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TITLE: A COMPARISON OF INITIAL STOCKINGS (SELECTION RATIO) OF 850 SERIES SEED ORCHARD SEEDLOT (GF13) IN TRIAL RO972, COMPARTMENT 123, ROTOEHU FOREST

AUTHOR(S): PIERS MACLAREN, MARK KIMBERLEY **DATE:** 6.7.90

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ABSTRACT*

A Rotoehu trial, planted in 1970 with genetically improved stock (GF 13), yielded the following results (when adjusted for bias due to microsite):

* There was a statistically significant trend in 1989 stumpage value with increasing selection intensity, the highest selection ratio tested (6:1) being worth $4000 more than planting at final stockings.

* Total volume and pruned volume were significantly affected by selection ratio (a difference between the extremes of 57 and 30 m^3/ha), but DBH was independent of it. In fact, the DBH at lower selection ratios was not inferior to that at higher selection ratios.

* Volume differences noted above can therefore be attributed solely to mean top height: there was a site index differential of 1.5 m between selection extremes.

* Value differences noted above can be attributed to both volume and straightness. The straightness of both the unpruned logs and the pruned butts was significantly improved with increasing selection.

"Routine" genetic stock (ie felling select) was significantly less valuable (by $3700/ha) than 850 stock at the same 6:1 selection ratio, had a DBH 1.8 cm smaller, 1.3 m lower mean top height, 50 m^3/ha less total volume and was significantly inferior in terms of straightness. Pruned volume differences, however, were not significantly different (although 13 m^3/ha less). 850 stock at a selection ratio of 1.1:1 was equivalent in stumpage value to felling select stock at a 6:1 selection ratio.

The cuttings were significantly worse in nearly all features examined, but this was no doubt due to the physiological age and poor type of stock used, and also perhaps to damage by mammalian pests through enhanced palatability.

The volume of internodal logs was small (c. 7m^3/ha) and indistinguishable between treatments.

*** Note: This material is unpublished and must not be cited as a literature reference**

FRI Project Record No. 2501

A COMPARISON OF INITIAL STOCKINGS (SELECTION RATIO) OF 850 SERIES SEED ORCHARD SEEDLOT (GF 13) IN TRIAL R972, CMPT 123, ROTOEHU FOREST

P.Maclaren

Report No.2?

June 1990

FRI/INDUSTRY RESEARCH COOPERATIVES

EXECUTIVE SUMMARY

A COMPARISON OF INITIAL STOCKINGS
(SELECTION RATIO)
OF 850 SERIES SEED ORCHARD SEEDLOT (GF 13)
IN TRIAL R972, CMPT 123, ROTOEHU FOREST

Piers Maclaren
Mark Kimberley

REPORT NO. 2? JUNE 1990

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The volume of internodal logs was small (c. 7m^3/ha) and indistinguishable between treatments.

BACKGROUND

Trial R972 was established in 1970 at Compartment 123, Rotoehu Forest, by Ryde James. Its main purpose was to examine initial stocking, or selection ratio, using genetically improved material. To this end, 0.2 ha plots were planted using selection ratios of 1:1, 2:1, 3:1, 4:1, 5:1 and 6:1. The final stocking in all cases was 250 stems/ha, achieved in 1977. Trees were pruned to 5.9 m. There are two replicates of each treatment.

As a comparison, there are two replicates of "routine" genetic stock at the 6:1 ratio, and also two replicates of cutting material at the 3:1 ratio.

In order to examine the effect of site on selection ratio, several "step-outs" of this trial were established elsewhere. Due to lack of resources, these have not been examined as part of this project. Further details of R972, and of the step-outs, are given in Appendix 1.

The trial has been well maintained and has suffered little mortality. Measurement has been regular and thorough, and has been undertaken in recent years by the Mensuration and Management Systems research field.

Previous studies

1. James, R.N., 1979. The influence of tree breeding and stocking rate on tree crop quality. NZ J. For. 24 (2): 230-40.

James presents results from a 1977 assessment of tree quality in R972, and concludes that "only four to six times the final crop stocking need be established for a direct regime". Regarding tree breed, he states that "the quality of the routine crop approximates that of crops derived from seed orchard seed but planted at only 500 to 750 stems/ha" (as opposed to 1500 stems/ha of routine stock actually planted). Neither was early selection effective, with the percentage of final crop trees correctly identified at low and medium pruning being, on average, 55% and 73%.

James "hoped that this trial will refute the earlier claims ... that seed orchard seed are no better (or even that they are worse) than trees from routine sources". As a part of this refutation he referred to a statistical difference in diameter growth rate.

His analysis involved the meticulous measurement or assessment of various characteristics of stem quality, but no attempt was made to quantify these in terms of economic importance.

2. Moore, S., Carson, M.J. and C.S. Inglis, 1987. Implications of planting improved radiata breeds at reduced initial stockings. FRI project record 1560, unpublished.

The conclusions of this later study differ from those of James. Moore et al declare that "ratios of 3:1 or less should be adequate when using trees of "850" or "268" series seed orchard origin". Other trials, including the R972 step-outs, influenced these conclusions. Like James' earlier study, their analysis was based on estimations of "% acceptable stems", and no attempt was made to quantify this in terms of volumes of log grades of various qualities, let alone revenue at harvest.

Planting stock used

1. The genetically improved stock. This was an early '850' selection from Gwavas seed orchard. The orchard had been in operation for only 10 years, and therefore it can be assumed that much of the pollen would have been from external (ie unimproved) sources. Moreover, the orchard had yet not been fully "rogued" as a result of information obtained from progeny tests. 11/2/0 stock was used of Wn/68/A1 Block 14 WO 4. An approximate rating would be GF 13.

2. The "routine" stock. This was also 11/2/0, but from R/67/795 Block 13 WO 4. It was from a 3600 kg seedlot obtained from selected trees felled in advance of harvesting operations throughout a number of compartments in Kaingaroa State Forest. An approximate rating would be GF 4.

3. The cutting stock. This is <u>not</u> indicative of the material that is being advocated by some researchers for use today, although material of similar physiological age has been used in plantations. No details are available, but it was apparently from older ortets (8-9?) of uncertain breed (probably unselected) (James, pers.comm.), and incurred various problems both in the nursery and at establishment. A rabbit-proof fence was erected to attempt to control the damage, which reportedly involved the leaders of "every single plant" (James, pers. comm.).

Acknowledgements

P.F.Olsen Ltd contributed the services of Jeff Nicholls, an experienced and very competent MARVL assessor. NZ Timberlands supported P.F.Olsen in their contribution. Mark Kimberley did the statistical analysis, Mike Carson provided the initiative and encouragement, and of course Ryde James established the trial in the first instance and provided access to raw data from earlier assessments.

METHODS

MARVL assessment

Every tree in every plot was assessed by the use of MARVL (Method for the Assessment of Recoverable Volume by Log types. Deadman and Goulding, 1978; Manley, Goulding and Lawrence, 1987). This technique classifies each section of a stem according to clearly defined quality codes, and the stem is subsequently "sawn" into logs by a computer programme, in such a way that value is maximised.

For MARVL to be a precise and effective tool, it is important to assess trees consistently, and to select an appropriate cutting strategy.

In this project, assessment of each tree was obtained by consensus of two experienced MARVL assessors (the author and J.Nicholls) and if there was bias, then it can be assumed to apply equally to all treatments.

