de France 103:* 309-313.

- fungi species recorded on hawkweeds

Clark, R. 1984. Man vs hieracium: how's the score? *New Zealand Journal of Agriculture 148(4):* 52-53.

- popular article

Cockayne, L.; Foweraker, C.E. 1915. Notes from the Canterbury College Mountain Biological Station No.4. The principal plant associations in the immediate vicinity of the station. *Transaction of the New Zealand Institute 48*: 166-186.

- no hawkweeds

Cockayne, L. 1928. *The vegetation of New Zealand*. 2nd Edition, Engelmann, Leipzig, Germany. 456 pp.

- no mention of hawkweeds

Connor, H.E. 1964. Tussock grassland communities in the Mackenzie Country, South Island, New Zealand. *New Zealand Journal of Botany 2*: 325-351.

- hawkweeds only rarely recorded in previous decade .

Connor, H.E. 1965. Tussock grasslands in the middle Rakaia Valley, Canterbury, New Zealand. *NZ Journal of Botany* 3: 261-276.

- hawkweeds rare

Connor, H.E. 1990. The distribution and abundance of *Hieracium* species in Canterbury in the 19608.
- unpublished report presented at Tekapo meeting

Connor, H.W.; MaCrae, A.H. 1969. Montane and Subalpine Tussock Grasslands in Canterbury. *In:* G.A. Knox (Editor), *7he Natural History of Canterbury*. Wellington: Reed pp. 157-204.
- mouse-ear generally absent or sparse in fescue and snow tussock though one site quarter cover, some king devil and snow grass on limestone.

Connors, I.L. 1967. An annotated index of plant diseases in Canada. *Canada Departmelll of Agriculture Publication*. 1251.
- diseases on native hawkweeds - none on introduced stoloniferous hawkweeds

Cossens, G.G.; Brash, D.W. 1980. Agronomic control of mouse-eared hawkweed *(Hieracium pilosella). New Zealand Me Annual Report 1978/9*. p266-267.
- report on fertiliser and oversowing trials in Otago

Cossens, G.G.; Mitchell, R.B.; Crossan, G.S. 1989. Matagouri, hawkweed and purple fuzzweed control with sheep, goats and legumes in the New Zealand tussock grassland. *Brighton crop protection conference,* pp. 879-884. British Crop Protection Council, London, UK.
- control of hawkweeds by fertiliser and oversowing

Crane, E., Walker, P., Bay, R. 1984. *Directory of important world honey sources*. International Bee Research Association, London.
- hawkweeds listed as a secondary bee fodder species

Cuff, J.R.I. 1974. Erosion in the upper Opihi Catchment. *South Canterbury Catchment Board publication no*. 6: 152 p.

Darlington, A. 1968. *A pocket encyclopedia of plalll galls in colour*. Blanford Press, London. 191 pp.
- leaf galls on hawkweeds

Daly, G.T.; Mason, C.R. 1988. Rhizomatous legumes for hawkweed dominated grasslands. *Proceedings of the New Zealand Grassland Association* 49: 218.

Davy, A.J.; Bishop G.F. 1984. Response of *Hieracium pilosella* in Breckland Grassland-heath to inorganic nutrients. *Journal of Ecology 72*: 319-330.
- over 4 years hawkweeds decreased under fertiliser but decrease offset in presence of rabbits

Dawes, D.S.; Maravolo, N.C. 1973. Isolation and characteristics of a possible allelopathic factors supporting the dominant role of *Hieracium aurantiacum* in the bracken-grasslands of northern Wisconsin. *Wisconsin Academy of Sciences, Arts and Letters, 61*, 235-61.

de Lacy. H. 1986. Weedy strangler stalks high country grasses. *New Zealand Farmer 107(8):* 12-15.
- popular article

de Retz, B. 1976. Contributions of the knowledge of Hieraciological Flora of France 4. Genus *Hieracium* in Corsica. *Bulletin de la Societe Botan/que de France 123(9):* 571-580.
- species and distribution

Delcourt, E. 1972. Contribution of l'etude cytotaxonomique de *Hieracium pilosella* L. *Bulletin Societie Botanique France 119*: 287-302.

Dethier, V.G. 1980. Food aversion learning in 2 polyphagous caterpillars *Diacrisa vlrginica* and *Estigmene congrua*. *Physiological Elllomology 5*: 321-328.
- Hawkweeds not among avoided species

Dick, R.D. 1952. The changing tussock grasslands. *Proceedings of the New Zealand Grassland Association 14*: 114-122.

