Detecting critical changes in mohua (*Mohoua ochrocephala*) abundance

Inferences from a second year's data

DOC SCIENCE INTERNAL SERIES 36

Barry Lawrence

Published by
Department of Conservation
P.O. Box 10-420
Wellington, New Zealand

DOC Science Internal Series is a published record of scientific research carried out, or advice given, by Department of Conservation staff, or external contractors funded by DOC. It comprises progress reports and short communications that are generally peer-reviewed within DOC, but not always externally refereed. Fully refereed contract reports funded from the Conservation Services Levy are also included.

Individual contributions to the series are first released on the departmental intranet in pdf form. Hardcopy is printed, bound, and distributed at regular intervals. Titles are listed in the DOC Science Publishing catalogue on the departmental website http://www.doc.govt.nz and electronic copies of CSL papers can be downloaded from http://csl.doc.govt.nz

ISSN 1175-6519

ISBN 0-478-22215-7

This is a client report commissioned by Otago Conservancy and funded from the Unprogrammed Science Advice fund. It was prepared for publication by DOC Science Publishing, Science & Research Unit; editing and layout by Geoff Gregory. Publication was approved by the Manager, Science & Research Unit, Science Technology and Information Services, Department of Conservation, Wellington.

CONTENTS

Detecting critical changes in mohua (*Mohoua ochrocephala*) abundance

Inferences from a second year's data

Barry Lawrence

Malaghan Road, RD1, Queenstown, New Zealand

ABSTRACT

A pilot study of techniques for detecting changes in the annual abundance of the endangered bird mohua had recommended ten 1 km transects repeated four times. It suggested five-minute bird counts might be an efficient use of surveyors' time, but rejected the use of 'Distance' analysis. Those recommendations have been reviewed with a further year's data, and the method of four repeats of ten line transects has been compared to the traditional walk-through method. It was concluded that the most cost-effective method of detecting annual changes in mohua populations of approx. 40% (and longer-term trends) was to establish a minimum of ten 1 km transects and repeat them four times during the territorial pre-nesting phase (the first three weeks in October). This gave an index of mohua groups per 'half-hour km'. The results suggested that it was not necessary to count the number of mohua in each group, as no significant changes in mean group size were shown despite changes in the proportion of clusters with two, three or four mohua. 'Distance' sampling for mohua monitoring was again not recommended, as the detection curve is very sensitive and the locations of transects (landforms) and spatial activity areas with respect to the zero line in any year seemed to affect it. It was also shown that 40 five-minute bird counts did not have the same power to detect change in mohua abundance as 20 line transects.

Keywords: mohua, yellowhead, *Mohoua ochrocephala*, population monitoring, line transects, 'Distance' sampling.

This paper may be cited as:
Lawrence, B. 2002. Detecting critical changes in mohua (*Mohoua ochrocephala*) abundance: Inferences from a second year's data. *DOC Science Internal Series 36*. Department of Conservation, Wellington. 24 p.

1. Introduction

Mohua (yellowhead) is an endangered bird that is subject to sudden drops in population (of the order of 40–50%) because of predation after periodic large-scale seeding of beech trees, a beech 'mast'. If a second drop follows without a recovery of population, the mohua is at very serious risk of local extinction.

There is a need to develop an index of mohua abundance to provide managers with a cost-effective method of measuring annual fluctuations and longer term trends in mohua (*Mohoua ochrocephala*) populations.

Starting with the methodology in O'Donnell (1996), the goal was to determine the effort required to detect a real change in annual abundance of a magnitude of 40%, and in doing so determine if a credible long-term trend could be measured (Lawrence & Palmer 2000). In Oct 1998 a pilot study was undertaken with a sampling design to allow the use of the programme 'Distance' (Buckland et al. 1993) to calculate an index of abundance—an 'index' because the method could not conform to all the assumptions to allow 'Distance' to calculate an estimate of absolute abundance. The approach was statistically reviewed and tested (Lawrence & Palmer 2000). The resulting report recommended ten 1 km transects repeated four times, and suggested five-minute bird counts might be an efficient use of surveyors' time, but rejected the use of 'Distance' analysis. With another year's data, those recommendations are reviewed; the method of four repeats of ten transects has been compared with the traditional walk-through method.

2. Study sites

These trial surveys were carried out in the Caples and Dart Valleys of the upper Wakatipu district. Both valleys are at similar altitude, rising from Lake Wakatipu (308 m) to 440 m in the Dart and 500 m in the Caples. In both valleys, red beech (*Nothofagus fusca*) dominates the valley floors, to which the transects and inferences are confined.

3. Methods

Mohua abundance was measured in Oct 1998 and 2000 by line transect and census, and, in 2000, five-minute point counts.

3.1 CENSUS

Census of mohua at the two 1 km^2 study sites of Sylvan and Millflat in the Dart Valley have been carried out annually in late November since 1992, based on territory mapping with a banded population since 1995.

3.2 LINE TRANSECT

In 1998 there were five 1 km line transects in the Caples repeated five times and four 1 km line transects in the Dart repeated three times. The Dart transects were, however, confined to the two 1 km^2 study sites at Sylvan and Millflat, whereas the Caples transects were spread over 12 km of valley. In 2000 the survey was changed, based on statistical design advice (Lawrence & Palmer 2000), to give ten 1 km line transects, repeated four times, spread over approx. 12 km in each valley. This meant that direct comparisons between Oct 1998 and Oct 2000 are limited to five 1 km transects repeated four times in the Caples, and four 1 km transects repeated three times in the Dart.

The line transects are not random, as they were constrained in a major way by topography, valley size (especially in the Caples), and practicality. The inference can only be to the areas of red beech on or near the valley floors of these two valleys (the most suitable mohua habitat according to Elliot 1992).

The method follows that outlined in Lawrence & Palmer (2000) and similar to O'Donnell (unpubl. report 1986; 1996). Transects were walked slowly (0.5–0.8 hour/km). When mohua were heard or seen, the clock was stopped, and up to 15 minutes were spent finding the group, counting clusters, and measuring the perpendicular distance from the point of first discovery to the transect. Where possible, the transects were repeated four times. As the total numbers of mohua per km were greater than 80 in each valley no further repeats were done. Although we attempted to limit the survey to the first three weeks of October, unsuitable weather meant it took all of that month.