A "cutting strategy" defines the required attributes for each log grade (minimum and maximum length, small-end diameter, large-end diameter) and gives each log grade a price. For many purposes, the prices need not be precise so long as the relative price between log grades is roughly correct. The cutting strategies used in this study are given in Appendix 4 and 5 and the associated quality code dictionary in Appendix 6.

The strategy used in Appendix 5 is one designed to distinguish the proportion of straight logs in the pruned and unpruned element, although in reality the market may not pay a premium for the minor differences in straightness identified here.

It is not necessary in a MARVL assessment to measure the height of every tree. This is a very time-consuming operation, therefore only sufficient height trees are measured to generate a Pettersen Height Curve so that heights of unmeasured trees can be estimated from their diameters. In this case, no heights were measured by the author as there was a sufficient quantity of reliable data available from a recent routine re-measurement.

Computer programmes used were: data from the VAX PSP system, micro-MARVL version 2.0, Genstat 5, Excel and Harvard Graphics.

Statistical analysis

A simple linear regression was used for most variables tested, with a logistic regression for straightness ratios, and a logarithmic transformation for selection ratio. Early measurements were used as covariates to examine height and diameter changes in greater detail.

CALCULATIONS

The raw results (height, diameter, and MARVL predictions) are given in Appendix 2.

Examination of residuals after regression fitting showed a systematic fertility trend across the trial for both DBH and height, and consequently for volume and value. An example of this is in Appendix 3, for which DBH residuals are given. Compensation for this effect took the form of introducing two dummy variables, representing the X and Y co-ordinates of the trial. Previous workers (Moore et al, 1987) had identified this complication but did not quantify the effects of it on their results.

Results smoothed by regression techniques, including the use of the dummy variables, are given in Tables 1 and 2, and Appendices 8 to 13.

Selection ratio

TABLE 1

Predicted values for different selection ratios.

Sel. ratio	$/ha 1989	Total vol	Pruned vol	MTH 1989	Mean DBH	Ratio A	Ratio B
1	13544	340	116	32.9	45.1	0.74	0.70
2	15074	362	127	33.5	45.2	0.84	0.80
3	15969	375	134	33.9	45.2	0.89	0.84
4	16604	384	139	34.1	45.2	0.91	0.87
5	17097	391	143	34.3	45.3	0.93	0.89
6	17500	397	146	34.5	45.3	0.94	0.90
Signif	**	**	*	**	N.S.	**	*
R sq.	0.59	0.58	0.56	0.91	0.59	0.70	0.59

Explanation of terms:

Sel. ratio. This is the initial stocking divided by the final stocking (250 stems/ha in all cases).

$/ha. This is the stumpage value, given the price assumptions and specifications for each log grade in Appendix 4.

Total vol. The total merchantable volume per hectare, given the assumptions in Appendix 4, and given the assumptions implicit in the volume and taper functions used.

Pruned vol. The total volume that is classified as P1 or

P2 logs (as in Appendix 4). Some pruned logs did not meet the specifications set for straightness, and were downgraded to pulp.

MTH. The mean top height (mean height of 100 stems/ha with largest DBH) as estimated from a Petterson Equation derived from data obtained in July 1989.

Ratio A. This is the ratio of good pruned logs (straight, round, no scars) to total pruned logs by volume as determined by the criteria in Appendix 5.

Ratio B. This is the ratio of straight unpruned logs to total unpruned logs by volume as in Appendix 5.

Signif. The statistical significance, or non-significance (N.S.), of the trend at the 5% level (*) or the 1% level (**).

R sq. The coefficient of determination, ie the proportion of variation explained by the regression equation. In the case of Ratio A and B a logistic regression was used, and the number represents the proportion of deviance explained.

Planting stock

TABLE 2

Predicted values for cuttings and "routine" seedlings

Stock (rat)	$/ha	Total vol	Pruned vol	MTH	Mean DBH	Ratio A	Ratio B
R (6)	13834	347	133	33.2	43.5	0.74	0.73
Signif	**	**	N.S.	**	*	**	*
C (3)	11549	316	103	32.2	41.6	0.72	0.70
Signif	**	**	**	**	**	*	N.S.

Explanations:

Stock (rat). The planting stock used, routine (R) and cuttings (C). The number in brackets is the selection ratio used, so that comparisons can be made with the appropriate box in Table 1.

Signif. The statistical significance, or non-significance (N.S.), at the 5% level (*) and the 1% level (**) of the difference between the given planting stock and the equivalent selection ratio of 850 stock. In all cases the routine stock and the cuttings are inferior to 850.

Early differences in DBH, Height

Diameter at breast height was recorded in 1977, immediately after thinning. In view of the discovery that there is no DBH difference in 1989 due to selection ratio, but there is a marked one due to planting stock, it may be instructive to observe the situation immediately after thinning. Table 3 gives the post-thinning situation with respect to diameter:

TABLE 3

Smoothed DBH measurements for 1977

Treatment	DBH 77	Signif.
1:1	19.26	N.S.
2:1	19.32	
3:1	19.36	
4:1	19.38	
5:1	19.40	
6:1	19.42	
R (6:1)	18.55	N.S.
C (3:1)	17.03	**

Unfortunately, no height measurements were recorded immediately after thinning. Table 4 gives the data for 1980, being the first year after thinning for which measurements are available.

TABLE 4

Smoothed MTH measurements for 1980

Treatment	MTH 80	Signif.
1:1	17.90	*
2:1	18.41	
3:1	18.71	
4:1	18.92	
5:1	19.08	
6:1	19.22	
R (6:1)	18.50	N.S.
C (3:1)	18.86	N.S.

Internodal logs

Internodal logs were defined as "sections of the tree that have greater than 60% of the length in straight internodes of 60 cm or greater; minimum length is 3.7 m and minimum small end diameter is 30 mm".

Concern has been expressed about the tendency of the Growth and Form (GF) Breed to have an increased number of whorls in a tree and thereby a reduction in the clearwood derived from the unpruned element. Be that as it may, in this study internodal logs (as distinct from yield of clearcuttings from ordinary unpruned logs) are a minor part of the total volume, and are probably not worth segregating out on the skid site. This is true for all treatments, including the unimproved "felling select" seedlot.

At a 6:1 selection ratio, internodal log volume was 4.9 m^3/ha in the 850 stock, representing only 1.2% of the total volume. At a comparable selection ratio, routine stock was predicted to yield 5.4 m^3/ha and cuttings 7.4 m^3/ha - not significantly different.

DISCUSSION

The selection process

James (1979) states the criteria that were used to determine selection. Trees were chosen according to these priorities:

1. Stem straightness.
2. Vigour. This is defined in terms of crown class (ie dominant, codominant, subdominant and suppressed).
3. Condition of the leader.

Spacing was not specifically mentioned as a criterion, although this was clearly important.

Given James' criteria, we would expect that there would be a noticeable difference in straightness today, especially in those logs that were formed by 1977. The trees were approximately 12 m tall in 1977.

This is indeed the case, as Table 1 indicates. There is a distinct difference in the proportion of straight material, both in the pruned butt logs (pruned height 6 m) and in the unpruned logs (6 m to 34 m).

"Vigour" was the next stated criterion for selection, and we should therefore expect to find evidence of this in the measurements that occurred immediately after final thinning. This is not the case for diameter growth. In Table 3 there was no statistically significant difference in 1977 diameter with selection ratio, and the observed difference between mean diameters of selection extremes was in fact less than 2 mm.