Dick, R.D. 1978. Towards greater understanding of the Waimakariri mountain tussock grasslands. *Proceedings of the conference on erosion assessment and control in New Zealand, Christchurch, Aug. 1978.* pp 43-61.
- hawkweeds hardly mentioned

Dunbar, G.A. 1977. Another *Hieracium*. *Tussock Grasslands and Mountain Lands Institute Review* 35: 68.
- comment on increasing importance of 'lachenali' *(H. lepidulum).*

Duquenois, P.E.; Greib, E.; Haag, M. 1956. Development et de activite 1 *Hieracium pilosella* L. au cours de sa vegetation. *Bulletin Societie Botanique France 103,* 426-9.

Ellenberg, H. 1974. Zeigerwerte de Gefa Bpflanzen Miteleuropus. *Scripta Geobotanica 9:* 1-97.
- fungi on hawkweeds in Europe

Ellenberg, H. 1986. Vegetation Ecology of Central Europe, 4th ed., Cambridge University Press. 731 pp.
- discusses hawkweeds spp. in context of general vegetation ecology

Espie, P.R. 1987. Edaphic ecology of *Festuca novae-zelandiae, Lotus pedunculatus* and *Trifolium repens* on Craigieburn high-country yellow-brown earth and related soils. Unpublished Ph.D. thesis, Lincoln College, University of Canterbury. 313 p.
- hawkweeds uncommon or rare in Waimakariri grasslands near lower Broken River

Evans, G.R. 1980. Phytomass, litter and nutrients in montane and alpine grasslands, Graigieburn Range, New Zealand. *New Zealand Forest Service, Forest Research Institute Technical Paper No. 70:* 956-109.
- *H. pilosella* contributed 34 % above ground biomass: 10% below ground biomass: high in N, P, K,, Mg, Ca content

Gadella, T.W.J. 1972. Biosystematic studies in *Hieracium pilosella* L and some related species of subgenus *Pilosella. Botaniska Notiser* 125: 361-369.

Gadella, T.W.J. 1987a. Life history in an apo-amphimictic species complex. XIVth International Botancial Congress. *International Botanical Congress Abstracts 17(0):* 440 pp.
- a series of paper on cytology and genetics of hawkweeds - in particular that NZ pentaploid race is probably apomictic

Gadella, T.W.J., 1987b. Biosystematic studies in *Hieracium pilosella* L. and some related species of the subgenus *Pilosella. Botaniska Notiser 125*: 361-360.

Gadella, T.W.J. 1987c. Sexual tetraploid and apomictic pentaploid populations of *Hieracium pilosella* (Compositae). *Plant Systematics and Evolution 157*: 218-245.

Gadella, T.W.J. 1988. Some notes on the origin of polyploidy in *Hieracium pilosella* aggr. *Acto Bot Neerl 37*: 515-522.
- Hawkweeds capable of producing many different hybrids

Gaumann, E. 1959. Die Rostpilze Mitterleuropus" Mittel, Buchdruckerei Buchler & Co. Bern.
- rusts on hawkweeds

Godwin, H. 1956. *The History of the British Flora*. Cambridge University Press, 384 pp. Paleobotany of hawkweed species recorded in the UK from the late-glacial period onwards

Grace, N.D.; Scott, D. 1974. Diet and mineral nutrition of sheep on undeveloped and developed tussock grasslands. I. the macro- and micro-element composition of blood plasma and herbage. *N.Z. Journal of Agricultural Research, 17*. 165-75.
- hawkweeds good mineral composition

Greib, E.; Duquenois, P. 1954. *Acadamie nationale de Medecia Bulletin 138*: 63-65.

Grieve, M. 1984. *A modern herbal*. Penguin Books. 912 pp.
- herbal properties of hawkweeds

Grime, J.P. 1979. *Plant strategies and vegetation on processes*. John Wiley & Son. 222 pp.
- concepts of competitors, stress toleration and rudera1s in species including hawkweeds

Grime, J.P.; Hodgson, J.G.; Hunt, R. 1989. *Comparative Plant Ecology. A functional approach to common British species*. Unwin Hyman, London. 742 pp.
- ecological and adaptive characteristics given

Grime, J.P.; Lloyd, P.S. 1973. *An Ecological Atlas of Grassland .Plants*. Edward Arnold, London.
- UK distribution of hawkweeds given and relationship to ecological factors

Grundy, T.P. 1989. An economic evolution of biological control of hieracium. *Agribusiness and Economics Research Unit, Lincoln University Research 202:* 41 p.
- estimate of cost of hawkweeds to agriculture and affordable investment in investigation into biological control options