3.3 FIVE-MINUTE BIRD COUNTS

At the beginning and end of each line transect, a five-minute point count of all bird species was done. In addition, the position of each bird was mapped (Ralph et al. 1993) and placed at more or less than 50 m from the observer.

3.4 ANALYSIS

Using the five 1 km transects (4×) in the Caples and four 1 km (3×) transects in the Dart that were common to both Oct 1998 and Oct 2000, a paired *t*-test was used to establish changes in abundance. Calculations to determine the power required for detecting 40% annual fluctuations (after Zar 1996) and 2% trends (after Gibbs 1995) were re-done to identify the implication of increased variances.

Using all transects available in each year, estimates of density were derived and compared for both years, using 'Distance' program (Buckland et al. 1993).

Five-minute bird counts provided a 'mean per count' for each species, after the repeats at each station were averaged. Comparisons between valleys for each species were done using a two-sample *t*-test. Estimates of the numbers of counts required to have a 0.9 power to detect change were undertaken. Density estimates based on Sutherland (1996) were calculated:

$$\text{Density} = [(n_1 + n_2)/(\pi\, r^2 m)]\ \log_e[(n_1 + n_2)/\ n_2\ ]$$

where r = radius of the first zone (second zone extends to infinity)

n_1 = number of birds counted within r

n_2 = number of birds counted beyond r

m = number of replicate points in the set.

4. Results

4.1 CENSUS

Census data for the two1 km^2 study sites in the lower Dart Valley are shown in Table 1. From 1998 to 2000 the census shows increases of 28 to 29 territories (3.5%) and 99 to 110 individuals (11%). This result was compared to the result of the paired *t*-test for the four 1 km transects (repeated three times) in the census area. That gave a 16% decrease in clusters (not significant $P = 0.59$). The census is well within the margin of error for the transect survey results, for that limited area (Table 4).

TABLE1. RESULTS OF THE ANNUAL NOVEMBER CENSUS AT THE 1 km^2 STUDY SITES OF SYLVAN AND MILLFLAT IN THE DART VALLEY.

		2000	1998
Sylvan	Territories*	15	14
	Individuals	58	49
Millflat	Territories*	14	14
	Individuals	52	50

*Not all of these territories are breeding groups.

4.2 TRANSECTS

The results of transect surveys of mohua in both 1998 and 2000 are summarised in Table 2. Details of mohua cluster encounters within 100 m are given in Appendix 1; full details of cluster size and distance are available from the author.

TABLE 2. SUMMARY OF MOHUA CLUSTER ENCOUNTER RATES.

	NO. OF 1 km TRANSECTS	NO. OF REPEATS	MEAN CLUSTERS PER TRANSECT
Caples Oct 1998	5	5	2.96
Caples Oct 2000	10	4	3.60
Dart Oct 1998	4	3, 4	2.79
Dart Oct 2000	10	3, 4	4.08

4.2.1 Cluster size

Clusters are not necessarily breeding pairs and associates, as a territorial group can often spend time as pairs within the territory especially just prior to nesting (pers. obs.). During the transect surveys not all of the groups detected were seen and counted. Cluster size is established only on groups counted (Fig. 1).

The frequency distribution of cluster size was considered and the Proportion Test (Statistix® computer software) used to determine significance. In the Caples the proportion of groups of two decreased significantly from 0.6 in 1998 to 0.34 in 2000 (P = 0.0018), while the groups with three and four mohua increased significantly from 0.26 in 1998 to 0.47 in 2000 (P = 0.012). In the Dart in each cluster size category no significant difference in proportion was found.

If just the mean cluster size is considered, there are no significant differences between years or between valleys in any one year (Table 3).

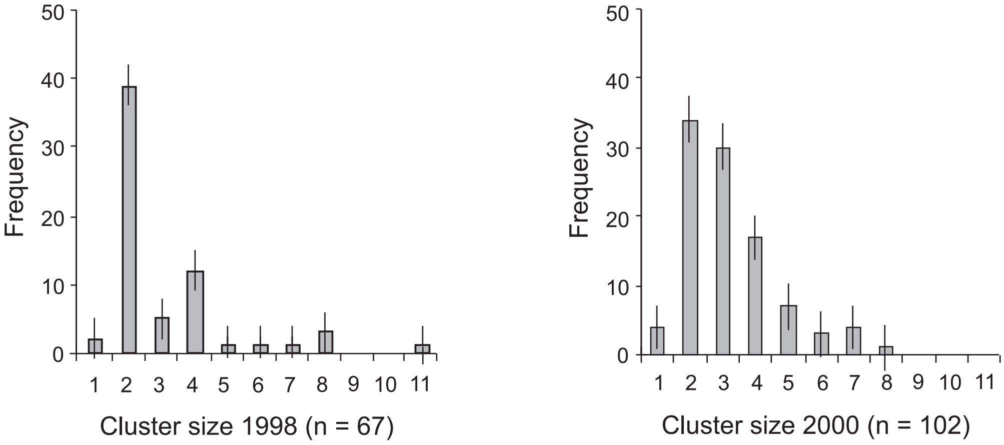

Figure 1. Histograms showing mohua cluster size in (left) 1998 and (right) 2000 in the Caples. (Error bars show standard error)

TABLE 3. MEAN NUMBER OF MOHUA PER CLUSTER IN CAPLES AND DART VALLEYS, 1998 AND 2000.

		n	MEAN MOHUA PER CLUSTER	95% CONFIDENCE INTERVAL
Caples	Oct 1998	65	3.0	2.5–3.4
	Oct 2000	100	3.1	2.9–3.5
Dart	Oct 1998	32	2.6	2.2–3.1
	Oct 2000	100	3.0	2.65–3.3

4.2.2 Paired *t*-test results

The number of mohua clusters per individual transect were compared (e.g. transect 1, year 1 with transect 1, year 2). The result of the paired *t*-test for the comparable transects Oct 1998 and Oct 2000 is shown in Table 4. (Note that only five transects were the same in both years in Caples, and four in Dart.)

TABLE 4. MEAN MOHUA CLUSTERS PER TRANSECT FOR DART AND CAPLES VALLEYS.

