AN APPRAISAL OF SELECTION OBJECTIVES AND CRITERIA FOR NEW ZEALAND ROMNEY SHEEP WITH PARTICULAR REFERENCE TO WOOL TRAITS

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ABSTRACT

Selection objectives and criteria were defined and appraised for a simple production system involving a New Zealand Romney breeding flock under North Island hill country conditions, in which all surplus offspring are sold as lambs.

Through the availability of New Zealand Wool Board auction data for the seasons 1976/77 to 1980/81, the influence of wool quality traits on price was analysed by regression techniques. Traits examined included mean fibre diameter (MFD), style(S), mean length (ML) and yield (Y). For the 1980/81 season only, further data from the Coded Sales Assistance Report (C.S.A.R.) was available for scouring indicator (SI), colour indicator (CI), felted (F), pen stain (P), cotted (Co), tender (T), mixed length (LV) and mixed quality (QV). In addition, the effects on price of three non-fleece variables, lot weight (LW), mode of offering (MO) and New Zealand Wool Board market intervention policies (Int), were considered.

Y was shown to have a major influence over greasy price. The relationship between price and ML was confirmed as being non-linear, with ML having a greater effect on the price of shorter wools. S and MFD were less influential. The control these four traits jointly exerted over greasy price ranged up to 74.0%, which was further enhanced by the introduction of quadratic terms. ML^2 was the most important quadratic term. The inclusion of the C.S.A.R. and non-fleece related traits, failed to provide any further control over price. CI proved to be an effective substitute for S.

Selection objectives were defined for greasy and clean wool, combined with short, long and mixed length categories. Economic weights for wool quality traits were directly calculated from the regression of auction price on the level of the traits. Economic weights for number of lambs weaned (NLW), weaning weight (WW), ewe body weight (EBW), greasy fleece weight (GFW) and clean fleece weight (CFW) were calculated using the marginal profit method. The relativities between the calculated economic weights were generally in good agreement with those of previously published estimates.

For the selection objectives defined, various selection criteria were appraised. These included the traits in the selection objective, or their respective criteria, as well as hogget body weight (HBW), quality number (QN) and fleece character grade (CHG). NLW (dam), HBW and HGFW were of major importance in the selection index. The remaining traits were of only minimal value. On the basis of cost of measurement and value within the index, the full index was converted to a reduced index of NLW (dam), HBW and HGFW. In terms of accuracy of prediction and economy, this index was considered suitable for most commercial conditions. Further reduced indices were computed which generated less overall genetic gain, but which individual breeders may consider more appropriate to their particular requirements.

Sensitivity analyses for HBW, NLW, GFW (CFW) and SC generally produced few changes of any consequence to the selection indices. Restriction of all genetic change in EBW significantly reduced the expected overall genetic gain.

DEDICATED TO THE MEMORY OF

IVAN DOUGLAS McPHERSON

(1912 - 1979)

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CHAPTER ONE

INTRODUCTION

New Zealand sheep breeders have tended to select for a wide variety of traits. The emphasis breeders place on each trait varies according to their own subjective evaluations, the practices of colleagues, clients and advisors, breed society regulations and the procedures of the national sheep performance-recording scheme, Sheeplan.

A precise definition of an appropriate selection objective has often been precluded by the lack of reliable estimates of economic values. This is particularly relevant to wool traits (Rae, 1974; Wickham, 1981, 1982; Morris *et al.*, 1982; Whiteley and Jackson, 1982). As a result, potentially important traits have been ignored, while many irrelevant traits have received undue consideration.

The current economic climate of escalating costs and fluctuating returns has placed a greater emphasis on the need to breed a more profitable flock. Thus, a re-appraisal of selection objectives and criteria in sheep breeding is timely.

The purpose of the present study was to re-assess economic weights, define selection objectives and examine suitable selection criteria for the New Zealand Romney (subsequently referred to as the Romney) under North Island hill country conditions. Particular attention was paid to wool traits, and data collected by the New Zealand Wool Board at wool sales during the 1976-81 period were analysed to provide recent and more complete estimates of the economic weights.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 DEFINITION OF SELECTION OBJECTIVES AND CRITERIA

The establishment of a clear goal of livestock production is the first requirement in implementing a successful animal breeding programme (Dickerson, 1970, 1982). It is with this goal in mind that selection objectives and criteria may be defined.

2.1.1 The goals of livestock production

Harris (1970), Scoville and Sarhan (1978) and Rae (1982) identified profit maximisation as the goal of most concern to commercial livestock production systems in "western" countries. Wickham (1966) stated that the goal of New Zealand sheep breeders should be to breed sheep that have the genetic ability to increase profitability.

Wickham (1975), Wilton *et al.* (1978), Ponzoni (1979) and Ross *et al.* (1982) suggested that this goal of profit maximisation be expressed in monetary terms, thereby enabling a comparison of inputs and outputs to be made on the same basis (i.e. Profit = Income - Expenses; Harris, 1970). Pearson and Miller (1981) point out that this "accounting" approach is the one taken in the absence of an adequate biological function able to translate an underlying production function into economic terms.

Having established a goal of economic efficiency, there remains a need to distinguish whose profit, animal breeding should maximise - the commercial breeder, the private investor (company) or the government representing the nation. It is possible for each party to have conflicting interests, especially during periods of high inflation (Taylor, 1977). Harris (1970), Moav (1973), Wilton *et al.* (1978), Miller and Pearson (1979) and Pearson and Miller (1981) have all addressed this issue. It was generally concluded that although the different sectors have the ability to influence one another to varying extents, the profit of the commercial breeder (the primary decision-maker) is the most important when formulating animal breeding policies under free-enterprise conditions.

The profit maximisation approach is based on the establishment of a superior population (flock) as opposed to the breeding of a single, outstanding individual (Rae, 1958). As suggested by Harris (1970), the primary selection unit of the commercial breeder is the individual animal, hence the commercial breeder's goal of profit maximisation is commonly expressed on a per animal basis, despite also being partly dependent upon the characteristics of the entire enterprise. This can be achieved by deriving an appropriate profit function, detailing items of income and expenditure associated with production.

Considerable attention has recently been directed towards developing profit functions, especially for dairy cattle enterprises in the U.S. (Andrus and McGilliard, 1975; Gill and Allaire, 1976 a, b; Lin and Allaire, 1977; Miller and Pearson, 1979; Balaine *et al.*, 1981; Pearson and Miller, 1981). The application of such profit functions remains uncertain. Firstly, estimated profit per animal could be used *per se* as a method of directly selecting animals. Secondly, it is preferable according to Miller and Pearson (1979), that the profit function be used in conjunction with classical genetic theory, where it is converted to a function of overall genetic merit (Wilton *et al.*, 1978), this conversion being the first step in the derivation of a selection index (Hazel, 1943).

Since an animal is capable of producing throughout its life, it is essential that profitability be evaluated on a lifetime basis. This approach is adopted by several of the above authors. Morris *et al.* (1982) weighted each trait by the frequency with which it was expressed in an average lifetime.

Harris (1970) proposed alternative, but allied, goals to profit maximisation. These were maximisation of return on investment (Income/Expenses) and minimisation of costs per unit production (Expenses/Product). Harris (1970) and Dickerson (1974) (cited by Wilton *et al.*, 1978) suggested that the goal of minimisation of costs can be utilised to account for quality factors. Dickerson (1982) stated that such a goal is more explanatory of consumer prices than the profit margin goal.

Profit maximisation is not, however, a universally accepted goal. Scoville and Sarhan (1978) and Cunningham (1982) showed that "eastern bloc" and "third world" nations place more emphasis on food supply, presumably with little consequence for production costs.

Lynch (1980) commented on the rationality of the profit maximisation philosophy,by claiming that there is a tendency to de-humanise farming and make it a cold business enterprise solely concerned with dollars and cents, rather than a way of life. On the same theme, McArthur (1982) suggested that many farmers are "profit satisfiers" when they can afford the luxury, rather than profit maximisers. In such circumstances, aesthetic factors assume greater importance in relation to profit motives. This is in agreement with previous statements made by Daniell (1970) and a review by Wickham (1981). However, as Morris *et al.* (1982) pointed out, satisfaction is difficult to quantify and hence cannot be readily incorporated into modern breeding programmes.

Maijala (1976) claimed that economic considerations have frequently been in conflict with biological expediency. Maijala suggested that economic goals are inadequate for accurately specifying selection objectives and a definition in terms of biological parameters is preferable. In contrast, Dickerson (1982) acknowledged the importance of biological considerations, but stated that breeding objectives must be determined finally by the effects on economic efficiency.

Fowler *et al.* (1976) compared the merits of the economic model (selection for economic efficiency i.e. profitability) with those of an alternative biological model (selection for biological efficiency i.e. food conversion ratio) for situations involving the selection of pigs. Although it was found that under a fixed situation, the two models were similar, Fowler *et al.* maintained that the biological model was preferable, as it was more explanatory of what selection policies should be under different situations. Wilton *et al.* (1978) subsequently suggested that if government policy is heeded and if the costs and prices used truly reflect efficiency and consumer requirements and preferences, then an economic goal will be similar to a goal based on biological efficiency.

Land (1981a) discussed the conservation of genetic resources as an alternative strategy and proposed that it be a supplement to existing policies. Wickham (1975) and McArthur (1982) agreed that, despite present market values, the production and preservation of animals bred for different objectives may provide some future genetic flexibility to cater for changes in demand and farming systems. Individual breeding groups and the government were suggested as likely candidates to take on such a responsibility.

Despite such alternatives, genetic improvement is commonly described in terms of the increase in profitability per animal, as a way of partly maximising the private profit of the commercial breeder. Ideally a comprehensive data set on each individual animal is required, to detail the inputs associated with production and the subsequent level of output achieved. In the words of Robertson (1973),

> ".... geneticists have for too long been
> naive in calling an animal superior merely

> because it has a high output, without paying attention to inputs".

Unfortunately, under a New Zealand sheep grazing situation, much of this type of information is beyond the resources of the available facilities in terms of both time and expense. Output (number of lambs reared, body weight, fleece weight etc) of individual animals can generally be readily measured at minimal cost. Input data are difficult to collect (Rae, 1982), especially under extensive grazing conditions, where the major cost is that associated with pasture production and utilisation (Carter, 1982; Morris *et al.*, 1982).

Hence, it is difficult to assess sheep under New Zealand conditions for economic efficiency. As a consequence, there is little information concerning the genetics of efficiency. Estimates of relevant genetic parameters are urgently required (Carter, 1982). Rae (1962) did however calculate a heritability of 0.38 for the biological efficiency of wool production, where efficiency was defined as the ratio of fleece weight/body weight.

With the exception of Morris *et al.* (1982) who accounted for some costs of production, the approach often taken to maximise profit has been to simply maximise gross, rather than net, income (Carter, 1982). The assumption is made that gross and net income have a reasonably high, positive correlation.

For wool production, this is supported by two New Zealand pen-feeding trials with Romney sheep (Clark *et al.*, 1965; Wodzicka-Tomaszewska, 1966) and by trials with Australian Merinos (Dolling and Moore, 1960; Hamilton and Langlands, 1969; Saville and Robards, 1971). These trials have shown that greater wool production is not solely a result of greater intakes or live weights, but that sheep with higher fleece weights do produce more wool per unit of feed consumed, and presumably per unit of input expressed in economic terms. Evidence to the contrary has been presented for Australian Merinos fed *ad libitum* by Pattie and Williams (1967) and Robards and Atkins (1976).

For lamb production, Joyce *et al.* (1976) showed that ewes from a Romney flock selected for high fertility, produce lambs more efficiently than a corresponding flock of control ewes. Efficiency was defined as kg of lamb weaned per 1000 kg of dry matter intake.

2.1.2 Methods of coping with multi-trait objectives

To maximise yield from a dual-purpose sheep breed like the Romney, where profitability is a function of both meat and wool production, the breeder is forced to give consideration to a variety of different traits when defining his selection objectives. These traits are unlikely to be of equal economic importance, to be improved at the same rate, or to be independent of each other. What then is the most efficient method of coping with multi-trait objectives?

Several methods of handling the multi-trait situation have been documented.

(a) Tandem Selection (Hazel and Lush, 1942)

One trait is selected until it is adequately improved, then a second, a third etc., until finally, all traits are at desired levels.

(b) Independent Culling Levels (Hazel and Lush, 1942)

For each trait, a lower limit is established, below which any individual is culled regardless of merit for other traits.

(c) Selection of Extremes (Abplanalp, 1972)

Selected individuals are the highest performing for any one trait, but not necessarily for several traits.

(d) Selection Index (Smith, 1936 and Hazel, 1943)

All traits are selected for simultaneously on the basis of a single index value, representing an individual's net merit or the combined worth of the traits considered.

Comparisons of the efficiency of the various methods, in terms of expected genetic gains in economic units, have been attempted by several authors (Hazel and Lush, 1942; Young, 1961; Abplanalp, 1972). The general conclusion from these studies is that, under certain simplifying assumptions, the selection index is never less efficient than independent culling levels or selection of extremes, which in turn are never less efficient than tandem selection. The superiority of the selection index increases as the number of traits selected for increases, but decreases with increasing differences in relative importance. Selection of extremes is only more efficient than independent culling levels if the selection intensity is low (i.e. greater than 50% of individuals available for selection are retained). Turner and Young (1969) discussed the practical application of these methods.

Thus, for multi-trait objectives under most conditions, use of a selection index is likely to result in the greatest genetic gains. Hence, it is not surprising that the literature contains a vast amount of discussion on selection index theory.

2.1.3 Selection objectives vs. selection criteria

Selection index theory requires a formal definition of the selection objectives and the selection criteria.

A linear selection objective, or aggregate genotype (H), was defined by Hazel (1943) as, the sum of its several genotypes (assuming a distinct genotype for each economic trait), each genotype) being weighted according to the economic weight of that trait.

Mathematically,

$$H = \Sigma a_i G_i$$

where a_i is the economic weight of the ith trait

G_i is the genotype (additive breeding value) of the ith trait.

Hence, the definition of a linear selection objective involves specifying the traits and assigning appropriate economic weights to each.

Lush (1961) and Miller and Pearson (1979) discussed situations where the selection objective may not be a linear function of its component traits. In such cases, the definition of a non-linear objective is more complex than that for a linear case, with mean values for each of the traits being included (Wilton *et al.*, 1978). Kempthorne and Nordskog (1959) suggested the use of squared variables to adjust for non-linearity, while Smith (1967) discussed traits consisting of products between variables. Wilton *et al.* (1968) and Wilton and Van Vleck (1968) discussed such quadratic objectives and compared various selection indices derived from them. Harris (1970) and Miller and Pearson (1979) suggested that such non-linear objectives be re-written linearly, or that they be avoided if possible as no unique economic weights exist and they must be altered as population means change.

For a trait to be justifiably included in the selection objective it should be of economic importance and be able to be improved genetically. Gjedrem (1972) found that the selection objective should contain all traits of economic importance (each weighted by its respective economic weight), even if some traits are not (or indeed can not be) measured.

Schlote (1977) used the product of the economic weight and the additive genetic standard deviation (with correlated effects added) as a guideline for including traits in the selection objective. This product is also referred to by Dickerson (1982). Miller and Pearson (1979) proposed that all traits having major effects on variable costs be considered. Morris *et al.* (1982) incorporated traits which had the most effect on net income and which respond to genetic selection.

Because direct selection for the objective is often impossible, it is necessary to implement selection plans using other traits as selection criteria. This is particularly true of an objective for lifetime production, using information available early in life (e.g. hogget production) as the basis for selection. Selection criteria need to be capable of being measured, preferably before breeding age, with minimum cost and technical difficulty (Ponzoni, 1979). The traits acting as selection criteria are combined in a selection index (I) and are assigned appropriate weights which maximise the correlation between the index and the objective. These index weights are dependent upon the heritabilities, variances and economic weights of traits in the objective and upon the correlations between all the traits in the objective and all the measured criteria. Mathematically,

$$I = \Sigma b_i X_i$$

where b_i is the multiple regression co-efficient which maximises the correlation between H and I

X_i is the phenotype of the ith trait in the index

The number of traits in the index need not be equivalent to the number in the objective. Gjedrem (1967 a,b) showed how the inclusion of economically unimportant, but correlated traits in the index can increase the efficiency with which an index predicts the objective.

2.1.4 Changing Romney objectives and criteria

Since the initial importation in 1853, the objectives of breeding Romney sheep in New Zealand have undergone major changes.

Prior to the turn of the century, little is known of what traits were being selected for (or against). It is probable that selection objectives were not clearly defined and that the majority of breeders were selecting on the basis of various personal whims and preferences for body conformation, evenness of fleece etc. (Wickham, *pers. comm.*). In 1907, the New Zealand Romney Sheep Breeders' Association (N.Z.R.S.B.A.) released a description of a typical Romney (N.Z.R.S.B.A., 1907). Subsequent N.Z.R.S.B.A. Flock Books contained similar, but progressively more detailed, descriptions. Thus, the selection objectives of registered N.Z.R.S.B.A. stud breeders, who at that time were largely responsible for initiating change in the breed through their ram sales, were generally governed by these stringent type requirements.

The literature of the day usually supported the breeding of Romneys to meet these objectives. Morton (1932) and Perry (1933) gave detailed descriptions of quality in the Romney, while Hewitt (1936) discussed the type of Romney he considered should be bred.

It is readily apparent that the ideal sheep that was commonly aimed for was pure, of good constitution, had good conformation (including anatomical structure), and was free of any faults which detracted from the appearance of the animal. Breeding of sheep in this fashion is a legacy dating back to at least Roman times (Varro, BC37; cited by Turner, 1956). Such visual characteristics were believed to be associated with high productivity. The absence of any reference to measured, economically productive traits is notable.

Not all Romney farmers were registered N.Z.R.S.B.A. stud breeders. Substantial differences arose between the selection objectives of the ram breeding and commercial flocks. Farmers with non-registered flocks were more interested in breeding economically profitable sheep by selecting on productive traits and not on type traits. The demand from commercial flocks for stock of higher genetic potential and economic worth steadily increased.

Support for the requirements of the commercial flocks appeared in the literature. Barton (1954) discussed various criticisms of the type of Romney produced by stud breeders. The basic message conveyed, concerned the undesirability of placing so much emphasis on unproductive or fancy breed points. The need for a more productive and profitable Romney was stressed. Rae (1954) discussed the objectives necessary to improve the Romney. To do this, Rae expressed the importance of each trait in the economic terms of Hazel (1943). For the period considered, it was shown that fertility and wool traits were of major importance.

Rae (1958) went on to state that the use of economic weights to determine the importance of traits, signalled the end of breed standards and breed points as the criteria of the commercial worth of an animal. It became evident that the traditional practices of the stud breeder were insufficient to meet the demands of the commercial flocks (Rae, 1964b).

Rae (1964b) stated that, for dual-purpose sheep, the traits that should be selected for were fertility (number of lambs weaned or total weight of lambs weaned), fleece weight and hogget body weight. The absence of conformation from the objective was justified by Kirton (1964) who reviewed and described experiments which indicated that conformation is of little significance from the meat production view point. Daniell (1970), Morris *et al.* (1982) and Rae (1982) have subsequently supported these claims.

Recently, commercial Romney breeders have been guided in their selection policies by the National Flock Recording Scheme (N.F.R.S.) and its successor, Sheeplan. The N.F.R.S. was inaugurated in 1968. The scheme produced within-flock genetic rankings of animals of dual-purpose breeds on an index consisting of weight of lamb weaned and hogget fleece weight. Further details are discussed by Clarke (1967).

A modified and expanded scheme, named Sheeplan, commenced in 1976 and is still operational. The traits included in Sheeplan are, number of lambs born, lamb weaning weight, hogget body weight and hogget fleece weight. In addition, fleece quality characteristics etc. can be recorded, but do not form part of the dual-purpose breed selection index. The technicalities of Sheeplan are documented by Clarke and Rae (1976, 1977), Dalton and Callow (1976), Callow (1981 a, b) and Daniell and Callow (1982).

Despite an increasing acceptance of measured traits, particularly fertility, as a major basis of selection, breeders still pay considerable attention to a variety of subjectively based wool traits. Wickham (1966) examined the emphasis that should be placed on wool characteristics. The tentative conclusions reached, show that of the many wool traits a breeder could select for, fleece weight was of paramount importance. Colour, cotting and tenderness, and in certain circumstances mean length and quality number (mean fibre diameter) were also of some economic significance. Character, handle, lustre, evenness and hairiness were relatively unimportant. These findings have subsequently been supported by N.Z.S.A.P. (1974) and Wickham (1975, 1981). Bulk has recently been defined as a trait of prime importance to the carpet industry which may warrant some selection attention (Carnaby and Elliott, 1980; Rae, 1982; Ross *et al.*, 1982).

2.2 THE ESTIMATION OF THE ECONOMIC WEIGHTS OF WOOL TRAITS

Hazel and Lush (1942) stated that the estimation of economic weights for each trait was the first step in specifying the selection objective. For the selection index formulation developed for animal breeding by Hazel (1943), the economic weight of a trait is defined as the amount by which profit may be expected to increase for each unit of improvement in that trait. Consequently, economic weights should not be simple expressions of price per unit product, but should indicate changes in profit or net returns when all other traits in the selection objective or aggregate genotype are held constant. It seems quite clear that net, rather than gross, economic weights are required. Miller and Pearson (1979) suggested that the use of gross economic weights may result in unwarranted emphasis being placed on traits with high returns or costs, thereby reducing the effectiveness of selection to maximise profit.

The estimation of accurate economic weights is not very easy and several techniques have been utilised.

2.2.1 Subjective assessment

Although not well-documented, the use of subjective economic weights, personally assessed by the sheep breeder, is likely to have originated in the early days of organised sheep breeding (Varro, BC37; cited by Turner, 1956). In these times, the breeder (and/or his family) would have had complete control over the production, processing and marketing phases of the wool. Under these conditions, the use of subjective estimates would have been reasonably successful as the breeder could readily evaluate which traits gave him the best final product, and presumably the greater returns (Wickham, 1981).

The advent of the specialist spinner and weaver saw the demise of the breeder-manufacturer. The breeder began selling his wool to such specialists and in doing so, lost his ability to determine the effect of various traits on the final product. It was still possible for the processor to supply the breeder with such information but, as the processing industries increased in complexity, the liaison between the two sectors deteriorated. The result was that breeders had difficulties in defining selection objectives (Lipson, 1972) and this lead to the assigning of unfounded subjective economic weights to various traits. Under these circumstances, the economic weights are intelligent guesses rather than accurate estimates.

Even today, outside the modern improvement programmes, subjective estimates of economic importance still influence sheep breeding policies. Compliance with breed society, showring and fleece-judging standards are examples.

This method is inaccurate and can easily impair genetic progress and profit maximisation. With the development of more precise, objective techniques, this method is not recommended for use by modern commercial breeders.

2.2.2 Genetic progress required

This technique is similar to that of subjective estimation, but has the advantage of being based on the quantitative criterion of genetic progress. In essence, successive approximations of the economic weights (or their substitutes) are made until the genetic progress of all traits reaches a subjective optimum. Pesak and Baker (1969) and Baker (1974) referred to this method as selection for desired gains.

With reference to pig selection, Schlote (1977) proposed that this technique is particularly suitable for the economic weighting of meat quality. For broiler production, Soller and Moav (1973) (cited by Miller and Pearson (1979)) suggested that when fertility is 95% and egg production is 50 eggs/hen egg number should receive 26.1 times as much weighting as growth rate, while for 95% fertility and 200 eggs/hen, egg number should receive only 1.6 times as much weight as growth rate.

Schlote (1977) maintains that this method can cope with restricted selection indices (Kempthorne and Nordskog, 1959) where the subjective optimum is replaced by a more strict, clearly defined objective.

2.2.3 Processing trials

One solution to the dependence of breeders on subjective economic weights is to strengthen the communication link between breeder and processor. However, individual processors often have a prejudiced view of the industry.

Direct evidence concerning the importance of varying wool traits in processing can be obtained from research trials. Invariably, the procedure followed by such trials has been to process wool with known levels of particular traits and compare the final product against the products from wool having differing levels of those same traits. Traits can be varied individually so that optimum levels can be determined or several traits can be varied simultaneously allowing any interaction between traits to be detected. Ross *et al.* (1982) pointed out that due to the common trade practice of blending different types of wools, especially for carpet processing, trials also need to be conducted where the percentages of the blend components are varied together with a trait of one of the components.

Only a limited number of trials have been performed and these have largely been restricted to Merino-type wool processed on the worsted system. An important feature of these trials is that they are approached and interpreted from the manufacturers' viewpoint. The relevance to the wool grower depends on whether or not he is paid accordingly (Skinner, 1965).

The main results from published trial work were recently reviewed by Dorgan (1972), Downes (1975) and Hunter (1980).

(a) Mean fibre diameter

In trying to assess the importance of mean fibre diameter (MFD), researchers face a major difficulty in obtaining wools differing in MFD only, as this trait is correlated with mean fibre length, crimp and strength.

Bastawisy *et al.* (1961) conducted a series of trials using the Ambler Superdrafter on the New Bradford worsted system. They compared the properties of various wool tops differing in MFD. Their results show that while coarse yarns can be manufactured from either fine or coarse wools, fine yarns can only be spun from fine wools. Equivalently, the effect of MFD was reduced as the required yarn count became coarser. It was also found that the finer the wool used, the more uniform the roving and the yarn became.

The overwhelming influence of a lower MFD on spinning performance has been quantified by several authors. Von Bergen (1963) suggested that MFD determined 80% of the variation between lots in worsted yarn manufacture. Other fibre properties (particularly length and strength) accounted for the remaining 20%. Skinner (1964) proposed that MFD controlled up to 90% of the spinnability of wool and Bastawisy *et al.* (1961) calculated that a 1 μm change in MFD in spinning is sufficient to outweigh a 10mm change in mean fibre length.

MFD is also important in influencing the properties of the final fabric. Baudinet and Jowsey (1978) conducted a trial where two series of worsted fabrics were manufactured from tops varying in MFD. Despite being of near-identical construction, the yarn and fabric produced from tops with a lower MFD had a softer handle, greater warmth and greater strength and extensibility. The adverse effects of greater MFD on crease recovery and of lower MFD on felting and abrasion resistance were discussed by Hunter (1980).

The superiority of wool of lower MFD for the production of most apparel products has been established for Merino-type wools. But does this advantage apply in the production and performance of carpets, now the major end use of Romney-type wool?

Akin to the worsted situation, wools of lower MFD processed on the woollen system can be spun into finer yarns if required (Ince, 1979).

Elliott and Agar (1979) experimented with wools ranging from 30 to 42 μm. The results show that MFD had little influence on processing and only small effects on carpet performance. However, differences in carpet appearance were considered to be of commercial significance. Carpets made from wools of lower MFD had greater yarn bulk, better carpet cover, higher resistance to abrasion (wear) and a softer handle.

Other research (Ross, 1978b; Ross *et al.*, 1980) using predominantly Romney wools and blends ranging in MFD from 30 to 40 μm shows;

(i) MFD alone has very little influence on carpet performance (including appearance retention)

(ii) Abrasion (or wear) resistance of carpets is not proportional to MFD, and in fact may be inversely proportional

(iii) Considerable changes in MFD only produce small and inconsistent differences in carpet handle.

Despite these research findings, the New Zealand carpet manufacturing industry, according to Ross (1978b), prefers MFD to be 36 μm or higher, because a high MFD is thought to be associated with;

(i) Strength which withstands modern processing forces, giving higher yarn yields

(ii) Less pile flattening - better resilience

(iii) Longer-wearing carpets - higher abrasion resistance
(iv) Lustre for specialty products
(v) Better appearance retention
(vi) Crisper handle and more medullation

(b) Fibre diameter variability

Opinion varies as to the importance of fibre diameter variability (VFD). Within the processing industry, a widely-held view is that blending of raw wools significantly different in MFD is undesirable, despite technical evidence that the processing performance of such blends is normal for most practical ranges (Downes, 1975a).

Bastawisy *et al.* (1961) compared the performance of two rovings of similar MFD, but with significantly different variations about that mean. Neither the spinning performance or yarn uniformity was significantly altered by using the more variable roving.

Corbett *et al.* (1968) also found that greater VFD did not produce any major differences in worsted spinning performance, but did tend to lower yarn breaking strength and uniformity. Such influences were concluded to be unimportant.

Downes (1975b) also found the effects of VFD in worsted processing to be minimal. An exception to this result occurred when spinning to the limit (i.e. the finest yarn from a particular wool). Even so this is relatively unimportant as spinning efficiency was only slightly reduced and under commercial conditions limit-spinning is rarely practised.

These trends are supported by Baudinet and Jowsey (1978) who again showed that VFD did not cause worsted spinning performance to deteriorate or produce fabrics of poorer quality.

Andrews and Rottenbury (1980) (cited by Whiteley and Jackson, (1982), have estimated that a 1% increase in the coefficient of variation is equivalent to only a 0.1 to 0.2 μm increase in MFD, for Merino-type wools.

A large VFD within a carpet blend is considered by the manufacturing industry to be most desirable, especially for the woollen system and woven carpets, but generally not for semi-worsted yarns or loop-pile carpets (Ross, 1978b). This VFD can be achieved by the addition of traditional carpet wools e.g. Drysdale wool. The finer fibres, located in the middle of the yarn, are associated with spinning performance and yarn bulk, while the coarser fibres, located on the outside of the yarn, give the desired handle and appearance (Carnaby and Grosberg, 1976; Ross, 1978b).

Elliott and Agar (1979) investigated the effects of VFD on carpet processing and subsequent performance. Their results are similar to those obtained for apparel production, in that only minor, insignificant effects were achieved. These findings are supported by Ross *et al.* (1980).

VFD thus appears to be of little importance in either apparel or carpet end uses.

(c) Mean fibre length - soundness

A number of research workers have shown that the effective processing length of a wool, i.e. the mean fibre length (MFL) after carding, depends not only on the initial staple length but also on the strength or soundness of the wool. This in turn is associated with fibre diameter. Bratt (1965) reported 14% breakage for 48/50s wool compared with 23% for 58/60s wool during worsted processing.

There are several other factors which contribute to fibre breakage besides the intrinsic strength of the fibre itself. Fibre entanglement during scouring is one factor which has its major effect during carding and combing, but also in drawing and spinning. Bacon-Hall *et al.* (1965) showed that fibre breakage during carding and combing increased with increasing MFL. Machine settings and processing techniques are related to the degree of breakage (Downes, 1975a).

The result of such breakage during processing is that, for a given set of equipment, the MFL of tops fall into a narrow range, despite large differences in the staple or fibre lengths of the raw wools (Walls, 1968). However, the relationship between unstretched staple length in the raw wool and MFL in the top is very strong, despite staple strength variation (Andrews and Rottenbury, 1975; Andrews, 1979).

MFL is a major determinant of the type of processing and machinery used. For example, longer wool (> 80mm) is required for worsted processing because the combing operation can only handle such fibres and the requirement is for fine, even yarn. In comparison, the woollen system is more suited to shorter wools, although almost any length is acceptable.

Bastawisy *et al.* (1961) compared three wools of differing MFL. Their results suggest that wool of greater MFL can be spun to a finer and stronger yarn with no affect on uniformity. The greater strength is derived from the increased length producing a greater frictional resistance to slippage between constituent fibres. These results were supported by Walls (1968). Bastawisy *et al.* (1961) also examined whether a limit to the beneficial effects of increased MFL could be attained. To do this, it was necessary for them to convert from wool to specially-made artificial fibres. It was demonstrated that a limit did exist around 100 mm i.e. MFL's greater than 100 mm didn't produce any processing or performance advantages. Hunter (1980) discussed further benefits of increasing MFL within reasonable bounds.

Bastawisy *et al.* (1961) also attempted to isolate the effect of fibre strength on processing performance by chemically weakening fibres to varying extents. As expected, the weakened fibres broke to a greater extent during processing and this in turn limited the spinning count of the yarn.

Ross *et al.* (1960) also investigated the effects of varying staple strength on worsted processing performance. The sounder wools were more satisfactory than equivalent tender wools in many aspects. In addition, Ross *et al.* found that the area of tenderness along the fibre had important consequences. Tenderness near the base or in the centre of long fibres had little effect. It is tenderness in other regions which reduce processing peformance. Unsurprisingly, Ross *et al.* found wool with a tender region one third of staple length from the base, produced a shorter top and longer noil than wool in which the tender region was closer to the base. This was confirmed by Bratt *et al.* (1964) and Andrews (1979).

Research reviewed by Hunter (1980) has demonstrated the proportional relationship between fibre strength and the corresponding strengths of yarns and fabrics.

In general, MFL seems to be of much more importance to the carpet yarn manufacturer than MFD. Ross (1978b) stated that the carpet industry has fairly rigid specifications, which require wools of 50-125 mm (staple length) for the woollen system and 75-150 mm, with perhaps some 75-175 mm for semi-worsted yarns. Short, second-shear wool under 50 mm are definitely not wanted as these give rise to excessive fibre loss, especially in cut-pile carpets. On the other hand, very long wools cause processing problems on the card and result in low bulk in the yarns (Ross, 1978b).

As new carpet technology is introduced, length and strength requirements are likely to become even more rigid. Blends for rotor open-end spinning need to be almost completely free from fibres longer than 100-125 mm, as these wrap around the outside of the yarn producing localised lean spots (Gore and Morgan, 1977) and a consequent grainy appearance in the carpet. DREF open-end-spun yarns can be made from fibres of all lengths (Ross, 1978b).

Fibre strength is of increasing importance as processing speeds continue to increase. For example, the technological change from woven to tufted carpet manufacture; the higher speed of the tufting needle produces not only higher stress loads on the yarn, but loads that fluctuate at high frequency (Ashworth, 1979; Elliott, 1979). The requirement under these conditions is for wool with much greater yarn strength and uniformity.

(d) <u>Fibre length variability</u>

As for VFD, opinion varies regarding the importance of fibre length variability (VFL) and there are few experimental results. Although fibre breakage reduces the range that MFL's of tops processed from different wools fall into, for a given lot of wool, breakage drastically increases VFL, even if noil is removed. McMahon (1976) estimated that only 20% of the VFL of tops was due to VFL of the raw wool - the remaining 80% being attributed to blending and fibre breakage in carding and combing.

Bastawisy *et al.* (1961), again using artificial fibres, investigated the effects of VFL on processing performance. The results showed that a 'variable' top (coefficient of variation (cv) = 20.8%) spun to a more uniform and higher count yarn than a "square" top (CV = 13.9%). A further trial was conducted with even greater VFL values (CV = 25% and 37.7%). This time there was no advantage to either top, leading to the conclusion that the greater variability had not, and probably could not, reduce undesirable fibre clustering from the drafting operation, to any further extent.

Bratt (1965) also found that VFL had a pronounced effect on worsted spinning performance of both 48/50s and 58/60s wools. Rovings with an almost diagonal cumulative frequency fibre diagram were superior to either more uniform or more variable rovings.

Thus, an optimum VFL probably exists for spinning performance and yarn properties, although Hunter (1980) also reviewed some research to the contrary. Preferred VFL obviously varies from one manufacture to another, but there is general agreement that, while the natural VFL of some wools is inadequate for efficient processing, too high a percentage of short fibre (less than 30 mm) is undesirable (Downes, 1975a). This would be equivalent to a CV of approx. 60%.

A similar situation exists within the carpet industry (Larsen, 1978). VFL is again a critical requirement for efficient processing, with wools ranging from 50-125 mm normally specified for the woollen system. An exception to this is the manufacturing of hard-twist yarns which contain a greater proportion of short fibres (Larsen, 1978). This is possible because the higher folding twist in the yarn is capable of sustaining yarn strength.

(e) Crimp

As for MFD, it is difficult to select wools differing only in crimp. Hunter (1980) discussed various aspects of this problem.

Staple crimp is poorly related to fibre crimp. In processing, it is fibre crimp which assumes more importance, as while it is reduced to some extent, staple crimp is totally destroyed in the carding operation.

Menkart and Detenbeck (1957) studied the significance of low and high fibre crimp frequency in worsted processing. Despite some disruption, fibre crimp survived processing and exerted a small but insignificant effect on the properties of the top, roving, yarn and fabric.

Lang and Sweetten (1960) processed 'normal' and 'doggy' Merino wools on the old worsted system. Doggy (or anomalous) wool is associated with ageing and is characterised primarily by a loss of crimp, and also a harsher handle and greater lustre. At high counts the spinning of the normal wools exceeded that of the doggy, but under normal commercial conditions there was little difference. Physical and subjective tests on yarns and fabrics failed to distinguish major differences between the two types of wool.

Contrary results have been obtained using the Ambler Superdrafter. Bastawisy *et al.* (1961) demonstrated that wools of low crimp can be processed on the worsted system into finer and stronger yarns than equivalent wools of high crimp. Hence, in this case, high fibre crimp has no advantage for the manufacturer, although a certain level is required for fibre adhesion. This result was confirmed by Bastawisy *et al.* in a further trial involving artificial fibres.

Carter *et al.* (1961) compared the performance of normal and doggy wools on both the Old Bradford and Ambler Superdraft spinning systems. In agreement with the previous studies, the results showed the superiority of normal wools on the old low-draft spinning system and the reverse for spinning on the Ambler Superdrafter.

Hunter (1980) suggested that the various conflicting reports can be attributed to an interaction between the trait and the processing techniques used, but concluded that while a minimum level of crimp is required, excessive levels can be deletarious for worsted processing.

As a sequel to the study of Menkart and Detenbeck (1957), Menkart and Joseph (1958) investigated the significance of low and high fibre crimp in woollen processing. In general, the results were nearly identical to those obtained previously for the worsted system, indicating that crimp level had little influence. In this case, it was considered to be surprising, as it had been expected that the more random and looser woollen structure might allow high levels of fibre crimp to manifest itself more clearly.