With respect to height, Table 4 indicates a (significant) height difference in 1980 with selection intensity and a range of 1.32 m between extremes of selection. This difference, however, is not primarily due to the last two selections. Covariance analysis of the 1980 data indicates that the variance can be largely explained by the 1975 differences. Analysis of heights taken in 1975, immediately after the first thinning, show a significant difference with selection, and a range of 1.04 m.

It is possible to state, therefore, that despite vigour being one of the explicit selection criteria there was no evidence that the vigour of the crop was improved with increasing selection, at least with respect to the final two selections. It is also possible that most of the 1.04 m difference recorded after the first selection could be the result of mutual protection afforded by higher initial stockings, rather than by selection per se (Maclaren, unpub. data). West et al (1987) show that, at a MTH of 7.8 m, we could expect an increase of 0.45 m due to selection of the best 250 stems from 1500 stems. There may be no corresponding diameter increase, because the marked effect of stocking on diameter may counteract any selection effect.

Nevertheless, the height differences recorded at the time of final selection have persisted, and have even increased. Covariance analysis of the 1989 data indicate that there is an effect present due to selection that cannot be explained by the 1980 differences (at the 1% level of confidence). They now represent a 1.6 m difference in site index between extremes, which has a marked influence on volume per hectare. On the other hand, the lack of diameter differences has persisted up to the present time.

The type of planting stock

1. 850 versus routine stock.

At the time of final thinning, 850 stock, although superior, was not significantly different from routine stock in DBH or height. But the disparity has increased over the intervening period and now there is a statistically significant difference (although the differences are not detectable unless site variation as in Appendix 3 is included). 850 stock has increased its DBH by 0.93 cm between 1977 and 1989 relative to routine stock.

Similarly, the difference in mean top height over the 12 years since final thinning has increased by at least half a metre, and probably by over one metre (uncertainty exists because height in 1977 must be interpolated).

The characteristic of 850 stock that is most pronounced is the improvement in straightness. This is not surprising in view of Thulin (1969), who stated that, in choosing the orchard material, there was "a high selection intensity for stem straightness, branching and absence of stem cones in the lower 18 m of the bole and a relatively low selection intensity for vigour".

In Table 1, the proportion of straight volume in routine stock was 0.74 (pruned butts) and 0.73 (unpruned). This is a sharp contrast to the equivalent treatments of 850 stock, which provided figures of 0.94 and 0.90.

There can be no hesitation, therefore, in endorsing James' early opinion that 850 genetic stock is definitely superior to routine stock. Moreover, we can affirm that this difference is not merely due to early growth, but - if anything - it increases with age. In terms of value, it appears that the selection intensity required for 850 stock in order to make it equivalent to a 6:1 selection for routine stock, is approximately 1.1:1, or a selection of 10 trees out of every eleven planted.

2. Cuttings versus seedlings.

It needs to be re-stated that the cutting material included in R972 is not in any way indicative of the material being advocated by most FRI scientists today. The purpose of including it in this analysis is because it is cost-effective to do so, and the information may be of some use to some future researcher.

The height of the cutting material was not significantly different from the equivalent selection ratio of 850 stock at the time of final thinning. On the other hand, DBH was 2.33 cm lower, which was highly significant.

Due to an oversight in trial maintenance, it appears that one of the cutting plots was not given its final pruning lift. (Pruned height for plot 5 averaged 4.5 m in contrast to the remaining trial mean of 5.9 m, and no other plot less than 5.5 m). This should have resulted in relatively enhanced diameter growth for this plot. Nevertheless, the cuttings continued to perform poorly, losing some further 1.27 cm in diameter growth relative to 850 and about 1.3 m in height growth. Its performance was worse than for routine stock at an equivalent selection ratio.

The cutting material could be expected to perform poorly in terms of growth in that it was derived from older ortets. But it was surprising to discover that the proportion of straight logs, both pruned and unpruned, was not obviously superior to that from routine stock. This could be attributable to browsing mammals (rabbits and possums), and possibly to increased wind damage, or else to lack of selection for straightness at the time of cutting collection.

<u>**Economic considerations**</u>

It is patently more expensive to grow stands with higher selection ratios, even if these high initial stockings yield a greater revenue at harvest. A comparison of the costs and benefits of selection ratio could be informative although interpretation will depend on:

* assumed silvicultural costs;
* assumed rate of time preference (discount or compound rate);
* assumed premium for straightness;
* assumed rotation length.

For this exercise, the regimes will be used that actually occurred in R972. Cheaper regimes could be devised, but cognizance should be taken of James' observations that early selection was relatively ineffective. Of the trees selected at final thinning, 73% were identified correctly at medium pruning and only 55% at early pruning.

Costs for these operations are derived from Lewis (1986) and not adjusted for inflation as the revenues were also derived for 1986.

Compound rates of 5%, 8% and 10% are assumed in order to straddle the range of rates likely to be used.

No premium for straightness is assumed. Provided that logs meet with the log-grade specifications in Appendix 4, their mean straightness is taken to make no difference in price. Moreover, it must be appreciated that MARVL is an assessment of the <u>external</u> characteristics of trees and pith deviation is likely to become hidden over time. James (1979) detected very great differences in stem straightness with selection ratio. For example, the 1:1 treatment had only 29% of trees recorded as straight (versus about 70% for this report). The treatment of sweep in this exercise, therefore, tends to favour lower selection ratios.

Rotation length is assumed to be 19 years. In practice, few silviculturalists advocate harvesting at this young age even if mean DBH is acceptable. This assumption is made because of practical difficulties in "growing on" (ie in the computer) the stand to age 28 or thereabouts. Developments in computer software may make this calculation easier and more reliable in future.

Cost assumptions are given in Appendix 7. They include only those costs which can be expected to vary with selection ratio.

Table 5 compares the costs and benefits of selection intensity at the two extremes of compound rate, 5% and 10%.

TABLE 5

A cost/benefit analysis of selection ratio
at 5% and 10% compound rates

Sel. ratio	Revenue	Compound costs @ 5 %	Compound costs @ 10 %	Diff. @ 5 %	Diff. @ 10 %
1	13544	1020	2006	12524	**11538**
2	15074	1818	3596	13256	11478
3	15969	2507	5004	13462	10965
4	16604	2820	5699	13784	10905
5	17097	3085	6297	14012	10800
6	17500	3360	6920	**14140**	10580

Two results are immediately apparent: first, a trade-off is occurring between the costs and benefits of selection ratio, so that there is no great difference in the end result. Second, choice of interest rate will affect the conclusions drawn. At a 10% compound rate, silvicultural costs adopt a greater importance and thereby lower selection ratios are favoured. Vice versa for 5% compound rate.

It is entirely possible that the silvicultural cost assumptions used here are inappropriate for some managers. It may therefore be useful to vary the costs and examine the sensitivity of "optimum" selection ratio to silvicultural costs. At the 5% discount rate, costs would have to be increased by 69% for the trend to be reversed. At the 10% costs would have to reduced by 20%.