		NO. OF 1 km TRANSECTS	REPEATS OF TRANSECT	MEAN NO. CLUSTERS /TRANSECT	MEAN DIFFERENCE, % INCREASE	*P* VALUE OF PAIRED *T*-TEST	AVERAGE WITHIN-TRANS. CV
Caples	Oct 1998	5	4	2.75	1.4 (0.8 – 2),	$P = 0.004$	44%
	Oct 2000	5	4	4.15	+52%		49%
Dart	Oct 1998	4	3	3.00	–0.5(–3 – +2),	$P = 0.59$	49%
	Oct 2000	4	3	2.50	–16%		126%

With few transects, high between-transect variation tends to have a large influence on the confidence interval, as in the Dart, with 12 data points and a confidence interval of 5 (Table 4), compared with the Caples with 20 data points and confidence interval of 1.2. Though not directly related to the *t*-test, the coefficient of variation (size of the variance of the sample in proportion to its mean) was calculated for each set of repeats for each transect. The averages of these CVs are presented (Table 4) to show the very large variance **within** the four Dart transects (measuring error) counted in Oct 2000.

By way of illustrating the advantage of the paired *t*-test method, a two-factor replicated analysis of variance (ANOVA) was carried out using the transects in Table 4 for the Caples. This partitioned the variances between transects and between years. While the difference in variance in numbers of clusters of mohua encountered between years was significant ($P = 0.01$), the difference in variance between transects in each year was also significant ($P = 0.04$). The analysis by paired *t*-test accounts for this location effect (difference between transects in each valley at a given time).

4.2.3 Power to detect annual differences

The power of the data to determine a difference in population if there is one (avoid a type II error) is reliant on the variance of the samples. In 1998 in the Caples the within-transect variance (measuring error) was 1.58. In 2000 the within-transect variance increased to 3.98 in the Caples and 3.53 in the Dart (these variances calculated using a single-factor ANOVA). This drops the power to detect a 40% change from 0.93 to 0.89 in the Caples and 0.90 in the Dart (after Zar 1996). The implication of reducing the number of transects or repeat transects is seen in Table 5; any reduction in either reduces the power to detect a 40% change.

4.2.4 Power to detect a trend

The power to detect a trend also decreases as variance increases. Using the program 'Monitor' (Gibbs 1995) we reassessed the ability to detect a change with the 2000 increased variance. Table 6 shows a small decline in power.

TABLE 5. POWER TO DETECT AN ANNUAL CHANGE IN MOHUA CLUSTERS (AFTER ZAR 1996, P. 109, 166).

NO. OF 1 km TRANSECTS	REPEATS OF TRANSECT	POWER TO DETECT 40% (33%) CHANGE WHERE VARIANCE IS:		
		1.58 [CAPLES 1998]	3.53 [DART 2000]	3.98 [CAPLES 2000]
10	4	0.93 (0.81)	0.90 (0.76)	0.89 (0.73)
10	3	0.85 (0.69)	0.80 (0.63)	0.79 (0.6)
10	2	0.68 (0.50)	0.63 (<0.5)	0.61 (<0.5)
10	1	<0.5 (<0.5)	<0.5 (<0.5)	<0.5 (<0.5)
8	4	0.85 (0.68)	0.82 (0.62)	0.78 (5.9)
8	3	0.73 (0.54)	0.70 (0.50)	0.65 (<0.5)

In Appendix 2 consideration is given to the disadvantages to the ability to detect smaller trend changes by reducing the number of times each transect was counted each year.

TABLE 6. ABILITY TO DETECT TRENDS USING THE 'MONITOR' PROGRAM AS VARIANCE INCREASES IN TEN TRANSECTS REPEATED FOUR TIMES.

VARIANCE	NO. OF YEARS	POWER TO DETECT +VE ANNUAL TRENDS	OVERALL CHANGE	POWER TO DETECT -VE ANNUAL TRENDS	OVERALL CHANGE
1.58 [1998 Caples]	5	7% Increase = 0.9	31 %	9% Decrease = 0.84	31 %
3.98 [2000 Caples]	5	8% Increase = 0.88	36 %	10% Decrease = 0.79	34 %
1.58 [1998 Caples]	15	2% Increase = 1.00	32 %	2% Decrease = 0.95	25 %
3.98 [2000 Caples]	15	2% Increase = 0.97	32 %	2% Decrease = 0.85	25 %

4.2.5 'Distance' analysis

The result of the 'Distance' analysis is given in Table 7, where effort is km of survey, sample size is clusters per transect, encounter rate is mean of all transects, and density is clusters of mohua per km. The Dart Oct 1998 result is based on limited effort and does not meet the recommended sample size of 80 (Buckland et al. 1993). These are indices only, as the basic assumption in the 'Distance' programme of finding all birds on the '0' line cannot be guaranteed. The results in Table 7 are based on data that is truncated at 90 m, with four distance intervals for both years. Note that in the Caples an increased encounter rate is computed as a decrease in density.More detailed results and discussion are attached as Appendix 3.

TABLE 7. INDEX OF POPULATION FROM 'DISTANCE' ANALYSIS. NOTE THAT THE BASIC ASSUMPTION OF OBSERVING ALL BIRDS ON THE TRANSECT LINE IS NOT MET SO THESE ARE INDICES ONLY.

	EFFORT (km)	SAMPLE SIZE	ENCOUNTER RATE (95% CI)	DENSITY (95% CI)
Caples Oct 1998	25	74	2.9 (2.2-4.0)	32.4 (23-44)
Caples Oct 2000	40	142	3.5 (2.8-4.5)	27.4 (22-34)
Dart Oct 1998	12	35	2.9 (0.7-11)	16.3 (6-44)
Dart Oct 2000	35	142	4.1 (3.0-5.5)	30.6 (20-45)

4.3 FIVE-MINUTE BIRD COUNTS

Seventy-six five-minute bird counts of all species were done at 20 sites in the Caples and seventy-two at 20 sites in the Dart. The results are listed in Appendix 4. The only signicant differences between the sites were that brown creepers were more abundant in the Caples, and bellbirds more abundant in the Dart.

The power of these counts to detect a change in mohua population was determined assuming analysis by paired *t*-test, and using the methodology of Zar 1996. Detailed results are shown in Appendix 5. Essentially there is a trade-off between number of repeats of counts at each point and number of count points; after four repeats there is little decrease in the numbers required. The number of five-minute counts required to detect change in mohua population with a power of > 0.9 (when each point is counted four times) is: 40% 288 (72 × 4); 33% 408 (102 × 4); 25% 720 (180 × 4).