To some extent, this was illustrated by Lipson (1972). He found that while greater crimp did not play a major role in processing performance, it did favourably influence the bulk and appearance of knitwear.

Some research has shown that crimp form, rather than crimp frequency, has a significant effect on processing. Whiteley (1966) found that fibres with planar crimp, as opposed to those with helical crimp, tended to felt to a greater extent. Conversely, the relevance of crimp form *per se* was questioned by Hunter (1980), as a result of reviewing conflicting evidence.

In the carpet industry, helical fibre crimp seems to be a desirable trait associated with bulk and resilience (Ross, 1978b). The crimp in Romney wool is usually planar, which accordingly gives yarns of poor bulk in comparison to Down-type wools which have poor staple crimp but high helical fibre crimp. Processors can artificially crimp low-crimp wools (Hunter, 1980), but the process is not widely used.

Ross (1978b) noted that semi-worsted yarns made from high-crimp wools may not need a setting treatment for cut-pile carpets, while low-twist yarns made from low crimp wool are very difficult to set.

(f) <u>Medullation and kemp fibres</u>

Trial work involving the effect of medullated and kemp fibres in processing dates back to the late 1930's, a time when there was concern over the hairiness of Romney wool.

Townend and McMahon (1944) compared the performance of 48/50s Romney hogget wool from the same flock that differed only in the level of medullated fibre (6% by medullameter index). It was found that neither the processing properties nor the fabric appearance and handle were influenced. This investigation was extended by Peryman *et al.* (1952) to Corriedale hogget wool of 56/60s quality. When spun as fine as possible, wool giving a medullameter reading of 6.3% had some inferior processing properties compared with wool of 2.9% medullation. No appreciable differences were detected in the appearance or handle of either woven or knitted fabrics.

Wool with a high proportion of medullated fibres is not normally used in apparel manufacture, except for some specialty tweed-type fabrics (N.Z.S.A.P., 1974). Conversely, highly medullated wool in the form of hairy crutchings or specialty carpet wool is acceptable to the carpet industry and is commonly regarded as a most desirable component of carpet blends. The actual proportion of such heavily medullated wool will vary according to the particular processing system (less for semi-worsted than for woollen), the product being manufactured (less for loop pile carpets than for cut pile carpets) etc., but is commonly about 20% (Ross, 1978b).

Medullated fibres are advantageous to carpet production because medullation is associated with the following properties of the finished carpet (Ross, 1978b).

(i) natural, non-synthetic appearance

(ii) crisp handle

(iii) increased fibre volume for a given weight of wool

(iv) increased bulk and better cover

(v) increased ability to hide soiling

(vi) recovery from compression, resilience and avoidance of tracking.

While long, continuously-medullated fibres are definitely wanted by the industry, short and very medullated kemp fibres are not. Ross (1978b) and Ross *et al.* (1982) suggested that 2 to 4% by weight is the maximum level of kemp fibres that can be tolerated. This is entirely due to the deleterious effects they exert on both processing and performance of the final product. Kemp fibres increase processing wastage, particularly during the carding and spinning operations. This not only reduces yarn yields (Deal, 1978), but increases the time spent cleaning and maintaining the machinery. The different dyeing and light reflection properties may produce an undesirable appearance in the finished product (Ross, 1978b). The short but coarse dimensions of kemp fibres ensure that they lie to the outside of the yarn, resulting in a harsh handle (Ross, 1978b) and excessive shedding during manufacture and in subsequent wear (Anderson and Clegg, 1963). Kemp fibres are acceptable, and to some degree necessary, for certain textures in some specialty products such as Berber carpet manufacture (Ross, 1978b; Wickham, *pers. comm.*).

(g) Colour

The importance of colour lies in the effect it can have on the appearance of the final product. Best results can be obtained from a white wool, as poor colour limits the range of shades to which a product can be dyed (N.Z.S.A.P., 1974; Wickham and Bigham, 1976). Styles and fabric designs with bright, pure colours, especially pastel shades, contrasting weaves and sharply defined colour patterns require a white, readily dyeable wool (Poats and Fong, 1957). Off-white wool tends to result in final dyed colours that are dull (Chang *et al.*, 1969) making it difficult to match material made from white and off-white wools, unless the final colour is very dark (Poats and Fong, 1957).

Similarly, the carpet industry requires white wools to obtain clarity in the final product. This is especially true of consumer-rich markets, where the range of carpet colours is subtle and one-colour pastel shades are popular (Ashworth, 1978). Recently developed carpet manufacturing techniques tend to impose stricter colour requirements. Firstly, the manufacture of plain white carpets for subsequent dye-printing techniques such as the computer controlled Millitron jet-printer (Ross, 1978a). As chance plays a major role in what colour a fibre is dyed, an all white carpet is required, hence whiteness in the raw wool is essential. Secondly, discolouration is often associated with poorer tensile strength, which produces more breakages under the greater stresses of the new tufting processes.

The amount of discoloured wool that can be used depends on the style and colour in demand by consumers (Poats and Fong, 1957). The major outlet for such wools has been in dark-dyed outerwear, industrial fabrics and felts, and in novelty products to give special effects. Although bleaching techniques are available for improving discoloured wools, they have adverse side-effects on resilience and processing capabilities etc. (Poats and Fong, 1957).

Naturally pigmented fibres, spread through an otherwise white fleece, are also definitely not wanted by apparel or carpet manufacturers, unless special effects are required. Black fibre is very obvious in white and pastel shade fabrics and their removal by hand-picking is costly (Poats and Fong, 1957). Carpets do not generally come under the same close scrutiny, so the presence of the occasional pigmented fibre is not so deleterious (Wickham, *pers. comm.*).

(h) Lustre

Wools with high levels of lustre are generally undesirable (Wickham and Bigham, 1976). When processed alone, they don't hold together due to their low inter-fibre friction. Like colour, lustre can restrict the range of products that can be manufactured (Dorgan, 1972) as it interferes with pattern definition by producing unwanted shading effects. Thus, lustre should be kept as low as possible (N.Z.S.A.P., 1974), although blending by manufacturers of high lustre wools with corresponding low lustre wools can alleviate the problem.

In some situations, specialty yarns are made to accentuate the features of high levels of lustre. For example, lustrous wools can be dyed to bright colours (Wickham and Bigham, 1976) while carpets are made from lustrous wools to compete with the lustrous carpets produced from synthetic fibres (Larsen, 1978). Sometimes chemical treatments are used to enhance the lustre of end-products (Wickham, *pers. comm.*).

(i) Handle

Handle is an indicator of softness or harshness. In general, the finer the wool, the softer the handle (Roberts, 1956; Campbell and Lang, 1965; Walls, 1968; N.Z.S.A.P., 1974). Roberts (1956) also identified crimp frequency as an important factor influencing handle.

Fabrics requiring a soft handle are therefore usually processed from fine wools. However, the relationship between fibre handle and fabric handle is not steadfast, as the latter is also dependent on yarn and fabric construction, and the finishing techniques that are used (Walls, 1968; N.Z.S.A.P., 1974). Consequently, fine wools can be made to produce firm, crisp or even harsh-handling fabrics, and conversely, coarse wools can give a softer handle if costly additional processing is conducted.

The carpet industry generally requires a crisp-handling wool, although there are also markets for soft-handling carpets (Ross, 1978b). Handle is thought to be a most important character at the point of sale (Ross, 1978b) - a crisp or harsh handle is associated with good floor performance (Deal, 1978).

(j) Bulk

Loose wool bulk is closely associated with helical crimp and fibre diameter (Ross *et al.*, 1982). Elliott and Carnaby (1980) have shown that loose wool bulk is the most important fibre trait influencing yarn bulk. Fibre medullation and lack of length also enhance yarn bulk. Ross (1978) stated that yarn bulk is associated with two important carpet properties,
(i) increased cover
(ii) greater resilience (resistance to compression)

Because of these, bulk has apparent value to the customer at the point of sale by appearing to give more value for money. Yarn bulk differences of greater than 15% are usually visible (Carnaby and Elliott, 1980).

As with handle, loose wool bulk and yarn bulk are not necessarily related. Yarn bulk is also influenced by manipulation before and during processing (blending, use of bulk enhancing treatments of the wool, fibre alignment before and during spinning, twisting and finishing techniques). This is fortunate for the Romney as its wool is notable for the lack of loose-wool bulk (Carnaby and Elliott, 1980).

(k) Cotting

Cotted wool needs to be subjected to vigorous opening procedures before processing (Henderson, 1968), otherwise it can jam the feed rollers and damage the clothing on a card (Deal, 1978). The mechanical separation leads to more fibre breakage and shorter fibre length (Henderson, 1968), which can reduce the spinning efficiency.

(l) Character

Different groups in the wool industry use the term character to denote different traits. As generally used in New Zealand, character is a subjective combination of factors including staple formation, regularity and distinctness of staple crimp and absence of tapering tip and medullation (Wickham and Bigham, 1976). As these factors have largely been discussed before in their own right, and as character is difficult to universally define, it will not be considered here in any further detail. Suffice it to say that, opinion varies greatly with respect to character's importance in processing, with virtually no direct experimental verification.

(m) Style

In a similar fashion to character, style is a subjective combination of factors, especially colour (Wickham and Bigham, 1976), but may include length, soundness, medullation and vegetable matter content (Dorgan, 1972). As these have been discussed individually, style will be given no more attention.

2.2.4 Marginal profit

Given that the primary objective of the breeder is to maximise profit, then the most convincing information on the importance of traits would be expected to come from the balance between the income received and expenses paid. The marginal profit method is a partial budgeting technique, based on the difference between income and expenses associated with a unit increase in production from the current level of productivity.

Schlote (1977) identified several different situations. For example, an improvement in profit can be achieved by increasing returns without affecting production costs. This is representative of the situation involving quality traits, where the market price of the product varies with the level of the trait. The economic weights are the variations in price per unit expression of the trait.

Another example is where selection reduces the costs without producing greater returns. This is representative of quantity traits. The economic weights are the prices of the reduced quantity of feed etc. required.

For Hazel's (1943) formulation, the economic weight (a) of a trait can be calculated by,

$$a = \Sigma q_i p_i - \Sigma q_j p_j$$

where q_i = the additional quantity of ith product

q_j = the additional quantity of jth input

p_i = the unit price of ith product

p_j = the unit price of jth input

In some circumstances, it is impossible to directly obtain certain unit prices or costs. Schlote (1977) suggested that in such cases, indirect opportunity cost values be used.

Morris *et al.* (1982) used a marginal profit approach to calculate economic weights for four major New Zealand sheep breed categories, including the Romney. Allowances were made for the costs associated with ewe replacements and the greater maintenance requirements of heavier ewes. It was considered necessary to evaluate animals on a lifetime basis, hence the traits were weighted by the frequency with which they are likely to be expressed in a ewe's lifetime.

The technique of Morris *et al.* (1982) has been applied to Australian Merino's by Ponzoni (1979) and to Australian prime lamb breeds by Stafford and Walkley (1979).

2.2.5 Regression of selling price on level of wool traits

The major disadvantage of the marginal profit method is that it cannot successfully allocate income and expenditure items simultaneously to traits concerned with quality. Consequently, the regression of long-term price averages on the levels of wool quality traits has been conducted. This procedure estimates the amount of control the independent variables (traits) have over the dependant variable (price) and their respective regression coefficients. Previous work in this area has been largely confined to Australian Merino fleece wool and hence the results are not directly relevant to Romney breeders in New Zealand.

Dunlop and Young (1960) conducted a linear regression analyses for the mean price of Australian Merino fleece types on quality number, length, character, colour, soundness, handle, fibre diameter and crimp frequency. Quality number was of greatest significance in controlling price. Length and colour also assumed some importance, but to a much lesser extent. The remaining traits were seemingly of limited value. All eight traits jointly accounted for 90% of the variation in price.

In an endeavour to isolate the importance of each trait, Dunlop and Young deleted variables from the analysis and noted how much of the control over price was lost after each deletion. Reduction to the three most valuable traits, viz. quality number, length and colour, had no effect on the ability to control price, as 91% of the variation in price was explained by these three traits. The importance of quality number was again demonstrated, with length and colour still of some significance. Thus, all the deleted traits were relatively insignificant and their absence did not harm the ability to predict price, given the presence of quality number, length and colour. It was also shown that fibre diameter and crimp frequency assumed importance in the absence of quality number.

Dunlop and Young calculated economic weights as the product of the simple regression coefficient and the average clean fleece weight.

Skinner (1965) performed similar analyses to those of Dunlop and Young (1960). Regression analyses were conducted for mean price on staple length, crimp frequency, handle, density, freedom of growth (cotting), character, colour, vegetable matter, weathering, crimp definition and crimp regularity. These eleven independent variables jointly controlled 91.9% of the variation in price. In agreement with Dunlop and Young (1960), crimp frequency (related to quality number), as well as staple length and colour, were of major significance. Deletion of variables to leave these three, only reduced the control over variation in price to 89.8%. The greater significance of crimp frequency was again displayed, while staple length and colour remained of similar importance.

Apart from the different set of independent variables used, the major difference between the two studies is that, while Dunlop and Young (1960) had previously only considered linear models, Skinner (1965) expanded his analyses to incorporate a curvilinear (quadratic) model. It was shown that the price-trait relationship was more accurately defined by a curvilinear model, as the use of a quadratic equation increased the control over price from 89.8% for the linear model to 93.9%. Crimp frequency was still of major significance, but for the curvilinear model, staple length was of more importance than colour.

Using analogous techniques to the previous studies, Mullaney and Sanderson (1970) examined data for both Merino and Crossbred wool types (Crossbred = Corriedale, Polwarth). The wool traits studied were the same as for Dunlop and Young (1960) with the exclusion of soundness. In contrast to Dunlop and Young who subjectively recorded wool traits on whole fleeces and estimated length, crimp and diameter on midside samples, and to Skinner (1965) who used bale lots, Mullaney and Sanderson measured or appraised all traits on a midside sample.

As in the earlier studies, quality number was of the utmost importance for both Merino and Crossbred wool types. In contrast to Dunlop and Young (1960), the subjectively appraised traits of colour, handle and character all assumed greater importance than length, albeit to a neglibible extent. Again, little control over price was lost when deletion procedures reduced the original seven traits to quality number, colour and handle. In the absence of quality number, the increased importance of either mean fibre diameter or crimp frequency was again illustrated.

McKinnon *et al.* (1973) considered four subjectively-appraised traits, quality number, style, vegetable matter content and staple length as price determinants of greasy Merino wool.

Their results substantiated those of the preceding investigations, in that quality number was of vital significance in controlling price, with the exception of one season when it was superceded by style, a trait which otherwise ranked second in importance. The four traits jointly accounted for up to 93% of the variation in price.

To account for a greater percentage of the variation in price, McKinnon *et al.* incorporated quadratic, cubic and product terms into the analysis. The resulting high statistical significance of terms for $(\text{length})^2$ in most seasons, supported Skinners' (1965) contention that the relationship between price and length is more accurately defined by a curvilinear model. The quadratic and cubic quality number terms were also statistically significant. The product term, quality number x style, proved to be of major importance. The inclusion of such quadratic, cubic and product terms, resulted in moderate to large increases in the control over price.

In an accompanying study to that just discussed, Whiteley and McKinnon (1973) evaluated the effects of both subjectively appraised traits (quality number, broker's yield, style, staple length and vegetable matter content) and objectively measured traits (fibre diameter, crimp frequency and tested yield) on greasy price of Merino wool. In contrast to previous work, no one particular trait proved to be of overwhelming importance. Various combinations of these traits could account for no more than 75% of the variation in price. The relationship between price and length was again shown to be curvilinear. A notable result was that the substitution of subjectively appraised traits by objectively measured traits produced a reduction in the control over price. This was not considered surprising as the wool was purchased using subjective evaluations and the relationship with the corresponding objective measurements is widely acknowledged as being imperfect.

Whiteley and McKinnon then conducted a similar series of regression analyses for clean price. Various combinations of the traits could account for no more than 64% of the variation in price. The inclusion of a quadratic term for staple length again resulted in an increase in price control. Contrary to the findings of McKinnon *et al.* (1973), the quality number x style product term produced only a negligible improvement in the ability to account for price variation.

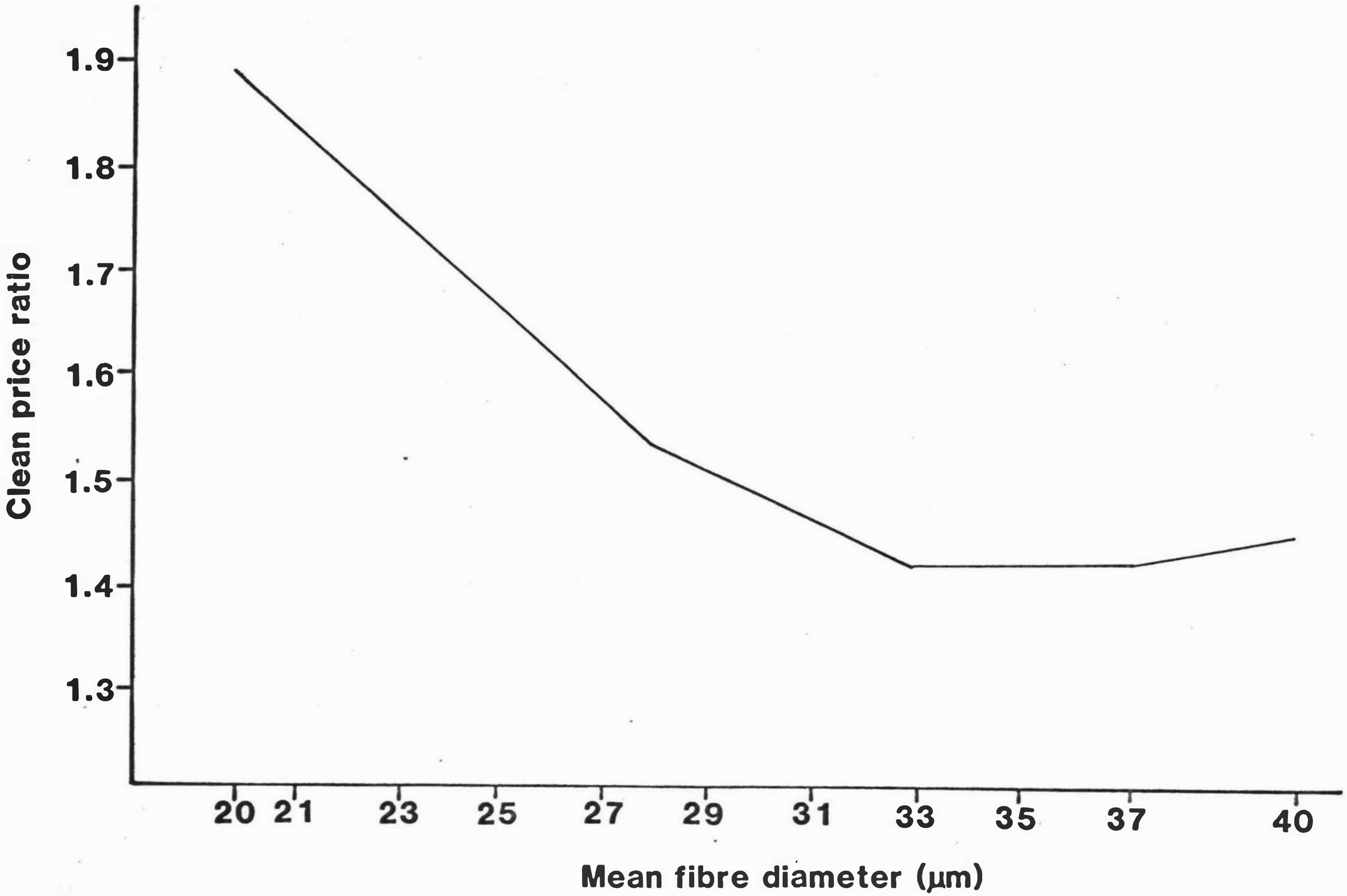
From all these studies, it is clearly illustrated that for subjectively-appraised Australian Merino fleece wool, price has been greatly influenced by quality number (crimp frequency) and to a lesser extent by colour, length and handle. No other trait was shown to consistently affect price.

2.2.6 New Zealand Wool Board relativities

Wiggins and Beggs (1979) described a method which they claim clarifys the signals received from the marketplace. After each auction, the New Zealand Wool Board calculates the adjusted weighted average sale price (A.W.A.S.P.) for the sale. A.W.A.S.P. is a measure of what the average price of all wool sold at the sale would have been, had all types been represented in the sale in their normal seasonal proportions at average yield (Wiggins and Beggs, 1979). To correct for the possibility that not all types will be on offer at any one particular sale, the New Zealand Wool Board maintains a re-assessable relativity value for each wool type which, according to Wiggins and Beggs, represents the 'normal' relationship of a type's price to the average price of all types.

The method proposed for estimating the relative importance of wool traits is based on these relativities. For example, Figure 2.1 shows the relationship between mean fibre diameter and price ratio for B style fleece wool of full length during the 1978/79 season. Price ratios can be

FIGURE 2.1: MEAN FIBRE DIAMETER VS. PRICE. 1978/79
(from Wiggins and Beggs, 1979)



converted to c/kg by multiplying by the appropriate A.W.A.S.P. It is evident that the relationship is definitely non-linear; i.e. premiums, as indicated by the slope of the line, change within the range of mean fibre diameter considered. In this particular example, using the average sale price for the 1978/79 season of 218.8 c/kg, every micron decrement from 33 μm to 21 μm produced a premium of 7.5 c/kg clean. This can be subdivided to give a premium of 4.5 c/kg clean between 33 μm and 28 μm, and 10.0 c/kg clean between 28 μm and 21 μm. Within the 33 μm to 40 μm range, into which the majority of Romney wool is classified, little or no premiums are shown to exist at that time.

The relationship between mean length and price ratio for 37 μm B style fleece wool during 1978/79 is shown in Figure 2.2. This wool type is not atypical of Romney fleece produced in New Zealand. As with mean fibre diameter, the relationship for mean length is non-linear in this example. Clean price increased by 0.45 c/mm in the 50-110 mm range, and by 0.07 c/mm from 110-175 mm.

The relationship between style and price ratio during 1978/79 is shown in Figure 2.3 for 37F-D wool which is again representative of Romney fleece wool. In contrast to the preceding traits, the relationship is virtually linear. In this example, each increment in style grade has realised a premium of 2.5 c/kg clean.

Obviously, these relationships between price and wool characteristics vary, not only within and between seasons but also between wool types. In recognition of this, the New Zealand Wool Board currently prepares monthly graphs depicting the relationships for a range of wool types. Suggested refinements to the methodology include a statistical measure of variation likely to be encountered and the extension of the current techniques to cover other traits such as colour, tenderness etc.

FIGURE 2.2: MEAN LENGTH VS. PRICE. 1978/79.
(from Wiggins and Beggs, 1979)

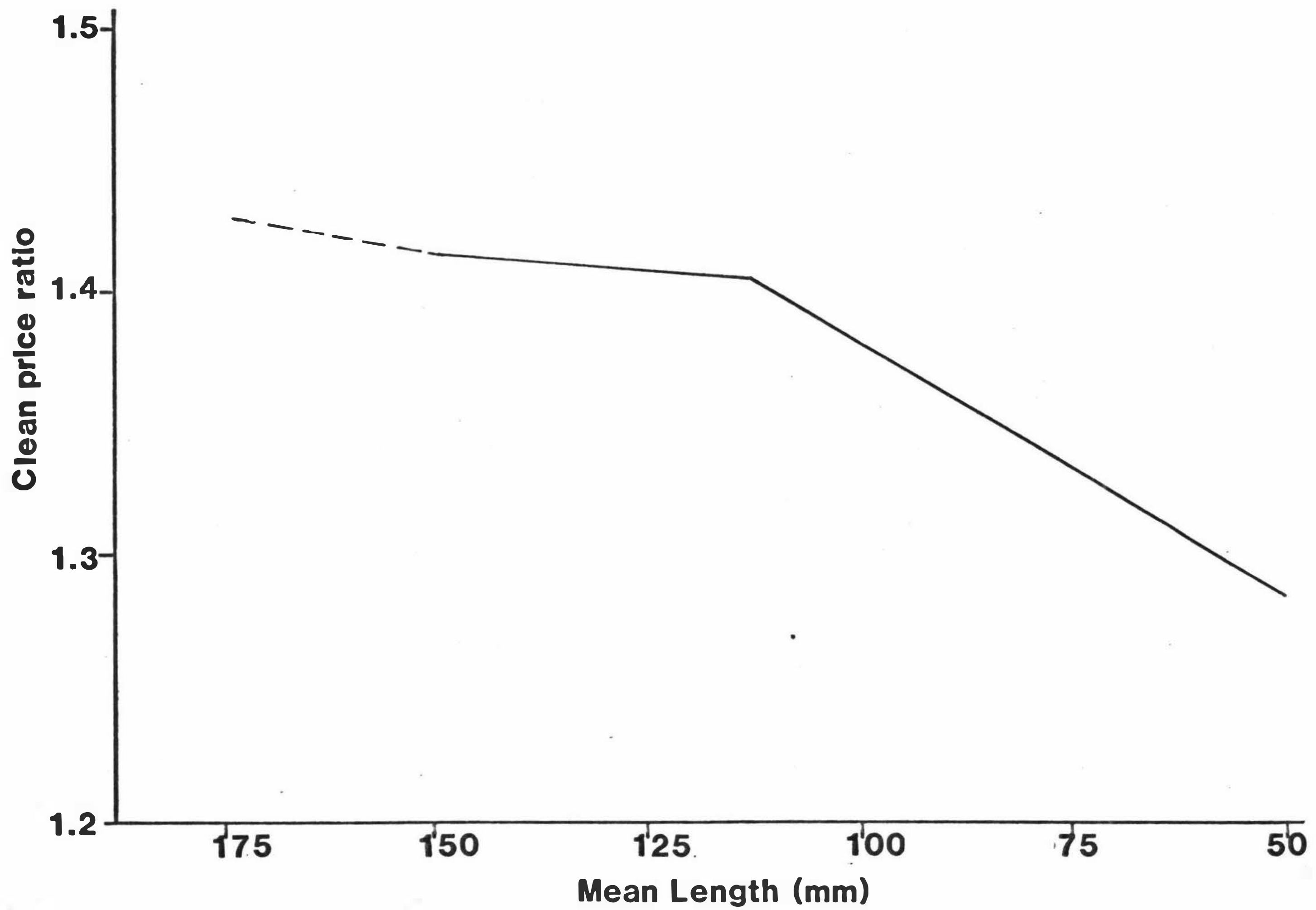
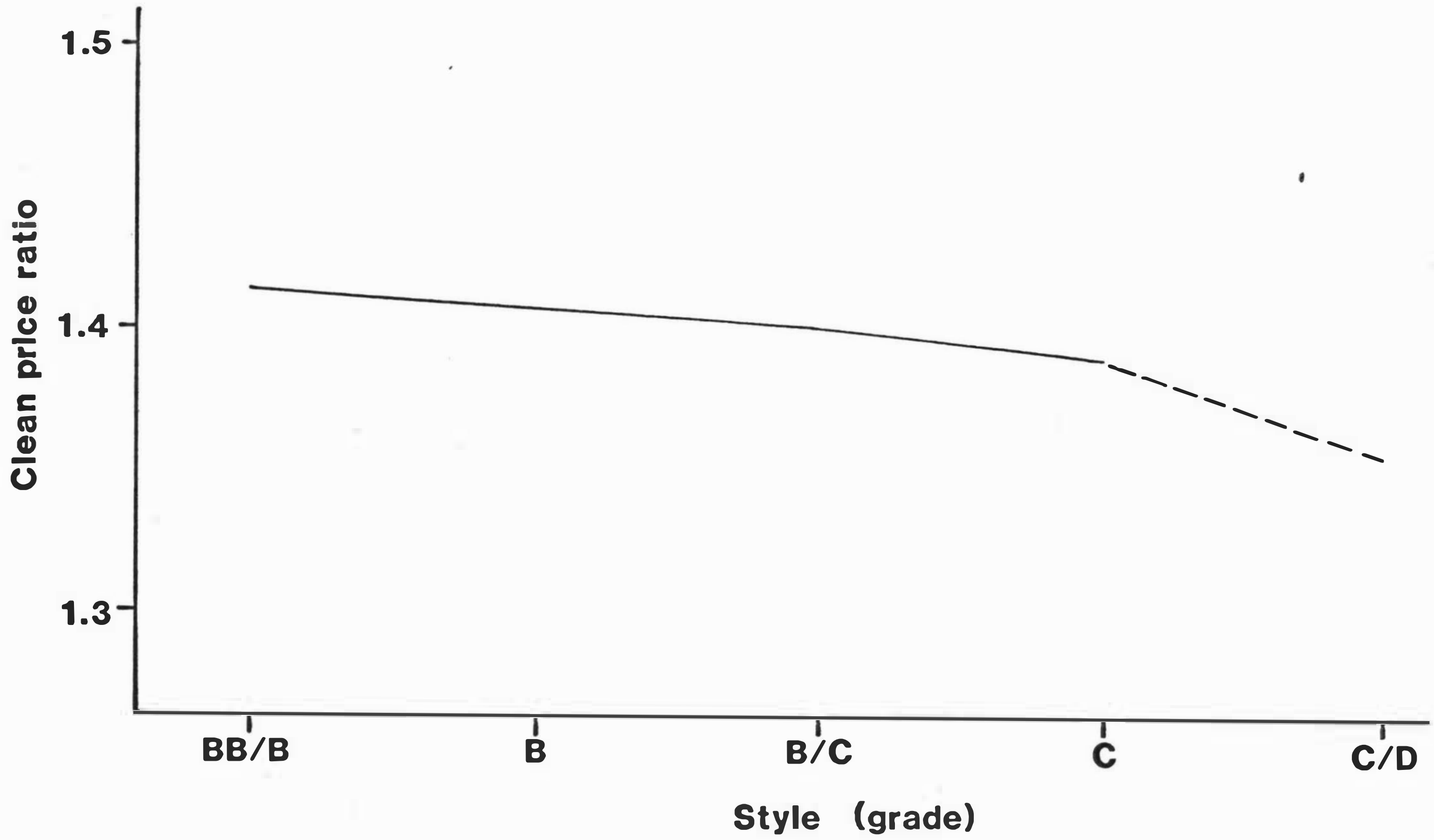


FIGURE 2.3: STYLE VS. PRICE. 1978/79
(from Wiggins and Beggs, 1979)



The major function of the work to date has been to identify trends. The application to animal breeding is not documented, but it can probably be implied that the values may be averaged over time and used as economic weights.

2.2.7 Regression of profit on the selection objective

This method is essentially the same as that previously described for wool quality traits (2.2.5). Profit replaces auction price as the dependent variable and the traits in the objective are included as independent variables. As outlined by Pearson and Miller (1981) for a U.S. dairy enterprise, a profit function is specified for each individual of a population of animals, preferably on a multi-herd basis. Inputs and outputs are weighted by their respective prices. The economic weights are then calculated as the partial regression coefficients of the profit function on the traits in the selection objective.

Problems can arise if important traits are omitted or if those used do not furnish accurate predictions. Changing economic conditions necessitate re-computation, although the results of Balaine *et al.* (1981) indicated that, if economic efficiency is defined on a profit per day basis, then different price regimes may have only a negligible effect on individual rankings.

Due to the high data collection costs of this method, Pearson and Miller (1981) recommended a limited application to only those herds having the greatest influence on genetic improvement. A major problem of using such a technique in the New Zealand sheep industry, would result from the difficulty of accurately estimating individual feed costs (Chapter 2.1.1). There would also be problems associated with exactly defining the value of the products produced, as the situation is not as clear cut as for the value of milk in the dairy industry (Wickham, pers. comm). If applicable, the method would most certainly be confined to ram breeding flocks.

2.2.8 Production systems analysis

All the methods discussed have been intended to give a description of economic efficiency on an individual animal basis. However, the improvement of a trait can change the optimal organisation of a farming enterprise. Hence, another approach involves expressing economic efficiency in a farm planning or production systems analysis context. As the name implies, such a method studies the entire production framework by taking into account resource limitations, changes in price and costs according to volume and other non-linear input-output relationships, which are ignored when the relatively simple 'per animal' profit functions are developed. The effect of such simplifications on selection accuracy is yet to be determined. Wilton (1979) discussed the applications of production systems analyses and its uses in formulating selection goals and mating plans.

Using beef cattle as an example, Melton *et al.* (1979) presented a procedure based on production systems analysis that is capable of estimating the economic weight of specified traits. Their method consisted of deriving a profit function and a production function. The production function, comprising both animal and breeder-supplied inputs, is substituted into the profit function. Under the assumption that profit is to be maximised, then the resultant function is maximised mathematically by equating the partial derivatives of that function, with respect to each variable, to zero and simultaneously solving the ensuing set of first-order equations. In this way the economic weights of each trait are determined, as well as the optimal levels of breeder-supplied inputs. The economic weights are, according to Melton *et al.*, a product of the average values of all traits considered, the available producer inputs and their prices, the price of the product and the specified production function.

The great advantage of this method is flexibility as it can be applied to suit the varying production conditions of individual breeders. Each breeder specifies his production function, input and output prices, and the average level of traits in his flock or herd. However, the vast amount of information required for such computation is generally beyond the scope of most breeders where there is only one major product, let alone for the dual-purpose Romney where both meat and wool production receive emphasis. The specified production functions cannot be easily derived. Because of this, Wilton *et al.* (1978) proposed that continued selection on a profit per animal basis is preferable, at least until the effects of the previously mentioned simplifications can be assessed.

Thompson (1980) critically discussed this method, suggesting that the profit function derived by Melton *et al.* (1979) favours animals with values for the traits in the profit function that are near the mean, i.e. such animals produce greater profit. In contrast, the linear selection index developed by Hazel (1943) favours animals with extreme values. This situation arises because the index is relevant for only part of the profit function. Thompson suggested that, given the profit function derived by Melton *et al.* (1979), it would be wiser to use an index appropriate for the whole function, such as the quadratic index developed by Wilton *et al.* (1968).

2.3 PUBLISHED ECONOMIC WEIGHTS FOR THE ROMNEY

A summary of the published literature concerning economic weights for the Romney is shown in Table 2.1. Inspection of the table reveals that fertility, lamb weaning weight and greasy fleece weight have been consistently emphasised. It is important to note that, with the exception of Morris *et al.* (1982), the economic weights are gross values. Morris *et al.* (1982) tried to account for some production costs in an effort to derive net values. This is probably why the resultant ratio of their estimates is lower than in previous studies.

TABLE 2.1: PUBLISHED ECONOMIC WEIGHTS FOR THE ROMNEY EXPRESSED AS RATIOS. (GFW = 1.0)

Source	Period	TRAITS											
		NLB	NLW	WW	LBC	LD%	LCW	LCG	HBW	ECW	GFW	QN	S
Rae (1954)[1]			5.0	0.2	0.1		0.4	0.2			1.0	0.1	0.5
NFRS[1,2] Clarke (1967)			7.8								1.0		
Taylor *et al.* (1980)	1960/61-64/65		6.0								1.0		
	1965/66-69/70		7.6								1.0		
	1966/67-70/71		8.4								1.0		
	1970/71-74/75		6.8								1.0		
Waihora GBS Hight *et al.* (1975)			5.8	0.1					0		1.0		
Sheeplan Clarke & Rae (1976)	1970/71-74/75	6.0		0.3					0		1.0		
Taylor *et al.* (1980)	1975/76-79/80		5.4								1.0		
Morris *et al.* (1982)			3.7	0.1		0.1				0	1.0		

1. Adjusted to metric measures

2. Total Weight of Lambs Weaned Converted to NLW (LWW = 23.3kg: Dalton & Rae (1979))

NLB = Number lambs born
NLW = Number lambs weaned
WW = Weaning weight
LBC = Lamb body conformation
LD% = Lamb dressing percentage
LCW = Lamb carcass weight
LCG = Lamb carcass grade
HBW = Hogget body weight
ECW = Ewe carcass weight
GFW = Greasy fleece weight
QN = Quality number
S = Style

In general, it is evident that the ratios between the traits exhibit a reasonable repeatability over the time period involved. Lately, an increasing relative emphasis on wool production may be claimed. These trends were confirmed by Taylor *et al.* (1980), who examined the relative movements in wool auction prices and lamb export schedule prices. It was shown that the two commodities have experienced reasonably simultaneous high and low points. Consequently, it follows that the economic weights using these, or related prices, have remained relatively constant.

With the exception of Rae (1954), there has been no consideration given to the economic weights of wool quality traits, hence their exclusion from many selection objectives. Rae (1954) also derived a value for face cover of 70 d/grade ($0.58/grade or 0.70 compared with greasy fleece weight of 1.00). Due to the incomplete nature of the information used, it was considered that that was not the best estimate available. Wickham (pers. comm.) subsequently suggested that face cover is not an objective, but a possible criterion for fertility, lamb growth and lower handling costs, and as such, should not have an economic weight assigned to it.

2.4 GENERAL PROBLEMS ASSOCIATED WITH THE USE OF ECONOMIC WEIGHTS

There exists an acute naivety of geneticists to economic parameters and of economists to animal breeding programmes. This has resulted in relatively little research having been directed toward examining the properties and problems of economic weights.

The selection index formulation of Hazel (1943) assumes that the economic weights assigned to individual traits are known, fixed constants. Vandepitte and Hazel (1977) discussed why this assumption is seldom true.

Firstly, economic weights are only estimates and must be recognised and treated as such. They can range from accurate estimates for the situation where complete information is available, to intelligent guesses in less desirable cases. Even if information is freely available, the estimates are still subject to reasonably large sampling errors (Vandepitte and Hazel, 1977).