At 8% compound rate, we get the somewhat confusing picture in Table 6:

TABLE 6

A cost/benefit analysis of selection ratio at 8% compound rate

Sel. ratio	Revenue	Compound costs @ 8 %	Diff.
1	13544	1533	12011
2	15074	2742	12332
3	15969	3803	12166
4	16604	4309	12295
5	17097	4743	12354
6	17500	5194	12306

There is no clear trend in the revenues less discounted costs, because the costs were derived from regressions based on workstudy data that were not always smoothly integrated. We can say, though, that at the 8% discount rate, and at the costs assumed here, selection ratio appears to be of trivial importance.

In practice, selection ratio would be based on factors outside the scope of this analysis. For example:

* risk. If selection ratios are low, there is a greater chance of a given percentage mortality resulting in underutilised land.
* availability of tree stock. There may be a restriction of good genetic tree stock, the benefits of which exceed the price differential over inferior stock. In that situation it may pay to plant lower initial stockings.
* cash flow. A manager may choose to adopt lower initial stockings in order to overcome cashflow bottlenecks, even if this solution is suboptimal in terms of stand profitability.

CONCLUSIONS

Selection ratio

Increasing selection intensity in trial R972 produced a taller and straighter crop, although diameter was unaffected. This resulted in a $4000 increase in value.

The increase in value through greater selection was offset by an increase in silvicultural costs associated with greater numbers of trees that required planting, pruning and thinning.

The initial stocking that yields the greatest profit, however measured, will depend on the type of regime chosen, on precise figures for silvicultural costs and on choice of discount (compound) rate. It is therefore misleading and erroneous to make firm pronouncements on a "rule-of thumb" optimum selection ratio.

In any case, it appears that selection ratio is not an important silvicultural issue. The differences in crop values resulting from selection are minor given the differences that stem from other factors, such as risk of poor establishment, poor form due to early wind damage, or cash-flow constraints. Choice of selection ratio would, and perhaps should, be made on the basis of criteria extraneous to the single hectare situation.

Genetic improvement

Even though the 850 stock used in trial R972 represents an orchard product arising from an early stage in the breeding programme, it is quite clear that it is capable of producing substantially better stands than felling select stock, at least on the Rotoehu site. 850 stock was superior in diameter, height and straightness, and generated a $3665/ha improvement in value for a trivial difference in cost. This improvement was noted at age 19, and will no doubt be substantially greater at at ages more normally associated with final felling.

A selection ratio of 6:1 for "routine" stock (felling select) appears to be equivalent in stumpage value at age 19 to a ratio of 1.1:1, for 850 stock. This is approximately the same as planting eleven trees for every ten that are required for the final crop.

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APPENDIX 1

History of R972 and associated trials

R972

Compartment 123, Rotoehu Forest. There are 16 plots, each of 0.2 ha, comprising eight treatments of two replicates each. Initial stockings of approx.* 250, 500, 750, 1000, 1250 and 1500 stems/ha were planted in seed orchard (850) stock, 750 stems/ha in cutting material of uncertain origin, and 1500 stems/ha in "routine" stock.

The seed orchard stock consisted of 11/2/0 of Wn/68/A1 Block 14 WO 4. An approximate rating would be GF 13. The "routine" stock was also 11/2/0, but from R/67/795 Block 13 WO 4. It was from a 3600 kg seedlot obtained from selected trees felled in advance of harvesting operations throughout a number of compartments in Kaingaroa State Forest. An approximate rating would be GF 4.

Trees were pruned to 2m at year 5 on not more than 750 select stems/ha, and the remainder were thinned to waste. At year 6, trees were pruned from 2-4 m on not more than 500 select stems and the remainder thinned to waste. At year 7, all trees (except the cuttings plot 5) were pruned 4-6 m on 250 stems/ha and the remainder thinned to waste.

Height measurements were taken in years 5, 10 and annually thereafter. Diameter measurements were recorded for year 5 and each subsequent year. Coincident with each thinning, crop trees were meticulously assessed for stem quality, but unfortunately the original data cannot be relocated. Were it ever to be rediscovered, it might provide invaluable data on the interchange of form between juvenile and mature trees.

In 1987 a sample of trees was assessed for the Management of New Breeds Cooperative, in order to determine branch index for 850 stock. In Feb 1990, another sample was assessed in more detail for the Agroforestry Collaborative, to provide the basis of an improved branching model for incorporation into STANDPAK. The MARVL assessment associated with this report took place in the same month.

*[Stockings are approximate only, because the trial was actually laid out in imperial units. Plots were 0.5 acre, and stocking rates 100 stems/acre, etc. But the approximation is very close.]

APPENDIX 1 cont

"Step-outs" of 850 stock at 3:1 selection ratios

a) R995. Lake Taupo Forest, Cmpt 28. Planted 1971, pruned to 6.0 m (nominal), diameters and heights measured annually since 1980. Single plot only.

b) R1008. Kaingaroa Forest, Matea, Cmpt 814. Planted 1971, pruned to 6.0 m (nominal), diameters and heights measured annually since 1982. Single plot only.

c) R994. Waimihia Forest, Cmpt 788. Planted 1971, pruned to 6.0 m (nominal), diameters and heights measured annually since 1980. Single plot only.

d) AK538. Whangapoa Forest, Cmpt 51. Planted 1973, fertilised 1973 (P, 10 kg/ha) and 1982 (P, 100 kg/ha). Heavy scrub and infertile soil. Tree form is superior to Rotoehu. Pruned to 6.2 m, and measured from 1982. In addition to two replicates of the 3:1 selection ratio, there are two replicates of 2:1 selection ratio. Therefore this trial could merit further examination. In 1987, branch index was assessed on behalf of the Management of New Breeds Cooperative.

e) R992. Whakarewarewa Forest, cmpt 37 (?). Planted 1971. Abandoned because of weed regrowth and subsequent poor survival. Never measured.

Other step-outs

R933. Whakarewarewa Forest, Cmpt 40. This is similar to the Rotoehu Trial R972, but selection ratios were tested against stock of cutting origin. Establishment and early survival were regarded as a failure (primarily due to tall broom and blackberry). Interest in this trial waned as it was realised that the ortet age (8-9 years) was not generally thought to be suitable. Last measurements recorded were in 1985.

Nevertheless, there are two plots of 850 stock planted in 1972 at 750 stems/ha and thinned to 250 stems/ha. This trial is currently being examined in detail by P.Wilcox.

APPENDIX 2

Raw MARVL results from R972

Sel. rat.	Plot no.	00'$/ha 1990		Total volume		Volume P1 & P2		Ratio A		Ratio B	
1	7	133	140	322	343	108	115	0.67	0.72	0.71	0.71
	15	147		364		122		0.76		0.70	
2	2	139	163	356	380	122	141	0.88	0.86	0.79	0.87
	14	188		405		159		0.84		0.95	
3	4	151	171	362	393	133	144	0.92	0.80	0.83	0.77
	16	192		424		154		0.69		0.71	
4	3	134	139	341	347	119	119	0.92	0.91	0.81	0.85
	6	143		354		119		0.90		0.88	
5	1	152	170	362	389	133	147	0.91	0.93	0.82	0.87
	12	188		416		161		0.95		0.92	
6	10	183	188	411	416	149	151	0.98	0.97	0.92	0.94
	11	192		420		154		0.96		0.96	
6R	8	142	139	357	346	133	132	0.67	0.72	0.70	0.74
	13	136		335		131		0.78		0.77	
3C	5	86	102	271	296	73	93	0.81	0.73	0.70	0.69
	9	118		322		112		0.68		0.69	

APPENDIX 3

Location diagram of R972,
showing distribution of 1989 DBH residuals
for plots containing 850 stock.
(Figures are in millimetres.)