Sutherland (1996) describes a method of density estimation from two recording zones. The calculation for mohua in October 2000 gives 96 mohua individuals per km^2 in the Caples and 70 mohua individuals per km^2 in the Dart.

Using 'Monitor' (Gibbs 1995) the present 20 × 4 regime's power to detect a 5% increasing trend (or a 10% decreasing trend) is 0.9 at ten years. At 15 years an increasing trend of 3% can be detected with a power of 0.95, and a decreasing trend of 6% can be detected with a power of 0.94.

5. Discussion

5.1 CENSUS COMPARISONS

The census shows a minimal increase of mohua abundance in the two study areas, from 1998 to 2000. The paired *t*-test on the transects in the census areas did not show a significant result and the census result is well within the margin of error for the transects. The important aspect is that this is over 2 km of valley, and may not been representative of the wider valley. The survey results over 12 km in the Caples suggest a considerable increase in mohua abundance over the two-year period (Table 4).

5.2 CLUSTER SIZE

Overall there was a decrease in the proportion of clusters with two mohua, and an increase in the proportion of groups with three and four mohua. These changes were not significant in the Dart but were in the Caples. The increased proportion of groups of 3–4 could indicate a higher percentage of juveniles surviving the winter. The results (Table 2) show no significant difference in mean group size, year to year, or between valleys in any one year. It will require several more years' data to establish that the mean group size does not change significantly, but, should this prove to be the case, counting the cluster size will not help estimating population and might be discontinued. This would speed up the transect time considerably. However, the changing proportions of clusters of two, three, and four birds may prove to be an important measure of the current population status, i.e. increases in the proportion of lone males may indicate levels of predation on females higher than recruitment rates. Therefore counting cluster size ought to be continued, at least in these trial surveys in the Dart and Caples.

5.3 *t*-TEST COMPARISONS

The paired *t*-test picked up a 52% increase in mohua clusters per transect in the Caples, in the five transects common to both years. The five additional Caples transects in 2000 had a reduced encounter rate, reducing the mean encounter rate from 4.1 (Table 4) to 3.6 mohua clusters per transect (Table 2). This is important justification for the increased number of transects so that the high level of variation in spatial distribution of mohua is better accommodated.

The ANOVA result showing a significant between transect variation ($P = 0.04$), reflects this spatial variation in mohua numbers. The term 'patchiness' may not be quite correct, but some locations have more mohua groups than others. Lawrence et al. (unpubl. report 2000) suggests that density of mohua territories on the terraces north of Chinamans Bluff in the Dart is twice that of other locations in the Dart and Caples. This is consistent with the results from the Oct 2000 results (Appendix 1, Dart Transects 6 and 7).

5.4 POWER TO DETECT A CHANGE

A 0.9 power to detect a change in the population with 95% confidence is probably required. Review of the power analysis shows that the increased variance 1998 to 2000 has an effect on power. However, the 10 × 4 /1 km transect design still has the ability to detect a 40% annual change at the specified 0.9 power (Table 5), and the ability to detect a long-term trend of 2% annually over 15 years (or total change of 25–32%)(Table 6). See Appendix 2 for the implications of reducing the number of repeat counts on the detection of the trend.

There is considerable resistance to doing repeats in each year of the traditional walk-through survey. If the 1 km transect is only done once in a year there is no way of establishing the within-transect variance ('measuring error'). The argument is that a 'normal' mohua variance of detection can be established and applied universally. However, this variance changes with density (Mayhew 1999), with location of each transect (Caples 2000 between transect difference significant, $P = 0.04$), and from year to year (Caples 1998 $s^2 = 1.58$; 2000 $s^2 = 3.99$). So we could use only the variance established by the 'once-through survey' itself, which combines the location effect with the measuring error (within-transect error). Table 8 illustrates how the precision increases (measuring error decreases) with repeated counts. This, of course, reduces the power of the survey to detect a difference, for equal effort. In fact, following the method of Zar (1996, p. 133 eq. 8.22) the number of km of transect required to detect a 40% change in mouha clusters is 50. This is 20% more effort than doing our recommended four repeats of ten 1 km transects.

TABLE 8. TREATING EACH REPEAT SERIES IN THE CAPLES 2000 AS A 'TRADITIONAL SURVEY'. The population surveyed is the same in each case.

CAPLES 2000	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	MEAN	CI
Survey 1	2	6	3	2	4	2	6	2	6	8	4.1	2.7–5.4 (2.7)
Survey 2	3	6	3	1	6	2	2	2	3	1	2.9	1.9–3.8 (1.9)
Survey 3	4	5	1	2	1	4	2	5	5	6	3.5	2.3–4.6 (2.3)
Survey 4	6	7	6	1	4	2	5	4	0	4	3.9	2.5–5.3 (2.8)
Combined	3.75	6	3.25	1.75	3.75	2.5	3.75	3.25	3.5	4.75	3.6	2.8–4.4 (1.6)

5.5 'DISTANCE' ANALYSIS

The application of a 'Distance' analysis to these data was not recommended (Lawrence & Palmer 2000), as the primary assumption—that all birds on the transect line would be detected—could not be met. It was undertaken here in the interests of completeness. The result of the 'Distance' analysis in the Caples shows a decrease in density in 2000 in the face of an increase in the encounter rate. It is self-evident (Appendix 3, Figs A3.1A and A3.1B) that the detection curve has changed. In 1998 the 'detection probability' was 51%; in 2000 the 'detection probability' was 72%. The detection curve fell off less quickly in 2000 (see Appendix 3), meaning that we heard more birds further from the zero or transect line. One explanation is that bird activity was centred towards the zero line the first year and away from the centre line in 2000. The observers were the same in both years. So the effect of not complying with the assumption of 100% detection along the transect line (which adjusts for observer variation in the analysis) should have minimal effect. It has been suggested that the data for both years be combined to establish a detection curve for both and then the data of each year could be combined with that curve (Ian Westbrooke pers. comm.). However, detectability will change between years (see discussion of variance above), so this course is not recommended here. It appears that repetition of transects may compound any biases in a particular transect and that the detection curve is sensitive to that (Appendix 3). Although the increase in the number of transects from 5 to 10 will reduce the effect of such bias it suggests that 40 km of transect without repeats is the ideal; this is not usually available in mohua habitat. The paired *t*-test gives a more robust and credible result and it is reaffirmed that the use of 'Distance' analysis for mohua is not recommended.