Secondly, economic weights only define the economic environment under which animals are expected to produce (Rae, 1958). Variations in the physical environment are seldom taken into account and the need for traits such as hardiness, longevity and adaptation is not directly considered (Rae, 1958).

Thirdly, the fractionated nature of the sheep industry, whether in terms of population structure tiers, geographical locations, farming systems or breed strains etc., can produce a variety of breeders with different ideas, objectives and economic frameworks (Rae, 1982), and consequently different sets of optimum economic weights. In this respect the New Zealand sheep industry is not as complexly stratified as those in other major sheep-farming countries. Hence, within a breed, conflict in the objectives between hill country and lowland farmers should be minimal (Rae, 1964b).

Morris *et al.* (1982) discussed the existence of conflict between the objectives of ram-breeding and commercial flocks. Only those traits of economic value to the commercial flock should be included in the selection objectives of ram-breeding flocks (Ponzoni, 1979; Morris *et al.*, 1982; Rae, 1982). To be economically feasible to the ram-breeder, it is necessary that the commercial farmers recognise superior rams and pay a premium for them. As pointed out by Harris (1970), auction sales in the past have provided little opportunity for genetically superior animals to attract premiums.

Finally, the animals selected now will not realise any profits until some time in the future. By that stage it is possible that the economic framework under which selection occurred has altered, thereby possibly influencing the efficiency of selection and the expected profitability of the selected animals. In the words of Vandepitte and Hazel (1977), economic weights reflect production costs and a consumer preference through the pricing mechanism. Consequently, economic weights are influenced by price trends, quantity and quality trends, technological innovations etc. In a slightly different context, Vandepitte and Hazel (1977) also discussed the problem of genetic improvement time lags induced by multi-tiered population structures. Consequently, the need for projected economic weights, which take into consideration expected future circumstances, has been highlighted by several authors (Rae, 1958; Wickham, 1966, 1975; Harris, 1970; Miller and Pearson, 1979; Morris *et al.*, 1982; Cunningham, 1982; Rae, 1982; Ross *et al.*, 1982).

The task of forecasting future economic conditions is formidable (Cunningham, 1982), requiring thorough and intensive analysis. Taylor (1977) documented the escalating costs and fluctuating returns facing the New Zealand sheep farmer. It is important to distinguish between general trends and short-term fluctuations (Rae, 1958; Taylor *et al.*, 1980). As suggested by Miller and Pearson (1979), current trends, for example resulting from technological or marketing advances, may intensify in the future. Techniques for the accurate prediction of future economic conditions, with respect to their influence on the relative importance of specified traits are lacking. Maijala (1976) in advocating the use of current economic weights, compromised between the ideal situation of having future predictions and the other extreme of not estimating any economic weights at all.

Consideration of these points reveals that there can be no unique set of economic weights which can be universally applied to achieve maximum response in economically important genetic improvement. The fixed constant concept of economic weights is erroneous. Economic weights need frequent reassessment, although Rae (1982) suggested the current economic weights for the Romney in Sheeplan are still adequate for present purposes. For administrative ease, breeding schemes are often forced to make sweeping generalisations concerning the application of economic weights. Sheeplan (Clarke and Rae, 1976) currently recognises breed differences by assigning different sets of economic weights to those breeds participating in the scheme. It does not distinguish between breeders at a more refined level. In this manner, an individual breeder may be assigned a set of economic weights that is sub-optimal for his particular conditions.

2.5 EFFECT OF ERRORS IN ECONOMIC WEIGHTS ON SELECTION INDEX EFFICIENCY

Optimum response would be expected if precise parameters are used. Erroneous estimates are likely to result in a loss in efficiency. Consequently, it is of importance to know the extent to which errors in economic weights reduce the efficiency of a selection index. Research efforts in this area have been minimal, despite the obvious importance of economic weights.

Pease *et al.* (1967) (cited by Vandepitte and Hazel, 1977) for pigs, and Cunningham and Gjedrem (1970) for sheep, made passing reference to the effects of erroneous economic weights. In both studies, errors of up to approximately 50% were not found to be of critical importance.

Ronningen (1971) examined the effects of false economic ratios on the efficiency of a two trait selection index for
(i) dairy cattle (milk yield and milk fat yield) and
(ii) sheep (number of lambs and fleece weight).
Ronningen concluded that the efficiency of the dairy cattle index was not substantially influenced by minor variations from the true economic ratio. As the deviations increased, there was a corresponding increase in the loss in efficiency.

Serious losses were incurred when the most economically important trait was assigned a negative economic weight in combination with a high heritability. Significant losses were also obtained in situations where the maximum gain from direct selection was small. Similar results were obtained for the sheep index, except losses in efficiency proved to be more serious.

Fowler *et al.* (1976) found that errors or changes in individual economic weights of 50% resulted in only trivial effects on the predicted efficiency of a selection index for pigs. In no circumstance, did such errors reduce the efficiency of the index by more than 2%.

Vandepitte and Hazel (1977) also used a pig selection index as a test case to investigate the effects of intentionally introduced errors. Their results confirm those of previous analyses, indicating that errors in single economic weights of ±50% generally had little effect as real genetic gain was reduced by less than 1% for each of the traits considered. The loss in relative efficiency when a biased selection index (resulting from errors in economic weights of up to 200%) is used instead of an unbiased index was illustrated. A marked non-linear dissymmetry in the loss of selection index efficiency was displayed. Negative errors (i.e. under-estimation of economic weights) result in a greater loss than positive errors (i.e. overestimation of economic weights) of the same magnitude. Errors of ±50% produced losses in relative efficiency of between 0.16% and 0.90%, while larger errors of ±200% generated more serious losses which ranged from 10.14% to 76.44%.

This study was then extended to consider the importance of simultaneous random errors in a set of economic weights. Using both Monte Carlo simulation and mathematical approximation, Vandepitte and Hazel demonstrated that small errors (C.V. < 0.50) reduced relative efficiency by less than 2.6%, whereas larger errors (CV = 1.0) resulted in a loss of approx. 15%. The same non-linear and non-symmetrical properties discovered previously were revealed again.

Ponzoni (1979) conducted a sensitivity analysis, in which he examined the effect of altering the relative prices of both meat and wool products for an Australian Merino sheep farming enterprise. The changes in market prices that were made, were considered by Ponzoni to be representative of extreme situations. Nevertheless, the resultant effect on genetic gain was slight, hence confirming previously published conclusions for a variety of production systems, that genetic progress is not substantially hindered by moderate errors in the economic weights. Stafford and Walkley (1979) conducted a similar analysis for Australian prime lamb production.

CHAPTER THREE

THE INFLUENCE OF WOOL QUALITY TRAITS ON PRICE

3.1 INTRODUCTION

Prior to each auction sale within New Zealand, the valuing staff of the New Zealand Wool Board appraise each lot of wool on offer. On the basis of their assessment, they assign to each lot, a New Zealand Wool Board 'type', defining mean fibre diameter (MFD), wool category, style grade (S) and length grade (ML). For example, a 37F2D type would represent a lot of main fleece wool (F) having a MFD assessed or measured at 37 μm (37), a B style grade (code 2) and from 100-150 mm in length (code D). Yield (Y) of greasy wool is also estimated, but not included within the type value.

Since the beginning of the 1980/81 season, further information has been recorded in the Coded Sales Assistance Report. This report consists of,

1. Scouring indicator (SI), assessing the suitability of the lot for local scouring (inversely proportional to vegetable matter content). It is graded 1 to 3, with 1 being suitable for scouring (little or no vegetable matter).

2. Colour indicator (CI), assessing the likely colour of the lot after scouring. It is graded 1 to 4, with 1 indicating good colour after scouring.

3. Additional information on any of up to three other traits. These are coded according to New Zealand Wool Board specifications. For example, tender wool is represented by T, pen stain wool by P. They are therefore graded on a 0-1 scale.

Further details of this valuing system are given by Corrigan (1979) and N.Z.W.B. (1980/81).

In addition to the physical attributes of the wool, information including sale date, centre of sale, mode of offering, number of bales and lot weight is also recorded for each lot.

At the completion of each sale, these data are combined with the price received for the particular lot and are transferred to New Zealand Wool Board computer files.

3.2 MATERIALS AND METHODS

The wool characteristic-price data required to establish the importance of the differing variables on price were obtained from the New Zealand Wool Board computer files.

Only data from wool sold at auction in New Zealand were considered (estimated to be approx. 75% of the total clip; N.Z.W.B., 1980). Wool that was sold by the extra choice scheme, by auction in the United Kingdom or passed in, was excluded. Wool reoffered through the auction system by the New Zealand Wool Board and wool purchased at auction by the New Zealand Wool Board under market intervention and strata price control strategies were not excluded.

The five selling seasons from 1976/77 to 1980/81 were selected for analysis. Within each season, all eight centres (Auckland, Napier, Wanganui, Wellington, Christchurch, Timaru, Dunedin and Invercargill) and all sales within those centres were included. Within sales, four modes of offering (reclassed, binned, interlotted and growers brand) were considered. No restriction was placed on lot size (lot weight).

The wool types selected for analysis conformed to the following type specifications;

MFD	:	33 to 40 µm
Category	:	Fleece wool (F)
S	:	1 to 5 grade
ML	:	B, C, D, E, J, O and R grades
Y	:	Not restricted within the greasy range, but scoured wool not included.

This was considered to be an adequate representation of possible Romney fleece wools. Further analyses would need to be conducted for wool types outside these limits e.g. for differing breed groups, wool oddments etc.

In addition, the traits considered from the Coded Sales Assistance Report in the 1980/81 season were;

Scouring indicator	(SI)
Colour indicator	(CI)
Mixed Quality	(QV)
Mixed Length	(LV)
Tender	(T)
Cotted	(Co)
Felted	(F)
Pen Stain	(P)

The number of records in each season was,

1976/77	:	31,792
1977/78	:	34,026
1978/79	:	35,505
1979/80	:	36,476
1980/81	:	36,949
Total	:	174,748

Before the data were analysed, several transformations were made.

The alphabetical length range codes were converted into single numerical values, according to the means of the ranges. The difference between these means was 25 mm. These values were then expressed on a smaller scale by division by a factor of 12. The resulting scale effectively equated each unit increment to an increase in length of 12.5 mm or 0.5 inches.

Code	B	C	D	E	J	O	R
Range (mm)	150-200	125-175	100-150	100-125	75-100	50-75	25-50
Mean (mm)	175	150	125	112	87	62	37
$\frac{\text{Mean}}{12}$	14	12	10	9	7	5	3

The selected variables from the Coded Sales Assistance Report were given numerical values of 1 if recorded and 0 if not recorded.

Greasy price was expressed as a percentage of the seasonal mean of all wool sold. The greasy price of each lot was multiplied by the appropriate seasonal constant given below.

	76/77	77/78	78/79	79/80	80/81
Mean price of all wool sold (c/kg)	219.58	190.43	218.80	265.09	247.48
Constant $(\frac{100}{\text{Mean}})$	0.4554	0.5251	0.4570	0.3772	0.4041

Assuming the relationship between the wool types and the seasonal means is constant, this should account for seasonal variations in price identified by W.M.S.G. (1967). A further set of constants derived from the seasonal means of 35-41 μm wools, was almost equivalent to those given above.

A multiple regression analysis was conducted using REG, a generalised least squares computer program (Gilmour, pers. comm). Price was treated as the dependent variable, while the wool traits and lot attributes were treated as the independent variables. To account for some of the within season variation identified by W.M.S.G. (1967), the effects of sale date were absorbed during the analysis (Searle, 1971). Essentially, this was done by treating sale date as another variable in the analysis.

Further data, where required, were extracted from N.Z.W.B. (1976/77, 1977/78, 1978/79, 1979/80, 1980/81).

3.3 RESULTS

3.3.1 Greasy analyses

The first set of analyses conducted using the New Zealand Wool Board data involved the effects of MFD, S, ML, Y, as well as lot weight (LW), mode of offering (MO) and New Zealand Wool Board market intervention policies (Int) on greasy price. Each of the five seasons were analysed individually and then the data from each were combined and the analyses repeated.

General statistics are shown in Table 3.1. There is relatively little difference between the five seasons, although it could be argued that MFD has increased and ML decreased over the period studied.

The simple correlations between the wool traits and greasy price are shown in Table 3.2. Y was consistently highly correlated with greasy price. Of the other traits, ML and S had moderate correlations, while MFD seemingly had no relationship with greasy price.

TABLE 3.2: SIMPLE CORRELATIONS WITH GREASY PRICE

	Season					
	76/77	77/78	78/79	79/80	80/81	All
MFD	0.01	-0.03	-0.01	0.03	-0.01	0.00
S	-0.27	-0.29	-0.29	-0.36	-0.35	-0.31
ML	0.33	0.44	0.25	0.23	0.38	0.33
Y	0.58	0.60	0.69	0.70	0.61	0.64

TABLE 3.1: GENERAL STATISTICS OF GREASY ANALYSES

		Season					
		76/77	77/78	78/79	79/80	80/81	All
Original No. of Records		31,792	34,026	35,505	36,476	36,949	174,478
No. of Records after Absorption		31,735	33,970	35,448	36,418	36,883	174,450
MFD (μm)	mean	35.45	35.50	35.60	35.66	35.86	35.62
	s.d.	1.62	1.61	1.53	1.55	1.58	1.58
S (grade)	mean	2.64	2.52	2.64	2.72	2.64	2.63
	s.d.	0.83	0.80	0.81	0.90	0.85	0.84
ML (mm)	mean	103.35	104.14	102.80	101.86	98.77	102.07
	s.d.	23.05	23.41	22.21	23.96	25.02	23.62
Y (%)	mean	77.70	77.28	77.74	78.35	77.73	77.76
	s.d.	2.79	2.86	2.93	3.00	3.18	2.97
Greasy Price (c/kg)	mean	236.05	207.43	232.46	284.90	266.67	245.57
	s.d.	10.98	10.00	10.03	13.12	14.53	12.65

The partial and standardised partial regression coefficients for Y, ML, S and MFD, along with the percentage control these traits collectively exerted over greasy price, are shown in Table 3.3. It is demonstrated that S was continually of major significance, reaching a peak premium of 4.36 c/kg/grade in the 1980/81 season. ML and Y also had important, but smaller effects. MFD was again of little concern, although it can be seen that its value has increased, particularly in the 1980/81 season. Jointly, these four traits were able to control from 57.3% to 74.0% of the variation in price.

In an effort to explain a greater percentage of the variation in price, the effects of three non-fleece related variables, viz. LW, MO and Int, were added to the regression model. The additional control afforded by these factors was negligible, ranging from 0.3% in 1977/78 to 1.3% in 1979/80. Appendix I (A and B) contains the mean LW, the actual control over greasy price achieved by introducing the three terms, as well as the respective partial regression coefficients and their implications.

The use of quadratic terms has featured in some of the Australian Merino analyses. Skinner (1965) and McKinnon *et al.* (1973) both showed length squared (ML^2) to be of importance, and McKinnon *et al.* (1973) also found that the product term, style x quality number (S x QN) was of some value. Guided by these results, squares and cross-products of the traits in the original model (Y, ML, S and MFD) were then added to that very same model.

It can be seen from Tables 3.4, 3.5, 3.6, 3.7, 3.8 and 3.9 that the introduction of such quadratic terms improved the control over price from a further 3.3% in 1978/79 to a further 10.4% in 1980/81. On the basis of statistical significance, terms were then deleted in turn from the analysis. It is evident in all of the seasons, that the only quadratic term of major importance was ML^2. The S x ML product term did assume increased value in the 1980/81 season. The importance of Y, ML and S is again demonstrated.

TABLE 3.3: WOOL TRAIT REGRESSION COEFFICIENTS[1] FOR GREASY PRICE

Season		Y	ML	S	MFD	% Control
76/77	P	2.41	2.56	-3.02	-0.06	57.3
	SP	0.86	1.33	-3.62	-0.04	
77/78	P	2.37	3.07	-2.94	-0.33	74.0
	SP	0.83	1.57	-3.68	-0.20	
78/79	P	2.55	2.28	-2.17	-0.27	67.4
	SP	0.87	1.23	-2.67	-0.17	
79/80	P	3.20	2.58	-3.53	-0.34	69.3
	SP	1.06	1.29	-3.91	-0.22	
80/81	P	2.94	3.35	-4.36	-1.27	66.7
	SP	0.93	1.61	-5.14	-0.80	
All	P	2.69	2.80	-3.20	-0.44	66.0
	SP	0.91	1.42	-3.80	-0.28	

P = partial regression coefficient
SP = standardised partial regression coefficient

(1) Y (c/kg/%), ML (c/kg/0.5in)
S (c/kg/grade), MFD (c/kg/μm)

TABLE 3.4: THE EFFECT OF QUADRATIC TERMS FOR Y, ML, S AND MFD ON EXPLAINING VARIATION IN GREASY PRICE FOR THE 1976/77 SEASON

Y	Y^2	ML	ML^2	S	S^2	MFD	MFD^2	MFD x S	MFD x ML	MFD x Y	S x ML	S x Y	ML x Y	% Control
+		+		+		+								57.3
+	+	+	+	+	+	+	+	+	+	+	+	+	+	63.5
+	+	+	+	+	+	+					+	+	+	63.5
+	+	+	+	+	+						+	+	+	63.5
+		+	+	+							+	+	+	63.3
+		+	+	+										62.8
+		+		+										57.2
+		+	+											56.5
+		+												52.0
+				+										37.5
		+		+										20.1

TABLE 3.5: THE EFFECT OF QUADRATIC TERMS FOR Y, ML, S AND MFD ON EXPLAINING VARIATION IN GREASY PRICE FOR THE 1977/78 SEASON

Y	Y^2	ML	ML^2	S	S^2	MFD	MFD^2	MFD x S	MFD x ML	MFD x Y	S x ML	S x Y	ML x Y	% Control
+		+		+		+								74.0
+	+	+	+	+	+	+	+	+	+	+	+	+	+	77.5
+	+	+	+	+	+	+					+	+	+	77.4
+	+	+	+	+		+						+	+	77.4
+	+	+	+	+		+								77.2
+		+	+	+		+								77.0
+		+	+	+										76.7
+		+		+										73.8
+		+	+											70.7
+		+												68.4
+				+										39.8
		+		+										30.3

TABLE 3.6: THE EFFECT OF QUADRATIC TERMS FOR Y, ML, S AND MFD ON EXPLAINING VARIATION IN GREASY PRICE FOR THE 1978/79 SEASON

Y	Y^2	ML	ML^2	S	S^2	MFD	MFD^2	MFD x S	MFD x ML	MFD x Y	S x ML	S x Y	ML x Y	% Control
+		+		+		+								67.4
+	+	+	+	+	+	+	+	+	+	+	+	+	+	70.7
+	+	+	+	+	+	+	+				+	+	+	70.7
+	+	+	+	+	+	+	+							70.6
+		+	+	+		+								70.1
+		+	+	+										69.9
+		+		+										67.2
+		+	+											66.4
+		+												64.2
+				+										50.5
		+		+										15.7

TABLE 3.7: THE EFFECT OF QUADRATIC TERMS FOR Y, ML, S AND MFD ON EXPLAINING VARIATION IN GREASY PRICE FOR THE 1979/80 SEASON

Y	Y^2	ML	ML^2	S	S^2	MFD	MFD^2	MFD x S	MFD x ML	MFD x Y	S x ML	S x Y	ML x Y	% Control
+		+		+		+								69.3
+	+	+	+	+	+	+	+	+	+	+	+	+	+	73.5
+	+	+	+	+	+	+	+				+	+	+	73.4
+		+	+	+	+	+					+	+	+	73.3
+		+	+	+	+	+								72.6
+		+	+	+										72.3
+		+		+										69.2
+		+	+											65.8
+		+												63.5
+				+										54.7
		+		+										19.6

TABLE 3.8: THE EFFECT OF QUADRATIC TERMS FOR Y, ML, S AND MFD ON EXPLAINING VARIATION IN GREASY PRICE FOR THE 1980/81 SEASON

Y	Y^2	ML	ML^2	S	S^2	MFD	MFD^2	MFD x S	MFD x ML	MFD x Y	S x ML	S x Y	ML x Y	% Control
+		+		+		+								66.7
+	+	+	+	+	+	+	+	+	+	+	+	+	+	77.1
+		+	+	+	+	+	+	+	+	+	+	+	+	77.1
+		+	+	+	+	+	+				+	+	+	76.4
+		+	+	+	+	+	+				+			76.1
+		+	+	+		+					+			75.7
+		+	+	+							+			73.6
+		+	+	+										72.3
+		+		+										64.8
+		+	+											65.2
+		+												58.5
+				+										44.2
		+		+										26.4

TABLE 3.9: THE EFFECT OF QUADRATIC TERMS FOR Y, ML, S AND MFD ON EXPLAINING VARIATION IN GREASY PRICE FOR ALL SEASONS

Y	Y^2	ML	ML^2	S	S^2	MFD	MFD^2	MFD x S	MFD x ML	MFD x Y	S x ML	S x Y	ML x Y	% Control
+		+		+		+								66.0
+	+	+	+	+	+	+	+	+	+	+	+	+	+	71.2
+	+	+	+	+	+	+	+				+	+	+	71.2
+		+	+	+	+	+					+	+	+	71.1
+		+	+	+	+	+					+			70.9
+		+	+	+	+						+			70.5
+		+	+	+	+									70.2
+		+	+	+										70.1
+		+		+										65.7
+		+	+											64.2
+		+												60.5
+				+										45.0
		+		+										22.0

As before, terms for LW, MO and Int, and also LW^2, were added to the initial quadratic model. It can be seen in Appendix II (A) that the introduction of these terms again had a negligible effect on increasing the control over price.

3.3.2 Clean analyses

The importance of Y in controlling greasy price has been well demonstrated. For this reason it was considered worthwhile to repeat the analyses for clean price, as opposed to greasy price. Clean price for each lot was calculated simply as,

$$\text{Clean price} = \text{greasy price} \times \frac{100}{Y}$$

In this way, Y is used multiplicatively and not additively as before.

The general statistics pertaining to the clean analyses are as for the greasy analyses (Table 3.1), with the exception of clean price which is presented in Table 3.10.

TABLE 3.10: ADDITIONAL STATISTICS OF CLEAN ANALYSES

		Season					
		76/77	77/78	78/79	79/80	80/81	All
Clean Price (c/kg)	mean	304.21	268.32	299.02	363.99	343.10	315.94
	s.d.	11.63	10.58	9.67	12.22	15.09	11.94

The simple correlations between the physical attributes of the wool and clean price are shown in Table 3.11. As for the previous greasy analyses, ML and S were well correlated with the price variable, while MFD showed no relationship. The moderate negative correlations between Y and clean price are thought to reflect the difference in yield assessment of the New Zealand Wool Board valuing staff and the eventual buyers of the wool. Thus, if the New Zealand Wool Board valuers under-estimate Y, relative to the buyers estimate, the calculated clean price would be higher and vice versa.

TABLE 3.11: SIMPLE CORRELATIONS WITH CLEAN PRICE

	Season					
	76/77	77/78	78/79	79/80	80/81	All
MFD	0.05	-0.01	-0.01	0.00	-0.09	-0.01
S	-0.21	-0.21	-0.16	-0.27	-0.29	-0.23
ML	0.54	0.72	0.58	0.53	0.59	0.59
Y	-0.24	-0.21	-0.25	-0.18	-0.17	-0.21

The partial and standardised partial regression coefficients for Y, ML, S, and MFD on clean price, along with the control they exerted over that variable are shown in Table 3.12. A similar pattern to the greasy analyses emerged, except that:

(1) Y has diminished in importance as would be expected for a clean analyses. The effect demonstrated is presumed to be a residual between valuations.

(2) control over price variation, attributable to the four traits has been severely reduced from 74.0% to 61.1% in 1977/78 to 69.3% to 40.0% in 1979/80.

The introduction of terms for LW, MO and Int again provided very little additional control. The actual percentage control achieved and the respective partial regression coefficients of these terms are given in Appendix I(C).

The addition of quadratic terms to the initial model enhanced the ability to determine price. This is illustrated in Tables 3.13, 3.14, 3.15, 3.16, 3.17 and 3.18. The improvement ranged from a further 4.6% in 1977/78 to a further 15.9% in 1980/81. As before, terms were gradually deleted from the analysis. ML^2 again proved to be virtually the only quadratic term of value, although in the later two seasons, the S x ML product term assumed increased significance.

The trivial increases in price control attained by adding terms for LW, LW^2, MO and Int to the quadratic model are shown in Appendix II(B).

TABLE 3.12: WOOL TRAIT REGRESSION COEFFICIENTS[1] FOR CLEAN PRICE

Season		Y	ML	S	MFD	% Control
76/77	P	-0.81	3.23	-3.99	-0.03	39.6
	SP	-0.29	1.68	-4.79	-0.02	
77/78	P	-0.40	3.95	-3.79	-0.43	61.1
	SP	-0.14	2.02	-4.74	-0.27	
78/79	P	-0.59	2.96	-2.77	-0.36	41.3
	SP	-0.20	1.60	-3.42	-0.24	
79/80	P	-0.58	3.25	-4.55	-0.42	40.1
	SP	-0.19	1.63	-5.04	-0.27	
80/81	P	-0.63	4.32	-5.55	-1.67	48.2
	SP	-0.20	2.07	-6.54	-1.06	
All	P	-0.60	3.58	-4.13	-0.57	45.1
	SP	-0.20	1.82	-4.90	-0.36	

P = partial regression coefficient

SP = standardised partial regression coefficient

(1) Y (c/kg/%), ML (c/kg/0.5in.), S (c/kg/grade), MFD (c/kg/μm)

TABLE 3.13: THE EFFECTS OF QUADRATIC TERMS FOR Y, ML, S AND MFD ON EXPLAINING VARIATION IN CLEAN PRICE FOR THE 1976/77 SEASON

Y	Y^2	ML	ML^2	S	S^2	MFD	MFD^2	MFD x S	MFD x ML	MFD x Y	S x ML	S x Y	ML x Y	% Control
+		+		+		+								39.6
+	+	+	+	+	+	+	+	+	+	+	+	+	+	47.8
+	+	+	+	+	+	+				+	+	+	+	47.7
+		+	+	+	+	+					+	+		47.6
+		+	+	+		+					+	+		47.4
+		+	+	+		+								47.1
+		+	+	+										47.1
		+	+	+										44.6
		+	+											35.9
		+		+										35.9
			+	+										21.2

TABLE 3.14: THE EFFECT OF QUADRATIC TERMS FOR Y, ML, S AND MFD ON EXPLAINING VARIATION IN CLEAN PRICE FOR THE 1977/78 SEASON

Y	Y^2	ML	ML^2	S	S^2	MFD	MFD^2	MFD x S	MFD x ML	MFD x Y	S x ML	S x Y	ML x Y	% Control
+		+		+		+								61.1
+	+	+	+	+	+	+	+	+	+	+	+	+	+	65.7
+	+	+	+	+	+	+	+	+		+		+		65.6
+	+	+	+	+		+	+							65.5
+		+	+	+		+								65.3
		+	+	+		+								64.6
		+	+	+										64.2
		+	+											55.8
		+		+										59.5
			+	+										41.1

TABLE 3.15: THE EFFECT OF QUADRATIC TERMS FOR Y, ML, S AND MFD ON EXPLAINING VARIATION IN CLEAN PRICE FOR THE 1978/79 SEASON

Y	Y^2	ML	ML^2	S	S^2	MFD	MFD^2	MFD x S	MFD x ML	MFD x Y	S x ML	S x Y	ML x Y	% Control
+		+		+		+								41.3
+	+	+	+	+	+	+	+	+	+	+	+	+	+	47.5
+	+	+	+	+	+	+	+				+	+	+	47.5
+	+	+	+	+	+	+	+							47.3
+		+	+	+		+								46.3
+		+	+	+										45.9
		+	+	+										43.8
		+	+											38.6
		+		+										38.0
			+	+										23.2

TABLE 3.16: THE EFFECT OF QUADRATIC TERMS FOR Y, ML, S AND MFD ON EXPLAINING VARIATION IN CLEAN PRICE FOR THE 1979/80 SEASON

Y	Y^2	ML	ML^2	S	S^2	MFD	MFD^2	MFD x S	MFD x ML	MFD x Y	S x ML	S x Y	ML x Y	% Control
+		+		+		+								40.1
+	+	+	+	+	+	+	+	+	+	+	+	+	+	47.7
+	+	+	+	+	+	+	+				+	+	+	47.6
+	+	+	+	+	+	+	+				+			47.4
+		+	+	+	+	+					+			46.9
+		+	+	+	+						+			46.6
		+	+	+	+						+			45.2
		+	+	+							+			44.9
		+	+	+										44.0
		+	+											32.6
		+		+										37.8
			+	+										24.5

TABLE 3.17: THE EFFECT OF QUADRATIC TERMS FOR Y, ML, S AND MFD ON EXPLAINING VARIATION IN CLEAN PRICE FOR THE 1980/81 SEASON

Y	Y^2	ML	ML^2	S	S^2	MFD	MFD^2	MFD x S	MFD x ML	MFD x Y	S x ML	S x Y	ML x Y	% Control
+		+		+		+								48.2
+	+	+	+	+	+	+	+	+	+	+	+	+	+	64.1
+		+	+	+	+	+	+	+	+		+			63.7
+		+	+	+	+	+	+				+			62.7
		+	+	+	+	+	+				+			62.0
		+	+	+		+					+			61.2
		+	+	+		+								58.9
		+	+	+										55.4
		+	+											45.5
		+		+										43.1
			+	+										24.4

TABLE 3.18: THE EFFECT OF QUADRATIC TERMS FOR Y, ML, S AND MFD ON EXPLAINING VARIATION IN CLEAN PRICE FOR ALL SEASONS

Y	Y^2	ML	ML^2	S	S^2	MFD	MFD^2	MFD x S	MFD x ML	MFD x Y	S x ML	S x Y	ML x Y	% Control
+		+		+		+								45.1
+	+	+	+	+	+	+	+	+	+	+	+	+	+	53.2
+	+	+	+	+	+	+	+				+	+	+	53.1
+		+	+	+	+	+	+				+			52.9
+		+	+	+	+	+					+			52.7
+		+	+	+	+	+								52.3
		+	+	+	+	+								50.9
		+	+	+		+								50.7
		+	+	+										50.0
		+	+											41.3
		+		+										42.3
			+	+										25.8

3.3.3 Coded Sales Assistance Report analyses

For the 1980/81 season only, data from the New Zealand Wool Board Coded Sales Assistance Report (C.S.A.R.) were available for analysis. In addition to MFD, S, ML and Y, it was possible to analyse the price-determining importance of the following variables; scouring indicator (SI), colour indicator (CI), felted (F), pen stain (P), cotted (Co), tender (T), mixed length (LV) and mixed quality (QV).

General statistics are presented in Table 3.19. It is important to reiterate that SI is expressed on a scale of 1, 2 or 3, CI 1 to 4 and the remaining C.S.A.R. variables are on a 0 or 1 scale.

The simple correlations between the wool characteristics and price (greasy and clean) are displayed in Table 3.20. Of the additional variables, only CI had any reasonable relationship with price, although correlations with 0-1 variables are not very valuable.

The C.S.A.R. traits were then fitted to the regression model, already containing MFD, S, ML and Y. Tables 3.21 and 3.22 contain the respective partial regression coefficients and the percentage control over price (greasy and clean). The inclusion of these traits resulted in only a further 0.3% to 0.4% control, given the presence of the MFD, S, ML and Y traits in the model.

Because of a suspected interdependence between the C.S.A.R. traits and MFD, S, ML and Y, the latter four traits were deleted in turn from the analyses. The effects of these deletions on the partial regression coefficients and the percentage control over price, are shown in the remainder of Tables 3.21 and 3.22.

The most significant result occurred when S was deleted from the analysis. For example, the control over greasy price by the original model was reduced from 66.7% to 60.3%, but

TABLE 3.19: GENERAL STATISTICS OF CODED SALES ASSISTANCE REPORT ANALYSES FOR THE 1980/81 SEASON

	Mean	S.D.
Original No. of Records	36949	
No. of Records after Absorption	36883	
MFD (μm)	35.86	1.58
S (grade)	2.64	0.85
ML (mm)	98.77	25.02
Y (%)	77.73	3.18
SI	1.38	0.63
CI	2.41	0.85
F	0.11	0.32
P	0.12	0.35
Co	0.05	0.22
T	0.01	0.12
LV	0.05	0.25
QV	0.02	0.14
Greasy Price (c/kg)	266.67	14.53
Clean Price (c/kg)	343.10	15.09

TABLE 3.20: SIMPLE CORRELATIONS BETWEEN PRICE AND THE CODED SALES ASSISTANCE REPORT TRAITS FOR THE 1980/81 SEASON

	Greasy Price	Clean Price
MFD	-0.01	-0.09
S	-0.35	-0.29
ML	0.38	0.59
Y	0.61	-0.17
SI	-0.16	-0.05
CI	-0.26	-0.25
F	-0.09	-0.05
P	-0.10	-0.11
Co	-0.07	-0.02
T	-0.03	-0.01
LV	-0.02	0.00
QV	0.00	0.04

TABLE 3.21: PARTIAL REGRESSION COEFFICIENTS[1] ON GREASY PRICE OF THE CODED SALES ASSISTANCE REPORT ANALYSES FOR THE 1980/81 SEASON

Y	ML	S	MFD	SI	CI	F	P	Co	T	LV	QV	% Control
2.94	3.35	-4.36	-1.27									66.7
2.96	3.35	-3.64	-1.27	-0.07	-0.91	-0.03	-1.03	0.97	1.42	1.56	1.15	67.0
+	+	+										64.8
2.90	3.19	-3.69		0.36	-0.90	-0.81	-1.18	0.00	1.93	1.17	2.11	65.2
+	+		+									60.3
3.00	3.41		-1.28	-1.02	-3.60	-0.40	-1.28	-0.92	1.24	1.56	1.07	65.6
+		+	+									44.5
2.66		-4.67	-0.52	0.66	-0.11	-0.60	-2.51	2.62	-0.48	0.09	2.11	45.2
	+	+	+									27.0
	2.74	-5.25	-0.72	-1.64	0.04	-2.61	-1.66	-1.74	-0.25	0.54	-0.98	27.9

(1) Y (c/kg/%), ML (c/kg/0.5in.), S (c/kg/grade), MFD (c/kg/μm)
SI (c/kg/grade), CI (c/kg/grade), Others (c/kg)

TABLE 3.22: PARTIAL REGRESSION COEFFICIENTS[1] ON CLEAN PRICE OF THE CODED SALES ASSISTANCE REPORT ANALYSES FOR THE 1980/81 SEASON

Y	ML	S	MFD	SI	CI	F	P	Co	T	LV	QV	% Control
-0.63	4.32	-5.55	-1.67									48.2
-0.61	4.32	-4.58	-1.66	-0.18	-1.17	-0.27	-1.45	0.93	1.73	1.87	1.58	48.6
+	+	+										45.2
-0.69	4.11	-4.64		0.38	-1.15	-1.29	-1.64	-0.33	2.39	1.37	2.84	45.8
+	+		+									38.6
-0.56	4.39		-1.68	-1.37	-4.54	0.73	-1.77	-1.45	1.50	1.87	1.48	46.7
+		+	+									14.1
-1.00		-5.90	-0.70	0.76	-0.14	-1.00	-3.36	3.06	-0.72	-0.01	2.82	15.2
	+	+	+									46.5
	4.44	-4.25	-1.78	0.14	-1.36	0.26	-1.32	1.49	2.07	2.08	2.02	47.1

(1) Y (c/kg/%), ML (c/kg/0.5in.), S (c/kg/grade), MFD (c/kg/μm), SI (c/kg/grade), CI (c/kg/grade), Others (c/kg)

subsequent inclusion of the C.S.A.R. traits, increased the control to 65.6%. Examination of the partial regression coefficients reveals that CI, and to a lesser extent SI, assumed much greater importance. A subsequent analysis showed that CI alone, controlled up to 69.3% of the variation in style grade (Table 3.23).

TABLE 3.23: REGRESSION ON S FOR SHORT AND LONG LENGTH CATEGORIES FOR THE 1980/81 SEASON

											% Control	
Y	ML	MFD	SI	CI	F	P	Co	T	LV	QV	Short	Long
+	+	+	+	+	+	+	+	+	+	+	73.7	67.4
			+	+	+	+	+				73.6	66.8
			+	+	+		+				73.5	66.7
			+	+			+				73.4	66.5
			+	+							72.6	64.0
				+							69.3	60.0

With the deletion of Y, ML and MFD, the addition of the C.S.A.R. traits produced no significant results. The partial regression coefficients of the C.S.A.R. traits exhibited marked variability.

Due to the recent upsurge in the use of sale-by-sample selling methods, a separate analysis was conducted for the 1980/81 season to determine the effect of objective measurement of traits on price. The only lots that were analysed were those that were offered through sale-by-separation. Consequently, not all tested wools were included and it was unknown whether or not MFD was tested in addition to Y. The limited nature of this particular analysis is obvious. Further details and results are contained in Appendix III.

3.3.4 Short and long length analyses

From the preceding analyses, the importance of the ML^2 term has been established. The consequence of this is that the relationship between ML and price is markedly non-linear (Figures 3.1, 3.2). The existence of such relationships poses problems in the estimation of economic weights for linear selection indices. To overcome this, the New Zealand Wool Board data (All seasons only) was re-organised into two separate groups according to length. Wools up to 100 mm (codes J, O and R) comprised the short category, while wools longer than 100 mm (codes B, C, D and E) were placed in the long category. The re-organisation was conducted on this basis because of the comparative ease of doing so and also because it approximately corresponds to the length of second-shear and full length wools respectively.