Gutherie-Smith, H. 1953. *Tutira: the story of a New Zealand sheep station*. William Blackwood & Son 444p
- hawkweeds not among many adventive species before 1940

Guyot, A.L.; Becker Y.; Massenot, M.; Montigut, J. 1951. Les excretions racinaeres toxiques chez lez vegetaus. *Bulletin Technique d'Information des Services Agricoles, 59:* 346-59.
- allelopathy

Harris, P.S. 1978 (unpublished). *A study of the grazing behaviour of sheep on a high country summer range*. M.Agr.Sc. thesis, Lincoln College, Canterbury, New Zealand.
- hawkweeds common

Harris, P.S.; O'Connor, K.F. 1980. Grazing behaviour of sheep on a high country summer range in Canterbury, New Zealand. *New Zealand Journal of Ecology 3*: 85-96.
- distribution of hawkweeds in one area and contribution to sheep diet

Hay, J.R.; Ouellettee, G.J. 1959. The role of fertilizer and 2,4-D in control of pastures weeds. *Canadian Journal of Plant Science* 39: 278-283.
- effect of herbicides

Healy, A.J. 1976. *Identification of Weeds and Clovers*. Editorial Services, Wellington. 271 pp.
- standard reference for identification and naming until superseded by Webb et al. 1988

Healy, A.J. 1984. Standard common names for weeds in New Zealand. *N.z. Weed and Pest Control Society*.

Heijne, B.; Heil, G.W.; Van Dam, D. Relations between acid rain and vesicular arbuscular mycorrhiza. *2nd European Symposim on Mycorrhizae*. 2

Henn, H.; Petit, D.;Vemet, P. 1988. Interference between *Hieracium pilosella* and *Arrhenatherum elatius* in colliery soils of North of France: allelopathy or competition. *Oecologia 76*: 268-272.
- allelopathy probably not the reason for success of hawkweeds over tall oat grass

Hopkins, B. 1978. The effects of the 1976 drought on chalk grassland in Sussex England. *Biological Conservation 14*: 1-12.
- susceptibility of hawkweeds to severe drought

Howard, W.E. 1958. The rabbit problems in New Zealand. *DSIR Information Series* 16.

Howes, F.N. 1979. *Plants and beekeeping*. Faber & Faber, London & Boston. 236 pp.
- hawkweeds listed as a secondary bee forage species

Hughes, J.G. 1975a (unpublished). *A study of the grazing preference of sheep on developed and undeveloped grass at a high-country site*. M.Agr.Sci. thesis, Lincoln College, University of Canterbury. 278 p.

Hughes, J.G. 1975b. What sheep eat on developed and undeveloped high country. *Tussock Grassland and Mountain Land Institute Review* 31: 20-30.
- popular account of above

Hunter, G.G. 1991. The distribution of hawkweeds *(Hieracium)* in the South Island, indicating problem status:
- Unpublished report (now published in *Review* 48: *Journal of the New Zealand Mountain Lands Institute* 21-31)

Ja1as, J.; Pellinen, K. 1985. Chromosome counts of *Erigeron, Hieracium Pilosella* and *Sonchus* (Compositae), mainly from Finland. *Annales Botanici Fennici* 22. 1, 45-47.
- range in ploidy levels

Johnson, M.F. 1977. The genus *Hieracium cichorieae* Asteraceae in Virginia USA. *VIrginia Journal of Science 28*: 151-156.

Johnson, C.D.; Thomas, A.G. 1978. Recruitment and survival of seedling of a perennial *Hieracium* species in a patchy environment. *Canadian Journal of Botany* 56: 572-80.
- low seed establishment of hawkweeds, greater in bare soil than in moss

Johnston, P.R. 1990. Potential of fungi for the biological control of New Zealand Weeds. *New Zealand Journal of Agricultural Research 25*: 503-510.
- potential for hawkweeds not regarded as good

Kerr, I.G.C. 1983. Production, performance and prospects in the high country. In *Proceedings of the* 1983 *Hill and High Country Seminar. Centre for Resource Management, Special Publication No*. 26.