5.6 FIVE-MINUTE COUNTS

Five-minute counts give an index for several of the more abundant forest species simultaneously, and the best utilisation of survey time suggested they be included to capture a wider picture of avifauna. However, the detection of gross changes in species populations is extremely limited with the level of effort allocated in this trial. This is illustrated by using the mohua data for detecting annual population changes in Section 4.3 and for detecting trends in Table 9.

TABLE 9. POWER TO DETECT TRENDS IN MOHUA POPULATIONS: FIVE-MINUTE BIRD COUNTS COMPARED WITH TRANSECTS (AT MODERATE TO HIGH POPULATION LEVELS).

METHOD	TREND	CHANGE OVER 5 YEARS			CHANGE OVER 15 YEARS		
		ANNUAL%	POWER	TOTAL	ANNUAL%	POWER	TOTAL
Five-minute counts	positive	10%	0.61	46%	3%	0.95	55%
	negative	10%	0.33	35%	5%	0.88	51%
10 × 4 transects	positive	8%	0.86	36%	2%	0.97	32%
	negative	10%	0.79	35%	2%	0.85	25%

The identification of female calls does not provide a sufficient sample to give a reliable guide to abundance and can only give a statement of presence (not absence, McKinlay 2001).

Lawrence & Palmer (2000) had recommended a 'Distance' method of five-minute bird counts be undertaken following Barraclough (2000). While this method would give better results, in this instance it was not practical, given observer fatigue and the extra time/resource involved. The quicker method used was division of birds into those closer to, and those further than 50 m (Ralph et al. 1993). This was difficult, and while it would be easier to determine if the division was at 30 m, this would lead to few mohua, for instance, being 'within', and give a poor density result. If these five-minute counts are to continue we recommend the 50 m radius be clearly and permanently marked in each direction.

The density calculation (after Sutherland 1996) was based on counts that showed marginally more mohua per count in the Dart (1.36 to 1.31). However, the proportion of those counts further away (greater than 50 m) was greater in the Dart (0.69) compared with the Caples (0.55). This led to quite different density estimates in the two valleys (96 mohua per km^2 in the Caples and 70 mohua per km^2 in the Dart). Neither estimate is credible, as the most dense mohua population estimated by territorial mapping at Borer Flat in the Dart in 1999 indicated 80 individual per km^2 (Lawrence et al. 2000). This Sutherland estimate would seem to suggest almost twice the population we expect in the Caples. This could be due to the observers consistently underestimating the cluster distance, leading to more mohua being placed within 50 m than there should be. The comparison of the means of the 'average of each count station' with a paired *t*-test is recommended as a measure of population change. The Sutherland index should not be used until the determination of distance closer or further than 50 m can be done with much greater confidence.

6. Conclusion

It is recommend that mohua surveys to detect changes in abundance be at least ten 1 km transects repeated four times during October, and analysed by paired *t*-test. This provides the power to detect a 40% annual population change and a 2% annual trend over 15 years.

7. References

Barraclough, R.K. 2000: Distance Sampling: A discussion document produced for the Department of Conservation *Science & Research Internal Report 175*. Department of Conservation, Wellington.

Buckland, S.T.; Anderson, D.R.; Burnham, K.P.; Laake, J.L. 1993: Distance Sampling: Estimating abundance of biological populations. Chapman & Hall, London.

Elliott, G.P. 1992: Habitat relationships and conservation of the yellowhead. *New Zealand Journal of Ecology* 16: 83-90.

Gibbs, J.P. 1995: Overview of Monitor (version 6.2) software. James P. Gibbs Department of Biology, Yale University, New Haven.

Lawrence, B.L.; Palmer, D. 2000: Detecting critical changes in mohua (*Mohoua ochrocephala*) populations. *Conservation advisory science notes 316*. Department of Conservation, Wellington.

Lawrence, B.L.; Palmer, D.; van Hal J.; Low, M.; Mc Innes, K.; McLeod, J.; Molloy, R. 2000: Report on field trial of trapping perimeters for stoat control: Dart and Caples Valley Upper Wakatipu 1999-2000. Unpublished report to Department of Conservation, Christchurch.

Mayhew, K. 1999: Contariness to detection in the bush canary: Variation in the detectability of mohua (*Mohoua ochrocephala*) relating to nesting phase, different populations and time of day. *University of Otago Wildlife Management Report 110.*

McKinlay, B. 2001: Counting terrestrial bird species in mixed habitats: an assessment of relative conspicuousness. *Notornis* 48: 47-53

O'Donnell, C.F.J. 1986: The Mohua Monitoring Programme. Unpublished report to the NZ Wildlife Service.

O'Donnell, C.F.J.1996: Monitoring mohua (yellowhead) populations in the South Island, New Zealand. *New Zealand Journal of Zoology* 23: 221-228.

Ralph, C.J.; Geupel, G.R.; Pyle, P.; Martin, T.E.; De Sante, D.F. 1993: Handbook for Monitoring Landbirds. *Pacific Southwest Research Station General technical Report PWS-GTR - 144.* USDA Forest Service

Sutherland, W.J.1996: Ecological Census Techniques. Cambridge University Press

Zar, J.H. 1996: Biostatistical Analysis. 3rd edn. Prentice-Hall.Inc., New Jersey.