The general statistics of the two length groups are shown in Table 3.24. The short category was on average, of better style, higher yielding and was offered in lower lot weights. Other differences between the groups were minor.

The simple correlations between the traits and price (greasy and clean) are shown in Tables 3.25 and 3.26. As expected, the correlation with ML is greater in the short group compared to the long group. The correlations with MFD change dramatically between the short and long categories, with a negative relationship indicated for long wools.

The partial and standardised partial regression coefficients for greasy and clean price are displayed in Tables 3.27 and 3.28 respectively. Under the full model (Y, ML, S and MFD), it is evident that both ML and S are of much greater importance in shorter wools, while MFD is of more significance in the longer group. Deletion of traits in turn verified this result. The control by the traits in the two length categories over greasy price was similar, but a substantial difference arose for clean price. In this latter case, the traits in the longer wool group controlled only half as much

FIGURE 3.1: THE RELATIONSHIP BETWEEN GREASY PRICE AND ML

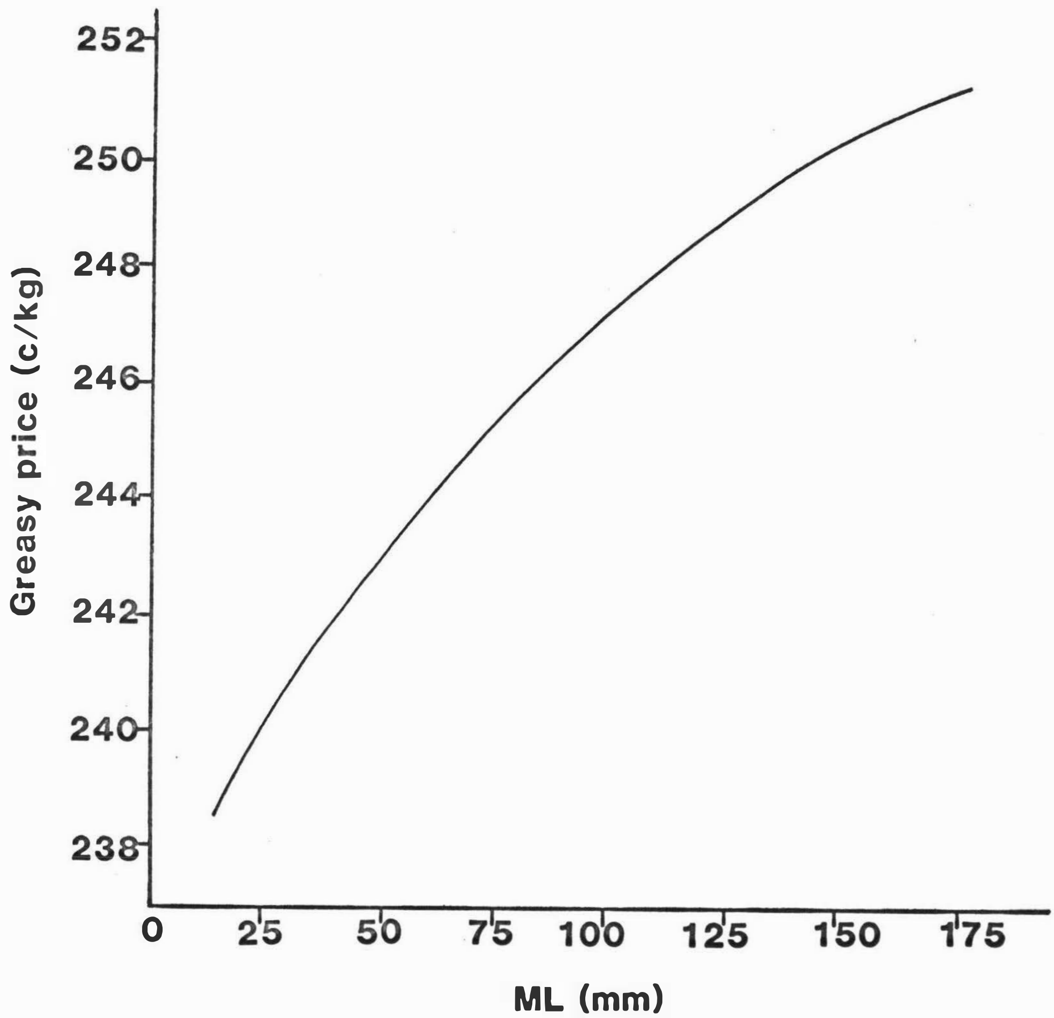


FIGURE 3.2: THE RELATIONSHIP BETWEEN CLEAN PRICE AND ML

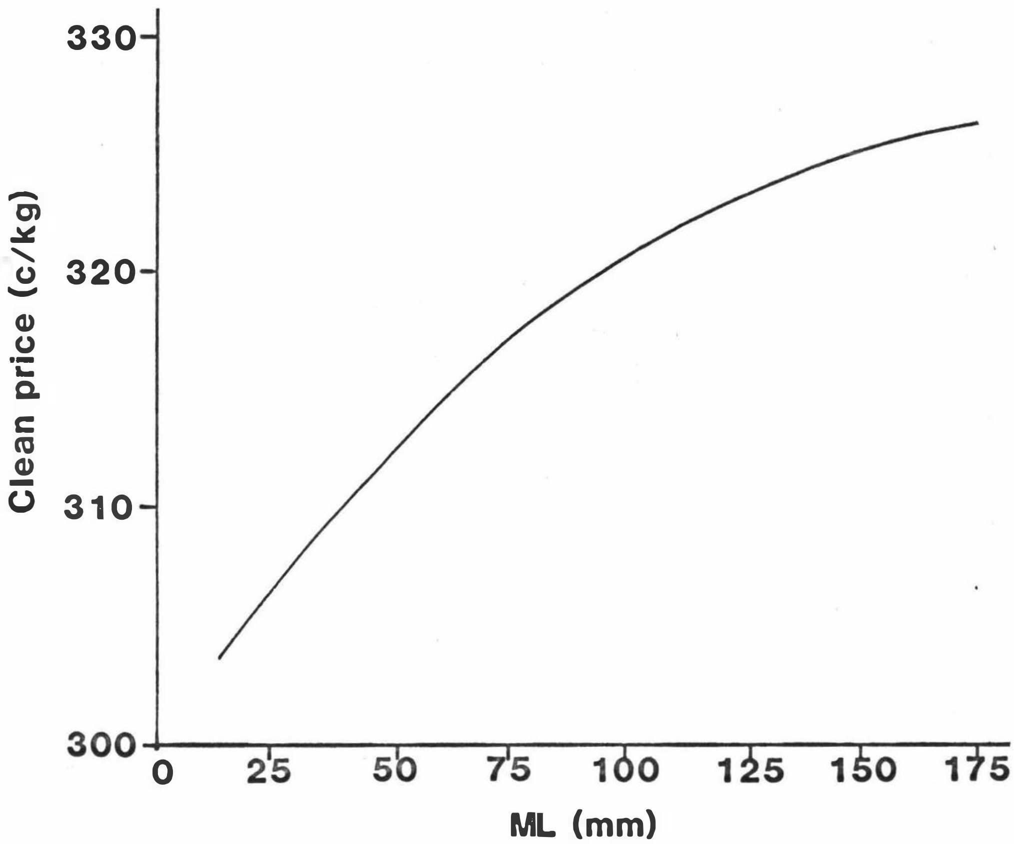


TABLE 3.24: GENERAL STATISTICS OF SHORT AND LONG LENGTH CATEGORIES (ALL SEASONS)

		Length Category	
		Short	Long
Original No. of Records		65,634	109,114
No. of Records after Absorption		65,336	108,816
MFD (μm)	mean	35.52	35.67
	s.d.	2.19	2.38
S (grade)	mean	2.53	2.80
	s.d.	1.17	1.24
ML (mm)	mean	75.63	118.92
	s.d.	17.16	23.85
Y (%)	mean	78.53	76.64
	s.d.	4.25	4.00
Greasy price (c/kg)	mean	241.33	247.45
	s.d.	17.10	15.39
Clean price (c/kg)	mean	307.40	322.82
	s.d.	15.64	12.49
Lot weight (T)	mean	1.62	2.13
	s.d.	2.05	2.73

TABLE 3.25: SIMPLE CORRELATIONS WITH GREASY PRICE FOR SHORT AND LONG LENGTH CATEGORIES (ALL SEASONS)

	Length Category	
	Short	Long
MFD	0.12	-0.10
S	-0.39	-0.33
ML	0.29	0.17
Y	0.70	0.79

TABLE 3.26: SIMPLE CORRELATIONS WITH CLEAN PRICE FOR SHORT AND LONG LENGTH CATEGORIES (ALL SEASONS)

	Length Category	
	Short	Long
MFD	0.07	-0.12
S	-0.39	-0.37
ML	0.48	0.21

TABLE 3.27: WOOL TRAIT REGRESSION COEFFICIENTS[1] FOR GREASY PRICE FOR SHORT AND LONG LENGTH CATEGORIES (ALL SEASONS)

Length Category		Y	ML	S	MFD	% Control
Short	P	2.74	4.34	-4.55	-0.26	70.1
Long	P	2.89	0.98	-2.82	-0.51	69.7
Short	SP	0.64	3.03	-3.87	-0.12	
Long	SP	0.72	0.49	-2.28	-0.22	
Short	P	2.73	4.26	-4.51		70.0
Long	P	2.90	0.89	-2.89		69.1
Short	P	2.91	4.13		-0.06	60.6
Long	P	2.98	1.55		-0.61	64.7
Short	P	2.63		-4.26	0.27	57.5
Long	P	2.91		-2.98	-0.40	68.2
Short	P		3.71	-5.87	0.21	25.2
Long	P		1.24	-3.79	-0.71	13.9

P = partial regression coefficient
SP = standardised partial regression coefficient

(1) Y (c/kg/%), ML (c/kg/0.5in.),
S (c/kg/grade), MFD (c/kg/μm).

TABLE 3.28: WOOL TRAIT REGRESSION COEFFICIENTS(1) FOR CLEAN PRICE FOR SHORT AND LONG LENGTH CATEGORIES (ALL SEASONS)

Length Category		ML	S	MFD	% Control
Short	P	5.58	-5.56	-0.40	40.2
Long	P	1.23	-3.50	-0.65	18.6
Short	SP	3.90	-4.74	-0.18	
Long	SP	0.62	-2.82	-0.27	
Short	P	5.39	-5.70		41.1
Long	P	1.16	-3.75		19.4
Short	P	5.23		-0.08	23.2
Long	P	1.50		-0.81	8.1
Short	P		-5.38	-0.33	17.1
Long	P		-3.87	-0.53	17.0

P = partial regression coefficient
SP = standardised partial regression coefficient

(1) ML (c/kg/0.5in.), S (k/kg/grade), MFD (c/kg/μm)

TABLE 3.29: PARTIAL REGRESSION COEFFICIENTS(1) WITH SC SUBSTITUTED FOR S (ALL SEASONS)

Category	Y	ML	SC	MFD	% Control
Greasy Short	2.74	4.34	-5.68	-0.26	70.1
	2.73	4.26	-5.63		70.0
Greasy Long	2.89	0.98	-3.53	-0.51	69.7
	2.90	0.90	-3.61		69.1
Clean Short		5.58	-6.95	-0.40	40.2
		5.47	-6.86		39.9
Clean Long		1.23	-4.38	-0.65	18.6
		1.12	-4.49		17.1

(1) Y (c/kg/%), ML (c/kg/0.5in.)
SC (c/kg/grade), MFD (c/kg/μm)

of the variation in clean price that was accounted for by those very same traits in the short category.

3.3.5 Scoured colour for style

From the viewpoint of defining selection objectives and criteria, the use of S is largely unsatisfactory. It is a subjective and inexplicit trait, capable of assuming different meanings to different people. Having shown, albeit for one season only, that CI (subsequently referred to as scoured colour, SC) alone can replace S in the regression model with only minimal loss in control over price, the analyses were repeated substituting SC for S. SC was predicted from S by the following equation obtained from a simple regression analysis of the 1980/81 data,

$$SC = 1.89 + 0.8\ (S)$$

The rather tenuous assumption which had to be made was that the relationship between S and SC (i.e. CI) for the 1980/81 season, was representative of all seasons considered.

The general statistics are as for the previous analyses on short and long wools (Table 3.24), with SC ranging from a mean of 2.31 with a s.d. of 0.94 in short wools, to a mean of 2.53 with a s.d. of 0.99 in long wools. The simple correlations with price (greasy and clean) are again as for the previous analysis (Tables 3.25 and 3.26). The correlations between S.C. and price are as for S and price.

The partial regression coefficients, with and without MFD in the model, are shown in Table 3.29. The conclusions reached from an examination of these estimates are as for the previous short and long analysis.

3.4 DISCUSSION

The intention of this chapter was to investigate the effects of the various selected wool characteristics on auction price for the five seasons from 1976/77 to 1980/81. The results obtained are difficult to place in an exact context as there has been virtually no comparable research conducted for Romney wools in New Zealand. Wiggins and Beggs (1979) presented a cursory study for the 1978/79 season. Subsequent to that report, Wiggins and Beggs (pers. comm.) have regularly produced monthly graphic representations of the relationships between price and the level of certain selected wool characteristics for a variety of common New Zealand wool types.

The greasy analyses reaffirmed the immense importance of Y as a factor influencing wool buyers' greasy price. Firstly, Y was consistently highly correlated with greasy price. Secondly, considerable reductions in the ability to control variation in greasy price were incurred when Y was omitted from the regression model.

ML similarly displayed important effects on price. While only moderate correlations with greasy price were observed, ML was highly correlated with clean price. This effect probably resulted from the removal of Y from the regression model for the clean analyses, and consequently a greater emphasis was placed on ML as a price determinant.

The significance of the ML^2 term in the initial analyses confirmed previous beliefs and studies (Wiggins and Beggs, 1979; pers. comm) that the relationship between ML and price was distinctly non-linear. The division of the data into short (up to 100 mm) and long (over 100 mm) length categories produced, within each group, an apparently linear price - ML relationship. As expected, ML was of greater importance in the short compared with the long category, as shown by greater correlations with price and also higher partial regression coefficients. For the clean analysis of All Seasons, a partial regression coefficient of 5.58 c/kg/0.5 inch was calculated for the short group, while the corresponding coefficient of the long group was only 1.23 c/kg/0.5 inch.

These estimates of the worth of ML over all five seasons considered, may be cautiously compared with those published by Wiggins and Beggs (1979) for the 1978/79 season. They were able to show that for wools between 50-110 mm, clean price increased by 10 c/kg/inch (i.e. 5 c/kg/0.5 inch), and for wools between 110 - 175 mm, clean price increased by 1.8 c/kg/inch (i.e. 0.9 c/kg/0.5 inch). The two sets of results are remarkably similar, despite a slight difference in the length categories studied, and considering that the current analysis was conducted over five seasons (1976/77 to 1980/81), whereas that of Wiggins and Beggs (1979) was limited to only 1978/79.

Substantial financial gains can thus be made in the short length or second shear category. Based on the greasy partial regression coefficient of 4.34 c/kg/0.5 inch, revenue can be increased by approximately $6.50 per greasy bale (for 150 kg bales) for every 0.5 inch increment in ML. The corresponding increase in revenue within the long wool category for 0.5 inch increments in ML, is only approximately $1.50 per greasy bale (for 150 kg bales).

The significance of ML may be intensified in the future. Table 3.1 suggests that over the five seasons considered, ML has decreased. An increased proportion of second shearing may be responsible. Whatever the cause, further reductions in ML may generate greater price differentials as buyers discriminate against short wools.

Another trait which was shown to consistently influence price was S. Moderate correlations with both greasy and clean price were obtained. The magnitude of the partial and standardised partial regression coefficients were higher than that of the two previously discussed traits, although deletion of S from the regression models didn't result in such deletarious consequences for control over price.

The partial regression coefficient for clean price for the 1978/79 season of 2.77 c/kg/grade is in good agreement with the 2.50 c/kg/grade premium calculated by Wiggins and Beggs (1979) for 37 μm, 100-150 mm wools during the same season. Consideration of all five seasons, resulted in a partial regression coefficient of 4.13 c/kg/grade for clean price.

Using the greasy partial regression coefficient of 3.20 c/kg/grade for All Seasons, each grade increment in S is equivalent to approximately an additional $4.80 per greasy bale, for 150 kg bales.

It has long been acknowledged that MFD is of little importance as a price determinant of New Zealand crossbred wools (N.Z.S.A.P., 1974; Wickham and Bigham, 1976; Bigham and Sumner, 1979; Wiggins and Beggs, 1979). The analyses completed in this study confirmed that in such coarse wools, there are no premiums for MFD. MFD was shown to be uncorrelated with either greasy or clean price, and the calculated partial regression coefficients were negligible in comparison with those obtained for Y, ML and S. Based on the greasy partial regression coefficient of 0.44 c/kg/μm for All Seasons, each micron increment would produce an increase in revenue equivalent to approximately only $0.66 per greasy bale, for 150 kg bales.

However, there are indications that this indifferent situation may be changing. As illustrated by the partial regression coefficients, MFD has increased in value over the five seasons considered, notably during the 1980/81 season. In this season, the comparatively rapid rise in value has been attributed to major Chinese participation in the marketplace. Their requirement was for wools at the finer end of the Romney range (34 μm and finer). The resultant effect on the market was the establishment of small premiums for MFD within the normally accepted crossbred range. Although such premiums within this range may increase further, they are unlikely to assume major importance.

The control over price afforded by all four selected traits (Y, ML, S and MFD) ranged up to 74.0% for the greasy analyses and up to 61.1% for the clean analyses. Although reasonably high, this control is low compared with that obtained for the Australian Merino studies (Dunlop and Young, 1960; Skinner, 1965; Mullaney and Sanderson, 1970; McKinnon *et al.*, 1973; Whiteley and McKinnon, 1973). In most of these analyses, at least 90% of the variation in clean price was explained by the wool traits considered. It is likely that this discrepancy has been caused by the virtually sole dependence of the price of the finer Australian Merino wool on MFD (quality number, crimp frequency). Whereas, the price of the coarser New Zealand Romney wool is controlled more equally by a combination of traits.

A further influential factor is that the Australian studies excluded seasons of extreme competition, in which little attention was paid to the physical properties of the wool. This was effected on the basis of low correlations with other seasons. No seasons were discarded from the present analyses. Few years data were available, and the appropriateness of excluding seasons was considered to be dubious from the view of growers' returns.

As with the Australian analyses, the introduction of quadratic terms in the regression models enhanced the control achieved over price. Up to a further 10.4% for the greasy analyses and 15.9% for the clean analyses were obtained. The major contributor being the ML^2 term. Unlike some of the Australian studies where the S x QN product term was of some importance, the MFD x S term in the current analyses was not. However, the S x ML product term did assume greater significance in the last few seasons considered.

The introduction of the C.S.A.R. traits into the 1980/81 analysis, failed to produce any valuable additional control over price, given the presence of Y, ML, S and MFD in the model. The most important features of the C.S.A.R. trait analysis were the moderate correlations between CI and price, and the virtually complete interchange that was possible between S and CI. It had long been believed that colour was the principal component of style grade (Wickham and Bigham, 1976). This analysis has confirmed that point. These results are in agreement with comments made by Whiteley and Jackson (1982) who suggested that traits such as S, which comprise several components, are diminishing in importance as the individual components are specified separately.

Using the greasy short partial regression coefficient of 5.68 c/kg/grade for SC for All Seasons, each increment in SC is equivalent to approximately an additional $8.50 per greasy bale, for 150 kg bales.

In general, the remaining C.S.A.R. traits exhibited a marked instability, dependent upon which traits were included in the regression model. It is likely that this is a result of their expression on a 0-1 scale, which hampers analysis and interpretation. A wider recording scale for these traits would be preferable.

The effectiveness of the regression analyses using the New Zealand Wool Board data rests on several factors. The ability of the various wool valuers to accurately appraise and record the characteristics of wool lots should be of a high standard to avoid introducing unwanted errors. The assumption is made that the assessment of the New Zealand Wool Board valuer is equivalent to that of the final buyer. If this is not a valid assumption, and errors are not random, seriously biased results will be obtained. The persisting importance of Y in the clean analyses, was ascribed to such errors.

The auction system, where the data for the present analyses originated, can subject prices to factors other than the physical characteristics of the wool (W.M.S.G., 1967). Variation in buyers' valuations and price limits, lot size, mode of offering, number of bidders (and competition between them), the economic conditions prevailing on the day of the sale, and unexplained chance elements are examples. Consequently, the true relationship betwen wool characteristics and price can be obscured.

The variables included in the various models could only account for up to 74.0% of the variation in greasy price. The remaining 26.0% being attributed to other unexplained sources. Of the possible sources of unexplained variation, lot weight, mode of offering and New Zealand Wool Board market intervention policies provided only negligible increases in price control given the presence in the model, of the previously discussed fleece variables.

An important consideration is that the data analysed are by nature, already historical. The regression techniques employed will produce findings concerning the significance of wool traits in such past years, but it does not necessarily follow that these same traits will be of similar importance in the future. Changing economic conditions, changing appraisal and marketing systems, and technological and end-use developments will all play a role in altering the prevailing market conditions and hence influencing the relative significance of wool traits.

CHAPTER FOUR

DEFINITION OF SELECTION OBJECTIVES

4.1 INTRODUCTION

Under classical selection index theory (Hazel, 1943), the definition of a selection objective requires the estimation of an economic weight for each trait in that objective. Several techniques of deriving such estimates exist (Chapter 2.2). In this chapter, use is made of two of the alternatives, viz. regression of selling price on the level of wool traits and marginal profit. Economic weights are calculated and selection objectives defined for a production and marketing system involving Romney sheep under North Island hill country conditions, where all surplus offspring are sold as lambs. It is assumed that the goal of livestock production is to maximise profit, under a given set of resource constraints.

4.2 MATERIALS AND METHODS

The calculation of economic weights for wool quality traits directly utilised the results from the regression analyses of the New Zealand Wool Board data (Chapter 3).

The calculation of economic weights for other traits of importance to sheep profitability was based on the marginal profit technique (Morris *et al.*, 1982). The necessary data relating to production, income and expenditure on North Island hill country farms were extracted from N.Z.M.W.B.E.S. (1977c, 1978a, 1978c, 1979a, 1979b, 1979c, 1980a, 1980b, 1980c, 1981b, 1981c) and M.A.F. (1979/80, 1980/81), and are shown in Appendix IV.

4.3 RESULTS

4.3.1 Calculation of economic weights for wool quality traits

Using the partial regression coefficients presented in Table 3.29, economic weights for the traits concerned were calculated.

The partial regression coefficients were expressed on a c/kg basis. It was therefore necessary to convert them into an expression per fleece and then a per lifetime basis (Morris *et al.*, 1982). The conversion factors required to do this are computed in Appendix VII. For example, consider the calculation of the economic weight for Y for a greasy, short length objective:

economic weight = 2.74 c/kg x 4.29 kg x 5.85 expressions
= 68.8 c/lifetime
= $0.69/lifetime for each 1% increment in Y.

The remaining economic weights were computed in the same manner, with and without MFD in the model, and are presented in Table 4.1. The ML estimates have undergone further conversion from per 0.5 in. to per cm.

Because the conversion factors from the partial regression coefficients to lifetime economic weights are constant, the calculated estimates also exhibit the features of the partial regression coefficients discussed in Chapter 3. Briefly, ML and SC have greater importance in short wools, while MFD is of more significance in long wools.

The probability that a ram breeder only sells rams to clients who second-shear or alternatively only to clients who don't second-shear is probably quite low. Wiggins (pers. comm.) suggested that 75% of North Island hill country farmers second-shear. To cover the eventuality that breeders service both types of clients, an all lengths objective was established by proportionally combining the economic weights pertaining to short and long lengths. For example, the

TABLE 4.1: LIFETIME ECONOMIC WEIGHTS[1] OF WOOL QUALITY TRAITS

Category	Y	ML	SC	MFD
Greasy Short	0.69 0.68	0.86 0.84	-1.43 -1.41	-0.06
Greasy Long	0.73 0.73	0.19 0.18	-0.88 -0.91	-0.13
Clean Short		1.10 1.08	-1.74 -1.72	-0.10
Clean Long		0.24 0.22	-1.10 -1.13	-0.16

(1) Y ($/lifetime/%), ML ($/lifetime/cm), SC ($/lifetime/grade), MFD ($/lifetime/μm)

economic weight for ML for the greasy all lengths objective was calculated as,

$$(75\% \times \$0.84) + (25\% \times \$0.19) = \$0.68$$

The economic weights of the other traits in the all lengths objectives were as for those in the short length objectives.

Two further traits of interest to wool growers are cotting (Co) and tenderness (T). The New Zealand Wool Board data previously analysed (Chapter 3), did not permit a thorough analysis of the effects of these traits on price. Instead, provisional estimates were obtained using data from N.Z.W.B. (1976/77, 1977/78, 1978/79, 1979/80, 1980/81).

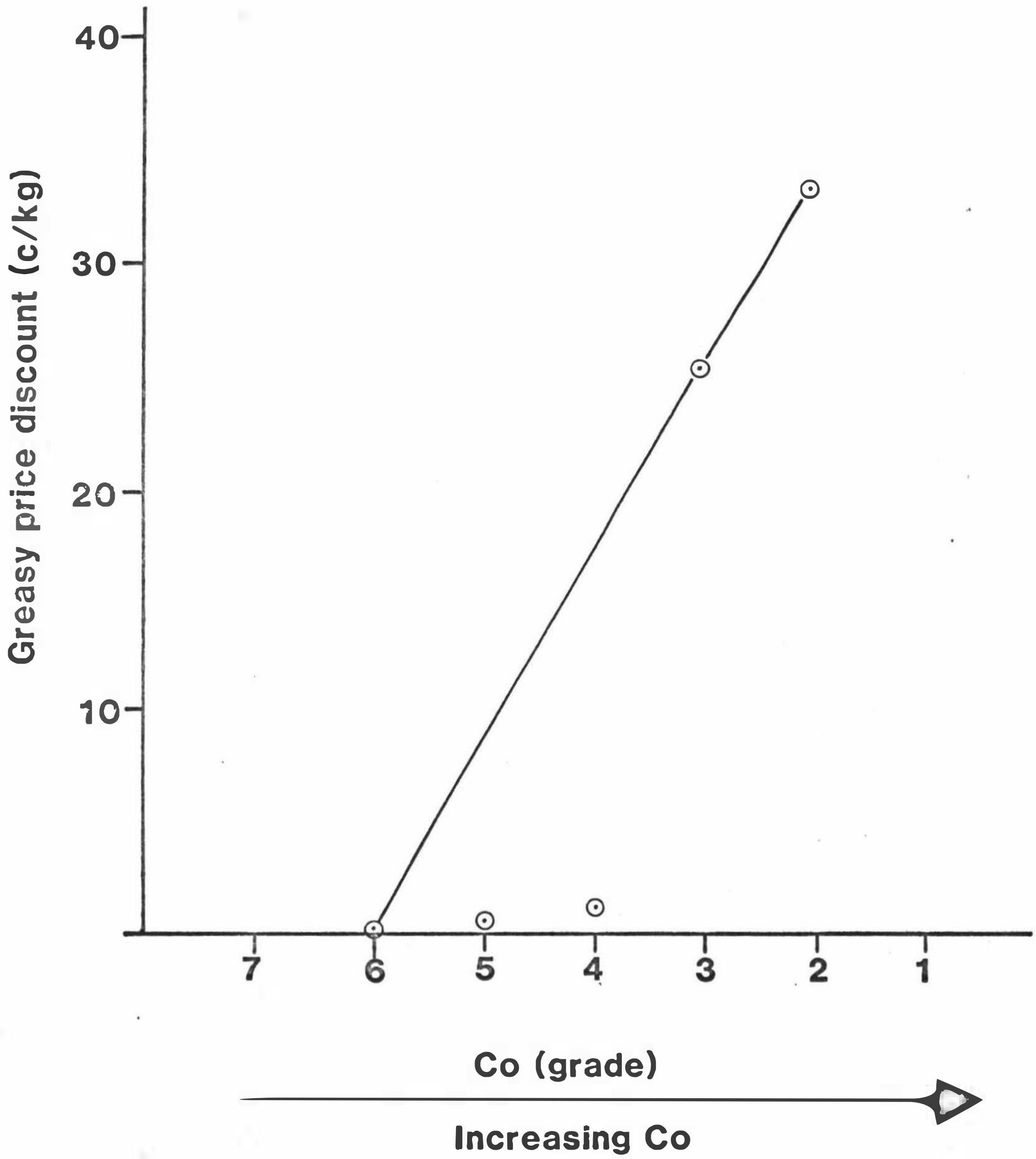
From Appendix V it can be seen that over the five seasons considered, the average greasy discount for soft cotts was 25.35 c/kg and for hard cotts was 33.66 c/kg. These categories were then related to the current Massey University system of grading cottiness (Wickham, pers. comm.).

Massey cott grade:	1	2	3	4	5	6	7
		Hard Cott	Soft Cott			Free	

Figure 4.1 suggests a linear relationship exists between the above grades and the discount received. The additional two points plotted on the graph for grades 4 and 5 were obtained from the analysis of the C.S.A.R. variables in the 1980/81 season. It was assumed that the cotted variable (indicating only minor cotting, as heavily cotted lines are categorised separately from fleece wool), corresponded to grade 4, while the felted variable represented grade 5 (Wickham, pers. comm.).

On the basis of the linear relationship depicted in Figure 4.1, the economic weight for Co is 8.41 c/kg/grade (33.66/4). Expressing this on a per fleece and per lifetime basis, the economic weight for Co becomes \$2.11/grade/lifetime. In comparison with the economic weights presented in Table 4.1 for other wool quality traits, Co appears to be of major importance.

FIGURE 4.1: THE RELATIONSHIP BETWEEN GREASY PRICE AND Co.



A similar assessment was made of the effects of T on greasy price. Appendix VI shows that over the five seasons considered, the average greasy discount for tender wools was 14.47 c/kg. Wickham (pers. comm). suggested that the New Zealand Wool Board appraisal was equivalent to three grades on the Massey University scale of 1 to 9. The economic weight for T is therefore 4.82 c/kg/grade (14.47/3) and on a per fleece and per lifetime expression it is $1.21/grade/lifetime. On this basis, T also assumes some significance.

4.3.2 Calculation of economic weights for other than wool quality traits

Economic weights for traits other than those associated with wool quality, were calculated using the lifetime marginal profit method of Morris *et al* (1982). The underlying assumptions and calculations are contained in Appendix VII. The final calculations of the economic weights for number of lambs weaned (NLW), weaning weight (WW), ewe body weight (EBW), greasy fleece weight (GFW) and clean fleece weight (CFW) are shown in Table 4.2

The estimate for EBW is of dubious accuracy. As stated in Appendix IV(B), variable costs such as interest, labour, fuel etc. could not be included. They may have had an important influence on the value of increases in EBW if they had been taken into consideration. In an effort to re-assess the economic importance of EBW, two alternative estimates of the economic weight were calculated. The underlying assumptions are contained in Appendix VIII. The alternative estimates were calculated as,

1. $0.26 - $0.20 = $0.06
2. $0.26 - ($0.083 x 4.70) = -$0.13

Due to the divergent nature of all three estimates, EBW was assigned an economic weight of 0.00 in accord with Sheeplan (Clarke and Rae, 1976, 1977) and Morris *et al.* (1982). In effect, the economic weight of 0.00 precludes EBW from the selection objective.

TABLE 4.2: LIFETIME ECONOMIC WEIGHTS[1] OF OTHER THAN WOOL QUALITY TRAITS

Trait	Calculation	Economic Weight
NLW	3.70 matings x \$12.73	\$47.10
WW	2.29 lambs x $\frac{47\%}{100}$ x $\frac{\$12.73}{13.24kg}$	\$ 1.03
EBW	$\frac{\$14.47}{13.24kg}$ x $\frac{\$11.43}{\$14.47}$ − $\frac{\$0.20}{\frac{45\%}{100}}$	\$ 0.42
GFW	5.85 expr. x \$2.28/kg	\$13.34
CFW (short)	5.85 expr. x \$2.28/kg x $\frac{100}{78.53\%}$	\$16.98
CFW (long)	5.85 expr. x \$2.28/kg x $\frac{100}{76.64\%}$	\$17.40

(1) NLW ($/lifetime/lamb weaned)
Others ($/lifetime/kg)

TABLE 4.3: LIFETIME ECONOMIC WEIGHTS[1] USING GOVERNMENT SUPPLEMENTARY MINIMUM PRICES

Trait	Calculation	Economic Weight
NLW	3.70 matings x 13.24kg x $1.45/kg	$71.03
WW	2.29 lambs x $\frac{47\%}{100}$ x $1.45/kg	$ 1.56
EBW	$1.45/kg x $\frac{\$11.43}{\$14.47}$ - $\frac{\$0.20}{\frac{45\%}{100}}$	$ 0.70[2]
GFW	5.85 expr. x $3.20/kg	$18.72

(1) NLW ($/lifetime/lamb weaned)
Others ($/lifetime/kg)

(2) No account has been made of cost increases.

TABLE 4.4: COMPARISON OF ECONOMIC WEIGHTS BEFORE AND AFTER GOVERNMENT SUPPLEMENTARY MINIMUM PRICES TAKEN INTO CONSIDERATION (Relative to GFW of 1.00).

	NLW	WW	EBW	GFW
Before	3.53	0.08	0.00	1.00
After	3.79	0.08	0.00	1.00

The introduction of greatly increased Government-guaranteed Supplementary Minimum Prices (SMP) to the farmer for the 1981/82 season, was suspected to influence the future applicability of the economic weights already calculated. Extending the SMP of $1.45/kg for PM lamb and $3.20/kg for wool to all lamb and wool produced respectively, the economic weights were re-estimated in Table 4.3.

As expected, the absolute values of the economic weights are greater using the SMP values, but of most concern in the relative movements (Table 4.4). There was little effect on such relativities, although a slightly greater emphasis on fertility is suggested.

4.3.3 Summary of selection objectives

A summary of the traits included in the various selection objectives is contained in Table 4.5. A detailed set of equations pertaining to these objectives is shown in Appendix IX. With respect to the traits contained, the selection objectives defined are very similar, although the value of the assigned economic weights varies.

TABLE 4.5: SUMMARY OF SELECTION OBJECTIVES

	Greasy			Clean		
Return Source	Short	Long	All	Short	Long	All
Surplus offspring	NLW WW	NLW WW	NLW WW	NLW WW	NLW WW	NLW WW
Wool	GFW Y ML SC	GFW Y ML SC MFD	GFW Y ML SC	CFW ML SC	CFW ML SC MFD	CFW ML SC

The only differences in the composition of the objectives concern the wool traits. Y and GFW, present in the greasy objectives, were naturally replaced in the clean objectives by CFW. On the basis of the economic weights calculated, MFD was judged to be of negligible importance in short wools, and consequently was only included in the long wool objectives.

4.4 DISCUSSION

The definition of selection objectives for profit maximisation requires the estimation of appropriate economic weights for individual traits. Economic weights are unfortunately not fixed constants, but are subject to both short- and long-term changes (Chapter 2.4). Unstable economic conditions generate dilemmas for animal breeders wishing to establish the economic significance of traits under consideration. Ideally, future economic weights should be used, but the prediction of such is a formidable task (Chapter 2.4). Consequently, the alternative commonly resorted to is the use of past economic data. The economic weights calculated from such data are really only relevant to the time periods actually considered. Within a variable economy, there is no guarantee that these estimates will predict future values accurately.

The current analyses generally used five year price averages to calculate economic weights. In doing so, it was anticipated that short-term fluctuations, as well as obsolete data from old selling methods etc. would both be avoided.

The economic weights of most of the wool quality traits were directly calculated from the results of the regression analyses of the New Zealand Wool Board data (Chapter 3). An initial problem to be encountered was the choice between the simple regression coefficient and the partial regression coefficient as the basis of the calculations. Rae (cited by Dunlop and Young, 1960) suggested the use of the simple regression coefficient. However, on the advice of Rae and Wickham (pers. comm.), the current calculations utilised the partial regression coefficients.

The relative magnitudes of the economic weights of the wool quality traits is equivalent to that of the partial regression coefficients from which they were calculated (Chapter 3). For the calculation of economic weights in this fashion, it was assumed that it is possible to directly extrapolate the results from valuations of wool lots (comprising many fleeces) to a single animal (single fleece) situation. This link may be rather tenuous.

The estimation of economic weights for Co and T was conducted in a very limited manner. The data set used was small, as was the initial scale of expression of these traits, especially T. A greater gradation of measurement would be expected to produce more accurate estimates. The legitimacy of the extrapolation onto the Massey scale may also be debatable. Finally, the data used for Co and T, was likely to have been confounded with the effects of length and colour, thereby making interpretation of results difficult. To remedy this problem, it would be preferable to put Co and T in a regression model along with other wool traits.

The validity of the economic weight estimates for Co and T is therefore questionable. Superficial comparison with the economic weights of the other wool traits calculated from the regression analyses, indicated that in relative terms, Co and T are very important. A more thorough analysis is clearly warranted.

The calculation of economic weights for traits other than those connected with wool quality, relied heavily on data collected by the New Zealand Meat and Wool Board Economic Service on North Island hill country farms. The breed of sheep on the farms surveyed is unspecified. Specific data on Romneys under such conditions are ideally required.

For example, in a very limited analysis (one season and one area), Taylor and Davison (1976) found that the meat grading pattern of Romney-sired lambs differed from that of the national pattern. Less Romney-cross lambs graded prime, while more graded in the leaner category. If this trend is indicative of the national industry situation, then it should be accounted for in calculating lamb returns for a straightbred Romney farming operation.