King, T.J. 1977. The plant ecology of ant hills in calcareous grasslands Part 1 Patterns of species in relation to ant hills in southern England. *Journal of Ecology 65*: 235-278.
- hawkweeds tends to be excluded from close proximity of ant hills because of soil deposition

Lambrechtsen, N.C.; Sheppard, J.S. 1979. *Hieracium* in New Zealand. *Water and Soil Division, Aokautere Science Centre Internal Report* PN 79/4.
- popular account

Lightwood 1986. *Hierac;um:* The Incredible Spreading Weed. *AgriSearch* 17:
- popular account

Lord, J.M. 1990. The maintenance of *Poa cita* grassland by grazing. *New Zealand Journal of Ecology 13*: 43-49.

Lucas, R.J.; White, J.G.H.; Daly, G.T.; Jarvis, P.; Meijer, G. 1981. Lotus, white clover and Caucasian clover oversowing, Mesopotamia Station, South Canterbury. *Proceedings of the New Zealand Grassland Association* 42: 142-150.
- hawkweeds present in plots

Macfarlane, M.J. 1980 (unpublished). *Allelopathic effects of white clover* (Trifolium repens *L.) on pasture species in the high country environments*. M.Agr.Sc. Thesis, Lincoln College, Canterbury, New Zealand.
- allelopathy of hawkweeds less than that of white clover

Macfarlane, M.J.; Scott, D.; Jarvis, P. 1983. Allelopathic effects of white clover, *N.Z. Journal of Agricultural Research* 25: 503-518.

McKendry, P.J.; O'Connor K.R. 1990. The ecology of tussock grasslands for protection and production. *Centre for Resource Management Occasional Report, June* 1999. 161 pp.
- noted increasing importance and concern of hawkweeds

MacKenzie, E.H.C. 1981. New Zealand rust fungi, additions and corrections. *N.Z. Journal of Botany 19*: 227-232.
- no rust on hawkweeds but closely allied species adventive on introduced and native species

McLennan, M.J. 1974. The alpine grassland in the upper Waimakariri Catchment from 1961 to 1972. *New Zealand Protection Forestry report no. 130:* 20 p.
- Hawkweeds not mentioned

Makepeace, W. 1976. Allelopathy of moUSCHm Hawkweed. *Proceedings of the 29th New Zealand Weed and Pest Control Conference*. 106-109.

Makepeace, W. 1980 (unpublished). *Ecological studies of* Hieracium pilosella *and* H. praealtum. Ph.D Thesis, University of Canterbury, Christchurch, New Zealand.
- detailed field, glasshouse and laboratory study of some aspect of hawkweeds in the Mackenzie and Cass. Most results reported in papers below

Makepeace, W. 1981. Polymorphism and chromosomal number of *Hieracium pilosella* L. in New Zealand. *New Zealand Journal of Botany 19*: 255-257.
- only pentaploid race in NZ

Makepeace, W. 1985a. Growth reproduction and production biology of mouse-ear and king devil hawkweed. *New Zealand Journal of Botany 23*: 65-78

Makespeace, W. 1985b. Some establishment characters of mouse-ear and king devil hawkweed. *New Zealand Journal of Botany 23*: 91-100.

Makepeace, W.; Dobson, A.T.; Scott, D. 1985. Interference phenomena due to mouse-ear and king devil hawkweed. *New Zealand Journal of Botany 23*: 79-90.
- allelopathy and plant competition studies

Malcolm, N.A. 1925 (unpublished). *Montane tussock grassland with special reference to the effect of spelling*. M.Sc. Thesis, Department of Botany, University of Canterbury. 127 pp.

Mark, A.F. 1955. Grassland and shrubland on Maungatua, Otago. *New Zealand Journal of Science &: Technology A37:* 349-366.
- hawkweeds not present

Mark, A.F.; Bliss, L.C. 1970. The high-alpine vegetation of Central Otago, New Zealand. *New Zealand Journal of Botany 8*: 381-415.
- no mention of hawkweeds

Mason, C.R. 1987 (unpublished). *Rhizomatous legumes for hawkweed dominated grasslands*. M.Applied.Sc. Thesis, Lincoln College, Canterbury .
- effect of zig-zag clover, caucasian clover, and crown vetch on hawkweeds

Matthews, L.J. 1975. *Weed control by chemical means*. Government Printer, Wellington.
- herbicide for hawkweeds

Maylaender, M.; Reuther, M.; Duquenois, P. 1968. La *pilosella* cultivee: variations morphologiques et chemiques sousl'influence des ingrais. *Plantes Medicinales et Phytotherapie, 3:* 13-25.
- chemical composition

Meeklah, F.A. 1980. Chemical Weed Control. *New Zealand MAF Annual Report* 1978/9.
- herbicide trials

Meeklah, F.A.; Mitchell, R.B.; McMillan, H. 1981. Chemical control of mouse-ear hawkweed. *Proceedings of the 34th Weed and Pest Control Conference:* 132-136.