Appendix 1

NUMBER OF MOHUA GROUPS PER TRANSECT

TRANSECT[1]	Repeat1	Repeat2	Repeat3	Repeat4	Repeat5	TOTAL	AVE.	SD	CV
Caples98 2	2	6	4	5	6	23	4.6	1.67	36
3	2	2	4	2	2	12	2.4	0.89	37
10	1	2	2	2	5	12	2.4	1.52	63
9	1	2	0	3	3	9	1.8	1.30	72
8	4	4	3	4	3	18	3.6	0.55	15
Total	10	16	13	17	21	74			
Per transect	2.0	3.2	2.6	3.2	3.8		2.96	1.19	
Average									45
Dart98 1	2	0	2	2		6	1.5	1.00	67
2	7	6	2	1		16	4	2.94	74
8	3	3	3			9	3	0.00	0
9	2	2	4			8	2.67	1.15	43
Total	14	11	11	3		39			
Per transect	3.50	2.75	2.75	1.50			2.79	1.27	
Average									46
Caples00 1	2	3	4	6		15	3.75	1.71	4
2	6	6	5	7		24	6	0.82	14
3	3	3	1	6		13	3.25	2.06	63
4	2	1	2	1		6	1.5	0.58	38
5	4	6	1	4		15	3.75	2.06	55
6	2	2	4	2		10	2.5	1.00	40
7	6	2	2	5		15	3.75	2.06	55
8	2	2	5	4		13	3.25	1.50	46
9	6	3	5	0		14	3.5	2.65	76
10	8	1	6	4		19	4.75	2.99	63
Total	41	29	35	39		144			
Per trans	4.1	2.9	3.5	3.9			3.6	0.53	
Average									64
Dart00 1	3	0	0			3	1.00	1.73	173
2	5	1	1			7	2.33	2.31	99
3	2	4	2			8	2.67	1.15	43
4	6	3	2			11	3.67	2.08	57
5	10	7	8	4		29	7.25	2.50	34
6	3	6	7	10		26	6.50	2.89	44
7	9	5	4	5		23	5.75	2.22	39
8	1	5	2			8	2.67	2.08	78
9	2	5	5	5		17	4.25	1.50	35
10	3	2	3	3		11	2.75	0.50	18
Total	44	38	34	27		143	4.08		
Per transect	4.4	3.8	3.4	2.7			3.88	0.71	
Average									62

[1] Transects numbered as per 2000 record. Groups further than 100 m not counted.

Appendix 2

NUMBER OF REPEAT TRANSECT SURVEYS

It has been suggested that a ‘universal’ measure of transect variance be established from all transects, and that removes the need to repeat counts of any one transect in any one year. The logic is that for trends over 15 years it does not matter if the between-transect variance and the within-transect variance (measuring error) are not separated because the number of total counts is so high. This of course assumes we are not interested in annual mohua population levels, which is to disregard the first ‘need to monitor’. It also ignores the finding (Mayhew 1999) that as density decreases so does detectability.

To determine if there was a disadvantage, when determining a trend, of reducing the number of repeat counts of each transect in each year to we ran the program ‘Monitor’. The ‘universal’ measure of transect variance we used is the average standard deviation (SD) for the mean of mohua clusters per transect for all transects in the Caples in 2000, where the program wanted the SD for the repeats of each transect. In Tables A2.1 and A2.2, this procedure is called ‘using

TABLE A2.1. TREND OVER FIVE YEARS SHOWING THE PERCENTAGE ANNUAL TREND, POWER TO DETECT THAT TREND, AND CHANGE OVER FIVE YEARS.

NO. OF	TREND	USING ACTUAL SD			USING ASSUMED SD			TOTAL
REPEATS	DIRECTION	ANNUAL%	POWER	TOTAL%	ANNUAL%	POWER	TOTAL%	TRANSECTS
1	Positive				10%	0.49	46%	50
1	Negative				10%	0.26	34%	50
2	Positive				10%	0.75	46%	100
2	Negative				10%	0.47	34%	100
3	Positive	10%	0.92	46%	10%	0.85	46%	150
3	Negative	10%	0.7	34%	10%	0.64	34%	150
4	Positive	9%	0.93	31%	9%	0.9	31%	200
4	Negative	10%	0.79	34%	10%	0.74	34%	200

TABLE A2.2. TREND OVER FIFTEEN YEARS SHOWING THE ANNUAL TREND, POWER TO DETECT THAT TREND, AND CHANGE OVER FIFTEEN YEARS.

NO. OF	TREND	USING ACTUAL SD			USING ASSUMED SD			TOTAL
REPEATS	DIRECTION	ANNUAL%	POWER	TOTAL%	ANNUAL%	POWER	TOTAL%	TRANSECTS
1	Positive				3%	0.9	51%	150
1	Negative				5%	0.86	51%	150
2	Positive				3%	0.97	51%	300
2	Negative				4%	0.89	44%	300
3	Positive	2%	0.95	32%	2%	0.88	32%	450
3	Negative	2%	0.84	25%	3%	0.91	37%	450
4	Positive	2%	0.97	32%	2%	0.95	32%	600
4	Negative	2%	0.85	25%	2%	0.8	25%	600

assumed SD'. This is compared with the actual SD of each transect, where we considered three and four repeats.

While the drop in trend detection is only 2 to 3% per annum for increasing trends (2 to 5% per annum for decreasing trends), this is an actual increase of the difference detected of 25 to 51 % over 15 years. The question is whether four times the effort is worth it. Maybe not for just the trends, but when the ability to determine annual changes is added, the effort is of value.

Appendix 3

'DISTANCE' ANALYSIS TO ESTABLISH ABUNDANCE OF MOHUA GROUPS

In the same transects in the Caples 1998 to 2000, 'Distance' says there was no increase in abundance despite a significant 52% increase in encounter rate (see Table A3.1) and sample sizes being about the level recommended (80) to get a good result (Buckland et al. 1993). The reason for this lies in the change in detection curve (Fig. A3.1A and B). As the majority of transects in both years were done by the same observer, either the detectability or the spatial distribution has changed. As increases in mohua are likely to increase the frequency of moderate to loud calling rates (Mayhew 1999) it is unlikely that detectability decreased, but it seems likely that the spatial average distance from the zero line increased (see Fig. A3.1A and B). To see if this was an aberration due to the small number of transects (5), I compared those 2000 transects to all 10 transects in 2000 (see Fig. A3.1C and D). There appears to be a greater chance of hearing groups at greater distances in the new transects, with the probability of detection at the 70–90 m range increasing from 0.35 to 0.46 (31%). This could be an artifact of the five original transects being on generally steeper hillsides. While we must be cautious of the Dart data due to small sample sizes, three of the four sites compared in Fig. A3.2A and B are very flat, and the detection probability shows little fall-off to 90 m. This is consistent with experiments conducted in 1998 on flat ground in which song and loud chatter were easily detected to 100 m but not detectable at 150 m, while moderate chatter could be heard at 70 m. In Fig. A3.2D, in the Dart, where seven of ten transects are flat, the detection probability is very slightly greater than in the Caples, where five of ten are flat (Fig. A3.1D).

If this tentative suggestion that topography alters detectability is correct, it is a factor not taken into account before. Ten transects in this case seem to have compensated for this (from comparison of Figs A3.1D and A3.2D, which have similar curves, and the contrast between Figs A3.1B and A3.2B, with just five and four transects, respectively).