The economic weights estimated are in good agreement with those of Morris *et al.* (1982), but differ slightly from earlier values used in formulating the current Sheeplan objectives (Clarke and Rae, 1976, 1977). Table 4.6 compares these estimates relative to an economic weight for GFW of 1.0. It is evident that in relative terms, wool has assumed more economic importance of late than fertility.

TABLE 4.6: COMPARISON OF ECONOMIC WEIGHT ESTIMATES (Relative to GFW of 1.00)

Source of Estimate	NLW	WW	EBW	GFW
Sheeplan (Clarke & Rae, 1976, 1977)	6.02 (1)	0.26	0.00	1.00
Morris *et al.* (1982)	3.73	0.09	0.00	1.00
Present estimates	3.53	0.08	0.00	1.00

(1) Number of lambs born

However, Rae (1982) suggested that fertility is always important whenever the farming system involves the sale of lambs. In addition, higher fertility levels enable a greater selection differential in replacement stock, thereby increasing the scope for genetic gain.

A comparison of all three calculated EBW estimates ($0.42, $0.06 and -$0.13) suggested that the zero value assigned to the trait by Sheeplan (Clarke and Rae, 1976, 1977) and Morris *et al.* (1982) is likely to be the most appropriate at present. Elliott and Johnson (1976) had similar problems for the Perendale. They concluded that the economic weight for EBW needed clarification for hill country production. The relationship between body weight and fertility is a further complicating factor.

In general, changes in the prevailing economic conditions do not seem to have dramatically influenced the relativity between traits (Tables 2.1 and 4.6). Cyclical trends are evident. It is also interesting to note that the SMP analysis failed to disturb the economic relationship between the traits concerned. The validity of this comparison is certainly questionable. The assumption that all lamb will receive $1.45/kg and all wool $3.20/kg is obviously not a true representation of what will occur, but it is further assumed that the degree of over-estimation is common to both products, thereby keeping relativities constant.

To a certain extent, the reasonably constant relativities exhibited, alleviate concern about the effectiveness of economic weights calculated from past prices, under future conditions.

CHAPTER FIVE

APPRAISAL OF SELECTION INDICES AND SENSITIVITY ANALYSES

5.1 INTRODUCTION

Once the selection objective has been defined, a selection index can be formulated which will predict the overall value of individual animals in relation to the selection objective. The selection index can consist of many traits, including those in the objective, as well as others not in the objective. Traits can be justifiably included in the selection index if they are easily and cheaply measured, and if they contribute towards the overall rate of genetic gain.

This chapter compares the worth of various traits as selection criteria and assesses the relative effect of changes in the selection objective on these criteria for the Romney. Previous authors have attempted similar analyses for other breeds (Elliott and Johnson, 1976; Lewer, 1978; Ponzoni, 1979; Stafford and Walkley, 1979; Ponzoni and Walkley, 1981).

5.2 MATERIALS AND METHODS

For the six selection objectives defined in Chapter Four (shown in Appendix IX), a series of full, reduced and restricted selection indices were calculated using Johnson's (1975) modified version of the selection index computer program, SELIND (Cunningham and Mahon, 1977).

The estimates of heritability, genetic and phenotypic correlations, and phenotypic standard deviations needed for this study were obtained from:

1. Sheeplan (Clarke and Rae, 1976, 1977)
2. Wickham and Rae (pers. comm.) after consideration of Chopra (1978), Blair (1981) and other sources of parameter estimates. Estimates were lowered if there

was substantial doubt concerning their validity.

3. New Zealand Wool Board data analysis for SC phenotypic standard deviation (Chapter 3).

The estimates used are shown in Appendix X.

5.3 RESULTS

5.3.1 Full and reduced selection indices

For the six selection objectives previously defined, full selection indices containing all the traits in the objective, or their respective criteria (i.e. NLW (dam) for NLW, hogget greasy (clean) fleece weight (HGFW, HCFW) for GFW (CFW) and staple length (SL) for ML) were computed. At this initial stage, hogget body weight (HBW) (criterion for EBW), quality number (QN) and fleece character grade (CHG) also formed part of the index, but not the objective. EBW was not included in the objective because of the earlier uncertainty concerning its economic worth (Chapter 4.3.2), and also this action was in agreement with previous authors (Clarke and Rae, 1976, 1977; Morris *et al.*, 1982). CHG was excluded on similar grounds (Lewer, 1978). QN was not included in the selection objective as it was considered a criterion of MFD (Lewer, 1978). The full indices computed for the respective objectives are shown in Tables 5.1, 5.2, 5.3, 5.4, 5.5 and 5.6 as Index 1.

The importance of NLW(dam) in the full index is readily apparent. With respect to the Greasy Short objective (Table 5.1), the rate of overall genetic gain would be reduced by 11.89% if NLW (dam) was omitted from the index. For the same objective, 52.18% of the overall gain is accounted for by gain in NLW. In a separate analysis, not reported here, the importance of NLW was shown to increase when three records are available on NLW (dam).

The two body weight traits considered were WW and HBW. WW was shown to be of very little value in the index (0.29%

TABLE 5.1: FULL AND REDUCED SELECTION INDICES FOR THE GREASY SHORT OBJECTIVE (One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	
INDEX 1										
B-Value	2.32	0.10	0.36	1.93	0.25	0.50	-0.61	0.65	-0.45	
Value of Variate	11.89	0.29	8.68	2.56	4.23	1.86	1.53	2.92	0.96	3.19
% Overall Gain	52.18	12.53	0.00	24.09	4.75	4.79	1.65	0.00	0.00	
Genetic Gain	0.03	0.39	1.17	0.06	0.22	0.18	-0.04	-0.02	0.00	
INDEX 2										
B-Value	2.33	0.09	0.36	2.02	-	0.48	-0.52	0.37	-0.31	
Value of Variate	13.19	0.27	9.22	3.09	-	1.94	1.24	1.19	0.50	3.05
% Overall Gain	52.16	13.43	0.00	28.43	-1.51	5.71	1.77	0.00	0.00	
Genetic Gain	0.03	0.40	1.18	0.06	-0.07	0.21	-0.04	0.00	0.00	
INDEX 3										
B-Value	2.33	-	0.39	2.11	-	0.46	-0.52	0.36	-0.31	
Value of Variate	13.27	-	13.86	3.48	-	1.78	1.22	1.12	0.50	3.04
% Overall Gain	52.34	12.58	0.00	28.99	-1.49	5.80	1.78	0.00	0.00	
Genetic Gain	0.03	0.37	1.18	0.07	-0.07	0.21	-0.04	0.00	-0.01	

Continued.

TABLE 5.1: CONTINUED

Variates in Objective	NLW	WW		GFW	Y	ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	
INDEX 4										
B-Value	2.33	-	0.39	1.99	-	0.41	-0.52	0.26	-	
Value of Variate	13.44	-	14.90	3.19	-	1.50	1.23	0.71	-	3.03
% Overall Gain	51.72	12.87	0.00	28.63	-0.82	5.91	1.69	0.00	0.00	
Genetic Gain	0.03	0.38	1.18	0.06	-0.04	0.21	-0.04	0.00	0.01	
INDEX 5										
B-Value	2.34	-	0.41	1.94	-	0.26	-0.42	-	-	
Value of Variate	13.75	-	16.79	3.08	-	0.84	0.88	-	-	3.01
% Overall Gain	49.07	13.42	0.00	28.79	0.86	6.10	1.75	0.00	0.00	
Genetic Gain	0.03	0.39	1.17	0.06	0.04	0.22	-0.04	-0.05	-0.01	
INDEX 6										
B-Value	2.34	-	0.41	1.94	-	0.26	-	-	-	
Value of Variate	14.02	-	17.12	3.14	-	0.86	-	-	-	2.98
% Overall Gain	49.95	13.66	0.00	29.30	0.87	6.21	0.00	0.00	0.00	
Genetic Gain	0.03	0.39	1.18	0.06	0.04	0.22	0.00	-0.03	0.00	
INDEX 7										
B-Value	2.34	-	0.42	2.32	-	-	-	-	-	
Value of Variate	14.26	-	19.27	5.41	-	-	-	-	-	2.95
% Overall Gain	51.62	14.58	0.00	29.59	0.00	4.20	0.00	0.00	0.00	
Genetic Gain	0.03	0.42	1.20	0.06	0.00	0.15	0.00	0.01	0.00	

TABLE 5.2: FULL AND REDUCED SELECTION INDICES FOR THE GREASY LONG OBJECTIVE (One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			MFD	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	MFD	
INDEX 1											
B-Value	2.31	0.10	0.37	1.57	0.26	0.22	-0.62	0.78	-0.48	0.19	
Value of Variate	12.57	0.35	9.41	1.64	4.63	0.38	1.66	4.17	1.16	0.88	3.10
% Overall Gain	57.54	13.26	0.00	23.45	5.41	0.74	0.76	0.00	0.00	-1.17	
Genetic Gain	0.04	0.40	1.18	0.05	0.23	0.12	-0.03	0.03	0.01	0.28	
INDEX 2											
B-Value	2.32	0.10	0.37	1.93	0.27	0.23	-0.48	0.68	-0.46	-	
Value of Variate	12.85	0.38	9.86	2.77	5.37	0.43	1.13	3.50	1.06	-	3.07
% Overall Gain	57.37	13.92	0.00	22.66	5.07	0.61	0.86	0.00	0.00	-0.49	
Genetic Gain	0.04	0.41	1.20	0.05	0.21	0.10	-0.03	0.04	0.01	0.12	
INDEX 3											
B-Value	2.33	0.10	0.37	2.03	-	0.22	-0.39	0.38	-0.30	-	
Value of Variate	14.64	0.36	10.73	3.45	-	0.43	0.85	1.40	0.53	-	2.91
% Overall Gain	58.41	15.27	0.00	27.89	-2.91	0.82	0.94	0.00	0.00	-0.41	
Genetic Gain	0.04	0.43	1.22	0.06	-0.12	0.12	-0.03	0.06	0.00	0.09	
INDEX 4											
B-Value	2.33	-	0.40	2.13	-	0.19	-0.39	0.37	-0.30	-	
Value of Variate	14.76	-	16.43	3.93	-	0.34	0.83	1.32	0.52	-	2.89
% Overall Gain	58.71	14.26	0.00	28.58	-2.91	0.84	0.95	0.00	0.00	-0.43	
Genetic Gain	0.04	0.40	1.22	0.06	-0.11	0.13	-0.03	0.07	0.00	0.10	

Continued.

TABLE 5.2: CONTINUED

Variates in Objective	NLW	WW		GFW	Y	ML	SC			MFD	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	MFD	
INDEX 5											
B-Value	2.33	-	0.41	2.29	-	-	-0.35	0.26	-0.25	-	
Value of Variate	14.90	-	18.85	4.90	-	-	0.72	0.98	0.39	-	
% Overall Gain	58.07	14.89	0.00	28.45	-2.62	0.60	0.95	0.00	0.00	-0.34	2.88
Genetic Gain	0.03	0.42	1.22	0.06	-0.10	0.09	-0.03	0.07	-0.01	0.07	
INDEX 6											
B-Value	2.33	-	0.41	2.15	-	-	-0.36	0.20	-	-	
Value of Variate	15.05	-	19.59	4.56	-	-	0.75	0.67	-	-	
% Overall Gain	57.66	15.04	0.00	28.12	-2.01	0.67	0.89	0.00	0.00	-0.38	2.87
Genetic Gain	0.03	0.42	1.22	0.06	-0.08	0.10	-0.03	0.08	0.01	0.08	
INDEX 7											
B-Value	2.33	-	0.42	2.10	-	-	-	0.16	-	-	
Value of Variate	15.33	-	20.03	4.44	-	-	-	0.43	-	-	
% Overall Gain	57.81	15.26	0.00	28.53	-1.59	0.74	-0.19	0.00	0.00	-0.55	2.85
Genetic Gain	0.03	0.42	1.23	0.06	-0.06	0.11	0.01	0.08	0.01	0.12	
INDEX 8											
B-Value	2.34	-	0.42	1.94	-	-	-	-	-	-	
Value of Variate	15.55	-	20.70	4.04	-	-	-	-	-	-	
% Overall Gain	55.69	15.38	0.00	28.69	0.00	0.94	0.00	0.00	0.00	-0.71	2.84
Genetic Gain	0.03	0.42	1.21	0.06	0.00	0.14	0.00	0.02	0.00	0.15	

TABLE 5.3: FULL AND REDUCED SELECTION INDICES FOR THE GREASY OBJECTIVE (One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	
INDEX 1										
B-Value	2.32	0.10	0.36	1.95	0.26	0.44	-0.61	0.65	-0.46	
Value of Variate	12.11	0.31	8.89	2.67	4.40	1.48	1.56	3.04	1.00	
% Overall Gain	53.29	12.82	0.00	23.98	4.69	3.55	1.68	0.00	0.00	3.16
Genetic Gain	0.03	0.39	1.18	0.06	0.22	0.16	-0.03	0.00	0.00	
INDEX 2										
B-Value	2.33	0.09	0.36	2.04	-	0.43	-0.53	0.37	-0.31	
Value of Variate	13.48	0.29	9.47	3.23	-	1.54	1.27	1.25	0.52	
% Overall Gain	53.42	13.78	0.00	28.46	-1.77	4.29	1.81	0.00	0.00	3.02
Genetic Gain	0.03	0.40	1.19	0.06	-0.08	0.19	-0.04	0.01	0.00	
INDEX 3										
B-Value	2.33	-	0.39	2.14	-	0.40	-0.52	0.36	-0.31	
Value of Variate	13.57	-	14.29	3.65	-	1.39	1.26	1.18	0.52	
% Overall Gain	53.62	12.91	0.00	29.05	-1.76	4.36	1.82	0.00	0.00	3.01
Genetic Gain	0.03	0.38	1.19	0.06	-0.08	0.19	-0.04	0.01	-0.01	
INDEX 4										
B-Value	2.33	-	0.40	2.01	-	0.35	-0.52	0.26	-	
Value of Variate	13.76	-	15.37	3.35	-	1.12	1.26	0.75	-	
% Overall Gain	52.99	13.21	0.00	28.68	-1.06	4.45	1.73	0.00	0.00	3.00
Genetic Gain	0.03	0.38	1.19	0.06	-0.05	0.20	-0.04	0.02	0.01	

Continued.

TABLE 5.3: CONTINUED

Variates in Objective	NLW	WW		GFW	Y	ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	
INDEX 5										
B-Value	2.34	-	0.41	1.96	-	0.20	-0.42	-	-	
Value of Variate	14.09	-	17.36	3.23	-	0.51	0.90	-	-	2.97
% Overall Gain	50.28	13.79	0.00	28.85	0.67	4.61	1.79	0.00	0.00	
Genetic Gain	0.03	0.39	1.18	0.06	0.03	0.20	-0.04	-0.04	-0.01	
INDEX 6										
B-Value	2.34	-	0.42	2.26	-	-	-0.42	-	-	
Value of Variate	14.23	-	19.06	5.09	-	-	0.91	-	-	2.96
% Overall Gain	51.42	14.46	0.00	28.98	0.00	3.34	1.81	0.00	0.00	
Genetic Gain	0.03	0.41	1.19	0.06	0.00	0.14	-0.04	0.00	-0.01	
INDEX 7										
B-Value	2.34	-	0.42	2.26	-	-	-	-	-	
Value of Variate	14.51	-	19.45	5.19	-	-	-	-	-	2.93
% Overall Gain	52.36	14.72	0.00	29.51	0.00	3.40	0.00	0.00	0.00	
Genetic Gain	0.03	0.42	1.20	0.06	0.00	0.15	0.00	0.02	0.00	

TABLE 5.4: FULL AND REDUCED SELECTION INDICES FOR THE CLEAN SHORT OBJECTIVE
(One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	
INDEX 1										
B-Value	2.32	0.08	0.33	4.91	-1.64	0.75	-0.75	0.77	-0.47	
Value of Variate	10.64	0.21	6.37	2.92	0.44	3.81	2.09	4.17	0.95	
% Overall Gain	47.10	10.81	0.00	32.30	0.00	7.61	2.18	0.00	0.00	3.36
Genetic Gain	0.03	0.35	1.13	0.06	0.06	0.24	-0.04	0.01	0.01	
INDEX 2										
B-Value	2.32	0.10	0.35	-	1.96	0.80	-0.70	0.64	-0.46	
Value of Variate	11.36	0.31	7.55	-	2.54	4.72	1.94	3.12	0.95	
% Overall Gains	49.10	11.69	0.00	28.99	0.00	7.90	2.32	0.00	0.00	3.26
Genetic Gain	0.03	0.37	1.16	0.05	0.06	0.24	-0.04	0.01	0.00	
INDEX 3										
B-Value	2.32	-	0.38	-	2.07	0.77	-0.69	0.62	-0.45	
Value of Variate	11.44	-	11.60	-	2.92	4.50	1.92	3.02	0.95	
% Overall Gain	49.29	10.85	0.00	29.51	0.00	8.02	2.34	0.00	0.00	3.25
Genetic Gain	0.03	0.34	1.16	0.06	0.06	0.24	-0.04	0.01	0.00	
INDEX 4										
B-Value	2.33	-	0.39	-	1.88	0.70	-0.69	0.47	-	
Value of Variate	11.71	-	12.87	-	2.53	3.92	1.95	2.16	-	
% Overall Gain	48.75	11.26	0.00	29.51	0.00	8.27	2.21	0.00	0.00	3.22
Genetic Gain	0.03	0.35	1.16	0.05	0.06	0.25	-0.04	0.02	0.03	

Continued.

TABLE 5.4: CONTINUED

Variates in Objective	NLW	WW		CFW		ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	
INDEX 5										
B-Value	2.33	-	0.40	-	1.86	0.64	-	0.37	-	
Value of Variate	12.25	-	13.89	-	2.57	3.41	-	1.41	-	
% Overall Gain	49.39	11.85	0.00	30.77	0.00	8.65	-0.67	0.00	0.00	3.16
Genetic Gain	0.03	0.36	1.18	0.06	0.06	0.25	0.01	0.02	0.03	
INDEX 6										
B-Value	2.34	-	0.42	-	1.79	0.42	-	-	-	
Value of Variate	12.77	-	16.36	-	2.45	2.11	-	-	-	
% Overall Gain	46.32	12.68	0.00	31.91	0.00	9.08	0.00	0.00	0.00	3.11
Genetic Gain	0.03	0.38	1.17	0.06	0.06	0.26	0.00	-0.06	0.00	
INDEX 7										
B-Value	2.34	-	0.44	-	2.42	-	-	-	-	
Value of Variate	13.33	-	19.78	-	5.53	-	-	-	-	
% Overall Gain	49.57	14.29	0.00	30.84	0.00	5.30	0.00	0.00	0.00	3.05
Genetic Gain	0.03	0.42	1.21	0.05	0.07	0.15	0.00	0.01	0.00	

TABLE 5.5: FULL AND REDUCED SELECTION INDICES FOR THE CLEAN LONG OBJECTIVE (One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			MFD	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	MFD	
INDEX 1											
B-Value	2.31	0.09	0.34	4.30	-1.51	0.41	-0.77	0.95	-0.53	0.24	
Value of Variate	11.57	0.28	7.19	2.38	0.41	1.23	2.43	6.27	1.31	1.29	
% Overall Gain	54.16	11.82	0.00	33.28	0.00	1.23	1.08	0.00	0.00	-1.57	3.22
Genetic Gain	0.04	0.37	1.15	0.06	0.06	0.16	-0.03	0.08	0.02	0.31	
INDEX 2											
B-Value	2.31	0.11	0.35	-	1.55	0.46	-0.76	0.85	-0.52	0.29	
Value of Variate	12.20	0.38	8.26	-	1.54	1.61	2.50	5.47	1.35	1.95	
% Overall Gain	56.33	12.51	0.00	30.38	0.00	1.29	1.12	0.00	0.00	-1.64	3.14
Genetic Gain	0.04	0.38	1.18	0.05	0.06	0.17	-0.03	0.07	0.01	0.32	
INDEX 3											
B-Value	2.32	0.11	0.36	-	2.09	0.47	-0.55	0.69	-0.47	-	
Value of Variate	12.79	0.42	8.95	-	3.25	1.82	1.51	4.08	1.15	-	
% Overall Gain	56.41	13.62	0.00	27.97	0.00	1.09	1.32	0.00	0.00	-0.42	3.08
Genetic Gain	0.04	0.41	1.22	0.05	0.06	0.14	-0.04	0.09	0.01	0.08	
INDEX 4											
B-Value	2.32	-	0.39	-	2.21	0.44	-0.55	0.67	-0.47	-	
Value of Variate	12.91	-	14.05	-	3.75	1.63	1.49	3.95	1.14	-	
% Overall Gain	56.75	12.60	0.00	28.63	0.00	1.12	1.33	0.00	0.00	-0.44	3.07
Genetic Gain	0.04	0.37	1.21	0.05	0.06	0.14	-0.04	0.09	0.00	0.08	

Continued.

TABLE 5.5: CONTINUED

Variates in Objective	NLW	WW		CFW		ML	SC			MFD	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	MFD	
INDEX 5											
B-Value	2.32	-	0.40	-	2.02	0.37	-0.55	0.52	-	-	
Value of Variate	13.28	-	15.69	-	3.28	1.20	1.51	2.91	-	-	
% Overall Gain	56.33	13.14	0.00	28.62	0.00	1.17	1.23	0.00	0.00	-0.49	3.03
Genetic Gain	0.04	0.39	1.22	0.05	0.06	0.15	-0.03	0.10	0.04	0.09	
INDEX 6											
B-Value	2.33	-	0.43	-	2.37	-	-0.48	0.34	-	-	
Value of Variate	13.68	-	19.20	-	5.13	-	1.23	1.78	-	-	
% Overall Gain	56.14	14.39	0.00	27.83	0.00	0.62	1.28	0.00	0.00	-0.26	2.99
Genetic Gain	0.03	0.42	1.23	0.05	0.06	0.08	-0.03	0.12	0.02	0.05	
INDEX 7											
B-Value	2.33	-	0.43	-	2.31	-	-	0.28	-	-	
Value of Variate	14.07	-	19.88	-	4.99	-	-	1.31	-	-	
% Overall Gain	56.65	14.75	0.00	28.80	0.00	0.72	-0.40	0.00	0.00	-0.52	2.96
Genetic Gain	0.03	0.42	1.24	0.05	0.06	0.09	0.01	0.12	0.03	0.09	
INDEX 8											
B-Value	2.34	-	0.44	-	2.01	-	-	-	-	-	
Value of Variate	14.62	-	21.26	-	4.13	-	-	-	-	-	
% Overall Gain	53.69	15.12	0.00	30.87	0.00	1.17	0.00	0.00	0.00	-0.86	2.92
Genetic Gain	0.03	0.43	1.23	0.05	0.06	0.14	0.00	0.02	0.00	0.16	

TABLE 5.6: FULL AND REDUCED SELECTION INDICES FOR THE CLEAN OBJECTIVE
(One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	
INDEX 1										
B-Value	2.32	0.09	0.33	4.88	-1.59	0.67	-0.75	0.78	-0.47	
Value of Variate	10.96	0.23	6.61	2.98	0.42	3.17	2.16	4.35	1.00	3.31
% Overall Gain	48.62	11.21	0.00	32.22	0.00	5.70	2.24	0.00	0.00	
Genetic Gain	0.03	0.36	1.14	0.06	0.06	0.22	-0.04	0.03	0.01	
INDEX 2										
B-Value	2.32	0.10	0.35	-	1.99	0.73	-0.70	0.64	-0.46	
Value of Variate	11.72	0.33	7.83	-	2.71	3.99	2.01	3.28	1.00	3.21
% Overall Gain	50.75	12.13	0.00	28.82	0.00	5.91	2.39	0.00	0.00	
Genetic Gain	0.03	0.38	1.18	0.05	0.06	0.22	-0.04	0.02	0.00	
INDEX 3										
B-Value	2.32	-	0.38	-	2.10	0.70	-0.70	0.63	-0.46	
Value of Variate	11.80	-	12.09	-	3.11	3.77	1.99	3.17	1.00	3.20
% Overall Gain	50.97	11.24	0.00	29.36	0.00	6.01	2.41	0.00	0.00	
Genetic Gain	0.03	0.35	1.17	0.05	0.06	0.22	-0.04	0.02	0.00	

Continued

TABLE 5.6: CONTINUED

Variates in Objective	NLW	WW		CFW		ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	
INDEX 4										
B-Value	2.32	-	0.39	-	1.92	0.62	-0.69	0.48	-	
Value of Variate	12.10	-	13.45	-	2.70	3.20	2.02	2.28	-	3.17
% Overall Gain	50.45	11.68	0.00	29.37	0.00	6.22	2.28	0.00	0.00	
Genetic Gain	0.03	0.36	1.18	0.05	0.06	0.23	-0.04	0.03	0.03	
INDEX 5										
B-Value	2.33	-	0.40	-	1.90	0.56	-	0.37	-	
Value of Variate	12.68	-	14.54	-	2.75	2.72	-	1.49	-	3.10
% Overall Gain	51.19	12.31	0.00	30.67	0.00	6.52	-0.70	0.00	0.00	
Genetic Gain	0.03	0.37	1.19	0.06	0.06	0.23	0.01	0.03	0.03	
INDEX 6										
B-Value	2.34	-	0.42	-	1.82	0.34	-	-	-	
Value of Variate	13.24	-	17.18	-	2.63	1.44	-	-	-	3.06
% Overall Gain	48.05	13.21	0.00	31.88	0.00	6.86	0.00	0.00	0.00	
Genetic Gain	0.03	0.39	1.18	0.06	0.06	0.24	0.00	-0.05	0.00	
INDEX 7										
B-Value	2.34	-	0.44	-	2.34	-	-	-	-	
Value of Variate	13.63	-	20.02	-	5.24	-	-	-	-	3.01
% Overall Gain	50.48	14.47	0.00	30.77	0.00	4.27	0.00	0.00	0.00	
Genetic Gain	0.03	0.42	1.21	0.05	0.06	0.15	0.00	0.02	0.00	

reduction in overall gain if omitted for the Greasy Short objective), although its inclusion in the objective did contribute to total gain (12.53% for the Greasy Short objective). Conversely, HBW was of value in the index as a predictor of the traits in the objective. For the Greasy Short objective, omission of HBW from the index would result in a loss in overall gain of 8.68%.

The importance of GFW followed a similar pattern to that of WW. The value of HGFW in the index was low (the loss in total gain if omitted was 2.56% for the Greasy Short objective), but its presence in the objective contributed substantially to the overall gains (24.09% for the Greasy Short objective).

The wool quality traits were generally of low importance, although Y was of more value in the index than HGFW for the greasy objectives. Two surprising results were obtained. Firstly, a negative index weight (B-value) was assigned to CHG, indicating selection against better CHG, although no actual genetic gain or loss was expected in the trait. Secondly, in the long wool objectives where QN and MFD are both included, the assigned index weights indicate (and are also expected to produce) wool with a higher QN (i.e. finer), but with a greater MFD (i.e. coarser).

A similar antagonistic situation occurs for the clean objectives. The assigned index weights indicate selection for CFW but against GFW when both are present in the index. Genetic gains are however made in both traits.

The value of ML in the long wool objectives and indices was shown to be much lower than that of the corresponding short wool objectives and indices. For the greasy objectives, the loss in overall gain if SL was omitted was 1.86% for the short category, but only 0.38% for the long category. The contribution that ML made to the overall gain by its inclusion in the objective was 4.79% for the short category, but only 0.74% for the long category.

Reduced indices were calculated by gradually deleting traits from the original full index on the criteria of,

i) cost of measurement
ii) value within the index

The first traits to be omitted from the indices, on the basis of cost, were Y and MFD for the greasy objectives and HCFW and MFD for the clean objectives. The value of the overall gain was reduced to varying extents in all of the objectives considered. For example, the Greasy Short objective, where the value of the genetic gain (achieved by one standard deviation of selection on the index) was lowered from \$3.19 to \$3.05 when Y was deleted. The relative importance of the remaining traits was altered slightly. The most obvious change occurred in the clean objectives where the deletion of HCFW resulted in HGFW being assigned a positive index weight and assuming greater significance.

The next trait to be deleted from the indices was WW due to its low value. As expected, the reduction in the value of overall gain was negligible (\$3.05 to \$3.04 for the Greasy Short objective). Progressive deletions of the remaining wool quality traits from the index, again on the basis of value to the index, only resulted in further negligible reductions in the value of overall gain.

The entire series of deletions finally converted the original full indices to reduced indices consisting of only three traits - NLW (dam), HBW and HGFW (i.e. Index 7, and Index 8 for the long wool category). The total reduction in the value of overall gain accompanying these deletions was minimal - \$0.24 (i.e. \$3.19 - \$2.95) for the Greasy Short objective. Use of these reduced indices would give similar genetic gains in each of the traits in the objective to those expected from use of the full indices.

5.3.2 Further reduced selection indices

Using the reduced index of NLW (dam), HBW and HGFW as a base, further deletions and additions were made to investigate alternative selection indices (Tables 5.7, 5.8, 5.9, 5.10, 5.11 and 5.12).

The first action was to delete HGFW. The result was a small decrease in the value of overall gain ($2.95 to $2.79 for the Greasy Short objective) and a much greater emphasis placed on HBW. To this two-trait index, SL was re-introduced. The loss in value of overall gain incurred when HGFW was deleted, was mostly regained ($2.89 compared with $2.95 for the Greasy Short objective). The greater reliance on HBW was also reversed. In order to recoup more of the loss associated with the deletion of HGFW, QN was re-introduced to the index. It was found that this produced no or very little improvement in the value of the overall gain ($2.89 to $2.89 for the Greasy Short objective).

Returning to the basic reduced index of NLW (dam), HBW and HGFW, WW was included once more. This produced no or very small increases in the value of the overall gain ($2.95 to $2.96 for the Greasy Short objective).

The omission of NLW (dam) was then investigated. Beginning with the reduced index of NLW (dam), HBW and HGFW, NLW (dam) was deleted. This action had a considerable effect on the value of the overall gain. For the Greasy Short objective it was lowered from $2.95 to $2.53. An increased reliance on HBW was again demonstrated. HGFW was then omitted and replaced by SL as before. A similar result was again obtained. SL was very nearly able to fully compensate for the loss in the value of overall gain associated with the deletion of HGFW ($2.46 compared with $2.53 for the Greasy Short objective). The importance of HBW was also further increased.

SL was then deleted to leave an index consisting of only HBW i.e. single trait selection on HBW. Compared to the indices consisting of HBW and HGFW, and HBW and SL, the value of the

TABLE 5.7: FURTHER REDUCED SELECTION INDICES FOR THE GREASY SHORT OBJECTIVE (One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	
INDEX 7										
B-Value	2.34	-	0.42	2.32	-	-	-	-	-	
Value of Variate	14.26	-	19.27	5.41	-	-	-	-	-	2.95
% Overall Gain	51.62	14.58	0.00	29.59	0.00	4.20	0.00	0.00	0.00	
Genetic Gain	0.03	0.42	1.20	0.06	0.00	0.15	0.00	0.01	0.00	
INDEX 8										
B-Value	2.33	-	0.52	-	-	-	-	-	-	
Value of Variate	15.92	-	44.30	-	-	-	-	-	-	2.79
% Overall Gain	63.69	17.51	0.00	15.83	0.00	2.97	0.00	0.00	0.00	
Genetic Gain	0.04	0.47	1.35	0.03	0.00	0.10	0.00	0.06	0.00	
INDEX 9										
B-Value	2.33	-	0.46	-	-	0.44	-	-	-	
Value of Variate	14.92	-	27.80	-	-	3.18	-	-	-	2.89
% Overall Gain	56.65	14.85	0.00	19.84	1.60	7.05	0.00	0.00	0.00	
Genetic Gain	0.03	0.42	1.27	0.04	0.07	0.24	0.00	-0.04	0.00	
INDEX 10										
B-Value	2.33	-	0.46	-	-	0.53	-	0.15	-	
Value of Variate	14.77	-	25.95	-	-	3.13	-	0.28	-	2.89
% Overall Gain	58.50	14.55	0.00	19.72	0.55	6.96	-0.27	0.00	0.00	
Genetic Gain	0.04	0.41	1.28	0.04	0.02	0.24	0.00	0.00	0.01	

Continued.

TABLE 5.7: CONTINUED

Variates in Objective	NLW	WW		GFW	Y	ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	
INDEX 11										
B-Value	2.34	0.06	0.40	2.28	-	-	-	-	-	
Value of Variate	14.22	0.12	13.93	5.10	-	-	-	-	-	2.96
% Overall Gain	51.50	15.22	0.00	29.22	0.00	4.06	0.00	0.00	0.00	
Genetic Gain	0.03	0.44	1.20	0.06	0.00	0.14	0.00	0.01	0.00	
INDEX 12										
B-Value	-	-	0.43	2.29	-	-	-	-	-	
Value of Variate	-	-	28.65	7.24	-	-	-	-	-	2.53
% Overall Gain	34.56	19.49	0.00	40.22	0.00	5.73	0.00	0.00	0.00	
Genetic Gain	0.02	0.48	1.37	0.08	0.00	0.17	0.00	0.00	0.00	
INDEX 13										
B-Value	-	-	0.47	-	-	0.44	-	-	-	
Value of Variate	-	-	43.56	-	-	4.32	-	-	-	2.46
% Overall Gain	40.35	20.16	0.00	27.58	2.19	9.72	0.00	0.00	0.00	
Genetic Gain	0.02	0.48	1.46	0.05	0.08	0.28	0.00	-0.06	0.00	
INDEX 14										
B-Value	-	-	0.52	-	-	-	-	-	-	
Value of Variate	-	-	99.96	-	-	-	-	-	-	2.35
% Overall Gain	48.73	24.35	0.00	22.66	0.00	4.25	0.00	0.00	0.00	
Genetic Gain	0.02	0.55	1.57	0.04	0.00	0.12	0.00	0.06	0.00	
INDEX 15										
B-Value	-	-	-	4.02	-	-	-	-	-	
Value of Variate	-	-	-	99.96	-	-	-	-	-	1.81
% Overall Gain	0.00	7.64	0.00	83.01	0.00	9.34	0.00	0.00	0.00	
Genetic Gain	0.00	0.13	0.40	0.11	0.00	0.20	0.00	-0.10	0.00	

TABLE 5.8: FURTHER REDUCED SELECTION INDICES FOR THE GREASY LONG OBJECTIVE (One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			MFD	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	MFD	
INDEX 8											
B-Value	2.34	-	0.42	1.94	-	-	-	-	-	-	
Value of Variate	15.55	-	20.70	4.04	-	-	-	-	-	-	
% Overall Gain	55.69	15.38	0.00	28.69	0.00	0.94	0.00	0.00	0.00	-0.71	2.84
Genetic Gain	0.03	0.42	1.21	0.06	0.00	0.14	0.00	0.02	0.00	0.15	
INDEX 9											
B-Value	2.33	-	0.50	-	-	-	-	-	-	-	
Value of Variate	16.87	-	42.87	-	-	-	-	-	-	-	
% Overall Gain	65.72	17.77	0.00	16.04	0.00	0.68	0.00	0.00	0.00	-0.22	2.72
Genetic Gain	0.04	0.47	1.34	0.03	0.00	0.10	0.00	0.06	0.00	0.05	
INDEX 10											
B-Value	2.33	-	0.48	-	-	0.17	-	-	-	-	
Value of Variate	16.71	-	33.64	-	-	0.53	-	-	-	-	
% Overall Gain	63.72	16.91	0.00	18.03	0.74	1.09	0.00	0.00	0.00	-0.50	2.74
Genetic Gain	0.04	0.45	1.31	0.04	0.03	0.16	0.00	0.02	0.00	0.10	
INDEX 11											
B-Value	2.33	-	0.47	-	-	0.28	-	0.18	-	-	
Value of Variate	16.46	-	30.96	-	-	0.94	-	0.44	-	-	
% Overall Gain	66.03	16.46	0.00	17.86	-0.76	1.06	-0.23	0.00	0.00	-0.42	2.75
Genetic Gain	0.04	0.44	1.33	0.04	-0.03	0.15	0.01	0.07	0.02	0.09	

Continued.