Y \ X	5	4	3	2	1
5	13				
4	9	11			
3	9	6			
2	4			-1	-10
1	-3	-12	-17	-8	

APPENDIX 4

A "REALISTIC" CUTTING STRATEGY
Stumpages from B.Manley (1986)

Log type (length m)	Min sed (cm)	Max sed (cm)	Max led (cm)	$/cu.m	Log qualities
P1 (2.7-5.7)	40	150	150	86	ABCD
P2 (2.7-5.7)	30	40	150	58	ABCD
S1 (5.5-5.5)	40	150	150	55	ABCDINEG
S2 (5.5-5.5)	30	40	150	40	ABCDINEG
S3 (3.1-6.1)	20	30	150	16	ABCDINEG
S4 (3.1-6.1)	15	20	150	12	ABCDINEG
L1 (5.5-5.5)	40	150	150	47	ABCDINEGJLK
L2 (5.5-5.5)	30	40	150	32	ABCDINEGJLK
L3 (3.1-6.1)	20	30	150	7	ABCDINEGJLK
L4 (3.1-6.1)	15	20	150	6	ABCDINEGJLK
Pulp (1.2-6.1)	10	150	150	5	ABCDINEGJLKP
Internodal (3.7-6.1)	30	150	150	56	ABCDIJ
Waste (0.0-20.0)	0	150	150	0	ABCDINEGJLKPW

Stump height: 0.3 m
Round-off length: 0.1 m
Cost per sawcut: 50c

APPENDIX 5

A CUTTING STRATEGY TO IDENTIFY PROPORTION OF SWEPT LOGS
Stumpages adjusted from B.Manley (1986)

Log type (length)	Min sed (cm)	Max sed (cm)	Max led (cm)	$/cu.m	Log qualities
Good prn (2.7-5.7)	30	150	150	86	A
Poor prn (2.7-5.7)	30	150	150	58	ABCD
Straight (3.1-5.5)	25	150	150	55	ABINEL
Crooked (5.5-5.5)	25	150	150	40	ABIJNEGLK
Pulp (1.2-6.1)	5	150	150	5	ABIJNEGLK P

Stump height: 0.3 m
Round-off length: 0.1 m
Cost per sawcut: 50c

Notes:

"Good prn". Good pruned logs. This category excludes logs with moderate sweep (see Appendix 6 for definition).

"Poor prn". Poor pruned logs. These can have moderate sweep, (but neither type of pruned log may have severe sweep, excessive fluting, ovality or bark damage). (See Appendix 6). The ratio of Good Prn to (Good + Poor Prn) is Ratio A in Tables 1 and 2.

"Straight". Unpruned logs of branch size up to 14 cm, but excluding logs of moderate sweep.

"Crooked". Unpruned logs of branch size up to 14 cm, but can include logs of moderate sweep. (Neither type of unpruned log can have branches in excess of 14 cm or severe sweep). The ratio of Straight to (Straight + Crooked) is ratio B in Tables 1 and 2.

APPENDIX 6

Standard dictionary of quality codes
(Ref: FRI Bulletin 132, page 3)

Code	Quality
A	Pruned, straight, peeler quality
B	Pruned, straight, not peeler quality
C	Pruned, mod. sweep, peeler quality
D	Pruned, mod. sweep, not peeler quality
E	Unpruned, branches < 6 cm, straight, not peeler
N	Unpruned, branches < 6 cm, straight, peeler
G	Unpruned, branches < 6 cm, mod. sweep
L	Unpruned, branches 6-14 cm, straight
K	Unpruned, branches 6-14 cm, mod. sweep
I	Internodal, branches < 6 cm, straight
J	Internodal, branches 6-14 cm, straight
P	Pulp
W	Waste

Notes

1. A log is not a peeler if two diameter measurements (measured with calipers) differ by more than 10%, if there is severe fluting, or if there is any bark damage. Note that many logs classified as "peeler" from external features will be downgraded on felling as a result of pith displacement.

2. Internodal logs have greater than 60% of their length in straight internodes 60 cm or greater.

3. There are four sweep classes (Gosnell, 1987), expressed here as a proportion of small end diameter. Sweep class 4 is waste, class 3 is pulp, class two is "moderately swept" (as above) and class 1 is "straight".

Class	For 5.5 m log	For < 3.7 m log
1	< D/8	< D/16
2	D/8 - D/4	D/16 - D/8
3	D/4 - D/2	D/8 - D/4
4	> D/2	> D/4

4. Logs can be downgraded to pulp for displaying one or more of the following types of defects: sweep category 3, a branch greater than 14 cm, or bark damage likely to indicate sapstain fungus.

APPENDIX 7

Silvicultural regimes used for R972
Numbers of trees planted pruned and thinned

Select ratio	Year 0	Year 5		Year 6		Year 7	
	Plant	Pr 1	Th 1	Pr 2	Th 2	Pr 3	Th 3
1	250	250	-	250	-	250	-
2	500	500	-	500	-	250	250
3	750	750	-	500	250	250	250
4	1000	750	250	500	250	250	250
5	1250	750	500	500	250	250	250
6	1500	750	750	500	250	250	250

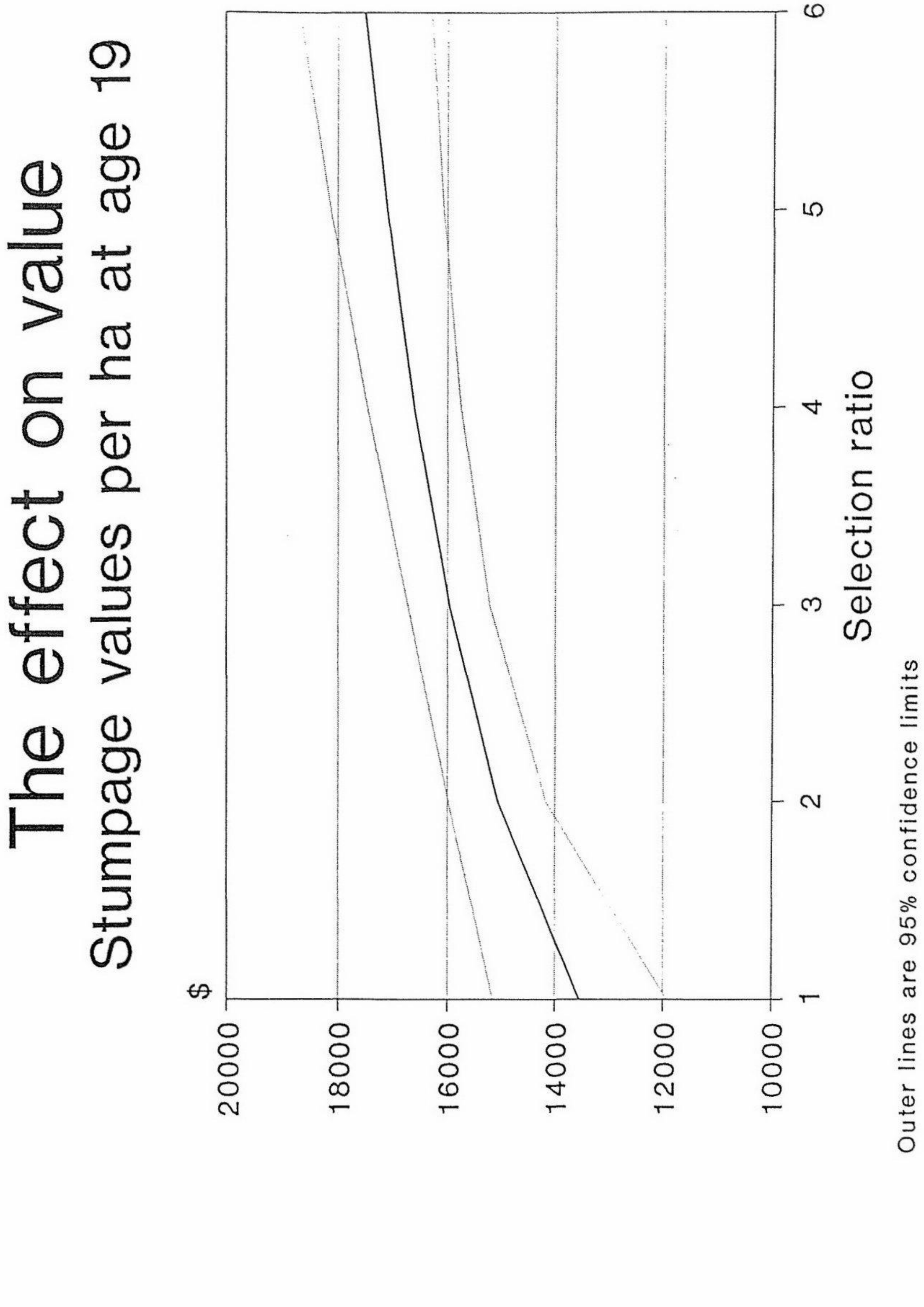
Costs of each operation
1986 values, interpolated from Lewis (1986)