Moar, N.T. 1985. Pollen analysis of New Zealand honey. *New Zealand Journal of Agricultural Research* 28: 39-70.
- hawkweeds pollen listed as present in honey from some areas

Moffat, R.W. 1957 (unpublished). *Ecological studies on montane tussock grassland*. M.Agr.Sci. Thesis, Lincoln College. 111 pp.

Moore, L.B. 1976. The changing vegetation of Molesworth Station New Zealand 1944 to 1971. *New Zealand Department of Scientific and Industrial Research bulletin 217*: 118 p.
• original rarity but great increase in hawkweeds

Murphy, M. 1878. *New Zealand Country Town 2*: 253.
• early report of hawkweeds from South Canterbury

New Zealand Office of the Parliamentary Commissioner for the Environment 1991. Sustainable land use for the dry tussock grasslands in the South Island. *Office of the Parliamentary Commissioner for the Environment, Wellington.*
• hawkweeds listed as of major concern in high country along with rabbits

Nieves Aldrey J.L. 1984. 1st data on the representatives of the family Ormyridae in Spain with the description of a new species *Hymenoptera chalcidoidae*. *Graellsia 40:* 119-128.
• insect gall attacking hawkweeds

Nikolaeva, V.G. 1977. Plants used by ethnic groups of the USSR for treating diseases of the liver and bile secretory system. *Rastitel nye Resursy 13(2):* 396-403.
• herbal effects of hawkweeds

Noel, W.O.; Belles, W.S.; Wattenburger, D.W.; Lee, G.A. 1979. Chemical control of orange hawkweed on rangeland. *Proceedings Western Society of Weed Science* 32: 77.
• herbicide

O'Connor, K.F. 1961. Nitrogen and grassland production in the mid-altitude zone of Canterbury, New Zealand III. The effects of nitrogenous and other fertiliser material on uncultivated pastures. *New Zealand Journal of Agricultural Research 4*: 709-721.
• king devil minor component increasing with fertiliser, mouse-ear not mentioned

Parmelee, I.A.; Saville, D.B.O. 1981. Autoecious species of *Puccinia* on Cichorieae in North America. *Canadian Journal of Botany 59*: 1078-1101.
• probable report of European hawkweeds rust adventive on adventive stoloniferous hawkweeds

Panebianco, R.; Willemsen, R.W. 1976. Seed germination of *Hieracium pratense,* a successional perennial. *Botanical Gazette* 137: 255-61.
• seed viability low but up to 2 years

Perring, F.H.; Walters, S.M. 1962. *Atlas of the British Flora*. Thomas Nelson 432 pp.
• distribution of *H. pilosella* mapped; widespread

Papp, M. 1987. A six year study of a secondary succession after deforestation in North Hungary. *Folia Geobotanica et Phytotaxonomica* 22: 405-413.
• hawkweeds present in forest and persisted following clearing

Pennycock, S.R. 1989. Plant diseases recorded in New Zealand. Plant Diseases Division, DSIR, Auckland. 3.
• nothing on hawkweeds

Peterson, R.L. 1979. Root buds in *Hieracium florentinum:* effects of nitrogen and observations on bud growth. *Botanical Gazette, 140:* 407-13.
• growth enhanced by N fertiliser

Pollock, K.M. 1989. Grass establishment and performance on a high country soil fertilised with nitrogen. *New Zealand Journal of Agricultural Research 32*: 7-15.
• hawkweeds of decreasing importance under high inputs

Pollock, K.M.; Scott, D. 1992. Production of persistence of five introduced grass species in dry hill country III High country, Tekapo. *New Zealand Journal of Agricultural Research* (in press).
• hawkweeds persistent under nil or low P but decrease under P & N

Pratt, R.M.; Putman, R.J.; Ekins, J.R.; Edwards, P.J. 1986. Use of habitat by free-ranging cattle and ponies in the New Forest, southern England. *Journal of Applied Ecology 23*: 539-557.
- hawkweeds abundant under long term pony grazing

Probst, R. 1909. Die specialisation der *Puccinia hieracii, Centralblattfur BakJeriologie* Ser *2 2:* 676-720.
- classical work on physiological races in rusts based on hawkweeds rusts

Quarante, M. 1970. Test of treatment of human brucellosis by *Hieracium pilosella:* Observation of clinical case contracted by a veternarian. *Review of Pathological Comparative Medical Experiment 70:* 85-88.
- medicinal effects of hawkweeds