TABLE 5.8: CONTINUED

Variates in Objective	NLW	WW		GFW	Y	ML	SC			MFD	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	MFD	
INDEX 12											
B-Value	2.34	0.08	0.39	1.87	-	-	-	-	-	-	
Value of Variate	15.45	0.29	14.21	3.68	-	-	-	-	-	-	
% Overall Gain	55.36	16.36	0.00	28.05	0.00	0.89	0.00	0.00	0.00	-0.67	2.85
Genetic Gain	0.03	0.45	1.22	0.06	0.00	0.13	0.00	0.02	0.00	0.15	
INDEX 13											
B-Value	-	-	0.43	1.91	-	-	-	-	-	-	
Value of Variate	-	-	32.14	5.53	-	-	-	-	-	-	
% Overall Gain	38.28	21.18	0.00	40.20	0.00	1.32	0.00	0.00	0.00	-0.99	2.40
Genetic Gain	0.02	0.49	1.40	0.07	0.00	0.17	0.00	0.01	0.00	0.18	
INDEX 14											
B-Value	-	-	0.48	-	-	0.17	-	-	-	-	
Value of Variate	-	-	58.84	-	-	0.71	-	-	-	-	
% Overall Gain	47.96	23.96	0.00	26.19	1.03	1.56	0.00	0.00	0.00	-0.71	2.28
Genetic Gain	0.02	0.53	1.54	0.04	0.03	0.19	0.00	0.01	0.00	0.12	
INDEX 15											
B-Value	-	-	0.50	-	-	-	-	-	-	-	
Value of Variate	-	-	100.00	-	-	-	-	-	-	-	
% Overall Gain	50.56	25.26	0.00	23.51	0.00	1.00	0.00	0.00	0.00	-0.32	2.26
Genetic Gain	0.02	0.55	1.57	0.04	0.00	0.12	0.00	0.06	0.00	0.06	
INDEX 16											
B-Value	-	-	-	3.62	-	-	-	-	-	-	
Value of Variate	-	-	-	100.00	-	-	-	-	-	-	
% Overall Gain	0.00	8.49	0.00	92.21	0.00	2.35	0.00	0.00	0.00	-3.05	1.63
Genetic Gain	0.00	0.13	0.40	0.11	0.00	0.20	0.00	-0.10	0.00	0.38	

TABLE 5.9: FURTHER REDUCED SELECTION INDICES FOR THE GREASY OBJECTIVE (One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	
INDEX 7										
B-value	2.34	-	0.42	2.26	-	-	-	-	-	
Value of Variate	14.51	-	19.45	5.19	-	-	-	-	-	
% Overall Gain	52.36	14.72	0.00	29.51	0.00	3.40	0.00	0.00	0.00	2.93
Genetic Gain	0.03	0.42	1.20	0.06	0.00	0.15	0.00	0.02	0.00	
INDEX 8										
B-Value	2.33	-	0.51	-	-	-	-	-	-	
Value of Variate	16.13	-	43.99	-	-	-	-	-	-	
% Overall Gain	64.14	17.57	0.00	15.88	0.00	2.41	0.00	0.00	0.00	2.78
Genetic Gain	0.04	0.47	1.35	0.03	0.00	0.10	0.00	0.06	0.00	
INDEX 9										
B-Value	2.33	-	0.47	-	-	0.39	-	-	-	
Value of Variate	15.35	-	29.03	-	-	2.47	-	-	-	
% Overall Gain	58.29	15.32	0.00	19.57	1.43	5.38	0.00	0.00	0.00	2.85
Genetic Gain	0.03	0.42	1.28	0.04	0.06	0.22	0.00	-0.03	0.00	
INDEX 10										
B-Value	2.33	-	0.46	-	-	0.48	-	0.15	-	
Value of Variate	15.18	-	27.05	-	-	2.57	-	0.29	-	
% Overall Gain	60.21	14.99	0.00	19.44	0.33	5.30	-0.28	0.00	0.00	2.86
Genetic Gain	0.04	0.42	1.29	0.04	0.01	0.22	0.00	0.01	0.01	

Continued.

TABLE 5.9: CONTINUED

Variates in Objective	NLW	WW		GFW	Y	ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	
INDEX 11										
B-Value	2.34	0.06	0.40	2.21	-	-	-	-	-	
Value of Variate	14.46	0.15	13.91	4.86	-	-	-	-	-	
% Overall Gain	52.40	15.43	0.00	29.09	0.00	3.28	0.00	0.00	0.00	2.94
Genetic Gain	0.03	0.44	1.20	0.06	0.00	0.14	0.00	0.01	0.00	
INDEX 12										
B-Value	-	-	0.43	2.23	-	-	-	-	-	
Value of Variate	-	-	29.15	6.98	-	-	-	-	-	
% Overall Gain	35.19	19.79	0.00	40.35	0.00	4.67	0.00	0.00	0.00	2.51
Genetic Gain	0.02	0.48	1.37	0.07	0.00	0.17	0.00	0.00	0.00	
INDEX 13										
B-Value	-	-	0.47	-	-	0.38	-	-	-	
Value of Variate	-	-	46.48	-	-	3.36	-	-	-	
% Overall Gain	42.05	21.00	0.00	27.49	1.97	7.49	0.00	0.00	0.00	2.41
Genetic Gain	0.02	0.49	1.48	0.05	0.07	0.26	0.00	-0.04	0.00	
INDEX 14										
B-Value	-	-	0.52	-	-	-	-	-	-	
Value of Variate	-	-	100.00	-	-	-	-	-	-	
% Overall Gain	49.13	24.55	0.00	22.85	0.00	3.47	0.00	0.00	0.00	2.33
Genetic Gain	0.02	0.55	1.57	0.04	0.00	0.12	0.00	0.06	0.00	
INDEX 15										
B-Value	-	-	-	3.95	-	-	-	-	-	
Value of Variate	-	-	-	99.96	-	-	-	-	-	
% Overall Gain	0.00	7.78	0.00	84.51	0.00	7.70	0.00	0.00	0.00	1.77
Genetic Gain	0.00	0.13	0.40	0.11	0.00	0.20	0.00	-0.10	0.00	

TABLE 5.10: FURTHER REDUCED SELECTION INDICES FOR THE CLEAN SHORT OBJECTIVE (One record on NLW (dam)).

Variates in Objective	NLW	WW	CFW			ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	
INDEX 7										
B-Value	2.34	-	0.44	-	2.42	-	-	-	-	
Value of Variate	13.33	-	19.78	-	5.53	-	-	-	-	
% Overall Gain	49.57	14.29	0.00	30.84	0.00	5.30	0.00	0.00	0.00	3.05
Genetic Gain	0.03	0.42	1.21	0.05	0.07	0.15	0.00	0.01	0.00	
INDEX 8										
B-Value	2.32	-	0.54	-	-	-	-	-	-	
Value of Variate	14.90	-	45.90	-	-	-	-	-	-	
% Overall Gain	61.42	17.20	0.00	17.62	0.00	3.76	0.00	0.00	0.00	2.88
Genetic Gain	0.04	0.48	1.37	0.03	0.03	0.10	0.00	0.06	0.00	
INDEX 9										
B-Value	2.33	-	0.47	-	-	0.59	-	-	-	
Value of Variate	13.38	-	25.33	-	-	5.19	-	-	-	
% Overall Gain	51.53	13.58	0.00	24.88	0.00	10.01	0.00	0.00	0.00	3.03
Genetic Gain	0.03	0.40	1.24	0.04	0.04	0.28	0.00	-0.07	0.00	
INDEX 10										
B-Value	2.32	-	0.45	-	-	0.80	-	0.34	-	
Value of Variate	12.88	-	22.07	-	-	6.31	-	1.29	-	
% Overall Gain	54.60	12.77	0.00	23.69	0.00	9.60	-0.66	0.00	0.00	3.07
Genetic Gain	0.03	0.38	1.26	0.04	0.04	0.27	0.01	0.01	0.03	

Continued.

TABLE 5.10: CONTINUED

Variates in Objective	NLW	WW		CFW		ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	
INDEX 11										
B-Value	2.34	0.05	0.43	-	2.38	-	-	-	-	
Value of Variate	13.30	0.09	14.53	-	5.25	-	-	-	-	
% Overall Gain	49.49	14.81	0.00	30.54	0.00	5.16	0.00	0.00	0.00	3.05
Genetic Gain	0.03	0.44	1.21	0.05	0.06	0.14	0.00	0.01	0.00	
INDEX 12										
B-Value	-	-	0.45	-	2.39	-	-	-	-	
Value of Variate	-	-	28.66	-	7.24	-	-	-	-	
% Overall Gain	33.17	18.70	0.00	41.05	0.00	7.07	0.00	0.00	0.00	2.64
Genetic Gain	0.02	0.48	1.37	0.06	0.08	0.17	0.00	0.00	0.00	
INDEX 13										
B-Value	-	-	0.48	-	-	0.59	-	-	-	
Value of Variate	-	-	37.35	-	-	6.85	-	-	-	
% Overall Gain	35.60	17.78	0.00	33.30	0.00	13.31	0.00	0.00	0.00	2.63
Genetic Gain	0.02	0.45	1.41	0.05	0.05	0.32	0.00	-0.09	0.00	
INDEX 14										
B-Value	-	-	0.54	-	-	-	-	-	-	
Value of Variate	-	-	99.96	-	-	-	-	-	-	
% Overall Gain	46.77	23.37	0.00	24.61	0.00	5.25	0.00	0.00	0.00	2.45
Genetic Gain	0.02	0.55	1.57	0.03	0.04	0.12	0.00	0.06	0.00	
INDEX 15										
B-Value	-	-	-	-	4.18	-	-	-	-	
Value of Variate	-	-	-	-	100.00	-	-	-	-	
% Overall Gain	0.00	7.34	0.00	81.13	0.00	11.53	0.00	0.00	0.00	1.88
Genetic Gain	0.00	0.13	0.40	0.09	0.11	0.20	0.00	-0.10	0.00	

TABLE 5.11: FURTHER REDUCED SELECTION INDICES FOR THE CLEAN LONG OBJECTIVE (One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			MFD	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	MFD	
INDEX 8											
B-Value	2.34	-	0.44	-	2.01	-	-	-	-	-	
Value of Variates	14.62	-	21.26	-	4.13	-	-	-	-	-	
% Overall Gain	53.69	15.12	0.00	30.87	0.00	1.17	0.00	0.00	0.00	-0.86	2.92
Genetic Gain	0.03	0.43	1.23	0.05	0.06	0.14	0.00	0.02	0.00	0.16	
INDEX 9											
B-Value	2.33	-	0.52	-	-	-	-	-	-	-	
Value of Variates	15.87	-	44.38	-	-	-	-	-	-	-	
% Overall Gain	63.58	17.50	0.00	18.34	0.00	0.85	0.00	0.00	0.00	-0.27	2.80
Genetic Gain	0.04	0.47	1.35	0.03	0.03	0.10	0.00	0.06	0.00	0.05	
INDEX 10											
B-Value	2.33	-	0.49	-	-	0.25	-	-	-	-	
Value of Variates	15.57	-	32.96	-	-	1.02	-	-	-	-	
% Overall Gain	60.52	16.24	0.00	22.42	0.00	1.54	0.00	0.00	0.00	-0.72	2.83
Genetic Gain	0.04	0.44	1.32	0.04	0.04	0.18	0.00	0.01	0.00	0.13	
INDEX 11											
B-Value	2.32	-	0.47	-	-	0.49	-	0.40	-	-	
Value of Variates	14.71	-	27.66	-	-	2.63	-	2.03	-	-	
% Overall Gain	63.95	14.98	0.00	20.76	0.00	1.43	-0.59	0.00	0.00	-0.52	2.89
Genetic Gain	0.04	0.42	1.32	0.03	0.04	0.17	0.01	0.10	0.04	0.09	

Continued

TABLE 5.11: CONTINUED

Variates in Objective	NLW	WW		CFW		ML	SC			MFD	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	MFD	
INDEX 12											
B-Value	2.34	0.08	0.41	-	1.95	-	-	-	-	-	
Value of Variate	14.53	0.26	14.72	-	3.77	-	-	-	-	-	
% Overall Gain	53.42	16.03	0.00	30.26	0.00	1.11	0.00	0.00	0.00	-0.82	2.93
Genetic Gain	0.03	0.45	1.23	0.05	0.06	0.13	0.00	0.02	0.00	0.15	
INDEX 13											
B-Value	-	-	0.44	-	1.98	-	-	-	-	-	
Value of Variate	-	-	32.15	-	5.53	-	-	-	-	-	
% Overall Gain	36.83	20.38	0.00	42.34	0.00	1.61	0.00	0.00	0.00	-1.17	2.49
Genetic Gain	0.02	0.49	1.40	0.06	0.07	0.17	0.00	0.01	0.00	0.18	
INDEX 14											
B-Value	-	-	0.49	-	-	0.24	-	-	-	-	
Value of Variate	-	-	54.69	-	-	1.37	-	-	-	-	
% Overall Gain	44.83	22.40	0.00	31.62	0.00	2.15	0.00	0.00	0.00	-1.01	2.39
Genetic Gain	0.02	0.52	1.53	0.04	0.05	0.21	0.00	-0.01	0.00	0.15	
INDEX 15											
B-Value	-	-	0.52	-	-	-	-	-	-	-	
Value of Variate	-	-	100.00	-	-	-	-	-	-	-	
% Overall Gain	48.64	24.30	0.00	26.23	0.00	1.21	0.00	0.00	0.00	-0.38	2.35
Genetic Gain	0.02	0.55	1.57	0.03	0.04	0.12	0.00	0.06	0.00	0.06	
INDEX 16											
B-Value	-	-	-	-	3.76	-	-	-	-	-	
Value of Variate	-	-	-	-	100.00	-	-	-	-	-	
% Overall Gain	0.00	8.17	0.00	92.59	0.00	2.85	0.00	0.00	0.00	-3.61	1.69
Genetic Gain	0.00	0.13	0.40	0.09	0.11	0.20	0.00	-0.10	0.00	0.38	

TABLE 5.12: FURTHER REDUCED SELECTION INDICES FOR THE CLEAN OBJECTIVE (One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	
INDEX 7										
B-Value	2.34	-	0.44	-	2.34	-	-	-	-	
Value of Variate	13.63	-	20.02	-	5.24	-	-	-	-	
% Overall Gain	50.48	14.47	0.00	30.77	0.00	4.27	0.00	0.00	0.00	3.01
Genetic Gain	0.03	0.42	1.21	0.05	0.06	0.15	0.00	0.02	0.00	
INDEX 8										
B-Value	2.33	-	0.53	-	-	-	-	-	-	
Value of Variate	15.15	-	45.50	-	-	-	-	-	-	
% Overall Gain	61.98	17.28	0.00	17.69	0.00	3.04	0.00	0.00	0.00	2.86
Genetic Gain	0.04	0.48	1.36	0.03	0.03	0.10	0.00	0.06	0.00	
INDEX 9										
B-Value	2.33	-	0.47	-	-	0.52	-	-	-	
Value of Variate	13.94	-	26.89	-	-	4.08	-	-	-	
% Overall Gain	53.69	14.19	0.00	24.47	0.00	7.64	0.00	0.00	0.00	2.98
Genetic Gain	0.03	0.41	1.26	0.04	0.04	0.26	0.00	-0.05	0.00	
INDEX 10										
B-Value	2.32	-	0.46	-	-	0.73	-	0.34	-	
Value of Variate	13.39	-	23.34	-	-	5.38	-	1.37	-	
% Overall Gain	56.84	13.33	0.00	23.22	0.00	7.30	-0.69	0.00	0.00	3.02
Genetic Gain	0.04	0.39	1.27	0.04	0.04	0.25	0.01	0.02	0.03	

Continued.

TABLE 5.12: CONTINUED

Variates in Objective	NLW	WW	CFW			ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	
INDEX 11										
B-Value	2.34	0.06	0.42	-	2.29	-	-	-	-	
Value of Variate	13.60	0.12	14.52	-	4.94	-	-	-	-	3.02
% Overall Gain	50.37	15.08	0.00	30.42	0.00	4.14	0.00	0.00	0.00	
Genetic Gain	0.03	0.44	1.22	0.05	0.06	0.14	0.00	0.01	0.00	
INDEX 12										
B-Value	-	-	0.45	-	2.31	-	-	-	-	
Value of Variate	-	-	29.28	-	6.91	-	-	-	-	2.60
% Overall Gain	33.94	19.07	0.00	41.25	0.00	5.74	0.00	0.00	0.00	
Genetic Gain	0.02	0.48	1.37	0.06	0.07	0.17	0.00	0.01	0.00	
INDEX 13										
B-Value	-	-	0.48	-	-	0.51	-	-	-	
Value of Variate	-	-	40.61	-	-	5.43	-	-	-	2.56
% Overall Gain	37.69	18.83	0.00	33.19	0.00	10.29	0.00	0.00	0.00	
Genetic Gain	0.02	0.47	1.43	0.05	0.05	0.30	0.00	-0.07	0.00	
INDEX 14										
B-Value	-	-	0.54	-	-	-	-	-	-	
Value of Variate	-	-	100.00	-	-	-	-	-	-	2.42
% Overall Gain	47.26	23.61	0.00	24.86	0.00	4.27	0.00	0.00	0.00	
Genetic Gain	0.02	0.55	1.57	0.03	0.04	0.12	0.00	0.06	0.00	
INDEX 15										
B-Value	-	-	-	-	4.09	-	-	-	-	
Value of Variate	-	-	-	-	100.00	-	-	-	-	1.84
% Overall Gain	0.00	7.50	0.00	82.99	0.00	9.50	0.00	0.00	0.00	
Genetic Gain	0.00	0.13	0.40	0.09	0.11	0.20	0.00	-0.10	0.00	

overall gain was not greatly affected ($2.53 and $2.46 respectively, to $2.35 for the Greasy Short objective). Relative to the basic reduced index of NLW (dam), HBW and HGFW, the loss in the value of overall gain was naturally greater ($2.95 to $2.35 for the Greasy Short objective).

HGFW then replaced HBW in the index i.e. single trait selection on HGFW. This substitution produced a large reduction in the value of overall gain ($2.35 to $1.81 for the Greasy Short objective).

5.3.3 EBW sensitivity analysis

The doubt concerning the accuracy of the previously calculated economic weight estimates for EBW, prompted an assessment of the effects that the varying estimates would have on the selection index formulation. Using the original full index with an economic weight estimate for EBW of $0.00 as a base, other indices were computed where the estimate was increased to $0.42, then decreased to -$0.13 and finally kept at $0.00 but with the provision that no genetic progress was to be made in the trait.

Tables 5.13, 5.14, 5.15, 5.16, 5.17 and 5.18 indicate that the use of economic weights for EBW ranging from -$0.13 to $0.42 have little influence on selection index computation. Neither the index weightings nor the calculated genetic gains for each individual trait were significantly altered. As expected, the value of the other traits in the index and their contribution to overall gain were shown to vary inversely with the estimated economic weight for EBW. Similarly, the value of the overall gain is proportional to the magnitude of the economic weight used.

The use of an economic weight for EBW of $0.00, accompanied by a complete restriction on genetic gains in that trait, had more serious effects on the calculated selection index. In contrast to previous indices, EBW was selected against in the index, as indicated by the negative index weighting for

TABLE 5.13: EBW SENSITIVITY ANALYSIS FOR THE GREASY SHORT OBJECTIVE FULL INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	
Economic Weight = 0.00										
B-Value	2.32	0.10	0.36	1.93	0.25	0.50	-0.61	0.65	-0.45	
Value of Variate	11.89	0.29	8.68	2.56	4.23	1.86	1.53	2.92	0.96	3.19
% Overall Gain	52.18	12.53	0.00	24.09	4.75	4.79	1.65	0.00	0.00	
Genetic Gain	0.03	0.39	1.17	0.06	0.22	0.18	-0.04	-0.02	0.00	
Economic Weight = 0.42										
B-Value	2.35	0.11	0.51	1.70	0.27	0.51	-0.63	0.72	-0.48	
Value of Variate	8.88	0.29	13.13	1.46	3.50	1.46	1.22	2.69	0.81	3.71
% Overall Gain	45.42	12.18	14.74	19.20	3.48	3.76	1.22	0.00	0.00	
Genetic Gain	0.03	0.44	1.30	0.05	0.19	0.17	-0.03	0.01	0.01	
Economic Weight = -0.13										
B-Value	2.31	0.09	0.32	2.00	0.25	0.49	-0.60	0.62	-0.44	
Value of Variate	13.06	0.29	7.20	3.04	4.49	2.00	1.64	2.98	1.01	3.04
% Overall Gain	54.25	12.44	-4.78	25.86	5.24	5.17	1.81	0.00	0.00	
Genetic Gain	0.03	0.37	1.12	0.06	0.23	0.19	-0.04	-0.03	0.00	
Economic Weight = 0.00 Genetic Progress Restricted (1)										
B-Value	2.21	0.04	-0.15	2.70	0.20	0.44	-0.53	0.39	-0.35	
Value of Variate	24.46	0.13	8.32	11.27	5.71	3.09	2.40	2.23	1.19	2.19
% Overall Gain	43.18	-2.01	0.00	37.17	10.26	7.95	3.45	0.00	0.00	
Genetic Gain	0.02	-0.04	0.00	0.06	0.33	0.21	-0.05	-0.17	-0.01	

(1) Dummy weighting factor = 1.43

TABLE 5.14: EBW SENSITIVITY ANALYSIS FOR THE GREASY LONG OBJECTIVE FULL INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			MFD	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	MFD	
Economic Weight = 0.00											
B-Value	2.31	0.10	0.37	1.57	0.26	0.22	-0.62	0.78	-0.48	0.19	
Value of Variate	12.57	0.35	9.41	1.64	4.63	0.38	1.66	4.17	1.16	0.88	3.10
% Overall Gain	57.54	13.26	0.00	23.45	5.41	0.74	0.76	0.00	0.00	-1.17	
Genetic Gain	0.04	0.40	1.18	0.05	0.23	0.12	-0.03	0.03	0.01	0.28	
Economic Weight = 0.42											
B-Value	2.35	0.12	0.52	1.38	0.28	0.24	-0.63	0.84	-0.51	0.17	
Value of Variate	9.28	0.34	14.05	0.91	3.82	0.32	1.26	3.59	0.95	0.53	3.62
% Overall Gain	49.21	12.79	15.19	18.54	3.90	0.59	0.56	0.00	0.00	-0.78	
Genetic Gain	0.04	0.45	1.31	0.05	0.19	0.11	-0.02	0.05	0.01	0.22	
Economic Weight = -0.13											
B-Value	2.30	0.10	0.32	1.64	0.25	0.21	-0.61	0.75	-0.47	0.20	
Value of Variate	13.86	0.36	7.85	1.95	4.92	0.40	1.82	4.36	1.23	1.03	2.95
% Overall Gain	60.20	13.20	-4.95	25.24	5.99	0.80	0.84	0.00	0.00	-1.32	
Genetic Gain	0.04	0.38	1.12	0.05	0.24	0.12	-0.03	0.02	0.01	0.30	
Economic Weight = 0.00 Genetic Progress Restricted (1)											
B-Value	2.21	0.05	-0.13	2.22	0.20	0.16	-0.58	0.55	-0.39	0.25	
Value of Variate	26.34	0.19	7.10	7.22	6.21	0.43	3.15	4.55	1.60	3.18	
% Overall Gain	53.60	-1.65	0.00	36.48	12.05	1.16	1.56	0.00	0.00	-3.21	
Genetic Gain	0.02	-0.03	0.00	0.06	0.35	0.13	-0.04	-0.10	0.00	0.52	

(1) Dummy weighting factor = 1.39

TABLE 5.15: EBW SENSITIVITY ANALYSIS FOR THE GREASY OBJECTIVE FULL INDEX
(One record on NLW (dam)).

Variates in Objective	NLW	WW		GHW	Y	ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	
Economic Weight = 0.00										
B-Value	2.32	0.10	0.36	1.95	0.26	0.44	-0.61	0.65	-0.46	
Value of Variate	12.11	0.31	8.89	2.67	4.40	1.48	1.56	3.04	1.00	3.16
% Overall Gain	53.29	12.82	0.00	23.98	4.69	3.55	1.68	0.00	0.00	
Genetic Gain	0.03	0.39	1.18	0.06	0.22	0.16	-0.03	0.00	0.00	
Economic Weight = 0.42										
B-Value	2.35	0.11	0.51	1.72	0.27	0.45	-0.64	0.73	-0.49	
Value of Variate	9.01	0.31	13.37	1.53	3.62	1.17	1.24	2.79	0.83	3.68
% Overall Gain	46.18	12.40	14.90	19.06	3.42	2.79	1.23	0.00	0.00	
Genetic Gain	0.04	0.44	1.31	0.05	0.18	0.15	-0.03	0.02	0.01	
Economic Weight = -0.13										
B-Value	2.31	0.09	0.32	2.02	0.25	0.43	-0.60	0.63	-0.45	
Value of Variate	13.32	0.31	7.39	3.17	4.68	1.59	1.68	3.11	1.05	3.01
% Overall Gain	55.48	12.75	-4.85	25.76	5.18	3.83	1.85	0.00	0.00	
Genetic Gain	0.03	0.37	1.12	0.06	0.23	0.17	-0.04	-0.01	0.00	
Economic Weight = 0.00 Genetic Progress Restricted (1)										
B-Value	2.21	0.05	-0.15	2.72	0.20	0.38	-0.53	0.39	-0.35	
Value of Variate	25.29	0.15	8.24	11.82	6.05	2.40	2.50	2.40	1.26	2.16
% Overall Gain	45.08	-1.82	0.00	37.15	10.25	5.78	3.55	0.00	0.00	
Genetic Gain	0.02	-0.04	0.00	0.06	0.33	0.18	-0.05	-0.15	-0.01	

(1) Dummy weighting factor = 1.42

TABLE 5.16: EBW SENSITIVITY ANALYSIS FOR THE CLEAN SHORT OBJECTIVE FULL INDEX
(One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	
Economic Weight = 0.00										
B-Value	2.32	0.08	0.33	4.91	-1.64	0.75	-0.75	0.77	-0.47	
Value of Variate	10.64	0.21	6.37	2.92	0.44	3.81	2.09	4.17	0.95	
% Overall Gain	47.10	10.81	0.00	32.30	0.00	7.61	2.18	0.00	0.00	3.36
Genetic Gain	0.03	0.35	1.13	0.06	0.06	0.24	-0.04	0.01	0.01	
Economic Weight = 0.42										
B-Value	2.35	0.10	0.48	4.88	-1.84	0.76	-0.76	0.83	-0.49	
Value of Variate	8.16	0.22	10.41	2.17	0.42	3.00	1.65	3.64	0.79	
% Overall Gain	41.76	10.86	13.73	25.95	0.00	6.04	1.65	0.00	0.00	3.86
Genetic Gain	0.03	0.41	1.26	0.06	0.06	0.21	-0.04	0.04	0.01	
Economic Weight = -0.13										
B-Value	2.31	0.08	0.28	4.92	-1.58	0.74	-0.74	0.76	-0.46	
Value of Variate	11.57	0.21	5.10	3.21	0.44	4.11	2.24	4.34	1.01	
% Overall Gain	48.64	10.60	-4.34	34.55	0.00	8.17	2.37	0.00	0.00	3.21
Genetic Gain	0.03	0.33	1.07	0.06	0.06	0.24	-0.04	0.01	0.01	
Economic Weight = 0.00 Genetic Progress Restricted (1)										
B-Value	2.21	0.03	-0.19	5.02	-0.95	0.69	-0.68	0.57	-0.39	
Value of Variate	19.94	0.06	11.74	6.11	0.29	6.48	3.42	4.50	1.31	
% Overall Gain	36.87	-3.07	0.00	49.56	0.00	12.38	4.27	0.00	0.00	2.39
Genetic Gain	0.02	-0.07	0.00	0.07	0.07	0.27	-0.06	-0.12	0.00	

(1) Dummy weighting factor = 1.46

TABLE 5.17: EBW SENSITIVITY ANALYSIS FOR THE CLEAN LONG OBJECTIVE FULL INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			MFD	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	MFD	
Economic Weight = 0.00											
B-Value	2.31	0.09	0.34	4.30	-1.51	0.41	-0.77	0.95	-0.53	0.24	3.22
Value of Variate	11.57	0.28	7.19	2.38	0.41	1.23	2.43	6.27	1.31	1.29	
% Overall Gain	54.16	11.82	0.00	33.28	0.00	1.23	1.08	0.00	0.00	-1.57	
Genetic Gain	0.04	0.37	1.15	0.06	0.06	0.16	-0.03	0.08	0.02	0.31	
Economic Weight = 0.42											
B-Value	2.34	0.11	0.49	4.29	-1.70	0.43	-0.78	1.00	-0.54	0.23	3.73
Value of Variate	8.71	0.28	11.47	1.76	0.38	0.99	1.84	5.16	1.05	0.85	
% Overall Gain	46.80	11.69	14.46	26.34	0.00	0.97	0.81	0.00	0.00	-1.08	
Genetic Gain	0.04	0.42	1.28	0.06	0.06	0.15	-0.03	0.10	0.02	0.25	
Economic Weight = -0.13											
B-Value	2.30	0.09	0.29	4.30	-1.45	0.40	-0.77	0.93	-0.52	0.25	3.07
Value of Variate	12.66	0.28	5.82	2.62	0.41	1.32	2.65	6.67	1.40	1.47	
% Overall Gain	56.45	11.64	-4.64	35.79	0.00	1.32	1.19	0.00	0.00	-1.76	
Genetic Gain	0.04	0.35	1.09	0.06	0.06	0.17	-0.03	0.08	0.02	0.34	
Economic Weight = 0.00 Genetic Progress Restricted (1)											
B-Value	2.20	0.04	-0.17	4.32	-0.87	0.35	-0.74	0.77	-0.46	0.29	2.25
Value of Variate	22.80	0.12	10.92	4.99	0.27	1.87	4.64	8.69	2.04	3.77	
% Overall Gain	49.69	-2.90	0.00	53.06	0.00	1.95	2.16	0.00	0.00	-3.96	
Genetic Gain	0.02	-0.06	0.00	0.07	0.07	0.18	-0.04	-0.03	0.02	0.56	

(1) Dummy weighting factor = 1.43

TABLE 5.18: EBW SENSITIVITY ANALYSIS FOR THE CLEAN OBJECTIVE FULL INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	
Economic Weight = 0.00										
B-Value	2.32	0.09	0.33	4.88	-1.59	0.67	-0.75	0.78	-0.47	
Value of Variate	10.96	0.23	6.61	2.98	0.42	3.17	2.16	4.35	1.00	3.31
% Overall Gain	48.62	11.21	0.00	32.22	0.00	5.70	2.24	0.00	0.00	
Genetic Gain	0.03	0.36	1.14	0.06	0.06	0.22	-0.04	0.03	0.01	
Economic Weight = 0.42										
B-Value	2.35	0.10	0.48	4.85	-1.79	0.69	-0.77	0.84	-0.50	
Value of Variate	8.35	0.24	10.71	2.20	0.40	2.49	1.70	3.77	0.82	3.82
% Overall Gain	42.84	11.17	13.99	25.79	0.00	4.52	1.68	0.00	0.00	
Genetic Gain	0.03	0.41	1.27	0.06	0.06	0.19	-0.04	0.05	0.01	
Economic Weight = -0.13										
B-Value	2.31	0.08	0.28	4.89	-1.53	0.67	-0.74	0.76	-0.47	
Value of Variate	11.95	0.22	5.31	3.27	0.43	3.42	2.32	4.55	1.06	3.17
% Overall Gain	50.33	11.02	-4.45	34.52	0.00	6.13	2.45	0.00	0.00	
Genetic Gain	0.03	0.34	1.08	0.06	0.06	0.22	-0.04	0.02	0.01	
Economic Weight = 0.00 Genetic Progress Restricted (1)										
B-Value	2.21	0.04	-0.19	4.99	-0.90	0.61	-0.68	0.58	-0.40	
Value of Variate	21.02	0.08	11.82	6.33	0.27	5.38	3.61	4.83	1.41	2.34
% Overall Gain	39.24	-2.93	0.00	49.97	0.00	9.24	4.47	0.00	0.00	
Genetic Gain	0.02	-0.07	0.00	0.07	0.07	0.25	-0.06	-0.10	0.00	

(1) Dummy weighting factor = 1.45

TABLE 5.19: EBW SENSITIVITY ANALYSIS FOR THE GREASY SHORT OBJECTIVE REDUCED INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	
Economic Weight = 0.00										
B-Value	2.34	-	0.42	2.32	-	-	-	-	-	
Value of Variate	14.26	-	19.27	5.41	-	-	-	-	-	
% Overall Gain	51.62	14.58	0.00	29.59	0.00	4.20	0.00	0.00	0.00	2.95
Genetic Gain	0.03	0.42	1.20	0.06	0.00	0.15	0.00	0.01	0.00	
Economic Weight = 0.42										
B-Value	2.37	-	0.58	2.07	-	-	-	-	-	
Value of Variate	10.32	-	27.23	3.04	-	-	-	-	-	
% Overall Gain	44.02	13.68	15.93	22.93	0.00	3.44	0.00	0.00	0.00	3.49
Genetic Gain	0.03	0.46	1.32	0.06	0.00	0.14	0.00	0.03	0.00	
Economic Weight = -0.13										
B-Value	2.33	-	0.37	2.40	-	-	-	-	-	
Value of Variate	15.85	-	16.53	6.47	-	-	-	-	-	
% Overall Gain	54.07	14.68	-5.32	32.09	0.00	4.47	0.00	0.00	0.00	2.80
Genetic Gain	0.03	0.40	1.15	0.07	0.00	0.15	0.00	0.01	0.00	
Economic Weight = 0.00 Genetic Progress Restricted(1)										
B-Value	2.23	-	-0.10	3.17	-	-	-	-	-	
Value of Variate	33.04	-	41.00	26.64	-	-	-	-	-	
% Overall Gain	45.04	-0.42	0.00	50.19	0.00	5.19	0.00	0.00	0.00	1.95
Genetic Gain	0.02	-0.01	0.00	0.07	0.00	0.12	0.00	-0.07	0.00	

(1) Dummy weighting factor = 1.39

TABLE 5.20: EBW SENSITIVITY ANALYSIS FOR THE GREASY LONG OBJECTIVE REDUCED INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		GHW	Y	ML	SC			MFD	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	MFD	
Economic Weight = 0.00											
B-Value	2.34	-	0.42	1.94	-	-	-	-	-	-	
Value of Variate	15.55	-	20.70	4.04	-	-	-	-	-	-	
% Overall Gain	55.69	15.38	0.00	28.69	0.00	0.94	0.00	0.00	0.00	-0.71	2.84
Genetic Gain	0.03	0.42	1.21	0.06	0.00	0.14	0.00	0.02	0.00	0.15	
Economic Weight = 0.42											
B-Value	2.37	-	0.58	1.68	-	-	-	-	-	-	
Value of Variate	11.04	-	28.97	2.13	-	-	-	-	-	-	
% Overall Gain	46.75	14.28	16.63	22.06	0.00	0.77	0.00	0.00	0.00	-0.50	3.38
Genetic Gain	0.03	0.47	1.34	0.05	0.00	0.14	0.00	0.03	0.00	0.13	
Economic Weight = -0.13											
B-Value	2.33	-	0.37	2.02	-	-	-	-	-	-	
Value of Variate	17.41	-	17.81	4.92	-	-	-	-	-	-	
% Overall Gain	58.66	15.53	-5.62	31.22	0.00	1.00	0.00	0.00	0.00	-0.79	2.68
Genetic Gain	0.03	0.40	1.16	0.06	0.00	0.14	0.00	0.02	0.00	0.16	
Economic Weight = 0.00 Genetic Progress Restricted (1)											
B-Value	2.23	-	-0.09	2.76	-	-	-	-	-	-	
Value of Variate	38.39	-	35.51	22.07	-	-	-	-	-	-	
% Overall Gain	52.18	-0.44	0.00	48.85	0.00	1.14	0.00	0.00	0.00	-1.73	1.84
Genetic Gain	0.02	-0.01	0.00	0.07	0.00	0.11	0.00	-0.06	0.00	0.24	

(1) Dummy weighting factor = 1.35

TABLE 5.21: EBW SENSITIVITY ANALYSIS FOR THE GREASY OBJECTIVE REDUCED INDEX
(One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	
Economic Weight = 0.00										
B-Value	2.34	-	0.42	2.26	-	-	-	-	-	
Value of Variate	14.51	-	19.45	5.19	-	-	-	-	-	
% Overall Gain	52.36	14.72	0.00	29.51	0.00	3.40	0.00	0.00	0.00	2.93
Genetic Gain	0.03	0.42	1.20	0.06	0.00	0.15	0.00	0.02	0.00	
Economic Weight = 0.42										
B-Value	2.37	-	0.58	2.00	-	-	-	-	-	
Value of Variate	10.47	-	27.48	2.89	-	-	-	-	-	
% Overall Gain	44.53	13.79	16.06	22.83	0.00	2.78	0.00	0.00	0.00	3.46
Genetic Gain	0.03	0.46	1.32	0.06	0.00	0.14	0.00	0.03	0.00	
Economic Weight = -0.13										
B-Value	2.33	-	0.37	2.34	-	-	-	-	-	
Value of Variate	16.15	-	16.68	6.22	-	-	-	-	-	
% Overall Gain	54.89	14.82	-5.37	32.03	0.00	3.62	0.00	0.00	0.00	2.78
Genetic Gain	0.03	0.40	1.15	0.07	0.00	0.15	0.00	0.01	0.00	
Economic Weight = 0.00 Genetic Progress Restricted (1)										
B-Value	2.23	-	-0.09	3.10	-	-	-	-	-	
Value of Variate	33.91	-	40.07	25.86	-	-	-	-	-	
% Overall Gain	46.21	-0.43	0.00	50.03	0.00	4.18	0.00	0.00	0.00	1.93
Genetic Gain	0.02	-0.01	0.00	0.07	0.00	0.12	0.00	-0.07	0.00	

(1) Dummy weighting factor = 1.38

TABLE 5.22: EBW SENSITIVITY ANALYSIS FOR THE CLEAN SHORT OBJECTIVE REDUCED INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	
Economic Weight = 0.00										
B-Value	2.34	-	0.44	-	2.42	-	-	-	-	
Value of Variate	13.33	-	19.78	-	5.53	-	-	-	-	
% Overall Gain	49.57	14.29	0.00	30.84	0.00	5.30	0.00	0.00	0.00	3.05
Genetic Gain	0.03	0.42	1.21	0.05	0.07	0.15	0.00	0.01	0.00	
Economic Weight = 0.42										
B-Value	2.37	-	0.60	-	2.16	-	-	-	-	
Value of Variate	9.74	-	27.49	-	3.16	-	-	-	-	3.58
% Overall Gain	42.44	13.37	15.58	24.26	0.00	4.35	0.00	0.00	0.00	
Genetic Gain	0.03	0.46	1.33	0.05	0.06	0.14	0.00	0.03	0.00	
Economic Weight = -0.13										
B-Value	2.33	-	0.39	-	2.50	-	-	-	-	
Value of Variate	14.77	-	17.12	-	6.57	-	-	-	-	
% Overall Gain	51.88	14.42	-5.22	33.29	0.00	5.63	0.00	0.00	0.00	2.89
Genetic Gain	0.03	0.40	1.16	0.06	0.07	0.15	0.00	0.01	0.00	
Economic Weight = 0.00 Genetic Progress Restricted (1)										
B-Value	2.22	-	-0.10	-	3.30	-	-	-	-	
Value of Variate	31.43	-	42.79	-	28.15	-	-	-	-	
% Overall Gain	42.92	-0.42	0.00	50.77	0.00	6.72	0.00	0.00	0.00	1.98
Genetic Gain	0.02	-0.01	0.00	0.06	0.07	0.12	0.00	-0.07	0.00	

(1) Dummy weighting factor = 1.45

TABLE 5.23: EBW SENSITIVITY ANALYSIS FOR THE CLEAN LONG OBJECTIVE REDUCED INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			MFD	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	MFD	
Economic Weight = 0.00											
B-Value	2.34	-	0.44	-	2.01	-	-	-	-	-	
Value of Variate	14.62	-	21.26	-	4.13	-	-	-	-	-	
% Overall Gain	53.69	15.12	0.00	30.87	0.00	1.17	0.00	0.00	0.00	-0.86	2.92
Genetic Gain	0.03	0.43	1.23	0.05	0.06	0.14	0.00	0.02	0.00	0.16	
Economic Weight = 0.42											
B-Value	2.37	-	0.59	-	1.76	-	-	-	-	-	
Value of Variate	10.47	-	29.29	-	2.21	-	-	-	-	-	
% Overall Gain	45.24	14.01	16.31	24.10	0.00	0.95	0.00	0.00	0.00	-0.60	3.46
Genetic Gain	0.03	0.47	1.34	0.05	0.06	0.14	0.00	0.03	0.00	0.13	
Economic Weight = -0.13											
B-Value	2.33	-	0.39	-	2.09	-	-	-	-	-	
Value of Variate	16.32	-	18.45	-	5.00	-	-	-	-	-	
% Overall Gain	56.52	15.30	-5.54	33.42	0.00	1.25	0.00	0.00	0.00	-0.96	2.76
Genetic Gain	0.03	0.41	1.18	0.05	0.06	0.14	0.00	0.02	0.00	0.16	
Economic Weight = 0.00 Genetic Progress Restricted (1)											
B-Value	2.22	-	-0.09	-	2.87	-	-	-	-	-	
Value of Variate	36.82	-	37.06	-	23.35	-	-	-	-	-	
% Overall Gain	50.25	-0.44	0.00	50.89	0.00	1.46	0.00	0.00	0.00	-2.16	1.87
Genetic Gain	0.02	-0.01	0.00	0.05	0.07	0.11	0.00	-0.06	0.00	0.25	

(1) Dummy weighting factor = 1.41

TABLE 5.24: EBW SENSITIVITY ANALYSIS FOR THE CLEAN OBJECTIVE REDUCED INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	
Economic Weight = 0.00										
B-Value	2.34	-	0.44	-	2.34	-	-	-	-	
Value of Variate	13.63	-	20.02	-	5.24	-	-	-	-	
% Overall Gain	50.48	14.47	0.00	30.77	0.00	4.27	0.00	0.00	0.00	3.01
Genetic Gain	0.03	0.42	1.21	0.05	0.06	0.15	0.00	0.02	0.00	
Economic Weight = 0.42										
B-Value	2.37	-	0.60	-	2.08	-	-	-	-	
Value of Variate	9.91	-	27.81	-	2.96	-	-	-	-	
% Overall Gain	43.08	13.52	15.74	24.16	0.00	3.50	0.00	0.00	0.00	3.55
Genetic Gain	0.03	0.47	1.33	0.05	0.06	0.14	0.00	0.03	0.00	
Economic Weight = -0.13										
B-Value	2.33	-	0.39	-	2.41	-	-	-	-	
Value of Variate	15.13	-	17.33	-	6.26	-	-	-	-	
% Overall Gain	52.90	14.60	-5.29	33.24	0.00	4.55	0.00	0.00	0.00	2.86
Genetic Gain	0.03	0.40	1.16	0.06	0.07	0.15	0.00	0.01	0.00	
Economic Weight = 0.00 Genetic Progress Restricted (1)										
B-Value	2.22	-	-0.10	-	3.21	-	-	-	-	
Value of Variate	32.50	-	41.60	-	27.14	-	-	-	-	
% Overall Gain	44.40	-0.42	0.00	50.62	0.00	5.40	0.00	0.00	0.00	1.96
Genetic Gain	0.02	-0.01	0.00	0.06	0.07	0.12	0.00	-0.07	0.00	

(1) Dummy weighting factor = 1.44

HBW. The value of both NLW (dam) and HGFW in the index was significantly increased (11.89% to 24.46% and 2.56% to 11.27% reductions respectively, for the Greasy Short objective). However, the contribution to overall gain of NLW and also of WW was decreased (52.18% to 43.18% and 12.53% to -2.01% respectively for the Greasy Short objective). As a consequence, the proportion of the overall gain attributed to the wool traits was increased. The value of the overall gain was considerably reduced ($3.19 to $2.19 for the Greasy Short objective). Apart from EBW whose genetic gain was deliberately restricted to 0.00, the only other individual trait to have its genetic gain significantly affected was WW (0.39 kg to -0.04 kg for the Greasy Short objective). The negative of the dummy weighting factor calculated for this particular index is the appropriate economic weight to assign to EBW for no genetic gains to be made in that trait (Cunningham and Gjedrem, 1970). For the Greasy Short objective, the required economic weight should be -$1.43.