Select ratio	Year 0		Year 5		Year 6		Year 7	
	Stock	Plnt	Pr 1	Th 1	Pr 2	Th 2	Pr 3	Th 3
1	33	60	135	-	135	-	147	-
2	65	109	251	-	251	-	147	80
3	98	152	440	-	251	66	147	80
4	130	194	440	63	251	66	147	80
5	163	232	440	107	251	66	147	80
6	195	275	440	150	251	66	147	80

Notes: the costs in year zero consist of tree stocks, planting costs, and spot spraying costs. The latter two are combined in the table.

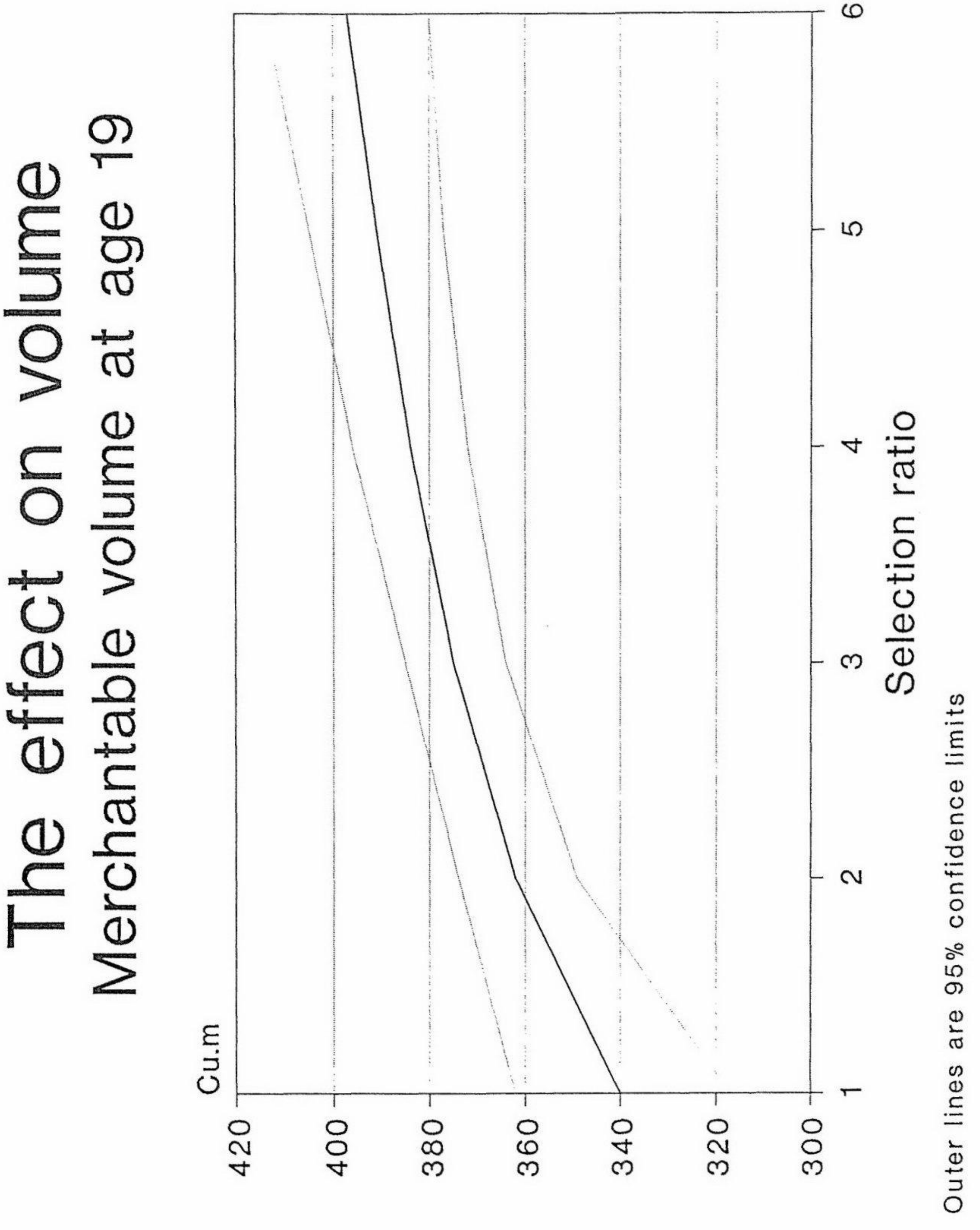
APPENDIX 8

FIGURE 1



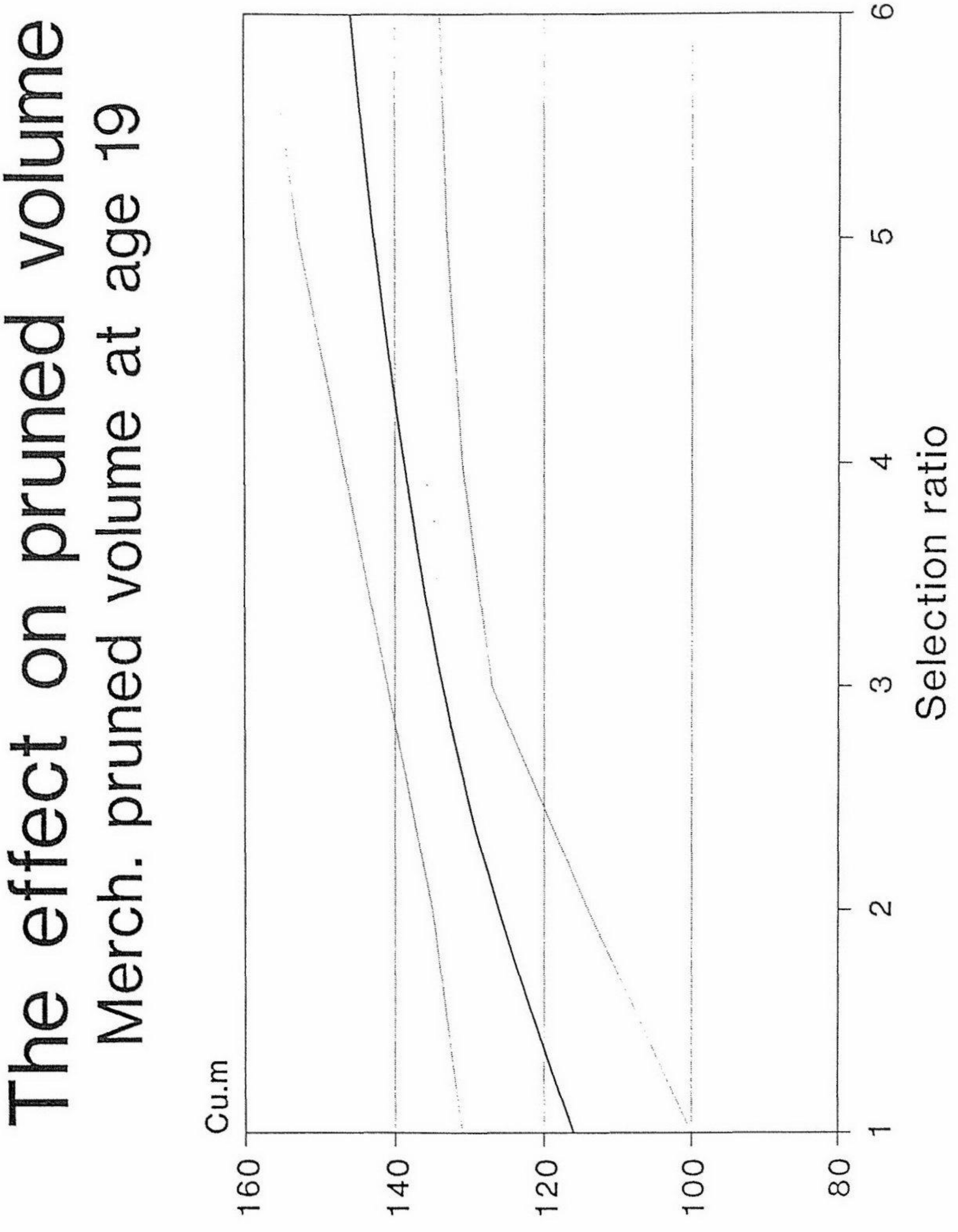
APPENDIX 9

FIGURE 2



APPENDIX 10