Raven, J. & Walters, M. 1956. *Mountain Flowers*. Colios 240 pp.
- popular discusses history of Hawkweeds taxonomy in the UK

Ravensdown Fertiliser 1991. Hieracium and fertiliser
- unpublished report on a Mackenzie country field day

Reader, R.J. 1978. Structural changes in a *Hieracium floribundum* (Compositae) population associated with the process of patch formation. *Canadian Journal of Bot any* 56: 1-9.
- soloniferous species adventive to Canada; resource allocation to rhizomes and vegetative growth increase as cover increase

Reader, R.J. 1985. Temporal variation in recruitment and mortality for the pasture weed *Hieracium floribundum:* implications for a model *of* population dynamics. *Journal of Applied Ecology 22*: 175-183.
- annual recruitment very variable; mainly related to predation and soil moisture

Reader, R.J. 1990. Competition constrained by low nutrient supply: an example involving *Hieracium floridundum* Wimm & Grub. (Compositae). *Functional Ecology 4* : 573-577.
- low fertility constrained competition and favoured hawkweeds

Reader, J.J.; Thomas, A.G. 1977. Stochastic simulation of patch formation by *Hieracium floribundum* (Composite) in abandoned pasture lands. *Canadian Journal of Botany 55*: *3075-3079*.
- growth related to patch density; c. 25 years to reach steady state

Reader, R.J.; Watt, W.H. 1981. Response of hawkweed *(Hieracium floribundum)* patches to NPK fertiliser in an abandoned pasture. *Canpdian Journal of Botany 59*: 1944-1949.
- improved fertility increased grass competition and limited hawkweeds growth

Roberts, H.A. 1986. Seed persistence in the soil and seasonal emergence *of* some plant species from different habitats. *Journal of Applied Ecology 23*: 639-656.
- hawkweeds limited seed life

Rose, A.B. 1983. Succession in fescue *(Festuca novae-zelandiae)* grasslands of the Harper-Avoca catchment, Canterbury New Zealand. *FRI bulletin no. 16*: New Zealand Forest Service.
- increasing importance of hawkweeds

Rynal, R.J. 1979. Population ecology of *Hieracium florentinum* (Compositae) in a central New York limestone quarry. *Journal of Applied Ecology 16*: 287-298.

Scott, D. 1975. Allelopathic interaction of resident tussock grasslands species on germination *of* oversown seed. *New Zealand Journal of Experimental Agriculture* 3: 135-41.
- hawkweeds in middle *of* range is comparison of species

Scott, D. 1985. Hawkweeds in run country. *Tussock Grasslands* and *Mountain Lands Institute Review 42*: 33-48.
- review of knowledge at that time

Scott, D. 1989. Hieracium (hawkweeds). Proceedings of Institute of Noxious Plants Officers Conference: 97-103.
- summary of previous

Scott D. 1990. Management for *Hieracium*. unpublished leaflet for soil conservators and DOC

Scott, D.; Bennell, A.P. 1992. Host/pathogen relationships of the hawkweed rust *Puccinia hieracii* var. *piloselloidarum. Annals of Botany* (in press)
- background investigation for possible biological control

Scott, D.; Dick, R.D;; Hunter, G.G. 1988. Changes in tussock grasslands in the central Waimakariri River basin, Canterbury New Zealand, 1947-1981. *New Zealand Journal of Botany 26*: 197-222.

Scott, D.; Maunsell, L.A. 1974. Diet and mineral nutrition of sheep on undeveloped and developed tussock grassland II. Vegetation composition and availability. *New Zealand Journal of Agriculture 17*: 177-189.
- vegetation data, including hawkweeds used by Hughes 1975

Scott, D.; Covacevich, N. 1987. Effects of fertilizer and grazing on a pasture species mixture in high country. *Proceedings of the New Zealand Grassland Association 48*: 93-98.
- hawkweeds dominant at low fertiliser input but suppressed at high

Scott, D.; Robertson, J.S.; Burgess, R. 1989. Species and fertiliser efficiency - a high country example. *Proceedings of the New Zealand Grasslands Association 50:* 157-162.