The EBW sensitivity analysis was then repeated for the reduced indices consisting of NLW (dam), HBW and HGFW. Tables 5.19, 5.20, 5.21, 5.22, 5.23 and 5.24 illustrate a similar set of results to those obtained with the full index.

5.3.4 NLW, GFW (CFW) and SC sensitivity analysis

Further sensitivity analyses were conducted for NLW, GFW (CFW) and SC. These traits were considered likely to be most affected by future economic conditions. The new economic weights assigned to each trait, with examples for the Greasy Short objective, were,

NLW	= + 50%	($47.10 to $70.65)
GFW (CFW)	= + 50%	($13.34 to $20.01)
SC	= + 200%	(-$1.41 to -$4.23)

Tables 5.25, 5.26, 5.27, 5.28, 5.29 and 5.30 compare the effects of altering the economic weights of single traits with the original full index.

TABLE 5.25: NLW, GFW AND SC SENSITIVITY ANALYSIS FOR THE GREASY SHORT OBJECTIVE FULL INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	
Original Economic Weights										
B-Value	2.32	0.10	0.36	1.93	0.25	0.50	-0.61	0.65	-0.45	3.19
Value of Variate	11.89	0.29	8.68	2.56	4.23	1.86	1.53	2.92	0.96	
% Overall Gain	52.18	12.53	0.00	24.09	4.75	4.79	1.65	0.00	0.00	
Genetic Gain	0.03	0.39	1.17	0.06	0.22	0.18	-0.04	-0.02	0.00	
NLW Economic Weight = 70.65										
B-Value	3.46	0.11	0.49	1.52	0.32	0.65	-0.75	1.08	-0.66	4.08
Value of Variate	16.54	0.22	9.72	0.96	4.10	1.93	1.39	5.02	1.26	
% Overall Gain	69.81	9.68	0.00	14.39	2.46	2.63	1.02	0.00	0.00	
Genetic Gain	0.04	0.38	1.19	0.04	0.15	0.13	-0.03	0.06	0.01	
GFW Economic Weight = 20.01										
B-Value	2.32	0.06	0.36	3.69	0.22	0.53	-0.61	0.66	-0.53	3.63
Value of Variate	9.02	0.10	6.45	7.44	2.50	1.64	1.16	2.36	1.03	
% Overall Gain	39.81	9.93	0.00	41.32	2.88	4.76	1.29	0.00	0.00	
Genetic Gain	0.03	0.35	1.09	0.07	0.15	0.21	-0.03	-0.03	0.00	
SC Economic Weight = -4.23										
B-Value	2.32	0.09	0.36	1.95	0.26	0.50	-1.45	0.66	-0.52	3.39
Value of Variate	10.45	0.26	7.60	2.33	3.78	1.67	7.91	2.68	1.12	
% Overall Gain	46.34	11.09	0.00	21.45	4.17	4.24	12.71	0.00	0.00	
Genetic Gain	0.03	0.36	1.10	0.05	0.21	0.17	-0.10	-0.04	-0.01	

TABLE 5.26: NLW, GFW AND SC SENSITIVITY ANALYSIS FOR THE GREASY LONG OBJECTIVE FULL INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			MFD	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	sc	QN	CHG	MFD	
Original Economic Weights											3.10
B-Value	2.31	0.10	0.37	1.57	0.26	0.22	-0.62	0.78	-0.48	0.19	
Value of Variate	12.57	0.35	9.41	1.64	4.63	0.38	1.66	4.17	1.16	0.88	
% Overall Gain	57.54	13.26	0.00	23.45	5.41	0.74	0.76	0.00	0.00	-1.17	
Genetic Gain	0.04	0.40	1.18	0.05	0.23	0.12	-0.03	0.03	0.01	0.28	
NLW Economic Weight = 70.65											4.05
B-Value	3.46	0.11	0.49	1.05	0.32	0.36	-0.79	1.24	-0.71	0.26	
Value of Variate	16.83	0.25	10.01	0.42	4.14	0.62	1.61	6.34	1.45	0.92	
% Overall Gain	73.56	9.79	0.00	13.70	2.78	0.40	0.44	0.00	0.00	-0.68	
Genetic Gain	0.04	0.38	1.18	0.04	0.15	0.08	-0.02	0.09	0.02	0.21	
GFW Economic Weight = 20.01											3.53
B-Value	2.31	0.07	0.36	3.22	0.22	0.25	-0.66	0.83	-0.58	0.26	
Value of Variate	9.53	0.12	6.94	5.38	2.63	0.38	1.47	3.63	1.26	1.22	
% Overall Gain	44.26	10.41	0.00	41.87	3.39	0.87	0.58	0.00	0.00	-1.38	
Genetic Gain	0.03	0.36	1.09	0.07	0.16	0.16	-0.02	0.00	0.01	0.37	
SC Economic Weight = -2.64											3.19
B-Value	2.31	0.10	0.37	1.62	0.26	0.22	-1.13	0.77	-0.53	0.17	
Value of Variate	11.82	0.34	8.84	1.64	4.44	0.37	5.37	3.92	1.29	0.68	
% Overall Gain	54.28	12.54	0.00	22.10	5.04	0.69	6.24	0.00	0.00	-0.90	
Genetic Gain	0.04	0.39	1.14	0.05	0.22	0.11	-0.07	0.01	0.00	0.22	

TABLE 5.27: NLW, GFW AND SC SENSITIVITY ANALYSIS FOR THE GREASY OBJECTIVE FULL INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	
Original Economic Weights										
B-Value	2.32	0.10	0.36	1.95	0.26	0.44	-0.61	0.65	-0.46	
Value of Variate	12.11	0.31	8.89	2.67	4.40	1.48	1.56	3.04	1.00	3.16
% Overall Gain	53.29	12.82	0.00	23.98	4.69	3.55	1.68	0.00	0.00	
Genetic Gain	0.03	0.39	1.18	0.06	0.22	0.16	-0.03	0.00	0.00	
NLW Economic Weight = 70.65										
B-Value	3.46	0.11	0.49	1.54	0.32	0.59	-0.75	1.09	-0.67	
Value of Variate	16.71	0.23	9.85	1.00	4.21	1.62	1.41	5.15	1.30	4.07
% Overall Gain	70.65	9.82	0.00	14.20	2.40	1.91	1.03	0.00	0.00	
Genetic Gain	0.04	0.39	1.19	0.04	0.14	0.11	-0.03	0.07	0.01	
GFW Economic Weight = 20.01										
B-Value	2.32	0.06	0.36	3.72	0.23	0.47	-0.61	0.67	-0.54	
Value of Variate	9.19	0.10	6.61	7.68	2.61	1.33	1.19	2.46	1.07	3.60
% Overall Gain	40.66	10.16	0.00	41.43	2.82	3.62	1.31	0.00	0.00	
Genetic Gain	0.03	0.35	1.10	0.07	0.15	0.19	-0.03	-0.02	0.00	
SC Economic Weight = -4.23										
B-Value	2.32	0.10	0.36	1.97	0.26	0.44	-1.45	0.66	-0.52	
Value of Variate	10.62	0.27	7.76	2.42	3.92	1.33	8.07	2.79	1.16	3.36
% Overall Gain	47.22	11.32	0.00	21.30	4.11	3.13	12.91	0.00	0.00	
Genetic Gain	0.03	0.37	1.11	0.05	0.20	0.15	-0.10	-0.03	-0.01	

TABLE 5.28: NLW, CFW AND SC SENSITIVITY ANALYSIS FOR THE CLEAN SHORT OBJECTIVE FULL INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	
Original Economic Weights										
B-Value	2.32	0.08	0.33	4.91	-1.64	0.75	-0.75	0.77	-0.47	3.36
Value of Variate	10.64	0.21	6.37	2.92	0.44	3.81	2.09	4.17	0.95	
% Overall Gain	47.10	10.81	0.00	32.30	0.00	7.61	2.18	0.00	0.00	
Genetic Gain	0.03	0.35	1.13	0.06	0.06	0.24	-0.04	0.01	0.01	
NLW Economic Weight = 70.65										
B-Value	3.47	0.09	0.46	5.23	-2.28	0.89	-0.87	1.15	-0.65	4.21
Value of Variate	15.48	0.16	7.75	2.13	0.54	3.44	1.77	5.85	1.15	
% Overall Gain	64.76	8.76	0.00	20.51	0.00	4.57	1.40	0.00	0.00	
Genetic Gain	0.04	0.36	1.16	0.05	0.05	0.18	-0.03	0.08	0.02	
CFW Economic Weight = 25.47										
B-Value	2.32	0.05	0.32	7.03	-1.62	0.84	-0.76	0.83	-0.54	3.96
Value of Variate	7.53	0.06	4.34	4.34	0.31	3.43	1.55	3.47	0.91	
% Overall Gain	33.91	8.03	0.00	49.18	0.00	7.30	1.58	0.00	0.00	
Genetic Gain	0.03	0.31	1.03	0.08	0.08	0.27	-0.04	-0.02	0.01	
SC Economic Weight = -5.16										
B-Value	2.32	0.08	0.33	4.89	-1.60	0.75	-1.78	0.79	-0.55	3.63
Value of Variate	9.01	0.18	5.37	2.47	0.35	3.29	10.45	3.66	1.12	
% Overall Gain	40.30	9.22	0.00	27.65	0.00	6.49	16.34	0.00	0.00	
Genetic Gain	0.03	0.32	1.04	0.06	0.06	0.22	-0.11	-0.02	-0.01	

TABLE 5.29: NLW, CFW AND SC SENSITIVITY ANALYSIS FOR THE CLEAN LONG OBJECTIVE FULL INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			MFD	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	MFD	
Original Economic Weights											
B-Value	2.31	0.09	0.34	4.30	-1.51	0.41	-0.77	0.95	-0.53	0.24	
Value of Variate	11.57	0.28	7.19	2.38	0.41	1.23	2.43	6.27	1.31	1.29	3.22
% Overall Gain	54.16	11.82	0.00	33.28	0.00	1.23	1.08	0.00	0.00	-1.57	
Genetic Gain	0.04	0.37	1.15	0.06	0.06	0.16	-0.03	0.08	0.02	0.31	
NLW Economic Weight = 70.65											
B-Value	3.46	0.10	0.46	4.51	-2.20	0.55	-0.94	1.36	-0.72	0.32	
Value of Variate	15.98	0.19	8.18	1.58	0.52	1.35	2.16	7.86	1.46	1.34	4.14
% Overall Gain	70.07	9.00	0.00	20.51	0.00	0.72	0.64	0.00	0.00	-0.95	
Genetic Gain	0.04	0.36	1.15	0.05	0.05	0.12	-0.02	0.13	0.03	0.25	
CFW Economic Weight = 26.10											
B-Value	2.31	0.06	0.33	6.27	-1.55	0.50	-0.86	1.07	-0.62	0.35	
Value of Variate	8.02	0.08	4.76	3.61	0.30	1.28	2.15	5.60	1.28	1.92	3.82
% Overall Gain	38.83	8.49	0.00	52.48	0.00	1.37	0.74	0.00	0.00	-1.91	
Genetic Gain	0.03	0.31	1.04	0.08	0.08	0.22	-0.02	0.02	0.02	0.46	
SC Economic Weight = -3.30											
B-Value	2.31	0.09	0.33	4.32	-1.47	0.41	-1.41	0.94	-0.58	0.22	
Value of Variate	10.61	0.26	6.59	2.22	0.35	1.16	7.70	5.72	1.45	0.98	3.35
% Overall Gain	49.84	10.92	0.00	30.53	0.00	1.11	8.77	0.00	0.00	-1.17	
Genetic Gain	0.03	0.35	1.10	0.06	0.06	0.15	-0.09	0.05	0.00	0.24	

TABLE 5.30: NLW, CFW AND SC SENSITIVITY ANALYSIS FOR THE CLEAN OBJECTIVE FULL INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	
Original Economic Weights										
B-Value	2.32	0.09	0.33	4.88	-1.59	0.67	-0.75	0.78	-0.47	
Value of Variate	10.96	0.23	6.61	2.98	0.42	3.17	2.16	4.35	1.00	
% Overall Gain	48.62	11.21	0.00	32.22	0.00	5.70	2.24	0.00	0.00	3.31
Genetic Gain	0.03	0.36	1.14	0.06	0.06	0.22	-0.04	0.03	0.01	
NLW Economic Weight = 70.65										
B-Value	3.47	0.09	0.46	5.24	-2.23	0.82	-0.87	1.15	-0.65	
Value of Variate	15.76	0.17	7.93	2.14	0.52	2.93	1.81	6.01	1.19	
% Overall Gain	66.02	8.96	0.00	20.22	0.00	3.37	1.42	0.00	0.00	4.18
Genetic Gain	0.04	0.36	1.16	0.05	0.05	0.16	-0.03	0.10	0.02	
CFW Economic Weight = 25.47										
B-Value	2.32	0.05	0.32	7.00	-1.57	0.76	-0.76	0.84	-0.55	
Value of Variate	7.75	0.06	4.50	4.43	0.30	2.92	1.60	3.62	0.95	
% Overall Gain	34.98	8.32	0.00	49.47	0.00	5.61	1.63	0.00	0.00	3.90
Genetic Gain	0.03	0.31	1.03	0.08	0.08	0.25	-0.04	-0.01	0.01	
SC Economic Weight = -5.16										
B-Value	2.32	0.09	0.33	4.86	-1.54	0.68	-1.78	0.79	-0.56	
Value of Variate	9.23	0.19	5.54	2.50	0.34	2.73	10.74	3.81	1.17	
% Overall Gain	41.43	9.51	0.00	27.47	0.00	4.84	16.75	0.00	0.00	3.59
Genetic Gain	0.03	0.33	1.05	0.06	0.06	0.20	-0.12	-0.01	-0.01	

The first trait to be analysed was NLW. The addition of 50% to the original economic weight resulted in a greater emphasis being placed on NLW (dam) in the index. For the Greasy Short objective, the index weight was increased from 2.32 to 3.46, and the value of NLW (dam) in the index rose from 11.89% to 16.54%. The importance of other traits was also shown to change, especially HGFW whose value in the index was reduced, and HBW and QN whose values were increased. The absolute value of the overall gain was naturally increased due to the greater economic weight assigned to NLW. The proportion of the overall gain accounted for by NLW increased (52.18% to 69.81% for the Greasy Short objective). This was at the expense of other traits, notably GFW.

The second trait to be investigated was fleece weight; GFW for the greasy objectives and CFW for the clean objectives. The 50% addition to the original economic weights increased the index weighting and the value to the index of HGFW and HCFW in their respective objectives (1.93 to 3.69 and 2.56% to 7.44% respectively for the Greasy Short objective). There was no major effect on the importance within the index of the other traits. The percentage of the overall gain attributed to GFW (or CFW) was increased (24.09% to 41.32% for the Greasy Short objective), while the contribution of the other traits, especially NLW, was reduced.

The final trait to be analysed was SC. The 200% increase in the economic weight for SC placed more emphasis on that trait, but had little effect on the remaining traits. For the Greasy Short objective, the index weighting of SC was changed from -0.61 to -1.45, the value of SC within the index increased from 1.53% to 7.91% and the percentage of overall gain accounted for by SC increased from 1.65% to 12.71%.

The NLW, GFW (CFW) and SC sensitivity analyses were then repeated for the reduced indices consisting of NLW (dam), HBW and HGFW. Tables 5.31, 5.32, 5.33, 5.34, 5.35 and 5.36 display a similar set of results to those obtained for the full index. The only exception was for SC, where the addition

TABLE 5.31: NLW AND GFW SENSITIVITY ANALYSIS FOR THE GREASY SHORT OBJECTIVE REDUCED INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	
Original Economic Weights										
B-Value	2.34	-	0.42	2.32	-	-	-	-	-	
Value of Variate	14.26	-	19.27	5.41	-	-	-	-	-	
% Overall Gain	51.62	14.58	0.00	29.59	0.00	4.20	0.00	0.00	0.00	2.95
Genetic Gain	0.03	0.42	1.20	0.06	0.00	0.15	0.00	0.01	0.00	
NLW Economic Weight = 70.65										
B-Value	3.50	-	0.57	1.73	-	-	-	-	-	
Value of Variate	20.25	-	21.90	1.82	-	-	-	-	-	
% Overall Gain	67.85	11.53	0.00	17.88	0.00	2.74	0.00	0.00	0.00	3.77
Genetic Gain	0.04	0.42	1.21	0.05	0.00	0.12	0.00	0.03	0.00	
GFW Economic Weight = 20.01										
B-Value	2.34	-	0.41	4.03	-	-	-	-	-	
Value of Variate	10.27	-	13.12	12.38	-	-	-	-	-	
% Overall Gain	37.57	11.42	0.00	46.87	0.00	4.14	0.00	0.00	0.00	3.45
Genetic Gain	0.03	0.38	1.10	0.08	0.00	0.17	0.00	-0.01	0.00	

TABLE 5.32: NLW AND GFW SENSITIVITY ANALYSIS FOR THE GREASY LONG OBJECTIVE REDUCED INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			MFD	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	MFD	
Original Economic Weights											
B-Value	2.34	-	0.42	1.94	-	-	-	-	-	-	
Value of Variate	15.55	-	20.70	4.04	-	-	-	-	-	-	2.84
% Overall Gain	55.69	15.38	0.00	28.69	0.00	0.94	0.00	0.00	0.00	-0.71	
Genetic Gain	0.03	0.42	1.21	0.06	0.00	0.14	0.00	0.02	0.00	0.15	
NLW Economic Weight = 70.65											
B-Value	3.50	-	0.57	1.35	-	-	-	-	-	-	
Value of Variate	21.42	-	22.87	1.15	-	-	-	-	-	-	3.68
% Overall Gain	71.10	11.87	0.00	16.79	0.00	0.60	0.00	0.00	0.00	-0.36	
Genetic Gain	0.04	0.42	1.21	0.05	0.00	0.11	0.00	0.04	0.00	0.10	
GFW Economic Weight = 20.01											
B-Value	2.34	-	0.41	3.64	-	-	-	-	-	-	
Value of Variate	11.21	-	14.09	10.89	-	-	-	-	-	-	3.31
% Overall Gain	40.63	12.09	0.00	47.19	0.00	0.95	0.00	0.00	0.00	-0.87	
Genetic Gain	0.03	0.39	1.12	0.08	0.00	0.17	0.00	0.00	0.00	0.22	

TABLE 5.33: NLW AND GFW SENSITIVITY ANALYSIS FOR THE GREASY OBJECTIVE REDUCED INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	
Original Economic Weights										
B-Value	2.34	-	0.42	2.26	-	-	-	-	-	
Value of Variate	14.51	-	19.45	5.19	-	-	-	-	-	
% Overall Gain	52.36	14.72	0.00	29.51	0.00	3.40	0.00	0.00	0.00	2.93
Genetic Gain	0.03	0.42	1.20	0.06	0.00	0.15	0.00	0.02	0.00	
NLW Economic Weight = 70.65										
B-Value	3.50	-	0.57	1.67	-	-	-	-	-	
Value of Variate	20.50	-	22.02	1.70	-	-	-	-	-	
% Overall Gain	68.47	11.59	0.00	17.73	0.00	2.20	0.00	0.00	0.00	3.75
Genetic Gain	0.04	0.42	1.21	0.05	0.00	0.12	0.00	0.04	0.00	
GFW Economic Weight = 20.01										
B-Value	2.34	-	0.41	3.96	-	-	-	-	-	
Value of Variate	10.45	-	13.24	12.16	-	-	-	-	-	
% Overall Gain	38.09	11.53	0.00	47.01	0.00	3.37	0.00	0.00	0.00	3.42
Genetic Gain	0.03	0.38	1.10	0.08	0.00	0.17	0.00	-0.01	0.00	

TABLE 5.34: NLW AND CFW SENSITIVITY ANALYSIS FOR THE CLEAN SHORT OBJECTIVE REDUCED INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	
Original Economic Weights										
B-Value	2.34	-	0.44	-	2.42	-	-	-	-	
Value of Variate	13.33	-	19.78	-	5.53	-	-	-	-	
% Overall Gain	49.57	14.29	0.00	30.84	0.00	5.30	0.00	0.00	0.00	3.05
Genetic Gain	0.03	0.42	1.21	0.05	0.07	0.15	0.00	0.01	0.00	
NLW Economic Weight = 70.65										
B-Value	3.50	-	0.59	-	1.83	-	-	-	-	
Value of Variate	19.25	-	22.37	-	1.94	-	-	-	-	
% Overall Gain	65.86	11.39	0.00	19.25	0.00	3.50	0.00	0.00	0.00	3.85
Genetic Gain	0.03	0.42	1.22	0.04	0.05	0.12	0.00	0.03	0.00	
CFW Economic Weight = 25.47										
B-Value	2.34	-	0.44	-	4.12	-	-	-	-	
Value of Variate	9.53	-	13.89	-	12.10	-	-	-	-	
% Overall Gain	36.10	11.23	0.00	47.50	0.00	5.17	0.00	0.00	0.00	3.57
Genetic Gain	0.03	0.39	1.12	0.07	0.08	0.17	0.00	-0.01	0.00	

TABLE 5.35: NLW AND CFW SENSITIVITY ANALYSIS FOR THE CLEAN LONG OBJECTIVE REDUCED INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			MFD	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	MFD	
Original Economic Weights											
B-Value	2.34	-	0.44	-	2.01	-	-	-	-	-	
Value of Variate	14.62	-	21.26	-	4.13	-	-	-	-	-	
% Overall Gain	53.69	15.12	0.00	30.87	0.00	1.17	0.00	0.00	0.00	-0.86	2.92
Genetic Gain	0.03	0.43	1.23	0.05	0.06	0.14	0.00	0.02	0.00	0.16	
NLW Economic Weight = 70.65											
B-Value	3.50	-	0.58	-	1.42	-	-	-	-	-	
Value of Variate	20.46	-	23.38	-	1.23	-	-	-	-	-	
% Overall Gain	69.26	11.75	0.00	18.68	0.00	0.75	0.00	0.00	0.00	-0.45	3.75
Genetic Gain	0.04	0.43	1.22	0.04	0.05	0.12	0.00	0.04	0.00	0.10	
CFW Economic Weight = 26.10											
B-Value	2.34	-	0.43	-	3.76	-	-	-	-	-	
Value of Variate	10.35	-	14.78	-	10.78	-	-	-	-	-	
% Overall Gain	38.84	11.85	0.00	49.17	0.00	1.17	0.00	0.00	0.00	-1.03	3.43
Genetic Gain	0.03	0.39	1.13	0.06	0.08	0.17	0.00	0.00	0.00	0.22	

TABLE 5.36: NLW AND CFW SENSITIVITY ANALYSIS FOR THE CLEAN OBJECTIVE REDUCED INDEX (One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	
Original Economic Weights										
B-Value	2.34	-	0.44	-	2.34	-	-	-	-	
Value of Variate	13.63	-	20.02	-	5.24	-	-	-	-	
% Overall Gain	50.48	14.47	0.00	30.77	0.00	4.27	0.00	0.00	0.00	3.01
Genetic Gain	0.03	0.42	1.21	0.05	0.06	0.15	0.00	0.02	0.00	
NLW Economic Weight = 70.65										
B-Value	3.50	-	0.59	-	1.74	-	-	-	-	
Value of Variate	19.55	-	22.53	-	1.78	-	-	-	-	
% Overall Gain	66.65	11.47	0.00	19.07	0.00	2.81	0.00	0.00	0.00	3.82
Genetic Gain	0.04	0.43	1.22	0.04	0.05	0.12	0.00	0.03	0.00	
CFW Economic Weight = 25.47										
B-Value	2.34	-	0.44	-	4.04	-	-	-	-	
Value of Variate	9.73	-	14.05	-	11.82	-	-	-	-	
% Overall Gain	36.75	11.37	0.00	47.69	0.00	4.18	0.00	0.00	0.00	3.53
Genetic Gain	0.03	0.39	1.12	0.07	0.08	0.17	0.00	-0.01	0.00	

of a further 200% to the economic weight did not affect the computation of the reduced index in any way. The index details were equivalent to those for the original reduced index, and were consequently not reproduced within the tables.

5.3.5 Cotting and tenderness

Economic weights for cotting (Co) and tenderness (T) were calculated in Chapter 4.3.1, but due to the lack of confidence in these estimates they were originally excluded from the selection objective and index. A further analysis investigated the effect on the previously computed full and reduced indices when these two traits were taken into consideration. The analysis was limited to only the long wool categories, where cotting and tenderness are most prevalent.

Tables 5.37 and 5.38 illustrate the consequences for the full index of including Co and T in the selection objective and index. The negative index weight assigned to Co indicates selection for cotted, rather than free, wools (-0.20 for the Greasy Long objective). However, selection on the calculated index would result in small, overall genetic gains toward less cotted wool (0.06 units for the Greasy Long objective). T was assigned a positive index weight, suggesting selection for less tender wool (0.22 for the Greasy Long objective). As for Co, only small genetic gains in T were expected (0.10 units for the Greasy Long objective). The value of both Co and T in the index was shown to be very low (0.04% and 0.26% respectively for the Greasy Long objective). Conversely, they contributed more to overall gain than some of the other wool quality traits (3.61% and 3.56% respectively for the Greasy Long objective).

The inclusion of Co and T also produced a small reduction in the importance in the index of the non-wool traits (NLW (dam), WW and HBW). Associated with this change was a slight increase in the value in the index of some of the wool quality traits, notably SC, QN and MFD. Genetic gains in individual

TABLE 5.37: THE EFFECTS ON THE FULL INDEX OF THE INCLUSION OF Co AND T IN THE GREASY LONG OBJECTIVE (One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			MFD	Co	T	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	MFD	Co	T	
Without Co and T													
B-Value	2.31	0.10	0.37	1.57	0.26	0.22	-0.62	0.78	-0.48	0.19			
Value of Variate	12.57	0.35	9.41	1.64	4.63	0.38	1.66	4.17	1.16	0.88			
% Overall Gain	57.54	13.26	0.00	23.45	5.41	0.74	0.76	0.00	0.00	-1.17			3.10
Genetic Gain	0.04	0.40	1.18	0.05	0.23	0.12	-0.03	0.03	0.01	0.28			
With Co and T													
B-Value	2.31	0.08	0.36	1.74	0.28	0.23	-0.75	0.98	-0.48	0.33	-0.20	0.22	
Value of Variate	10.76	0.20	7.79	1.66	4.65	0.37	2.14	5.61	0.98	2.23	0.04	0.26	3.32
% Overall Gain	52.30	11.22	0.00	24.10	5.23	0.79	0.69	0.00	0.00	-1.50	3.61	3.56	
Genetic Gain	0.04	0.36	1.12	0.06	0.24	0.14	-0.03	0.03	0.02	0.38	0.06	0.10	

TABLE 5.38: THE EFFECTS ON THE FULL INDEX OF THE INCLUSION OF Co AND T IN THE CLEAN LONG OBJECTIVE (One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			MFD	Co	T	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	MFD	Co	T	
Without Co and T													
B-Value	2.31	0.09	0.34	4.30	-1.51	0.41	-0.77	0.95	-0.53	0.24			
Value of Variate	11.57	0.28	7.19	2.38	0.41	1.23	2.43	6.27	1.31	1.29			3.22
% Overall Gain	54.16	11.82	0.00	33.28	0.00	1.23	1.08	0.00	0.00	-1.57			
Genetic Gain	0.04	0.37	1.15	0.06	0.06	0.16	-0.03	0.08	0.02	0.31			
With Co and T													
B-Value	2.30	0.06	0.34	4.70	-1.50	0.44	-0.88	1.17	-0.51	0.40	-0.45	0.07	
Value of Variate	9.89	0.09	6.21	2.45	0.35	1.20	2.71	7.97	1.07	2.93	0.35	0.17	
% Overall Gain	49.42	9.98	0.00	33.30	0.00	1.26	0.86	0.00	0.00	-1.89	3.66	3.40	3.45
Genetic Gain	0.04	0.33	1.10	0.07	0.07	0.18	-0.03	0.08	0.03	0.41	0.06	0.10	

TABLE 5.39: THE EFFECTS ON THE REDUCED INDEX OF THE INCLUSION OF Co AND T IN THE GREASY LONG OBJECTIVE (One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW	Y	ML	SC			MFD	Co	T	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HGFW	Y	SL	SC	QN	CHG	MFD	Co	T	
Without Co and T													
B-Value	2.34	-	0.42	1.94	-	-	-	-	-	-			
Value of Variate	15.55	-	20.70	4.04	-	-	-	-	-	-			2.84
% Overall Gain	55.69	15.38	0.00	28.69	0.00	0.94	0.00	0.00	0.00	-0.71			
Genetic Gain	0.03	0.42	1.21	0.06	0.00	0.14	0.00	0.02	0.00	0.15			
With Co and T													
B-Value	2.34	-	0.42	2.42	-	-	-	-	-	-	-	-	
Value of Variate	14.08	-	18.75	5.82	-	-	-	-	-	-	-	-	
% Overall Gain	50.86	14.40	0.00	29.91	0.00	0.95	0.00	0.00	0.00	-0.77	1.78	2.86	2.97
Genetic Gain	0.03	0.41	1.19	0.07	0.00	0.15	0.00	0.01	0.00	0.17	0.02	0.07	

TABLE 5.40: THE EFFECTS ON THE REDUCED INDEX OF THE INCLUSION OF Co AND T IN THE CLEAN LONG OBJECTIVE (One record on NLW (dam)).

Variates in Objective	NLW	WW		CFW		ML	SC			MFD	Co	T	Value of Overall Gain
Variates in Index	NLW (dam)	WW	HBW	HCFW	HGFW	SL	SC	QN	CHG	MFD	Co	T	
Without Co and T													
B-Value	2.34	-	0.44	-	2.01	-	-	-	-	-			
Value of Variate	14.62	-	21.26	-	4.13	-	-	-	-	-			
% Overall Gain	53.69	15.12	0.00	30.87	0.00	1.17	0.00	0.00	0.00	-0.86			2.92
Genetic Gain	0.03	0.43	1.23	0.05	0.06	0.14	0.00	0.02	0.00	0.16			
With Co and T													
B-Value	2.34	-	0.44	-	2.50	-	-	-	-	-	-	-	
Value of Variate	13.26	-	19.29	-	5.86	-	-	-	-	-	-	-	
% Overall Gain	49.12	14.17	0.00	31.90	0.00	1.18	0.00	0.00	0.00	-0.93	1.75	2.81	3.05
Genetic Gain	0.03	0.42	1.20	0.06	0.07	0.15	0.00	0.01	0.00	0.17	0.02	0.07	

traits were largely unaltered, while the value of overall gain increased slightly due to the additional gains of Co and T being taken into account.

The analysis was repeated for the reduced index of NLW (dam), HBW and HGFW. In this situation, Co and T were included in the objective, but not the index. Similar results to the full index were obtained (Tables 5.39 and 5.40).

5.3.6 Sheeplan comparison

A final sensitivity analysis was conducted by comparing the current Sheeplan index (Clarke and Rae, 1976, 1977) with an equivalent index calculated using the economic weight estimates from Chapter 4. The two sets of economic weights used for the four traits involved (NLB/NLW, WW, EBW and GFW) were previously displayed in Table 4.6. Identical genetic and phenotypic data were used in the construction of both indices, with the exception that the phenotypic standard deviation for NLB in the Sheeplan index was 0.57, and for the alternative index, the phenotypic standard deviation for NLW was 0.65.

Table 5.41 illustrates the differences between the Sheeplan and alternative Sheeplan indices. It is shown that while the index weight assigned to HGFW has remained nearby the same (2.06 compared with 1.91), the weights of the remaining traits have been considerably reduced. The value in the index of NLW (dam) and HGFW have both been increased, while the value of WW and HBW have been lowered. Similarly, the proportion of overall gain attributable to NLW and GFW has been increased at the expense of WW. The greater emphasis placed on GFW was manifested in the increased genetic gain expected in that trait (0.04 kg to 0.06 kg). Conversely, the expected genetic gains in WW and EBW were reduced.

TABLE 5.41: SHEEPLAN COMPARISON[1]
(One record on NLW (dam)).