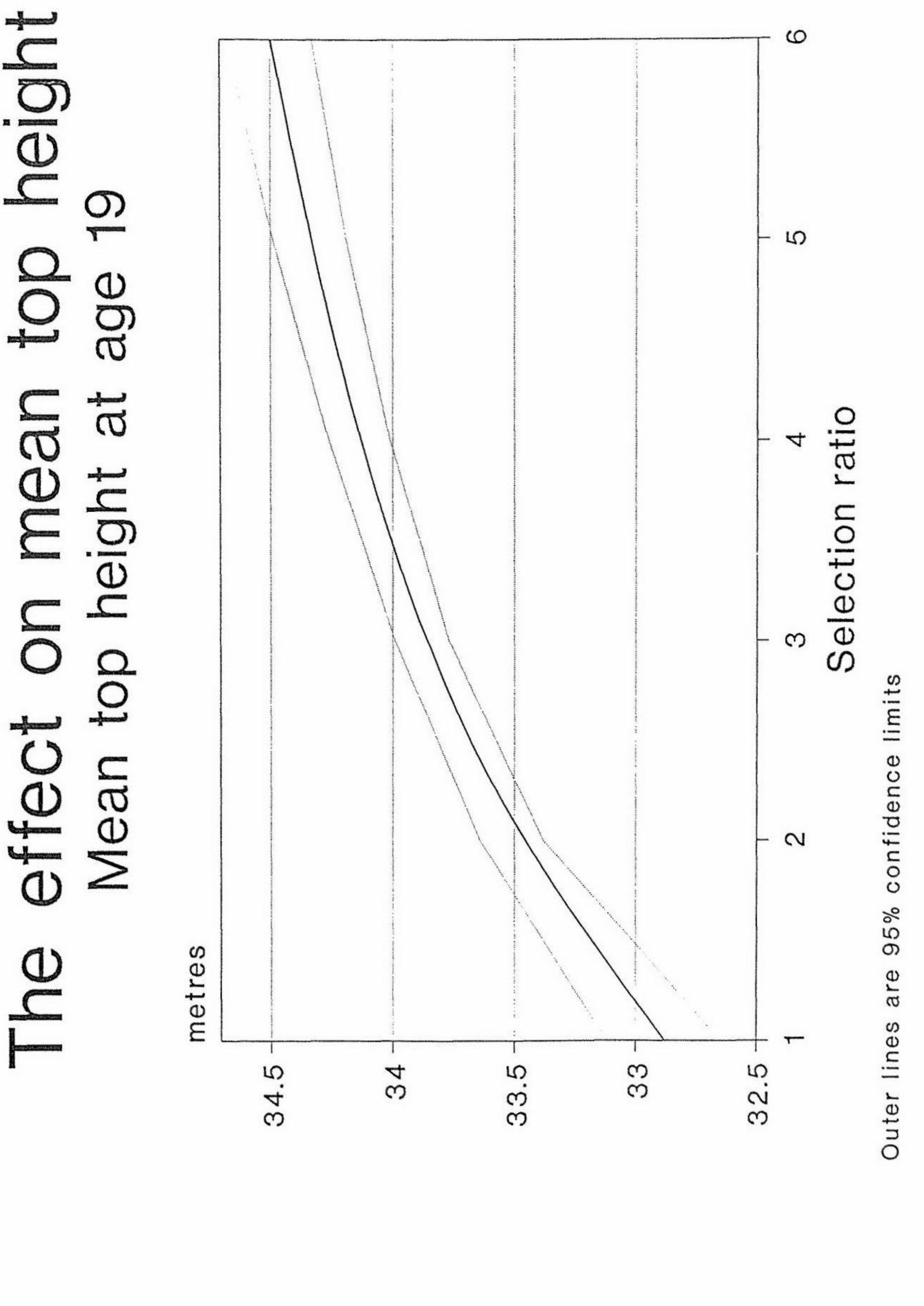
FIGURE 3



Outer lines are 95% confidence limits

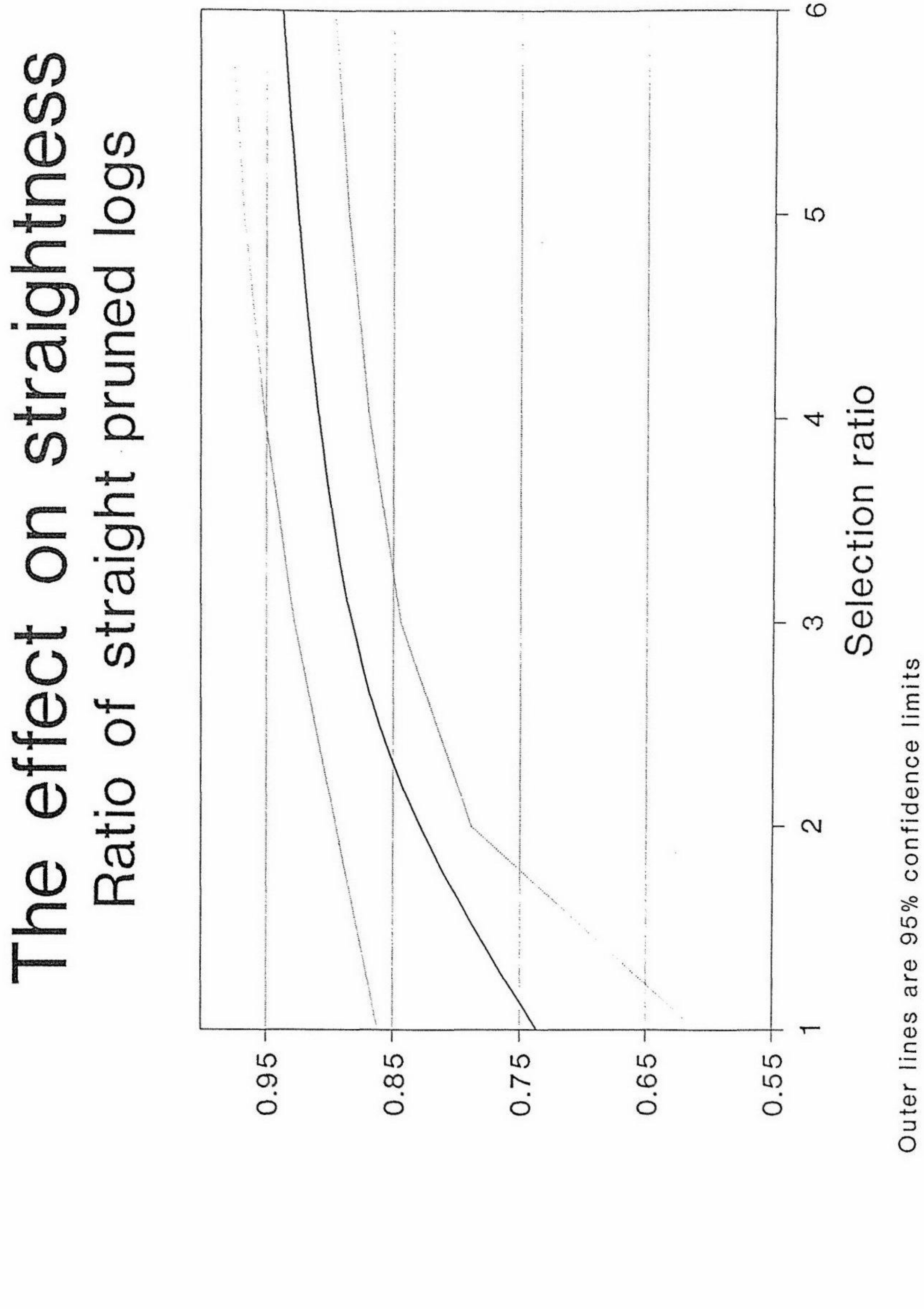
APPENDIX 11

FIGURE 4



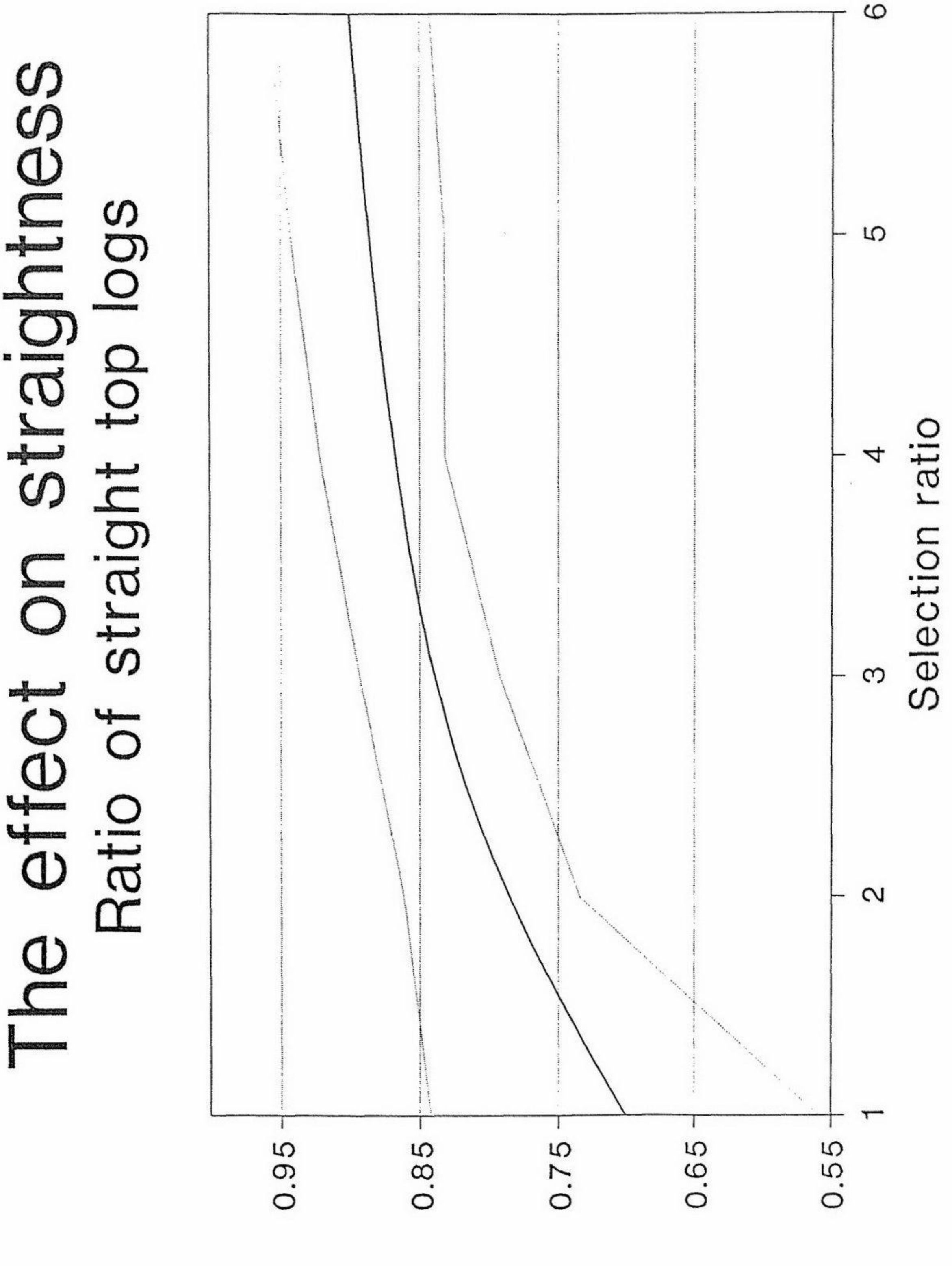
APPENDIX 12

FIGURE 5



APPENDIX 13

FIGURE 6



Outer lines are 95% confidence limits