Of more concern for the credibility of the 'Distance' result is the suggestion here that from year to year birds can on average move towards or away from the

TABLE A3.1. INDEX OF POPULATION FROM 'DISTANCE' ANALYSIS.

	EFFORT (km)	SAMPLE SIZE	ENCOUNTER RATE (95% CI)	DENSITY (95% CI)
Caples Oct 1998	5 × 5	74	2.9 (2.2–4.0)	32.4 (23–44)
Caples Oct 2000	5 × 4	83	4.1 (2.9–5.9)	32.5 (23–47)
Caples Oct 2000	10 × 4	142	3.5 (2.8–4.5)	27.4 (22–34)
Dart Oct 1998	4 × 3	35	2.9 (0.7–11)	16.3 (6–44)
Dart Oct 2000	4 × 3	30	2.5 (1.1–6.0)	26.5 (12–60)
Dart Oct 2000	10 × 3.5	142	4.1 (3.0–5.5)	30 (20–45)

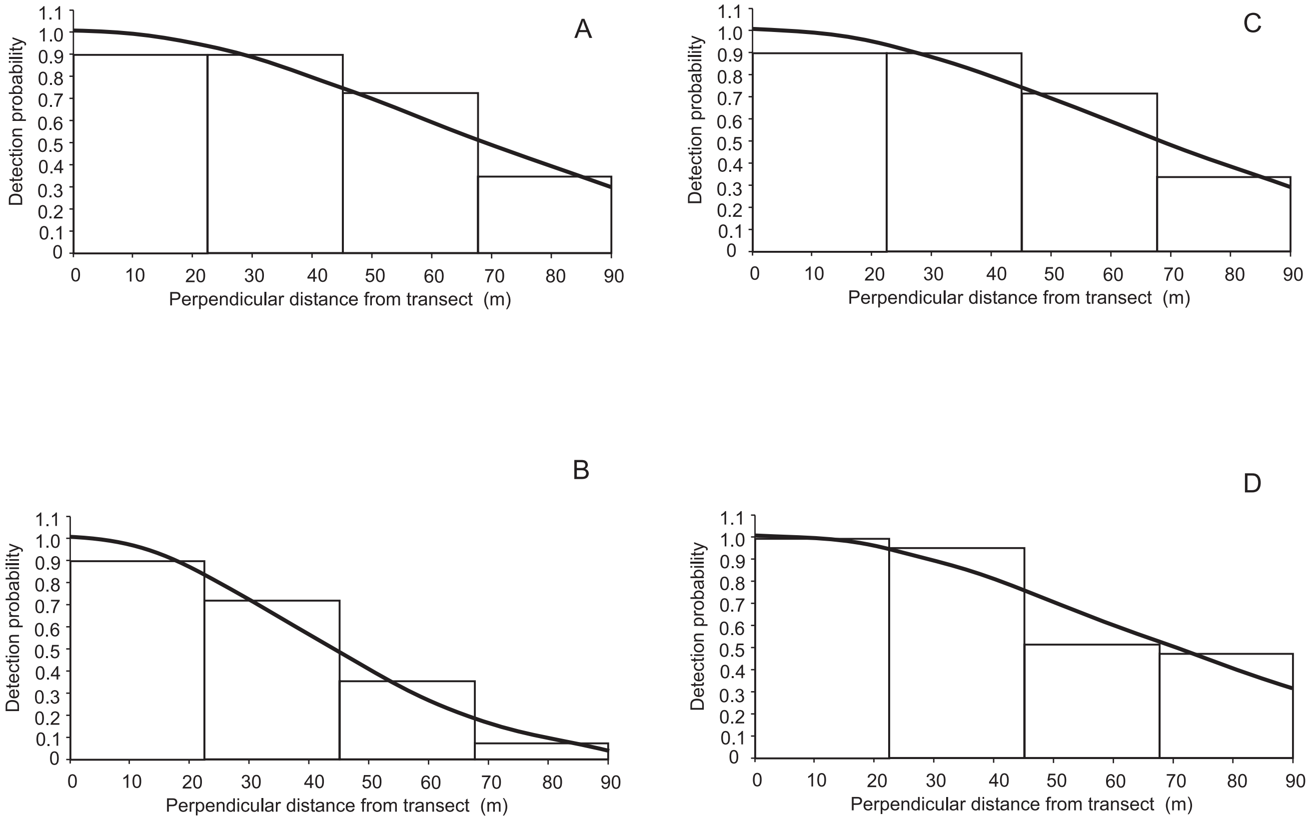

Figure A3.1. Comparing detection probability plots for different sets of transects, using 'Distance', Caples data. A. 2000, using the five 1998 transects. B. The five 1998 transects. C. 2000, the five 1998 transects. D. 2000, all ten transects.