Variates in Objective	NLW	WW		GFW
Variates in Index	NLW (dam)	WW	HBW	HGFW
B-Value	27.54	3.16	5.28	2.06
	2.34	0.09	0.39	1.91
Value of Variate	11.18	2.89	18.12	0.03
	15.54	0.31	13.81	3.87
% Overall Gain	49.44	39.97	0.00	10.59
	55.27	16.33	0.00	28.39
Genetic Gain	0.03	0.57	1.38	0.04
	0.03	0.45	1.21	0.06

(1) Upper value = Sheeplan

Lower value = Alternative Sheeplan

5.4 DISCUSSION

The function of this chapter was to investigate the effectiveness of various traits as selection criteria (or predictors) for a given selection objective. To do this, it was necessary to select a genetic and phenotypic framework to work within. It is important therefore to appreciate that the results obtained are applicable only to that particular framework. Ideally, the parameters used need to be estimated from the population under selection. Economic considerations generally prevent this and demand that estimates from research flocks be used instead.

As outlined previously, the major requirement of a selection criterion is that it is readily and cheaply measured while contributing towards the prediction of the selection objective. Cost of measurement is often a limiting factor in deciding how many animals can be tested for every animal eventually selected. With ram selection, the costs incurred can often be recouped due to the potentially great number of progeny that a ram can produce. However, in the case of ewe selection, such costs can seldom be recovered, and hence accuracy must be compromised by consideration of economy and efficient time utilisation.

Currently, wool testing in New Zealand test houses is largely confined to auction lots and has seldom been extended to give measurements on individual animals suitable for animal breeding purposes. The costs involved at this stage of testing individuals in such laboratories would probably be prohibitive, unless it could provide off-peak work when there are few wool sales (New Zealand Wool Testing Authority, pers. comm). Alternatively, Lincoln College currently provides a wool testing service for sheep breeders.

The incorporation of measurement costs into the economic weight estimation of each trait has been suggested, but is generally not recommended (Miller and Pearson, 1979). It is argued that such costs are a function of the entire farming enterprise, rather than an attribute of individual animals, and hence should be accounted for by a systems analysis approach.

In the current analysis, NLW (dam) was shown to be of importance as a selection criteria. The reduction in overall genetic gain if NLW (dam) was omitted from the full index was 11.89% for the Greasy Short objective. Sheeplan (Clarke and Rae, 1976, 1977) originally used NLW (dam), but switched to NLB (dam) (number of lambs born (dam)) as input information was able to be processed earlier. At that time, there was also some suggestion that the heritability of NLB was greater than that of NLW, although existing heritability estimates of the two traits are similar (Wickham, pers. comm).

Although EBW was not initially included in the selection objective, HBW proved to be a most useful selection criterion. A reduction of 8.68% in overall gain was calculated for the Greasy Short objective, following omission of HBW from the full index. As traits were progressively omitted, HBW assumed further importance, gradually surpassing the value to the index of NLW (dam). In contrast, WW was of virtually no value at all as a selection criterion. Overall genetic gain was not influenced by the absence of WW from the index. However, commercial farmers often prefer to use WW as a selection criterion on the grounds that it is available earlier and is the only weight available to them that is not biased by prior selection (Rae, pers. comm.).

HGFW was eventually another useful criterion, particularly as a cost-efficient substitute for HCFW for the clean objectives. This is in agreement with Poggenpoeland van der Merwe (1975), Wickham (1981) and Rae (1982) who suggested that HCFW might be used for ram selection, where a high degree of accuracy was required, but HGFW was more generally applicable. The value of HGFW increased as other traits were deleted from the index (particularly SL), but it still ranked behind HBW and NLW (dam) in importance as a predictor.

The wool quality traits generally appear of limited value as selection criteria. Y however displayed some importance, but the measurement costs would generally outweight the extra benefits that could be derived by retaining Y in the selection index. The negative index weighting for CHG (i.e. selection against better CHG) is in agreement with the finding of Lewer (1978) for the Perendale. A similar result was obtained for Co when it was included in the long wool selection objectives and indices. These unexpected negative index weightings were attributed to correlated effects, i.e. a function of the chosen genetic and phenotypic framework. Although assigned a negative weighting, little genetic change was predicted in these traits.

On the basis of cost and value within the index, traits were deleted from the original full indices until a reduced index consisting of NLW (dam), HBW and HGFW was obtained. The loss in overall gain associated with these deletions was judged to be negligible, especially in comparison with the costs incurred to measure and record the deleted traits. In terms of accuracy and economy, the three-trait reduced index was considered to be suitable for commercial conditions. The reduced index is similar to that currently used by Sheeplan (Clarke and Rae, 1976, 1977), except WW is not included and a greater emphasis on wool production is evident.

Although the three-trait reduced index is recommended for most practical purposes, it is likely that some breeders will prefer an even simpler index. To cater for this possibility, several alternative indices were computed. As expected, these indices generated less overall genetic gain, but individual breeders may feel that they are more applicable to their particular requirements and/or preferences.

The deletion of HGFW greatly increased the value of HBW within the index. This response was attributed to the moderately high genetic correlation of 0.30 between the two traits. Sheeplan (Clarke and Rae, 1976, 1977) currently uses the same estimate. Whether or not this is the best estimate available is open to conjecture. Chopra (1978) and Blair (1981) reported estimates of 0.1 and 0.6 - 0.7 respectively.

The substitution of HGFW by SL produced an index which furnished nearly as much overall genetic gain. Such an index would obviously suit breeders who do not wish to weigh fleeces during the potentially hectic shearing operation. Alternatively, both HGFW and SL can be excluded, leaving a selection index of only NLW (dam) and HBW. This results in a further reduction in overall genetic gain.

NLW (dam) is sometimes regarded as a criterion which is time consuming and difficult to measure. Omitting NLW (dam) from the selection index produced reasonably large losses in overall genetic gain. However, individual breeders may still be willing to forgo such gain for the reduction in measurement offered by the exclusion of NLW (dam).

The efficiency of single-trait selection for HBW and HGFW was computed. HBW alone was a reasonably good predictor of the selection objective, whereas HGFW was less effective. Compared to the three-trait index of NLW (dam), HBW and HGFW for the Greasy Short objective; the value of the overall genetic gain was reduced from \$2.95 per standard deviation of selection on the index, to \$2.35 and \$1.81 respectively for HBW and HGFW. This result has direct implications for the New Zealand Wool Board's hogget fleece weighing scheme, where selection decisions are based purely on HGFW. Assuming that the selection objectives are similar, and the genetic and phenotypic parameters assumed are reasonably correct, the current findings suggest that the New Zealand Wool Board use HBW instead of HGFW, or preferably incorporate both HBW and HGFW into a selection index.

The sensitivity analyses, where the economic weights of selected traits (HBW, NLW, GFW (CFW) and SC) were deliberately altered, produced few changes of any consequence. This result was in agreement with previous sensitivity analyses and literature on the effect of errors in economic weights on the efficiency of selection indices (Chapter 2.5). On the basis of these findings, it can be reasonably concluded that changes in the economic climate will not seriously interfere with the ranking of animals generated by a particular selection index.

The selection of ewes for NLW, GFW (CFW) and WW generally produces a correlated increase in EBW. This may be associated with a greater ewe maintenance cost. The optimum EBW has often been debated, but is difficult to accurately define.

Restriction of all genetic change in EBW seriously influenced the calculated selection indices. The value of the overall genetic gain was substantially reduced from $3.19 per standard deviation of selection on the index to $2.19 for the Greasy Short objective. This finding was contrary to that of Cunningham and Gjedrem (1970) who found that EBW may be held constant (genetically), with only a negligible effect on the response of the aggregate genotype (overall gain). This discrepancy can be attributed to differences in the set of genetic and phenotypic parameters used. The correlations between HBW and other traits (notably WW) used in the current study were considerably higher than those assumed by Cunningham and Gjedrem. This is indicative of the wide variation which exists between estimates from different sources.

The results of the present study can only be interpreted within the genetic and phenotypic framework chosen. Extrapolation to alternative situations may be erroneous. The results obtained also suggest that further refinement may be required of multi-trait selection indices where component traits are highly correlated.

CHAPTER SIX
GENERAL DISCUSSION

The present study has defined selection objectives and appraised selection criteria for the Romney, with particular reference to wool traits. A simple production and marketing system involving a Romney breeding flock under North Island hill country conditions, where all surplus offspring are sold as lambs, was chosen. The relevance of the results obtained to alternative systems is questionable. Dickerson (1982) indicated that selection objectives changed with differing production and marketing systems for pork production.

The definition of an appropriate selection objective is of paramount importance to the success of any animal breeding programme. Long-term genetic progress will be greatest for breeders who are capable of defining objectives which maximise future profit and who consistently base their selection decisions on these objectives (Taylor *et al.*, 1980).

Clearly defined objectives for wool production have been lacking (Rae, 1974; Wickham, 1981, 1982; Morris *et al.*, 1982; Whiteley and Jackson, 1982). This has largely been a result of confusion concerning which wool traits are important during processing and in the end-product.

Although data from processing trials and manufacturing experience have been built-up (Chapter 2.3.3), the data are limited in their applicability. Technical knowledge is incomplete in certain areas. Even if a comprehensive set of trials could be conducted for the various levels of the traits over all combinations of possible processing methods and end-products the raw wool may be subjected to, the practical significance to the breeder would be restricted for the following reasons: -

(i) The breeder who offers his wool for sale on the open market (i.e. through the auction system) has no control over who purchases his product. Consequently when breeding his sheep, he has limited knowledge of how his wool is to be processed (whether or not it is blended) and the nature of the final product. Under such conditions of uncertainty, the breeder is advised to follow general guidelines and not try to meet the individual requirements of potential purchasers.

(ii) Although such trials give some indication of the importance of various traits, different traits influence processing in different ways. Hence, it is often difficult to compare one wool trait with another and it is even more difficult to compare wool and non-wool traits.

(iii) There is no guarantee that the trade will pay for the traits in relation to their processing importance. Given that the breeder's objective is to maximise profit, then he would be unjustified in changing his selection policies if he was not financially rewarded for doing so.

Unless the importance of the various wool traits during processing and in the end-product is clearly elucidated, and the trade pays for them accordingly, commercial breeders will largely continue to respond to the signals they receive from the market place.

The reliance on past prices alone to establish selection objectives is essentially unsatisfactory. The breeder has the formidable task of formulating selection plans which will not have their effect (and hence their financial return) until sometime in the future. The selection objective attempts to stabilise an inherently dynamic situation. Past prices alone can not furnish the breeder with a reliable predictive equation for the future. Changing economic conditions, improved appraisal and marketing systems, as well as technological and end-use developments will all contribute toward the need to have selection objectives periodically reviewed. Economic weights will need to be re-calculated and

and consideration of alternative traits may be necessary.

Several wool traits were not considered in the present study due to the lack of reliable price data. Of these, bulk is likely to be of most importance in the future. Some importance is now placed upon it by carpet manufacturers. However, whether or not it will be of relevance to the Romney is undecided. It has been predicted that low variation in bulk in the Romney (Carnaby and Elliott, 1980) may limit genetic progress.

Character has generally been shown to be of minor significance during processing and in the end-product (Chapter 2.2.3). Price data are still required to provide conclusive proof concerning its importance. When such information is forthcoming, assuming it confirms the processing trials already conducted, the futility of such selection should be obvious to those breeders who have in the past placed emphasis on character in their selection policies. The appraisal of suitable selection indices for the selection objectives previously defined for the Romney (Chapter 5), also illustrated character to be of minimal value as a selection criterion.

Crimp was not included in any selection objective, partly because of the lack of economic data and also it was considered to be a criterion for MFD, and not an objective in its own right.

In the absence of reliable price data, the importance of medullation in the Romney is also questionable. However, Rae (1982) and Ross *et al.* (1982) have suggested that there is little point in including medullation in a selection objective for the Romney.

Uniformity within the fleece has traditionally been selected for by many breeders. However, fibre diameter uniformity and fibre length uniformity have been shown to have relatively little value in processing (Chapter 2.2.3). Further, some fibre length variability is required for efficient processing.

The rather limited C.S.A.R. analyses (Chapter 3.3.3) failed to identify any significant influence on price by either fibre diameter variability or length variability. Selection for uniformity is thus not worthwhile and represents a waste of selection potential as previously suggested by Bottomley and Howe (1979), Rae (1982) and Whiteley and Jackson (1982).

As with many of the wool quality traits, there are insufficient economic data to consider meat quality traits in a selection objective. Even if reliable economic weights were calculated, they would probably be changing rapidly at present (Wickham, pers. comm.). As a consequence of increasing consumer resistance, the genetics of level of fatness has received considerable attention recently (Purchas, 1981).

Disease resistance and structural soundness are not easily incorporated into selection objectives. For this reason, they have usually been ignored when objectives have been defined (Morris *et al.*, 1982). It is generally assumed that the sheep under selection are thrifty and structurally sound, allowing selection to be based purely on productive performance. Thus, seriously diseased or unsound sheep should be carefully eliminated prior to index selection. There exists a possible danger of setting too high a culling level. A combination of appropriate independent culling levels and index selection should ensure that a check on the level of expression of such traits is maintained, while genetic progress in productive characteristics can be achieved.

Easy-care and hardiness characteristics are essential if hill-country breeders are to minimise costly shepherding and labour inputs. Again, there is a difficulty in including such attributes in a selection objective, thus natural selection and independent culling levels for these traits prior to index selection will be advantageous. As before, independent culling levels that are set too high may be detrimental.

A wide variety of alternative selection criteria have been or are currently under investigation and may assume importance in the future. Cockrem (1962) and Land (1981b) suggested that selection of animals on physiological criteria may improve the efficiency of selection by recognising genetically superior animals at an early age and avoiding the restriction placed on selection by sex-limited traits. Wikcham (1982) reviewed research on selection criteria for the early breeding of sheep including ovulation rate and the ability to lamb as a hogget (for fertility), wool follicle measurements (for fleece weight) and birthcoat characteristics (for fleece quality and, as discussed by McCutcheon *et al.* (1981), possibly for lamb survival). The Wool Research Organisation of New Zealand is currently investigating differences in the structure and protein composition of tender wools in an endeavour to select for soundness (W.R.O.N.Z., 1981). The development of the ultrasonic probe has provided a ready criterion for assessing levels of fatness. Campbell *et al.* (1981) discussed selection for facial eczema resistance and the search for a possible biochemical criterion. The adoption of new selection criteria will rest on their accuracy, simplicity and economy of prediction.

In conclusion, the methodology used in the current study to select superior sheep was based on productivity per head (gross income). It is apparent that the most productive sheep are not necessarily the most profitable. Unfortunately, a suitable methodology for selecting sheep for efficiency of production (net income) under New Zealand grazing conditions is lacking. Assuming that the major cost is that associated with pasture production and utilisation (Carter, 1982; Morris *et al.*, 1982), several difficulties are evident. For example, how can individual food intakes be accurately and economically measured under grazing conditions? Is body weight a reliable indicator of food intake as suggested by Ferguson (1956)? Can the overall profitability of an enterprise (including the effects of inflation and capital gains) be distinctly apportioned into profitability per individual, so that accurate selection decisions can be made on a per animal basis?

Until the appropriate methodology is developed, it will be impossible to base selection decisions directly upon efficiency. It seems likely then, that selection for increased productivity per head will remain as an indirect method of increasing efficiency of New Zealand sheep production within the immediate future.

A P P E N D I C E S

APPENDIX I

THE EFFECT OF LOT WEIGHT, MODE OF OFFERING AND NEW ZEALAND WOOL BOARD INTERVENTION ON PRICE.

A. LW Statistics (T)

	Season					
	76/77	77/78	78/79	79/80	80/81	All
Mean	1.92	1.91	1.92	2.06	2.20	2.01
S.D.	1.75	1.66	1.67	1.71	1.75	1.71

Examination of the mean LW suggests that over the last five wool-selling seasons, LW has been increasing. However, the size of the standard deviations precludes any definitive conclusion.

B. Effect on Greasy Price

	PARTIAL REGRESSION COEFFICIENTS (1)							% Control	
	Lot Weight	Mode of Offering (2)				Intervention (3)		Without	With
Season		R	B	I	GB	Pur.	Reoff.		
76/77	-0.04	-0.42	-0.32	0.65	0.09	-3.72	-	57.3	57.8
77/78	0.10	-0.16	-0.69	0.58	0.27	-0.71	-1.54	74.0	74.3
78/79	0.02	-0.26	-0.66	0.39	0.53	-8.46	-2.62	67.4	68.0
79/80	-0.03	-0.18	-0.12	0.21	0.09	-6.07	-3.03	69.3	70.6
80/81	-0.24	0.36	0.15	-0.43	-0.08	-6.74	-3.03	66.7	68.6
All	-0.04	-0.22	-0.30	0.29	0.24	-3.40	-2.04	66.00	66.6

(1) For model including Y, ML, S and MFD
Lot weight (c/kg/T), Others (c/kg compared with average of all wool sold)

(2) R = Reclassed B = Binned I = Interlotted GB = Grower's Brand

(3) Pur = Purchased by New Zealand Wool Board
Reoff = Reoffered by New Zealand Wool Board

C. Effect on Clean Price

	PARTIAL REGRESSION COEFFICIENTS[1]							% Control	
	Lot Weight	Mode of Offering				Intervention		Without	With
Season		R	B	I	GB	Pur.	Reoff.		
76/77	-0.03	-0.55	-0.48	0.86	0.18	-4.50	-	39.6	40.4
77/78	0.11	-0.22	-0.87	0.78	0.32	-1.01	-2.09	61.1	61.5
78/79	0.02	-0.32	-0.86	0.50	0.68	-10.75	-3.22	41.3	42.4
79/80	-0.03	-0.16	-0.27	0.33	0.10	-7.25	-3.78	40.1	42.2
80/81	-0.32	0.56	0.16	-0.59	-0.14	-8.63	-3.60	48.2	51.2
All	-0.05	-0.27	-0.42	0.39	0.31	-4.24	-2.54	45.1	45.9

(1) As for B

From B and C, it is demonstrated that the inclusion of terms for LW, MO and Int are of little use in predicting price, given that Y, ML, S and MFD are already present in the model.

Examination of the partial regression coefficients highlights the following points: -

1. LW had a variable effect, in terms of sign, from season to season, although the magnitudes of such effects was unimportant.

2. Reclassing attracted discounts of up to 0.42 c/kg greasy and 0.86 c/kg clean compared with the average of all wool sold, in all but one season. The implications to the wool grower are obvious, in that on top of escalating reclassing costs, the wool is being sold at a lower price.

3. Binning followed a similar pattern to reclassing, attracting discounts of up to 0.69 c/kg greasy and 0.87 c/kg clean, compared with the average of all wool sold, in all but one season.

4. Interlotting showed the opposite trend by attracting premiums of up to 0.65 c/kg greasy and 0.86 c/kg clean, compared with the average of all wool sold, in all but one season.

5. Growers own brand similarly attracted premiums of up to 0.53c/kg greasy and 0.68c/kg clean, compared with the average of all wool sold, in all but one season.

6. The New Zealand Wool Board market intervention policies have resulted in the Board;

   (i) puchasing wool at up to 8.46c/kg greasy and 10.75c/kg clean, less than the average of all wool sold.

(ii) selling reoffered wool at up to 3.02c/kg greasy and 3.78c/kg clean, less than the average of all wool sold.

A comparison of these estimates is complicated in that wool would have been bought by the New Zealand Wool Board on the basis of their appraiser's valuation, whereas reoffered wool purchased by others, would be on the basis of the buyer's own valuation. To determine whether or not the New Zealand Wool Board realises a financial profit from their market intervention policies, the effects of buying and selling on different markets (inflation, storage and handling costs, opportunity costs etc.) must be taken into account.

APPENDIX II

THE EFFECT OF LOT WEIGHT, (LOT WEIGHT)^2, MODE OF OFFERING AND MARKET INTERVENTION ON EXPLAINING PRICE VARIATION

A. Effect on Greasy Price Prediction

Season	% Control of Quadratic Model without LW, LW^2, MO and Int.	% Control of Quadratic Model with LW, LW^2, MO and Int.
76/77	63.5	64.1
77/78	77.5	77.7
78/79	70.7	71.2
79/80	73.5	74.6
80/81	77.1	78.2
All	71.2	71.6

B. Effect on Clean Price Prediction

Season	% Control of Quadratic Model without LW, LW^2, MO and Int.	% Control of Quadratic Model with LW, LW^2, MO and Int.
76/77	47.8	48.5
77/78	65.7	66.0
78/79	47.5	48.4
79/80	47.7	49.6
80/81	64.1	65.8
All	53.2	53.8

APPENDIX III

SALE-BY-SEPARATION ANALYSIS FOR THE 1980/81 SEASON

A. General Statistics

		All Wool (1)	Separation Wool
Original No. of records		36,949	2,752
No. of Records after Absorption		36,883	2,736
MFD (μm)	mean	35.86	35.67
	s.d.	1.58	1.69
S (grade)	mean	2.64	2.75
	s.d.	0.85	0.88
ML (mm)	mean	98.77	88.55
	s.d.	25.02	21.31
Y (%)	mean	77.73	77.61
	s.d.	3.18	3.32
SI	mean	1.38	1.28
	s.d.	0.63	0.63
CI	mean	2.41	2.57
	s.d.	0.85	0.91
F	mean	0.11	0.09
	s.d.	0.32	0.31
P	mean	0.12	0.17
	s.d.	0.35	0.44
Co	mean	0.05	0.02
	s.d.	0.22	0.19

Continued

A. Continued

		All Wool(1)	Separation Wool
T	mean	0.01	0.00
	s.d.	0.12	0.08
LV	mean	0.05	0.03
	s.d.	0.25	0.22
QV	mean	0.02	0.01
	s.d.	0.14	0.11
Greasy price (c/kg)	mean	266.67	259.30
	s.d.	14.53	15.73
Clean price (c/kg)	mean	343.10	334.24
	s.d.	15.09	15.98
Lot Weight (T)	mean	2.20	2.80
	s.d.	1.75	1.84

(1) Includes sale-by-separation wool

From the above table it may be argued that the wool offered by sale-by-separation was slightly poorer in style and colour, and shorter in length than all wool sold in the same season. These and other differences in wool traits were not great and were associated with large standard deviations. Sale-by-separation wool was however, offered in larger lot weights (a result of the minimum lot size required) and received lower prices.

B. Partial Regression Coefficients[1] on Greasy Price

												% Control	
Y	ML	S	MFD	SI	CI	F	P	Co	T	LV	QV	Sepn.	All
3.09	4.29	-6.97	-0.73									73.0	66.7
3.13	4.30	-5.16	-0.76	0.06	-2.21	1.16	-0.79	3.03	2.49	1.74	-0.41	73.8	67.0
+	+	+										72.4	64.8
3.10	4.20	-5.13		0.30	-2.20	0.83	-0.81	2.78	2.65	1.47	-0.36	73.2	65.2
+	+		+									57.8	60.3
3.18	4.34		-0.75	-0.91	-6.18	0.59	-1.11	1.10	1.56	1.86	-0.23	71.5	65.6
+		+	+									50.5	44.5
2.79		-5.61	-0.16	0.51	-1.31	2.17	-1.68	4.50	3.22	1.07	-1.14	51.5	45.2
	+	+	+									31.9	27.0
	3.43	-6.62	-0.23	-1.32	-0.89	-1.20	-1.29	-0.54	7.04	-1.06	-3.35	32.6	27.9

(1) Y (c/kg/%), ML (c/kg/0.5 in), S (c/kg/grade), MFD (c/kg/μm), SI (c/kg/grade), CI (c/kg/grade), Others (c/kg)

C. Partial Regression Coefficients[1] on Clean Price

												% Control	
Y	ML	S	MFD	SI	CI	F	P	Co	T	LV	QV	Sepn.	All
-0.31	5.51	-8.79	-0.93									57.9	48.2
-0.25	5.52	-6.43	-0.97	0.00	-2.83	1.38	1.09	3.62	3.03	1.98	-0.68	59.1	48.6
+	+	+										56.9	45.2
-0.30	5.39	-6.40		0.31	-2.81	0.96	-1.12	3.31	3.23	1.63	-0.62	58.1	45.8
+	+		+									34.5	38.6
-0.19	5.57		-0.95	-1.20	-7.78	0.67	-1.49	1.21	1.87	2.13	-0.46	55.7	46.7
+		+	+									22.0	14.1
-0.70		-7.02	-0.19	0.58	-1.68	2.68	-2.24	5.50	3.97	1.12	-0.34	23.5	15.2
	+	+	+									57.5	46.5
	5.59	-6.31	-1.01	0.11	-2.94	1.57	-1.05	3.91	2.66	2.21	-0.45	58.9	47.1

(1) As for B

Comparisons of B and C with Tables 21 and 22 respectively, indicates a similar pattern occurring in both categories. Trends were however, amplified in the sale-by-separation analysis. For example, more control over price was achieved in all cases and the partial regression co-efficients were greater in magnitude. A notable exception to the latter was MFD, which had a smaller coefficient for the sale-by-separation analysis.

APPENDIX IV

NORTH ISLAND HILL COUNTRY DATA

A. Production and Income Data

	Season					
	76/77	77/78	78/79	79/80	80/81	Mean
1.						
Lambing % (No. lambs tailed / Ewes mated)	96.1	90.5	93.2			93.3
Lamb losses (% lambs marked)	4.8	4.7	4.7			4.7
Sheep losses (% sheep)	5.4	5.0	4.9			5.1
2.						
Export lambs sold	803	755	795			784
Store lambs sold	169	201	169			180
Ratio (Export : Store)	4.7:1	3.7:1	4.7:1			4.3:1
Average return for Export lambs ($)	13.01	11.73	15.39	16.45[a]	17.82[a]	14.88
Average return for Store lambs ($)	11.33	8.90	14.40	13.94[b]	15.10[b]	12.73
Average return for Mixed age ewes ($)	11.81	8.69	10.57	13.25[c]	12.84[c]	11.43
3.						
Average Export lamb Carcass Weight (kg)	13.35	12.85	13.28	13.61	13.12	13.24
4.						
Lamb dressing %						47.00
Ewe dressing %						45.00
5.						
Average greasy wool Price (c/kg)	219.58	190.43	218.80	265.09	247.48	228.28

Sources of data:

1. N.Z.M.W.B.E.S. (1978a, 1979a, 1980a)
2. N.Z.M.W.B.E.S. (1979b, 1980b, 1981b)
3. N.Z.M.W.B.E.S. (1977c, 1978c, 1979c, 1980c, 1981c)
4. Morris *et al.* (1982)
5. N.Z.W.B. (1976/77, 1977/78, 1978/79, 1979/80, 1980/81)

a. M.A.F. (1979/80, 1980/81) (farm gate price for PM lamb)

b. Store return = 0.847 x export return (based on average store-export relationship from 1976/77 to 1978/79).

c. M.A.F. (1979/80, 1980/81) (farm gate price for ML1 mutton).

B. Food Related Variable Costs

	Season					
	76/77	77/78	78/79	79/80[1]	80/81[1]	Mean
Fertiliser, lime and seeds ($/s.u.)	0.95	1.37	1.52	2.63	3.99	2.09
Feed and Grazing ($/s.u.)	0.11	0.17	0.16	0.19	0.19	0.16
Animal health, weed and pest control ($/s.u.)	0.45	0.46	0.58	0.64	0.74	0.57
Rates ($/s.u.)	0.26	0.29	0.34	0.39	0.48	0.35
Total ($/s.u.)	1.77	2.29	2.60	3.85	5.40	3.17

Source: N.Z.M.W.B.E.S. (1978a, 1979a, 1980a)

1. Costs calculated from previous season with adjustment for price movements (Brook, 1981).

	79/80	80/81
Fertiliser, lime and seeds	72.8%	51.7%
Feed and grazing	18.1%	0.2%
Animal health, weed and pest control	9.9%	16.2%
Rates	16.0%	23.7%

(N.B. These itemised movements are for the All-Classes category and not N.I. Hill Country. The overall price movement of the two classes is similar).

Due to the lack of reliable estimates, no account is made of labour, vehicles/power, fencing and maintenance. It is assumed that interest on fixed liabilities is compensated for by capital gains.

APPENDIX V

THE EFFECT OF COTTING ON GREASY PRICE

Using the New Zealand Wool Board Statistical Handbooks for the five wool-selling seasons from 1976/77 to 1980/81, the effect of Co on greasy price in the 33 - 40μm MFD range was investigated.

Season	Category	Average Greasy Price	Average Discount
		c/kg	c/kg
76/77	FF	247.85	
	SC	220.93	26.92
	HC	209.60	38.25
77/78	FF	213.30	
	SC	185.03	28.27
	HC	185.43	27.87
78/79	FF	228.12	
	SC	218.67	9.45
	HC	208.70	19.42
79/80	FF	291.40	
	SC	262.32	29.08
	HC	254.50	36.90
80/81	FF	269.97	
	SC	236.95	33.02
	HC	224.13	45.84

FF = Full Fleece, SC = Soft Cott, HC = Hard Cott

Hence, the mean discount over the five seasons considered was 25.35 c/kg for soft cotts and 33.66 c/kg for hard cotts.

APPENDIX VI

THE EFFECT OF TENDERNESS ON GREASY PRICE

Using the New Zealand Wool Board Statistical Handbooks for the five wool-selling seasons from 1976/77 to 1980/81, the effect of T on greasy price in the 33 - 40 μm MFD range was investigated.

Season	Category	Average Greasy Price	Average Discount
		c/kg	c/kg
76/77	FF	247.85	
	T	223.96	23.89
77/78	FF	213.30	
	T	186.56	26.74
78/79	FF	228.12	
	T	227.53	0.59
79/80	FF	291.40	
	T	277.82	13.58
80/81	FF	269.97	
	T	262.42	7.55

FF = Full fleece, T = Tender

Hence, the mean discount over the five seasons considered was 14.47 c/kg.

APPENDIX VII

UNDERLYING PRODUCTIVITY ASSUMPTIONS AND CALCULATIONS

Unless stated otherwise, basic data is from Appendix IV.

1. Number of Matings per Lifetime

Assuming there are four age groups in the flock and a mortality rate of 5.1%, the proportion of two-tooths in the flock

$$= \frac{1}{1 + 0.949 + 0.901 + 0.855}$$

$$= 0.27\ (27\%)$$

Hence, the number of matings per lifetime

$$= \frac{1}{0.27}$$

$$= 3.70$$

2. Average Value of Lambs Sold

Given an export : store lamb ratio of 4.3 : 1, and an average return of $14.88 for export lambs and $12.73 for store lambs, the average value of lambs sold.

$$= \frac{(14.88 \times 4.3) + (12.73 \times 1.0)}{5.3}$$

$$= \$14.47$$

3. Value of an Extra Lamb

The value of an extra lamb was calculated in a similar way to Cunningham and Gjedrem (1970) by accounting for the detrimental effects of twin births on lamb value.

Single	80% export	0.80 x $14.88
	+ 20% store	+ 0.20 x $12.73
		$14.45
Twin	40% export	0.40 x $14.88
	+ 60% store	+ 0.60 x $12.73
		$13.59 x 2 = $27.18

The value of an extra lamb is

$27.18 - $14.45 = $12.73

Other costs involved with rearing twins, compared with singles, have been ignored. These incluse the extra feed costs of the ewe which will depend on seasonal conditions, the greater period of time twins may be kept on the farm and the greater drenching costs associated with more lambs.

4. Average Annual Fleece Weight per Lifetime

The average annual fleece weight per lifetime was calculated from production data presented by Dalton and Rae (1978).

Category	Annual Wool Production		Times Shorn	Total Wool Production	Time in Category
	Range	Mean			
	kg	kg		kg	months
Lamb	0.85-1.70	1.27	1	1.27	5
Hogget	2.70-4.20	3.45	1	3.45	10
Mature	3.50-5.40	4.45	4	17.80	48
Total				22.52	63

Hence, the average annual fleece weight per lifetime is,

$$\frac{22.52}{63} \times 12 = 4.29 \text{ kg}$$

It is assumed that the production data from Dalton and Rae (1978) for research flocks is applicable to commercial conditions. Examination of N.Z.M.W.B.E.S. (1979b, 1980b, 1981b) suggest that they do correspond. It is further assumed that the value per kg of the wool from the different age categories is equivalent.

5. Total Annual Expressions of Fleece Production

Years of fleece production up to final lambing

= 3.70 matings + 1
= 4.70

Plus, production from final lambing to culling

= 0.5

Plus, accreditation of production from culled ewe hoggets.

$$= \frac{(0.5 \times 0.89 - 0.27)}{0.27} \quad \text{(See 6 for 0.89)}$$

= 0.65

Total annual expressions of fleece production

= 4.70 + 0.50 + 0.65

= 5.85

6. Lamb Production per Lifetime

Given a lambing % of 93.3% and a mortality rate of 4.7%, the percentage of lambs weaned

= 93.3 x 0.953

= 88.9% or 0.89 lambs per year

On a lifetime basis, the number of lambs weaned

= 3.70 x 0.89

= 3.29

Less on replacement

= 2.29

7. Ewe Marginal Food Cost

Given a ewe body weight of 55 kg, and assuming maintenance requirements are proportional to (body weight)$^{0.75}$, then a 1 kg increase in ewe body weight produces an increase in maintenance costs of

$$\frac{(56)^{0.75} - (55)^{0.75}}{(55)^{0.75}} = 1.34\%$$

Food related variable costs = \$3.17/s.u./year
Therefore, the increased costs per kg = \$3.17 x 1.34%
= \$0.0425

Expressing this on a lifetime basis gives a ewe marginal lifetime food cost per kg body weight of

\$0.0425 x 4.70 = \$0.20

APPENDIX VIII

ALTERNATIVE ASSUMPTIONS AND CALCULATIONS FOR EWE BODY WEIGHT

1. Given a mean export mutton carcass weight of 19.35 kg (N.Z.M.W.B.E.S., 1977c, 1978c, 1979c, 1980c, 1981c) and an average return for mixed-aged ewes of \$11.43, the returns per kg carcass weight

$$= \frac{\$11.43}{19.35\text{kg}}$$

$$= \$0.59/\text{kg}$$

Assuming a dressing % of 45%, a 1 kg increase in live weight produces a 0.45 kg increase in carcass weight. Therefore, returns from a 1 kg increase in live weight are increased by

$$0.45 \times 0.59 = \$0.26/\text{kg}$$

2. Increasing live weight by 1 kg produces a 1.34% increase in food related costs. It may be assumed that this leads to a decrease in stocking rate of 1.34% of a stock unit, if there is no extra feed available in the system.

Average net farm income for the North Island Hill country farm class was \$6.17/s.u. for the seasons 1976/77 to 1978/79 (N.Z.M.W.B.E.S., 1978a, 1979a, 1980a). Hence, the reduction in net farm income

$$= \$6.17 \times 1.34\%$$

$$= \$0.083$$

APPENDIX IX

SELECTION OBJECTIVE EQUATIONS

The equations defining the six selection objectives can be written as: -

Greasy Short = 47.10 NLW + 1.03 WW + 13.34 GFW
+0.68 Y + 0.84 ML - 1.41 SC

Greasy Long = 47.10 NLW + 1.03 WW + 13.34 GFW
+0.73 Y + 0.19 ML - 0.88 SC - 0.13 MFD

Greasy All = 47.10 NLW + 1.03 WW + 13.34 GFW
+0.68 Y + 0.68 ML - 1.41 SC

Clean Short = 47.10 NLW + 1.03 WW + 16.98 CFW
+1.08 ML - 1.72 SC

Clean Long = 47.10 NLW + 1.03 WW + 17.40 CFW
+0.24 ML - 1.10 SC - 0.16 MFD

Clean All = 47.10 NLW + 1.03 WW + 16.98 CFW
+0.87 ML - 1.72 SC

APPENDIX X

GENETIC AND PHENOTYPIC PARAMETERS

Traits	Phenotypic S.D.	Heritabilities and Correlations[1]												
		NLW	WW	HBW	HCFW	HGFW	Y	SL	SC	MFD	QN	CHG	Co	T
NLW[2]	0.65 (lamb)	0.10	0.12	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00
WW	3.00 (kg)	0.12	0.20	0.70	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HBW	4.50 (kg)	0.15	0.50	0.35	0.30	0.30	0.00	0.20	0.00	0.05	0.10	0.00	0.15	0.20
HCFW	0.40 (kg)	0.00	0.30	0.40	0.25	0.90	0.00	0.50	0.00	0.50	-0.30	0.00	0.40	0.60
HGFW	0.45 (kg)	0.00	0.30	0.40	0.90	0.25	0.00	0.40	0.00	0.40	-0.20	0.00	0.40	0.60
Y	4.00 (%)	0.00	0.00	0.00	0.40	0.15	0.30	0.20	0.00	0.30	-0.50	0.00	0.10	0.20
SL	1.70 (cm)	0.05	0.10	0.30	0.50	0.45	0.25	0.35	0.00	0.50	-0.60	0.00	0.00	0.40
SC	0.94 (grade)[3]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.20	0.20	0.20	0.30	-0.20
MFD	2.70 (μ)	0.10	0.15	0.20	0.50	0.45	0.30	0.40	0.20	0.50	-0.40	0.00	0.60	0.40
QN	1.75 (QN grade)	0.00	-0.05	-0.05	-0.35	-0.25	-0.40	-0.55	0.20	-0.40	0.35	0.50	0.50	-0.20
CHG	1.10 (grade)[4]	0.00	0.00	0.00	0.05	0.10	0.00	0.00	0.10	0.00	0.35	0.25	0.50	0.00
Co	0.50 (grade)[4]	0.00	0.00	0.15	0.20	0.20	0.00	0.00	0.20	0.20	0.20	0.20	0.15	0.20
T	1.20 (grade)[4]	0.00	0.00	0.20	0.30	0.30	0.00	0.30	0.10	0.20	-0.10	0.00	0.15	0.10

1. Genetic above
   Phenotypic below
   h^2 on diagonal
2. Repeatability = 0.15
3. New Zealand Wool Board 1 to 4 grade
4. Massey University 1 to 9 grade

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