Scott, D.; Robertson, J.S.; Archie, W.J. 1990. Plant dynamics of New Zealand tussock grassland infested with *Hieracium pilosella*. I. Effects of seasonal grazing, fertiliser and overdrilling: II Transition matrices of vegetation changes. *Journal of Applied Ecology 27*: 224-241.
- hawkweeds trends in 6-7 years in a 2 site x 2 development comparison

Scott, D.; Sutherland, B.L. 1981. Grazing behaviour of merinos on an undeveloped semi-arid tussock grassland block. *New Zealand of Experimental Agriculture 91:* 1-9.
- king devil an abundant species in study area

Scott, D.; Wallace, A.R. 1978. Effect of ground cover and tussock proximity on legume establishment. *New Zealand Journal of Agricultural Research 21*: 93-105.
- king devil a common ground cover on driest site

Scott, D.; Keoghan, J.; Cossens, G.C.; Maunsell, L.A; Floate, M.J.S.; Wills, B.J.; Douglas, G. 1985. Limitation to pasture production and choice of species. *In* Burgess, R.E., Brock, J.L. (Editors), *Using herbage cultivars. Grasslands Research and Practice Series No.3*. New Zealand Grasslands Association Palmerston North.
- concepts of species niche, including hawkweeds, in relation to gradients of moisture, temperature, soil fertility and management

Sell P.D. 1974. Material of a flora of Turkey XXX - *Hieracium. Notes for the Royal Botanical Gardens, Edinburgh 33*: 241-244.

Sell, P.D. 1987. An Introduction to the study of British Hieracia 1. History and Classification. *Watsonia 16 (4):* 365-371.
- case for separation of stoloniferous hawkweeds into separate genus *Pilosella*

Sell, P.D.; West, C. 1967. Notes on British Flora. *Watsonia 6 (5):* 313-314.

Sell, P.D.; West, C. 1975. *Pilosella* Hill. *In:* Stace, C.A. (Editor), *Hybridisation of the flora of the British Isles*. Academic Press, London, New York, San Francisco pp 433-438.
- lists hybridism in *Hieracium* and *Pilosella*

Sell, P.D. 1976. *Hieracium*. In: Tutin, T.G.; Heywood, V.H.; Burges, N.A.; Moore, D.A.; Valentine, D.H.; Walters, S.M.; Webb, D.A. (Editors), *Flora Europaea Vol. 4*. Cambridge University Press. 358-410.
- current European standard flora with many species, all retained with *Hieracium* but with stoloniferous species in subgenus *Pilosella*

Sewell, T.G. 1952. Tussock grassland investigations. *Proceedings of the New Zealand Grasslands Association 14*: 123-132.
- no mention of hawkweeds

Smale, M.C. 1990. Ecology and *Dracophyllum subulatum* - dominant heathland frost flats at Rangitaiki and north Pureora, central North Island, New Zealand. *New Zealand Journal of Botany 28(3):* 225-248.
- presence and spread of hawkweeds in central North Island

Stergios, B.G. 1976. Achene production dispersal, seed germination and seedling establishment of *Hieracium aurantiacum* in an abandoned field community. *Canadian Journal of Botany, 54*: 1189-97.

Stevens, E.J., Hughes, J.G. 1973. Distribution of sweet briar, broom, and ragwort on Molesworth Station. *Tussock Grasslands & Mountain Lands Institute Special Publication No.9*.
- some reference to hawkweeds

Suzuki, S.; Narayama, T. 1977. Orange hawkweed *(Hieracium aurantiacum* L.) as an alien pasture weed in Hokkaido. *Hokkilido National Agricultural Experimental Station Research Bulletin No. 117*: 45-55.
- as an adventive problem weed in parts of Japan

Taylor, R.A.; MacBryde, B. 1972. *Vascular plants of British Columbia*. University of British Colombia Press, 754 pp.
- lists occurrence and abundance of hawkweed species in B.C.

Thomas, A. G. 1972. *Autecological studies of Hieracium in Wellington County Ontario*. Ph.D. Thesis, University of Guelph.

Thomas A.G. 1975. The role of seed reproduction in the dynamics of established populations of *Hieracium floribundum* and a comparison with that of vegetative reproduction. *Canadian Journal of Botany 53*: 3022-31.

Thomas, A.G.; Dale, H.M. 1974. Zonation and regulation of old pasture populations of *Hieraciumfloribundum*. *Canadian Journal of Botany 52*: 1451-58.
- stolons only produced from flowering rosettes; significant within patch demography differences

Thomas, A.G.; Dale, H.M. 1975. The role of seed reproduction in the dynamics of established populations of *Hieracium floribundum* and a comparison with that of vegetable reproduction. *Canadian Journal of Botany 53*: 3022-3031.
- seedling establishment very low, only 1 % of population

Thomas, A.G. 1976. Cohabitation of three *Hieracium* species in relation to the spatial heterogeneity in an old pasture. *Canadian Journal of Botany* 54: 2517-20.