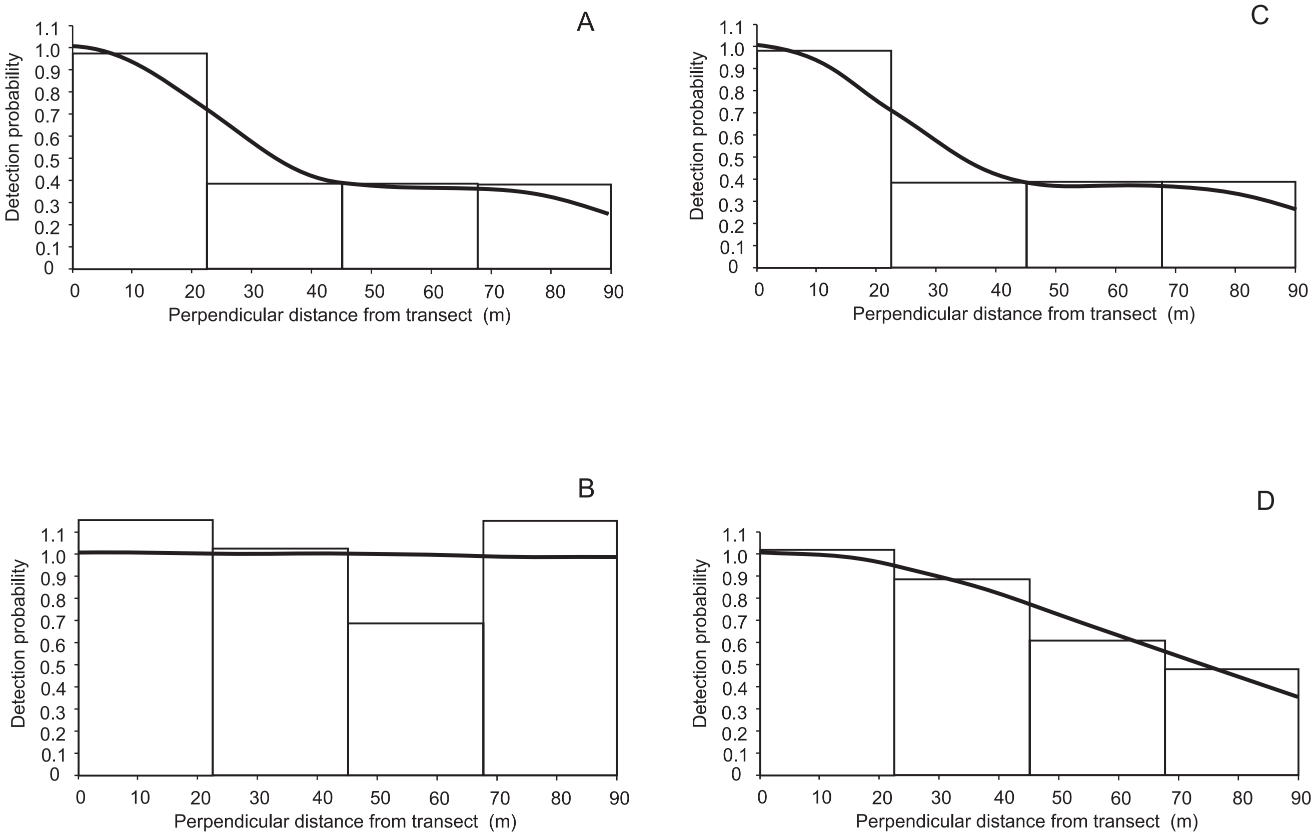

Figure A3.2. Comparing detection probability plots for different sets of transects, using 'Distance', Dart data. A. 2000, using the four 1998 transects. B. The four 1998 transects. C. 2000, the four 1998 transects. D. 2000, all ten transects.

transect line (Fig. A3.1A and B). In the Caples the five transects repeated four and five times gave the minimum practical sample of 80, yet the groups' spatial activity areas are not random enough in respect of their distance to the transect line to avoid this bias. It is one of the problems of sampling the same small number of transects repeatedly, because in any one year the position of the territorial area can be closer or further away from the transect. It appears that, with the number of transects increased to ten, a more random pattern of mohua groups is obtained.

Appendix 4

FIVE-MINUTE BIRD COUNTS

Summary of means of each count station[1].

BIRD	VALLEY	MEAN	95% LOW	95% HIGH	BETWEEN-VALLEY *t*-TEST
Mohua	Caples	1.31	0.93	1.68	*P* = 0.88
	Dart	1.36	0.74	1.97	
Brown creeper	Caples	0.59	0.26	0.92	***P* = 0.041**
	Dart	0.23	0.10	0.34	
Tomtit	Caples	0.23	0.09	0.36	*P* = 0.79
	Dart	0.26	0.11	0.40	
Rifleman	Caples	0.87	0.63	1.11	*P* = 0.100
	Dart	0.48	0.31	0.66	
Grey warbler	Caples	0.96	0.69	1.22	*P* = 0.36
	Dart	1.17	0.87	1.35	
Fantail	Caples	0.19	0.10	0.27	*P* = 0.28
	Dart	0.28	0.13	0.43	
Robin	Caples	0.34	0.19	0.49	*P* = 0.65
	Dart	0.39	0.19	0.59	
Parakeet	Caples	4.12	2.97	5.26	*P* = 0.16
	Dart	3.22	2.56	3.88	
Bellbird	Caples	0.15	0.05	0.26	***P* = 0.0003**
	Dart	0.73	0.49	0.97	
Chaffinch	Caples	2.36	1.93	2.78	*P* = 0.140
	Dart	1.89	1.41	2.37	
Turdus species	Caples	0.60	0.37	0.82	*P* = 0.78
	Dart	0.53	0.08	0.98	
Redpoll	Caples	0.24	0.10	0.37	*P* = 0.1
	Dart	0.10	0.01	0.20	
OTHER SPECIES TOTALS					
Greenfinch	Caples	14 heard		Dart	7 heard
Finch species	Caples	10 heard		Dart	6 heard
Falcon	Caples	2heard		Dart	0 heard
Tui	Caples	0 heard		Dart	1 heard
Kaka	Caples	0 heard		Dart	2 heard
Long-tailed cuckoo	Caples	0 heard		Dart	1 heard
Kea	Caples	1 heard		Dart	0heard
Gull	Caples	0 heard		Dart	2 heard
Magpie	Caples	2 heard		Dart	0 heard
Paradise shelduck	Caples	4 heard		Dart	1 heard

[1] At both Caples Valley and Dart Valley there were 20 count stations; all stations were counted three times, most four—totals at Caples, 77; Dart, 72.

Appendix 5

POWER TO DETECT CHANGE USING FIVE-MINUTE BIRD COUNTS

Results were based on the total counts of mohua at each point.

The issues of observer variation and the declining detectability with density (Mayhew 1999) were not addressed.

POWER	NO. OF COUNT POINTS	REPEAT COUNTS OF EACH POINT	PERCENTAGE CHANGE TO BE DETECTED	WITHIN-POINT VARIANCE	TOTAL FIVE-MINUTE COUNTS
0.9	110	3	40	4	330
0.8	81	3	40	4	243
0.9	159	3	33	4	477
0.8	120	3	33	4	360
0.9	280	3	25	4	840
0.8	210	3	25	4	630
0.9	72	4	40	3.4	288
0.8	54	4	40	3.4	216
0.9	102	4	33	3.4	408
0.8	76	4	33	3.4	304
0.9	180	4	25	3.4	720
0.8	133	4	25	3.4	532
0.9	60	5	40	3.4*	300
0.8	43	5	40	3.4*	215
0.9	81	5	33	3.4*	405
0.8	61	5	33	3.4*	305
0.9	142	5	25	3.4*	710
0.8	108	5	25	3.4*	540

*As five repeats were not undertaken the variance for four repeats is used, which means the number of counts is conservative and is likely to be lower.