Travers, W.T.L. 1884. *New Zealand Country Town 8*: 408-412.
- early report of hawkweeds from South Canterbury

Treskonova, M. 1991. Changes in the structure of tall-tussock grasslands and infestation by species of *Hieracium* in the Mackenzie Country. New Zealand. *New Zealand Journal of Ecology 15*:
- place of hawkweeds in vegetation degradation sequence inferred from resampling of releves after 26-28 years

Turesson, B. 1972. Experimental studies' in *Hieracium pilosella* L. II. Taxonomy and differentiation. *Botaniska Notiser* 125: 223-240.

Turesson, G.; Turesson, B. 1960. Experimental studies in *Hieracium pilosella* L. I. Reproduction, chromosome number and distribution. *Hereditas 46*: 717-736.

Tussock Grassland Research Committee 1954. The high-altitude snow-tussock grassland in South Island, New Zealand. *New Zealand Journal of Science and Technology 36*: 335-364.

USDA 1960. Index of plant diseases in the United State Agriculture Handbook No. 165. U.S. Government Printing Office.
- diseases on native hawkweeds - none on adventive stoloniferous species

Vanderkloet, S.P. 1978. Biogeography of *Hieracium pilosella* L. in North America with special reference to Nova Scotia. *Proceedings Nova Scotia Institute of Science Volume 28*: 127-134.
- abundant in Nova Scotia but not further south

Voss, E.G.; Bohlke, M.W. 1978. The status of certain hawkweeds *(Hieracium* subgenus *Pilosella)* in Michigan. *The Michigan Botanist 17*: 35-47.
- adventive from Europe

Walsh, R.S. 1967. *Nectar and pollen sources*. National Beekeepers Association of New Zealand.

Wardle, P. 1991. *Vegetation of New Zealand*. Cambridge University Press 672pp
- noted general increase in hawkweeds

Watt, A.S. 1962. The effect of excluding rabbits from grassland. A (Xerobrometum) in Breckland, 1936-60. *Journal of Ecology 50:* 181-98.

Watt, A.S. 1981a. A comparison of grazed and ungrazed grassland. A. In East Anglian England UK Breckland. *Journal of Ecology 69*: 499-508.
- 38 year study of vegetation and hawkweeds change with rabbit exclosure

Watt A.S. 1981b. Further observations on the effects of excluding rabbits from grassland A, in East Anglia England UK Breckland : the pattern of change and factors affecting it 1936-1937. *Journal of Ecology 69*: 509-536.

Webb, C.J.; Sykes, W.R.; Garnock-Jones, P.J. 1988. *Flora of New Zealand. Vol IV. Naturalised pteridophytes, gymnosperms, dicotyledons*. DSIR Botany Division, Christchurch. 1365 pp.
- present standard for identification and naming of hawkweeds species in New Zealand

Whitby, M.C. 1979. Economics of pastoral development in the Upper Waitaki. *New Zealand Man and the Biosphere Report* No. 3 220 pp.

Widera, M. 1978. Competition between *Hieracium pilosella* L. and *Festuca rubra* L. under natural conditions. *Ekologia Polska 26*: 359-90.
- similar in habit and interaction dependent on soil fertility and allelopathy

Wilson, M.; Henderson, D.M. 1966. *British Rust Fungi*. Cambridge University Press.
- rusts on hawkweeds

Wraight, M.J. 1963. The alpine and upper montane grasslands of the Wairau River Catchment, Marlborough. *New Zealand Journal of Botany 1*: 351-376.
- no mention of hawkweeds

Wraight, M.J. 1966. The alpine and upper montane grasslands of the Waimakariri catchment. *New Zealand Forest Research Institute Protection Forestry Report no*. 29 (unpublished).

Yeung, E.C.; Peterson, R.L. 1972. Studies on the rosette plant *Hieracium floribundum*. L. Observations related to flowering and axillary bud development. *Canadian Journal of Botany 50:* 73-8.

Zarzycbi, K. 1983. The competitive performance of grassland plants on acid soils as influenced by fertilization and with different plant competitors in semi-natural meadows in the Pieniny National Park, Poland. *Verhandlungen der Gesellschaft fur Olwlogie 11*: 505-509.

- hawkweeds on acid soils and decreased markedly with P fertiliser

Zotov, V.D. 1938. Survey of the tussock grasslands of the South Island, New Zealand. *New Zealand Journal of Science and Technology 20A:* 212-244.

- hawkweeds not mentioned